ABSTRACTS

of the

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III International Weed Science Congress

FOREWORD

The abstracts herein are those that were reviewed and accepted by April 5, 2000. It is likely that a few poster contributions were submitted after this date, and thus are not included in this book. Nearly all abstracts were submitted electronically. In spite of certain difficulties, often related to Web access, more than 70% of the abstracts were submitted through the abstract submission site developed by Allen Press. All others were submitted via e-mail. Abstracts appear in this book according to the program order. Author and subject indexes are found at the end of the book. Both indexes use abstract numbers for referral.

Given the number of abstracts submitted and the tight time frame to produce this book, it was impossible to conduct an in-depth review of the abstracts. The abstracts were edited for format and grammar only. However, in this process, I may have inadvertently introduced errors or ambiguities in some abstracts. If this is the case, please accept my most sincere apologies. Ideally, final versions of abstracts should have been verified by authors. Unfortunately, this was impossible, again because of the deadlines with which I had to operate.

This collection of abstracts is the work of authors. It is also the work of session organizers and that of the Program Chair, Dr. Jonathan Gressel, who created a coherent and interesting program out of these hundreds of abstracts. But it is also results from the unique contribution of Jeremy Keeler, our site manager at Allen Press, and that of Patrick Lévesque in my lab. They both made this book possible and helped me keep that little panic feeling at bay, especially in the last stretches. To all, we owe our most sincere gratitude.

This book speaks for itself. The interest in the Third International Weed Science Congress has been outstanding. More than 500 papers were submitted, from all reaches of the planet. Topics covered include nearly all aspects of Weed Science, as it is researched and practised daily, in the high-tech laboratories as well as in the fields of smallholder farmers. As I write this, I can foresee that this conference will bring unique opportunities for debate, exchange, and growth for all participants. My wish to each and everyone of you: *Carpe diem*!

Anne Légère
ABSTRACT EDITOR
Agriculture and Agri-Food Canada
Sainte-Foy, QC
5 April 2000

III International Weed Science Congress

Main Topics, Sessions and Organizers

PROGRAM CHAIR: Jonathan Gressel

ALL CONGRESS LECTURES (2–6)	**Jonathan Gressel**
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1.2. Management of seed banks (14–38)	Frank Forcella
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1.5. Community interactions (70–83)	Robert Gallagher
1.6. Ecosystem and community dynamics (84–98)	Claudio Ghersa
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2. INTEGRATED WEED MANAGEMENT*	**Clarence Swanton**
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3.5. Modeling biocontrol effects (181–185)	Margaret C. Smith
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****Main Topic Sponsor:* DUPONT**	

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12.W. Geopolitics of limiting world movement of invasives (447–448) — Peter Jenkins

Main Topic Sponsor: **USDA-APHIS**

13. GLOBAL AQUATIC WEED PROBLEMS — **R. Charudattan**

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13.3. Eco/Environmental issues with aquatics (462–469) — Osvaldo A. Fernandez

14. COMMUNICATING WEED SCIENCE — Steven A. Dewey

14.2. Educating farmers/managers/professionals (470–478) — Steven Dewey
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16. SPOTLIGHTS ON WEED PROBLEMS IN GLOBAL CROPS — Ricardo Labrada

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** Main Topic Sponsor:* **FAO**

From scarcity to security: a global perspective on weed science and the future food situation (2)

TIMOTHY G. REEVES, KENNETH D. SAYRE, PETER R. HOBBS, JOEL K. RANSOM, DENNIS FREISEN, KELLY CASSADAY
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Whether developing countries encounter food scarcity or food security over the next two decades will depend on many factors. This paper reviews projections of the supply and demand for food, especially wheat and maize, in developing countries in the next twenty years. Agricultural research will be essential to meet the rising demand for food in developing countries, and scientists will need an integrated research approach, in which researchers from several disciplines collaborate in identifying the best germplasm and most suitable practices for particular environmental and social conditions. Researchers at the International Maize and Wheat Improvement Center (CIMMYT), which has a global mandate for maize and wheat research, are using such an approach in developing strategies that poor farmers can use to counteract two pernicious, widespread weed problems: *Phalaris minor* in Asia and *Striga* spp. in sub-Saharan Africa. After describing this research and progress to date, the authors turn their attention once more to the global context, discussing trends such as globalization and international property rights that may dramatically affect how soon new agricultural practices and technologies, including those describe in this paper, can benefit farmers and consumers.

Novel controls of millennial weeds (3)

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Global crop monocultures have resulted in the appearance of global ‘‘millennial’’ weeds that are not being adequately controlled world wide. For example, increased labor costs have caused a shift to direct seeding in rice, exacerbating problems of feral and wild rices that were never controlled by herbicides, adding to the problem of wide spread herbicide resistance in *Echinochloa* spp. The wheat of the world is plagued by the evolution of graminicide-resistant grass weeds, and where resistance has not evolved, other naturally-resistant grass weeds are filling the void. Maize and sorghum throughout sub Sahara Africa are infested with parasitic *Striga* species. None of these millennial weed problems were nearly as acute half a century ago in labor-intensive, mixed agriculture when there was a greater biodiversity of weeds. We cannot go back to the old methods without putting more land under the plow and increasing the rural population. A few solutions will derive from better management, new selective herbicides (in many cases with protectants and/or synergists), or from new cultivation technologies, especially when all are integrated. The solutions will not come from organic agriculture where weed problems are rampant, and land use inefficient. Many of the novel solutions to the millennial weed problems will come from biotechnology. These solutions will extend beyond (but include) transgenic herbicide-resistant crops, where biotechnology must now deal with gene introgression from some crops to their related weeds. Genomics and proteomics are being used to find new herbicide targets and design chemicals. Gene technology can be considered for use to directly spread deleterious genes throughout populations of some weeds. Transgenes can be added to biocontrol organisms to enhance their virulence without affecting their weed specificity, and other genes will serve as failsafes to preclude spread. Biotechnology should be used to render crops more competitive with weeds via allelochemicals, by enhanced mineral nutrition efficiency, by enhanced stress tolerances, and by more efficient photosynthesis to allow faster growth. A paradigm shift is needed in this millenium; use biotechnology to obtain more competitive crops instead of just for killing weeds. Weed scientists must understand the potential of all these novel technologies to assist in their rational development.

Getting weed management technologies to farmers in the developing world (4)

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Many advances have been made in weed science within the last five decades. They range from progress in weed biology and ecology through predicting economic thresholds, to better targeting of weeds using various weed control options. Traditional boundaries of herbicide action on plants have been extended through the introduction of transgenic crops. Recently, weed scientists have started asking profound questions about the environment and many of these questions have ethical implications for the biosphere. Most of these developments have taken place in the developed countries of the world while weed control practices in smallholder agriculture of the developing countries (DCs) have remained unchanged. The fragile nature of agroecosystems in the DCs requires that appropriate weed management technologies be system-based and ecological in their approach. Technologies that have the best chance of farmer acceptance are those that are developed with farmer participation, tested on farmers' fields, are simple to use, control weeds economically, safe to the environment, and support food production on a sustainable crop yield basis. Examples of on-the-shelf system-based technologies that meet these guidelines include live (living) mulch, slash/mulch, planted fallow, and integrated weed management systems. Quality weed science literature is nearly nonexistent in the DCs. Weed scientists in the developed world can encourage their regional weed science societies to backstop weed science development in the DCs by launching an International Weed Abstract. They should work towards the goal of getting weed management technologies to farmers in the DCs. This goal can be achieved if we help the DCs to have a critical mass of professionally trained weed scientists. This is one way that weed scientists can contribute to improvements in a world where some farmers grow crops using weed control methods that are at the cutting edge of weed science technology, while others control weeds with tools that are primitive and methods that are full of drudgery.

Is Weed Science a science? The perception of agricultural administrators (5)

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Is Weed Science a science? I first faced this question as an early career scientist hired by USDA-ARS in 1967 to work on mechanism of herbicide action. That the question remains unanswered more than thirty years later in my current position as an agricultural administrator, points to the root of the problem. Weed Scientists must reach concensus on a definitive yes as a once and for all answer to this question and move on. The focus must shift to an aggressive communication plan that defines Weed Science; clearly communicates what Weed Science has done for agriculture in the past; and sets forth clear goals that translate into an aggressive, problem-solving action plan. Weed Science can than emerge from its identity crisis and lead agriculture in this new millenium.

The great global exchange. A perspective on the global movement of invasive species (6)

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Throughout most of geological history, plants and animals have evolved in isolation in a large variety of ecosystems around the world, and were more or less restricted to their native habitats by environmental and physical barriers. However, in recent times, humans have become major vectors, deliberately and inadvertently spreading many organisms far beyond their native ranges to distant lands - usually without their co-evolved predators and parasites. While most alien species do not survive in new habitats, a small

percentage of exotics do become established, grow, adapt, multiply and spread, sometimes causing tremendous economic and environmental damage in their new environment. Even though the long distance spread of invasive species through travel and trade is an age old problem, modern travel and global trade have opened many new pathways and greatly increased the rate at which invasives species are spreading. One has to only examine the records to find examples of ecological disasters caused by biological invasions The total destruction of the American Chestnut in the early 20th century, by the alien chestnut blight is a classic example of an environmental disaster caused by an invasive species.. The large scale movement of species around the world, is now considered to be a clear and present danger to biodiversity and the sustainability of agricultural production. The term ôHomogeoceneö has been coined to describe this largely unfettered global sharing of utilitarian species. The first line of defense against invasive species is prevention. Strategies that are being used by a number of countries for prevention of invasion include requiring the production of pest free commodities for export, requiring that permits and certificates be obtained before export so as to regulate what can be imported, and the inspection and clearance of commodities at ports of entry. Important elements in the second line of defense against biological invasions include early detection, containment, and eradication of incipient infestations of invasives. A proactive worldwide effort is needed now to prevent the international movement of invasive weeds. A holistic system of early detection, reporting and rapid response is needed to prevent invasive species from becoming widespread. Invasive species must be recognized as biological pollutants that threaten not only agricultural productivity but managed and natural ecosystems as well. We face a mighty challenge if we are to protect agricultural productivity as well as the sustainability of our managed and natural ecosystems for future mankind.

Ecological impacts of non-native invasive weeds in natural areas (7)

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Invasive, non-native plants are recognized as a major threat to many endangered native species and to many parks, preserves and other natural areas around the world. Research clearly demonstrates that invasions by certain species have dramatically altered soil chemistry, vegetation structure and ecosystem processes like fire intensity and frequency, hydrology and nutrient cycling. Invading plants have also displaced native species, promoted non-native animals, fungi and other microbes, interfered with dispersal of native species and altered the genetic make up of native species populations through hybridization. Impacts have been especially obvious on oceanic islands like the Azores, Galapagos, Hawaii, Mauritius, New Zealand and Tahiti. Continental natural areas are also heavily affected, however, and well-documented examples of significant negative impacts of weed invasions are available from Argentina, Australia, Canada, Czech Republic, South Africa, the United Kingdom, the United States, Venezuela and other parts of the world. These invasive pests come from a wide variety of families, growth forms and source areas and when considered together they invade and degrade a wide variety of habitat types from the subarctic to the equatorial tropics. Tens of thousand of plant species have been introduced to and become established in new parts of the world. Only a small percentage of these cause significant problems in natural areas, however. In the US and Canada, for example, over 400 species are regarded as serious natural area pests. Research clearly documenting the negative impacts of invasive plants has spurred land managers, policy makers and legislators in many nations to take action to prevent, contain and control the invaders.

Time-lags between introduction, establishment and rapid spread of introduced environmental weeds (8)

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Time-lags between the introductions of exotic plants, their establishment and their subsequent spread are commonly observed in many species. Major changes in a biotic (e.g. grazing, pollinator, seed disperser) or an abiotic (e.g. fire, wind, flood, logging) factor determine the duration of time-lags and there is little published evidence to support the importance of other factors and genetic adaptations in particular. Human activities and perception (e.g. interest in and ability to detect the spread of an invasive) are also common explanations for some observed time-lags. The importance of time-lags in predicting and preventing the spread of introduced species is highlighted.

Effects of mycorrrhizae on interactions among *Centaurea* species and their old versus new neighbors (9)

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Many exotic invaders are relatively poor competitors in their native habitats, but competitively exclude virtually all neighbors in habitats that they invade. These dramatic reversal of fortunes are generally attributed to exotics leaving behind their natural enemies when they migrate, and finding the freedom to exert their full competitive potential in new habitats. Perhaps because of this assumption, little attention has been paid to the possibility that fundamental differences exist in the ways that exotics interact with old versus new neighbors. The direct and indirect effects of mycorrhizae were investigated on two *Centaurea* species, the interactions of these *Centaurea* species with grass species native to *Centaurea*'s original communities, and with grass species native to North American communities that the *Centaurea* species have recently invaded. The direct effects of mycorrhizae were weak or even negative, but the indirect effects of mycorrhizae were strong with North American grasses, apparently allowing *Centaurea* species to parasitize these species for carbon. In other words, *Centaurea* species were much larger in the presence of mycorrhizae and a grass than in the presence of either alone. Mycorrhizae did not substantially enhance the competitive effects of *Centaurea* on grasses from Eurasian communities. Further experiments indicated that common mycorrhizal networks allow *Centaurea* to respond in a highly compensatory manner to defoliation, suggesting that mycorrhizae connections with native species may reduce the inhibitory effect of biocontrol herbivory. These results indicate that complex interactions among exotic invaders and newly encountered native species may be substantially different than those in the exotic's original habitat, and that the success of some exotic species may not be only due to escaping natural enemies.

Historical and contemporary colonisation of novel environments by hybrid *Onopordum* thistles (10)

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We present molecular data confirming the isolation of and subsequent evolution of hybrid lineages from parental species of the Eurasian thistle genus *Onopordum*. Contemporary patterns of genetic diversity in Australian (alien) and historical patterns from European (native) *Onopordum* both indicate that hybridisation has played a significant role in the evolution of these thistles. Adaptation to novel environments, such as may have been found when *Onopordum* colonized Australia from Europe, or Europe from Asia, may be promoted by the transfer of genes between lineages and assortment of these genes under different selection regimes.

Results of a three year survey of weed species in Giza, Egypt (11)

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Weeds cause serious losses to crops in Egypt. The objective of the present work is to gain more complete knowledge of weeds to help farmers in their effort to control weed infestations. This survey started late 1995 with fruit orchards in a governorate where fruit orchards constitutes 60% of the total cultivated area. The flora of Egypt includes about 400 weed species, but only 100 species are considered of economical importance. Each orchard or field was visited twice, once in winter and once in summer during September '95 to July '98. Special record cards were designed which included the names of over 80 weed species. To show the degree of infestation, a scale of 1-5 was used for each weed species (1 = slight to 5 = very heavy infestation). Over 6000 orchards and over 4000 crop and vegetable fields were covered in the present survey. The order of weed infestation percentage based on the average of 3 year records in fruit orchards showed that perennials were present in 60-87 % of the orchards, and that annual weeds were present in up to 58% of the orchards, according to species. Lower percentages of weed infestations and different distribution order were observed in vegetable and crop fields compared to in fruit orchards. These surveys of weed infestation will enable growers to select weed control systems that can minimize costs and allow them to select an effective method, whether mechanical or chemical.

Weed flora of processing tomato in Portugal (12)

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One hundred tomato fields were surveyed during two years (1998-1999) in the south of Portugal. The main objectives were to identify the weed flora in processing tomato, in regions where the crop most important, and to determine the effect of edaphic factors on the distribution of weeds. A total of 158 taxa were identified, distributed among 34 families with a predominance of Compositae (23%) and Gramineae (12%). An abundance index was attributed to the species, which allowed the calculation of mean abundances, and infestation degree. *Solanum nigrum* L. ssp. *nigrum* presented a high infestation degree. The following species *Amaranthus retroflexus* L., *Chamamelum mixtum* (L.) All., *Chenopodium album* L., *Cyperus esculentus* L., *C. rotundus* L., *Datura stramonium* L., *Digitaria sanguinalis* (L.) Scop., *Echinochloa crus-galli* (L.) P. Beauv., *Oryza sativa* L. (red rice), *Paspalum paspalodes* (Michx) Scribn., *Physalis ixocarpa* Hornem., *Polygonum aviculare* L., *Portulaca oleracea* L., *Sonchus asper* (L.) Hill, and *S. oleraceus* L. presented a median infestation degree. To evaluate the edaphic preferences of the main weeds, the ecological profiles of the corrected frequencies were calculated, and ecological preference and groups were determined. The importance of same species on diseases and pests dispersion are enhanced. (Sponsored by PRAXIS XXI - Project 2309).

Biological invasions of noxious weeds in a man-made reservoir. A case study of Timah Tasuh, Perlis, Malaysia (13)

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Timah Tasuh is a 13.3 km^2 five-year old man-made lake in Perlis, Malaysia, submerging sites of what used to be low-lying rice fields and villages in 1992. The lake supplies water for domestic and industrial uses for the state of Perlis. The lake is relatively shallow reservoir, ranging from 1-2 m on the edges to a maximum depth of ca. 10-12 m. Field surveys were conducted every 6-month to assess the extent of spread and infestation of aquatic weeds in Lake Timah Tasuh since 1996. Despite control measures taken by the management authorities to alleviate the weed menace, noxious weed species, viz: *Salvinia cucculata* Roxb. ex Bory., hitherto unrecorded in Malaysia, along with *Typha augustifolia* L. *Phragmites australis* (Cav.) Trin. Ex Steud., *Panicum repens* L., *Rhynchospora corymbosa* (L.) Britt., *Ludwigia repens* J. R. Forst. and *Leeersia hexandri* (Doell.) Swartz., inter-alia, have invaded the lake with increasing intensity, covering no less than 50 % of the water surface in December 1999. The infestation and spread of these aquatics were only ca. 13, 27 and 43% in 1996, 1997 and 1998, respectively while that of *Hydrilla verticillata* (L. F.) Casp./Royle were mostly within the shallow edges of the lake, registering ca. 45, 67, 76 and 76% of the lake water body in 1996, 1997, 1998 and 1999, respectively. The intricacy on the source of infestation of these weeds, especially *S. cucculata*, remains a frontier issue although exploratory studies on the soils recovered from the lake bottom serve as reservoirs of weed seeds. No less than US$500,000 is spent annually to alleviate the weed menace through mechanical and manual means.

Management of seed banks in crops (14)

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Managing seed banks with maximum success requires knowledge not only of seed densities and distributions (depth and breadth) of species and biotypes, but also information on their viability, dormancy, germination, and emergence responses to soil microclimate variables. Knowledge of density and distribution allows managers to make general decisions (Level I) about control. Level I decisions might include choice of tillage systems and herbicides. The fine-tuning of Level I decisions constitutes Level II selections, and these necessitate understanding of seed bank responses to microclimate. Level II decisions involve the timing and rate of implementaion of control techniques. This involvement could include, for example, the depth of tillage and application rate of herbicide, but more importantly the timing of implementation of any of these control measures. In fact, understanding seed bank responses to microclimate, even just partially and in the absence of density data, allows weed scientists to develop highly useful information packages for management purposes. These information packages should be based on locally derived and real-time microclimatic data. They thereby permit managers to implement control techniques (both chemcial and physical) in a more timely fashion than otherwise would be possible in the absence of seed bank information. Such information packages are now only in their infancy. Their further development and improvement will provide scientists who study weed seed banks with a medium by which to extend and publicize research on this important topic.

Cultivating the seedbank through simulation models (15)

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To predict the optimum weeding period and to successfully apply alternative control strategies, an estimate is needed of the size, timing and duration of a flush of weed emergence. The position of a weed seed within the seedbank has a large effect on its germination and emergence, however weed seeds are spatially heterogeneous within the soil, both horizontally and vertically. In addition, it is known that each species has a characteristic emergence response to burial depth and models have been developed to describe the response for a range of common weed species. The main source of seed redistribution within the soil is cultivation and a number of descriptive studies prompted the development of models to quantify this movement of weed seeds. Whilst studies of both seedling emergence from different depths and of the distributions of seeds in different tillage systems are important individually, it is necessary to combine these models to improve their practical application. A cultivation simulation model has been developed at HRI Wellesbourne. Transition matrices are used to predict the vertical distribution of seeds following a single cultivation with either a spring tine, spader, rotovator or power harrow. The simulation model also incorporates a depth of burial model to simulate the likely outcome of different multiple-pass sequences of implements on subsequent weed seedling emergence. The results from a number of simulated cultivation sequences have demonstrated how cultivation could be used to modify the distribution of seeds and hence seedling emergence. This could be useful to optimise control strategies that utilise soil disturbance, such as the stimulation of emergence using the stale seedbed technique. For example, the simulation model found that sequences including multiple passes of a spader resulted in an increased number of emerged seedlings. The combined model system has also helped to identify areas of weed seed ecology requiring further study. A greater understanding of the ecology and dynamics of weed seeds in the soil through such modelling and computer simulation techniques may highlight potential future management strategies.

The impact of agronomic practices on the weed seed bank (16)

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The seed bank is the source of weeds that persist in agricultural fields. Changes in seed density and species composition frustrate control efforts and predictions of weed populations. Seed density and species composition are governed by crop, soil, and weed management practices interacting with environmental conditions. A review of seed bank studies worldwide shows conflicting results on the importance of agronomic practices in determining seed bank size and composition. In general, tillage affects the seed bank due to seed placement. Seeds concentrate at the soil surface in no-tillage (NT), are uniformly distributed in moldboard plow (MP), and are intermediate in chisel plow (CP) systems. Consequently, seed survival declines in MP due to enhanced germination compared with other tillage systems. Predation and mortality losses are highest for seeds at the surface in NT. Characteristic species are associated with NT, especially perennials, biennials, and winter annuals, and occasionally summer annuals. Thus, NT selects for smaller seeds and species with flexible germination time. With annual seed return the seed bank in MP comprises recently shed seeds and previously buried seeds that germinate following soil disturbance. In NT, seed return increases seed density near the soil surface while seeds below the germination zone are preserved. Without seed return, seed density declines in MP as germination is stimulated; however, in NT shallow seeds germinate rapidly but those buried deeply are preserved. Crop rotation affects seed banks due to herbicides used in the various crops. Seed densities are lower in rotation than monoculture fields. Fallow periods in a rotation speed seed bank decline if new seeds are not returned. Herbicides can drive seed density toward zero, but persistent seeds can produce seedlings that rapidly re-infest a site. Herbicides strongly influence species composition due to differential weed tolerance. During three growing seasons, we characterized the seedbank in 35-year-old tillage and rotation studies. *Chenopodium album* and *Setaria* spp. dominated seed banks. Seed density and species diversity decreased as soil disturbance increased. Seeds of winter annuals and species capable of germinating in fall or spring increased where hay was included in a 3-crop rotation, but not in monoculture or 2-crop rotations. Seeds were concentrated near the surface in no-till and uniformly distributed in moldboard plow plots. Rotation influenced species composition more than did tillage. More information is needed on mechanisms responsible for observed effects of agronomic practices, particular chemical, biological, and physical factors responsible for seed mortality and other losses that hasten the decline of seeds in the seedbank.

Smoke derived from burnt vegetation stimulates germination of arable weeds (17)

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Smoke and smoke solutions, prepared from burnt vegetation, may play an important ecological role in the management and reestablishment of native communities. These treatments have been shown to stimulate the germination of native species. However, little is known on how they will affect introduced weed seeds present in the seed bank. A commercially available smoke water solution stimulated the germination of caryopses and intact seeds of wild oat (*Avena fatua* L.). The solutions were most effective when used diluted (5-50%) in distilled water or when presented to caryopses or seeds that had been partly dry after-ripened. The same stimulatory effect was observed in partly after-ripened caryopses of nine different wild oat biotypes coming from three different countries. When freshly harvested caryopses were imbibed in the full strength solution (100%) for 7 days then transferred to distilled water, a much higher germination percentage was possible than when continuous imbibition in smoke solutions were used alone. The stimulatory effect of smoke water on germination was similar to that of gibberellic acid and less like that of potassium nitrate. The same smoke water solution was tested on the germination of 18 other temperate arable weed species. All of the monocotyledonous species tested (*Avena sterilis* ssp. *ludoviciana*, *Alopercurus myosuroides*, *Sorghum halepense*, *Phalaris paradoxa*, *Bromus dyandrus*) were strongly stimulated by smoke solutions whereas the dicotyledonous species were either strongly stimulated (*Malva neglecta*, *Galium aparine*), slightly stimulated (*Polygonium persicaria*, *P. pennsylvanicum*, *P. convolvulus*, *Veronica persicaria*), unaffected (*P. aviculare*, *Sinapis arvensis*, *Heracleum sphondylium*, *Angelica sylvestris*, *Mercurialis annua*, *Veronica hederifolia*) or inhibited (*Lamium purpureum*). When the unaffected species were retested following a 10 day chilling treatment, smoke water provided a small promotory response for two (*P. aviculare* and *V. hederifolia*) of the six species studied. When four different smoke water solutions (Kings Park and Botanic Gardens Smoky Water, Regen 2000, a solution prepared from charred wood and a wheat straw smoke solution) were tested on two representative species (*A. fatua*, and *M. neglecta*) three solutions were effective in promoting the germination of both species while the fourth (the charred wood solution) was only active on *A. fatua*. Three of the four solutions were active at 2-20% dilutions while the other (Regen 2000) was only active at 1-2% and was very toxic to the seeds at higher .

Soil seed bank evaluation for weed control strategy in tobacco: first results of a European Community funded project (18)

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Chemical weed control is one of the most widely debated agronomic techniques for an environmentally safe agriculture. To reduce weed control impact, a key factor is the knowledge of weed dynamics and their relative infestation thresholds, above which crop damage will exceed the cost of the herbicide treatment. This is very important for tobacco (*Nicotiana tabacum* L.) quality, since combustion, in the presence of herbicide residues, could induce to formation of complexes, potentially toxic for human health. Hence, simulation of weed dynamics could be of crucial importance for weed control strategy: an answer to the questions ‘‘if’’ and ‘‘how’’ to weed. An agronomic research has been carried out since 1998 at various sites of three European countries: Italy (Verona, Udine and Perugia); Greece (Drama, Xanthi and Agrinion); and Spain (Rosalejo). Indeed one of the most ambitious aims of this project has been to investigate, for each experimental site, the relation between potential and real flora, i.e. between soil seed bank and actual emerged seedlings. For an early knowledge of this relation (before weed control decision) some minigreenhouses were arranged in the fields, in order to ‘‘force’’ weed seedlings to emerge earlier as affected by the warming up effect of transparent PE or polycarbonate soil covers. Infestation dynamics was investigated by photographic stills, shot at three eleven-day intervals. In the near distance of these minigreenhouses, soil cores (4 cm-diameter, 14 cm long) had been previously sampled, and later washed to separate seed, for seed identification. In spite of the soil-climate differences among the experimental areas, the major part of their soil seed banks included weeds typically able to overcome the agronomic disturbance of the tobacco crop: *Amaranthus retroflexus*, *Chenopodium album*, *Portulaca oleracea*, *Echinochloa crus-galli*, *Solanum nigrum* and *Polygonum aviculare*. As expected, the actual number of seeds of the various species was highly site-specific as a function of the past tobacco agrotechnics. However, observed emergence rates were much lower than those expected on the basis of the soil seed reserve, and were consistently below 1%. The lowest emergence rates were recorded for *C. album* (0.13%), *P. aviculare* (0.18%), *S. nigrum* (0.14%), and *P. oleracea* (0.14%). These low rates were probably due to marked seed dormancy characteristics. *A. retroflexus* and *E. crus-galli* showed however somewhat higher emergence rates (0.32 and 0.71%, respectively). In the future years, the project will investigate the role of agronomic and climate factors in seed germination and seedling emergence, with the aim at determining whether the data obtained so far truly represent weed emergence dynamics in Mediterranean environments.

Long term viability of *Senecio jacobaea* (L.) seed buried at three depths in four soils (19)

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Senecio jacobaea (tansy ragwort, ragwort) is a problem weed in dairy pastures in New Zealand and is well established in many other countries world wide. Traditionally controlled with 2,4-D, recent moves to integrated weed management have required a better understanding of its reproductive biology. In a long term study the viability of *S. jacobaea* seed buried at three depths in four different soils was investigated over a 16-year period. Batches of seed mixed with sterilised soil from each site were placed at 0-2, 4-6 and 19-21 cm depths within perforated, open ended polythene tubes which were buried vertically at each site. At each sampling date several tubes were retrieved and seed viability assessed by germinating in the greenhouse. Seed buried in the top 2 cm soil layer underwent exponential decay (R^2: 0.85-0.96) with half lives of 2.1-3.2 years. When buried at 4-6 cm and 19-21 cm, numbers declined steadily over the study period and a linear decline (R^2: 0.79-0.99) better described their viability. Predictions from fitted regressions show that some *S. jacobaea* seed could remain viable for 13 years in the clay soil and for 18 years in the sandy soil if buried as fresh seed at 5 or 20 cm depth. Viability in the peat and silt loam soils was intermediate. The long term viability of seed did not differ markedly between soils. Seeds remaining on or near the soil surface will be lost from the soil seedbank quite quickly while those buried deeper (by trampling or falling into cracks) will remain viable slightly longer. Thus it could take 10-15 years to deplete the reservoir of seed in the soil if management regimes that stop the return of seed to the soil are implemented.

Genetic and environmental differences among Canadian canola cultivars (*Brassica napus* and *B. rapa*) in their ability to be induced into secondary dormancy (20)

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Recent weed surveys conducted on the Canadian prairies have indicated that volunteer canola (*B. napus*) has rapidly become a more prominent weed, surpassing traditionally more important weeds such as Canada thistle (*Cirsium arvense* (L.) Scop.) and kochia (*Kochia scoparia* (L.) Schrad.) in relative abundance. Concurrently, investigations conducted in Europe have shown the potential for *B. napus* seeds to be induced into secondary dormancy. This trait has been linked to the longevity of volunteer canola seed banks in Europe. As part of our effort in addressing the increase in volunteer canola observed on the Canadian prairies we have screened 16 *B. napus* and 5 *B. rapa* cultivars currently available to Canadian producers for their potential to be induced into secondary dormancy. Four replicates of 100 seeds were placed in petri dishes and incubated in a polyethylene glycol solution with an initial water potential of -1.5 MPa at 20 C in darkness for four weeks. Under a green safe light, all germinable seeds were then transferred weekly to new plates containing distilled water. After two weeks, the non-germinated seeds were evaluated. The assay showed very high potential for the development of secondary dormancy in a number of *B. napus* cultivars. To date, the range of secondary dormancy in *B. napus* was between 98.2% and 6.0% of viable seeds among cultivars, locations and replications of the experiment. Most *B. napus* genotypes exhibited similar potential for the induction into secondary dormancy relative to each other, independent of location. Our results indicate that *B. rapa* may rely on a different persistence mechanism than *B. napus* or that the assay conditions may not be ideal for the evaluation of the induction of secondary dormancy in *B. rapa* cultivars as the majority of seeds decomposed during the assay. The proportion of the initially viable *B. rapa* seeds that were induced into secondary dormancy was highly variable and below 5% in all cases.

Seed germination of five *Rottboellia exaltata* ecotypes (21)

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The purpose of this research was to evaluate the germination of the seeds of five ecotypes of *Rottboellia exaltata* in: Jujuy (Argentine), Santa Cruz (Bolivia), Piracicaba, Campinas and Junqueira (Brazil). The experiment was performed in the laboratory using two samples of seeds: one composed by caryopsis (denominated ‘‘nude’’ seeds - NS) and another composed by spikelets with the section of the rhachis (‘‘covered’’ seeds - CS). Four temperatures were tested which are 20-30 C (20 C without light during 16 hours, and 30 C for 8 hours with fluorescent white light), 25, 27 and 30 C constant, with light for 12 hours. The statistical analysis were based on completely randomized designs, with four replicates of 100 seeds and comparison of means were made through Tukey’s test at a 5% probability level. The results showed that for ‘‘nude’’seeds, the temperature of 20-30 C was more appropriate, while for ‘‘covered’’ seeds, it varied in function of the ecotypes. The effects in the germination, of the removal of glumes, lemma and palea that involve the caryopsis varied with the ecotypes and temperatures studied.

Effects of soil water status and depth of burial on dormancy changes in *Polygonum aviculare* L. seeds (22)

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Although there is much information about the role of temperature on annual changes of dormancy of buried weed seeds, little is known about how seed dormancy can be modified by soil water status and depth of burial. In order to highlight these questions, seeds of *Polygonum aviculare* contained in nylon mesh bags, were buried in the field at two depths (5 and 15 cm) and subjected to three different hydric conditions: irrigated, dry and rainfed. At regular intervals, seeds were exhumed and the population dormancy level was assessed through: i) the range of temperatures suitable for germination and ii) sensitivity to light. Data from successive extractions, showed that seeds entered secondary dormancy soon after burial, but to a different extent depending on the water regime given to the seeds in the field and on the depth of burial. For example, seeds buried at 5 cm in rainfed plots were able to germinate in a wider thermal range than seeds buried under other conditions, showing that those seeds entered secondary dormancy at a lower rate. On the other hand, depth of burial played an important role in determining changes in light sensitivity; seven months after burial seeds buried at 15 cm were more sensitive to light than seeds exhumed from 5 cm; only when the seeds were held at high soil water content (irrigation), could seeds placed at 5 cm respond to light as did seeds buried at 15 cm. These results suggest that the effect of depth on seed dormancy could be mediated by the different water conditions that prevail at the different depths. Overall, these results, show that soil water status and depth of burial play an important role in determining changes in the dormancy level of weed seed banks.

Reproductive system behavior of *Borreria verticillata* L. in agroforestry systems established in degraded pasture areas in the Brazilian Central Amazonia (23)

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Borreria verticillata species are present in Amazonian pastures, especially after introduction of *Brachiaria humidicola* (Amazonian Quicuio). The species will produced fruits all year round, which will happen more frequently during the dry season (May-October). The objective is to compare the blooming rate for the *B. verticillata* population in three types of soil which are characteristic of the Brazilian Central Amazonia. The selected areas were abandoned pastures (Pa) for 5 years and two agroforestry systems (SAF) in degraded and abandoned pasture areas, located at Manaus-Boa Vista. *Borreria verticillata* populations were altered to different densities. During the phase of stablishment and development for the perenial crops, *B. verticillata* populations tended to decrease from 4 to 1 individual m^{-2} while trees formed canopies which shaded the sub-forest. Data has shown that *B. verticillata*, in abandoned pasture conditions, presents an average of 272 inflorescences per plant, compared to 68 and 0.5 in understory of the agroforestry systems. In abandoned pasture conditions, where the majority of blooming occurs (99%), each individual plant presents an average of 34 primary splittings (bifurcacoes) and 59 secundary splittings. In agroforestry systems, both primary and secondary splittings have been reduced, with a greater impact for the conditions in Saf, which presents an average of 4 splittings and less then 1 secondary, resulting in a reduction of 99% in the blooming rate for *B. verticillata*. Considering that the seeds production has been severely afected by the environmental conditions (mainly light) imposed by the agroforestry systems, we can predict that the probability of re-infestation through the soil seeds bank will be very low, favoring an effective control on the population of *B. verticillata*. This could also be applied to the other invading weeds under similar conditions, making it evident a great advantage for the use of agroforestry systems which demands less quantities of agro-chemical inputs for the control of weeds.

Relationship between the seedbank and actual weed flora in one agricultural soil in Queluz (24)

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In arable fields, the vast majority of weed species are annuals and the seedbank is the major source for the renewal of weed species. In addition, agricultural practices such as ploughing, crop cultivation and the application of herbicides impose periodical disturbance on the entire system that limits the growing conditions of the weeds. Thus, a high concordance between the seedbank and the vegetation is to be expected. Previous studies have been conducted to understand the relationship between the seedbank and the above-ground weed flora in a cultivated soil in the Botanical Park of Ajuda. This communication presents the data from field and greenhouse studies carried out during 1998 and 1999 in a cultivated soil located in Queluz, in order to investigate the correlation between the above-ground weed flora and weed seedbank of this soil. Both studies adopted the methodology of the European Weed Research Society Working Group ‘‘Seedbanks and Real Flora of Agricultural Land’’ and were submitted to correlation analysis. For the seedling flora, 25 rectangles (10 x 50 cm) were placed on the soil, on a 2 x 2 m grid. Each week, all seedlings present in each quadrat were identified, counted and pulled out. For the seedbank, 100 soil sampling units were systematically taken at a 10 cm depth at 1 m intervals throughout the sampling area. Samples were taken with a core sampler device and then placed in a greenhouse under a sprinkler irrigation for germination. Seedlings were identified and counted weekly. Twenty-four species were recorded in the seedbank and 22 species in the above ground flora. The above ground flora and the seedbank had the same dominant species: *Euphorbia peplus* L. and *Polycarpon tetraphyllum* (L.) L. Nevertheless, *Oxalis corniculata* L. in the seedbank, *Picris echioides* L. it is also a dominant species in the above-ground flora.

Soil seed bank in a tropical organically-managed agroecosystem (25)

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Few studies have addressed the influence of organic soil management upon seedling weed flora and seed bank although it is important to know the effects of changes in agricultural practices on the assessment of these variables. Seed banks may have determining effects on the composition and pattern of the vegetation within the community and is the main source of weed infestation in crops. Studies on dynamics of soil organisms and seeds raise problems related sampling specially in tropical agroecosystems where the distribution of seeds is extremely erratic. This paper describes the changes in seed bank composition according to the number of samples collected from a tropical agroecological farm which has been organically managed for 6 years at Embrapa - Agrobiology in Rio de Janeiro, Brazil. Fifty soil samples (1.5 L) were collected from a 10 m^2 area under different crops (*Brassica oleracea*; maize; manihot and native vegetation) at 0-15 cm depth. These were placed in boxes (10 x 5 x 20 cm) and germinated plants were identified during 6 months when any new plant was found. Results show that, beyond 18 samples, no changes were observed in the recovery of plants (38-45 species under any crop), suggesting that there is a greater influence of soil management and soil type on seed bank than the crop and that, for the area studied, 20 samples should be adequate to recover most of the seed bank.

Field emergence patterns of *Silene gallica* in relation to changes in dormancy and germination responses to temperature (26)

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We present results from experiments on the facultative winter annuals *Silene gallica* i) to determine thermal conditions that induce or release dormancy, ii) to investigate to what extent changes in dormancy level resulting from those thermal conditions explain the seasonal pattern of emergence, and iii) to estimate required thermal time and base temperature for the germination of non-dormant seeds. Recently shed seeds of *Silene gallica* presented a high dormancy level. Seeds were buried in the soil of the beginning of the summer. When seeds were exhumed in the autumn, they showed a very low dormancy level, and were able to germinate under a wide thermal range. The dormancy level remained low for seeds exhumed in winter and in spring, thus suggesting that low winter temperatures did not induce secondary dormancy as expected for a winter annual. Dormancy relief was enhanced by dry storage at 25 C, and the response to low temperature was different depending on moisture conditions; prolonged exposure to moist-chilling maintained the high dormancy level of the population, while dry storage at 4 C relieved dormancy in the long term. Changes in the thermal range permissive for germination as a result of dormancy modifications explained to a large extent the timing of the emergence periods observed in the field. Thermal time required for germination varied with dormancy while base temperature and optimal temperature for germination were constant (T_b=0 C and T_o=12 C).

No-till and glyphosate reduce the emergence and tuber bank of *Cyperus rotundus* L. (27)

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Cyperus rotundus is one of the most important weed in the northern crop land of Santa Cruz. Few selective herbicides can control effectively this weed in soybean, maize and rice. The purpose of this research was to ascertain the effect of glyphosate and soil inversion in the soil-tuber bank and emergence of *C. rotundus*. The experiment was designed in a factorial structure with and added control. The treatments were conventional tillage with glyphosate and without glyphosate (lactofen+sethoxydim), no-till with glyphosate and without glyphosate and a control in no till system (paraquat). The initial tuber population of 1831 m^{-2} in the upper 0.2 m of soil was recorded. Twenty days before spraying the chemical the no-till (NT) plots were chopped and the conventional tillage (CT) treatment were disk ploughed. Before spraying the no-till treatments had 317, the control 389 and the conventional treatments 525 seedlings of *C. rotundus* m^{-2}. The disk plough breaks the dormancy of parent tuber and promotes greater germination. At 28 days after applying the chemical treatments, glyphosate had fewer seedlings (35 and 52 seedling m^{-2} NT and CT respectively) than the control (86 seedlings m^{-2}) and lactofen+sethoxydim (280 and 444 seedlings m^{-2} NT and CT respectively). After 23 weeks, the velvetbean (*Mucuna deeringiana*) was incorporated or chopped and the chemical treatments were applied to the no-till plots. The number of tubers in the soil was reduced when treated with glyphosate (1162) compared to the control (1808) and lactofen+sethoxydim (1886 tubers m^{-2} x 0.2 m). The number of tubers declined by 36% when treated with glyphosate compared to the initial tuber population. The emergence of *C. rotundus* was less when treated with glyphosate in a second season in NT and CT compared to lactofen+sethoxydim and the control. NT reduced by 45% the emergence of *C. rotundus* when compared to CT regardless of the chemical treatment.

The effects of the preparation of the soil in a dynamic populations of *Rottboellia exaltata* (28)

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Rottboellia exaltata L.f. (ROOEX) is the world worst weed in sugar cane. At the present moment there are 24 countries above 30 latitude where this weed infests. The knowledge of the dynamism of the population is the mainly importance for the management of the sugar cane. The effects of the preparation of the soil in dynamic populations were realized in a 3 m X 50 m area with natural infestation of ROOEX through monthly plowing and grading the soil. A monthly evaluation was done in the area. The experimental design was ramdomized blocks with 6 replications in a plot of 0.2 m X 5 m where the density and the phythomass (70 C, after 48 hours) were determined after 30 days during 6 years. The data was submitted by a polynomial regression analysis to determine the mathematical adjust model. The most significantty model was the cubic regression influenced by climatic conditions and photoperiodism. The maximum populational development associated with the preparation of soil occurred from September to October period when the photoperiodism is 11.8-12.5 hours, the water balance is 90-100 mm and minimum temperature is 12.8-16 C.

Planted fallow reduces weed seedbank in south-western Nigeria (29)

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Weeds are a major constraint to crop production in smallholder farms in tropical Africa. Weed seedbank and annual recruitment are the main sources of weed infestation in crops. This study evaluated the effect of

two types of planted fallow [alley cropping with *Leucaena leucocephala* (Lam.) de Wit), and live mulch with *Pueraria phaseoloides* (Roxb.) Benth] and a natural fallow in four land-use intensities on weed seedbank after 4 years in Ibadan, Nigeria. Land-use intensities consisting of continuous cropping, 1 cropping year followed by 1, 2 and 3 years of fallow were the subplots. Thirteen soil cores were taken to a depth of 10 cm with a precision bucket auger of diameter 5-cm in 1990 and 1994 from each subplot. Soil samples taken in 1990 formed the baseline data. Direct germination in the screen house was used to estimate the seedbank. After 4 years the seedbank was 50 and 44% lower in plots seeded to *Pueraria* compared to natural bush and *Leucaena* plots, respectively. The difference in seedbank between *Leucaena* and natural fallow was marginal (11%). Seed density of annual broadleaf weeds was high (38-85%) and dominated the seedbank of both planted and natural fallow. Weed seeds of grasses and sedges occurred in very low populations in all plots cultivated after 2-3 years of fallow. Seed density of perennial broadleaf weeds increased as land-use intensity decreased. Major annual broadleaf weed seeds included *Ageratum conyzoides* L., *Spermacoce ocymoides* Burm. f. and *Spigelia anthelmia* L. Major perennial weed seeds were *Chromolaena odorata* (L.) King & Robinson and *Talinum triangulare* (Jacq.) Willd while *Mariscus alternifolius* Vahl. was the most dominant sedge. Live mulch with *Pueraria*, especially when combined with 2-3 years of fallow, lowered the seedbank.

Control of *Setaria viridis* (L.) Beauv. and *Digitaria sanguinalis* (L.) Scop in fallows during the autumn prior to no-till corn seeding (30)

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In the south east of Buenos Aires Province, Argentina, the presence of annual grass weeds in soybean and corn in no-till farming is associated with weed management in previous crops and fallows. The objective of these studies was to evaluate the importance of controlling annual grass weeds after harvest of the previous crop to diminish their incidence in the next season. Soil samples, contained in cylinders of 15 cm diameter and 12 cm deep, with cover of previous crop, with and without autumn control of weeds were taken from fields and placed in greenhouse. Atrazine at 4 kg a.i. ha^{-1}, and in mixtures at 1.5 kg a.i. ha^{-1} with metolachlor at 1.9 kg a.i. ha^{-1} or dimethenamid at 1.5 kg a.i. ha^{-1} were sprayed on the cylinders, all in mixtures with 1.2 kg a.i. ha^{-1} of glyphosate. Two controls without herbicides were used: one keeping residues and another in which residues were taken off with the top 2 mm of soil (cut sample). Weeds were counted at spray of pre-emergent herbicides and 35 and 52 days after treatment. In 1997/98 and 1998/99, four strip tests were performed and 32 fields were scouted in which application of 1.2 kg a.i. ha^{-1} of glyphosate were to allow or not production of seeds by grass weeds. Scouting of weeds was performed when corn reached 3 leaves At first count in the greenhouse experiment, number of individuals of *Setaria viridis* in samples of untreated cylinders in autumn was significant different ($p < 0.05$) to cut sample and to autumn sprayed. Weed counts at 35 and 52 days after spraying showed few individuals in all cylinders, but those with autumn treatments still showed significant less than the ones without autumn treatment or cut sample. Data of last treatment showed that most of seedlings came from seeds produced in the previous autumn. In the scouting of 32 fields the most wide spread weed was *Digitaria sanguinalis*. Data showed that significant differences in number of both grass weeds m^{-2} in the strip tests and in scouted fields were achieved when autumn application of herbicides for weed control was performed.

Seedbank reduction with rotations of *Arachis hypogaea, Mucuna aterrima* and *Zea mays* (31)

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A field experiment with crop rotation was laid out in order to study its influence on the seedbank on a alfissol, with fine sandy texture. in the Region of Pindorama, Sao Paulo State, Brazil. The treatments were:

1. rotation of *Mucuna aterrima*, non fertilized corn and peanuts; 2. the same but with fertilized corn; 3. rotation of peanuts and fertilized corn; 4. peanuts grown only in summer with no rotation, all with four replications. Corn and *M. aterrima* were planted in the dry season. The first planting started in summer 1993 and the rotations ended in 1998, when four soil samples from 0 to 10 cm and from 10 to 20 cm were collected in each plot. The soil samples were put on trays and the seeds left to germinate. Twenty-two different species occured: *Gnaphalium spicatum* Lam, *Galinsoga parviflora* Cav, *Cyperus rotundus* L., *Digitaria sanguinalis* (L.) Scop and *Eragrostis pilosa* (L.) Beauv. being the most frequent. The total number of germinated seeds was 192 380, for the treatment with peanuts only, considered the check. Seedbank reduction for the three treatments were situated between 60 and 68%, in general, for both soil depths sampled. For *G. spicatum* the seedbank reduction were 79% for #1; 74% for #2 and 66% for #3. For *G. parviflora* reductions were: 70% for #1; 90% for #2 and 88,5% for #3. For *C. rotundus* reductions were 76% for #1; 89% for #2 and 86,5% for #3. For *D. sanguinalis* reductions were: 0,0% for #1; 39% for #2 and 36% for #3. For *E. pilosa* reductions found were: 73,6% for #1; 77.7% for #2 and 81% for #3. Rotation with corn alone and with both fertilized corn and *M. aterrima* showed to be more efficient in reducing the seedbank in the considered area.

Regulation of winter annual emergence by alfalfa cultivars with contrasting dormancy during winter (32)

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The long term growth of weed populations is regulated by the crop presence, through the effect of competition on individual seed production and other demographic rates. An aspect that has been less studied is the possibility of using crop characteristics for the regulation of the germination - emergence process of weeds. In order to determine whether alfalfa (*Medicago sativa* L.) cultivars presenting different behaviors during winter (one dormant, the other active), can differentially regulate weed emergence dynamics, seeds from a number of winter annuals were put in the interrows of alfalfa crops having different degree of winter dormancy (groups 4 and 9) and in bare soil (control plots). Selected species were *Carduus acanthoides* L., *Cirsium vulgare* (Savi.) Ten, *Sisymbrium altissimum* L., *Brassica campestris* L. and *Rumex crispus* L. Autumn emergence was regulated in relation to the emergence that took place at bare soil by the presence of both kinds of cultivars. The only exception was *Brassica campestris* whose emergence was regulated by the winter-dormant cultivar only. During the winter, the emergence of all evaluated species were regulated by the cultivar without winter dormancy. In contrast, the cultivar presenting winter dormancy was not able to regulate the emergence of weeds. The exceptions were *Brassica campestris* and *Rumex crispus* whose emergence was somehow regulated by the winter-dormant cultivar. These results indicate that crop characteristics as, for example, degree of winter dormancy can be considered as an alternative for a most efficient management of weed populations.

Seedbanks of weed species in agroforestry systems in the Manaus region, Amazonas (33)

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In the Brazilian Amazon, the main causes of abandonment of agricultural areas are diminution of soil fertility and proliferation of weed species. Precise estimates of density and species richness of viable seeds

are important in the prediction of probable infestations and planning of management programs. In this study, I analysed seedbanks from 4 agroforestry systems at farms off the AM-070 Highway and BR-174 Highway, in the Manaus region. At each site, I collected 20 soil samples of 15 x 15 cm from 0-5 cm, totaling 80 soil samples. The census and identification were made in the greenhouse using seed germination. The seedlings were identified first by morphotype and afterwards to species. The census was made over nine months. In total, there were 13 024 seeds from 4 agroforestry systems, on average, corresponding to 7 236 seeds m^{-2}. There was a significant diference in seed densities (Kruskal Wallis, pτ0,05) among the sites. The average number of seeds in each site varied from 75 to 215. The seedbanks consisted of herbaceous species characteristic of agricultural and disturbed areas (56%). The species richness varied from 26 to 44. There was little similarity in the species composition between the agroforestry systems. The small farmers leave the weed species in the soil after to weed out, that leads to the incorporation of seeds in the soil, causing new infestations. I suggest the inclusion of green covers or litter to inhibit weed seed germination.

Senna obtusifolia **seed dynamics as affected by corn and soybean cropping systems** (34)

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Senna obtusifolia (L.) Irwin and Barneby is one of the most common and troublesome annual weeds in crops grown in the southeastern Unites States. It is important to have an understanding of the impact crop production practices have on seed dynamics so that effective long-term control strategies can be developed. *S. obtusifolia* soil seed bank density was monitored over a 4-year period under various crop and herbicide systems. Corn and soybean were grown no-tillage following a winter rye covercrop. Soil cores were collected and *S. obtusifolia* seed were separated and counted to establish the baseline soil seed bank prior to study initiation. Changes in the *S. obtusifolia* seed bank were monitored from soil cores collected in the spring prior to crop establishment and in the fall after crop harvest. Soil seed bank density of *S. obtusifolia* initially declined for all treatments regardless of whether *S. obtusifolia* was controlled with herbicides and tillage in a fallow system or by crop competition and herbicides in either corn or soybean. By the spring of the third season seed bank density was reduced 50 to 70% compared with plots where seed rain was allowed to occur unabated. During the third season, however, severe grazing by game animals resulted in loss of the soybean crop and eliminated competition with *S. obtusifolia*. Seed banks levels in the plots where the soybean crop was destroyed dramatically increased to levels near that of the untreated plots. Thus it is imperative to maintain a high level of *S. obtusifolia* control even after soil seed bank density has been reduced to a relatively low level for effective long-term control.

Some observations on the germination and dormancy of *Nicandra phaseoloides* (L.) (35)

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The plant *Nicandra phaseoloides* is one of the most important weed in soybean and maize crops in Brazil, resulting in yield and quality losses. The plant produces several fruit and each fruit produces more than 400 seeds. Because of its particular dormancy, seeds germinate at different times and contribute to the weed soil bank. The germination is erratic and slow, remaining in the soil for several months. The objective of this paper was to study the mechanism of dormancy of *Nicandra* in tropical region. Several trials were conducted at Embrapa from 1996 to 1999. In the first trial, constant temperatures from 18 to 32 C were

studied whereas in the second trial, alternating temperatures in the presence of GA3 and ethylene were considered. In the third trial, seeds were conditioned in the presence of KNO_3. The seedlings were counted as germinable when reaching 2 cm long. Each Petri dish consisted of 50 seeds imbibed in water or solution. Of all treatments tested, only the treatment with KNO3 was effective in breaking dormancy. With KNO_3, seeds germinated 92% against the control 8%. *Nicandra* seeds have two layers of cell surrounding the tip of the roots, which impose dormancy. The mechanism for the breaking of dormancy proposed was that NO_3 enhanced the activity of the enzyme (mannanase) and allowed germination. This NO_3 mechanism illustrates what happens in the soil and why seed of *Nicandra* usually germinated later, after soybean and corn have been sown.

Sequential application of herbicides at pre-planting for the control of weeds in bean crops (36)

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The sequential application of herbicides at pre-planting can be used as a strategy to reduce the effect of the competition of the weeds with the bean plants due to the elimination of the first flow of weeds. The objective of the assay was to quantify the germination flush of weeds with the different pre-planting treatments and the effect on reducing the use of post-emergent herbicides. The assay was conducted in the field in Santo Antonio de Goias, GO, Brazil, in 1998. Weeds present were *Cenchrus echinatus* and *Euphorbia heterophylla*. The design used was randomized blocks with four replicates and the treatments consisted of sulphosate (1200 g a.i. ha^{-1}) at 20 days before planting and a supplementary treatment of paraquat (200 g a.i. ha^{-1}) at planting and application of sulphosate (1200 g a.i. ha^{-1}) at 7 days before planting. Application in sub-plots consisted of fomesafen + fluazifop-p-butyl at the doses of 100 + 80; 200 + 160 g a.i. ha^{-1} and a control. At the time of planting, the plots where the pre-planting applications of herbicides were made in advance (at 20 days), presented a higher number of emerged plants of *C. echinatus* and *E. heterophylla* (compared with those treatments where pre-planting application was made 7 days before planting), which were controlled by the herbicide paraquat. The advanced germination of weeds with treatments consisting of pre-planting application at 20 days resulted in a lower number and stages of development of weeds at 30 days after germination which resulted in a decrease of 50% in the doses of post-emergent products needed to obtain an efficient control. It is concluded that the sequential application of herbicides (systemic and contact) to prepare the area for no-till planting of beans results in the elimination of the first germination flush of weeds, therefore reducing the doses of post-emergent herbicides.

Loss of viability of *Ipomoaresoea purpurea* (L.) Roth seeds stored at several depths and effect of sowing depth on emergence rate (37)

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Ipomoea species are common weeds occurring in several crops in northern Argentina. No-tillage system, of increasing importance in the agricultural production of Argentina, implies changes in weed seed position in the soil and probably affects the demography of weedy species. Aim of this study was to evaluate the loss of viability of *I. purpurea* seeds buried to several depths and the emergence rate from different sowing depths. Seeds of the weed were placed just level with the soil surface and buried to a depth of 4 and 16 cm to test the loss of viability. Emergence was periodically registered and all 4-month germination tests were conducted with exhumed seeds. In another experiment, the percentage of emergence, and emergence time of seedlings from 2, 4, 8 and 12 cm was investigated. Emergence was registered daily during one month. The number of viable seeds diminished clearly in the first 4 months after burial in spring at several soil depths, following a negative exponential function. Thereafter, there was no significant reduction of seed viability up to 2.5 years after burial. The depth of burial had little or no effect on seed longevity. Around 98 % of the seeds were dormant and germination took place only after seed coat scarification. Seedling emergence was significantly reduced when planted deeper than 12 cm. Percent emergence could be explained by a Gompertz function. Emergence time increased with planting depth and the velocity of emergence, calculated as the inverse of emergence time, decreased linearly with planting depth. Both parameters represent important demographic factors of the seed bank dynamic and can be included in an emergence model as a part of population dynamics models.

Water constraints on the photoinduction of weed seed germination during tillage (38)

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Germination of light-requiring seeds may be induced by very brief exposures to sunlight during soil disturbance through the very low fluence (VLF) mode of phytocrome action. We studied the effect of soil water availability after cultivation on the photoinduction of seed germination in two important weed species: *Datura ferox* and *Chenopodium album*. In daily-irrigated plots, seedling density was one to four times greater in plots cultivated during daytime than in those tilled at night. When plots were not irrigated soon after tillage and rainfall was excluded, no significant differences were often observed between seed germination in daytime vs. night-time cultivated plots; although seedling emergence in night-time cultivated plots was higher than in non-cultivated controls. The average critical value of soil water potential required for the expression of VLF-induced germination was higher than -0.5 MPa. Dark germination was less sensitive to decreasing soil moisture than light-induced seed germination. The promotive effect of the light signal perceived by the seeds during daytime cultivations is maintained for several days in drying soil, even though laboratory data suggest that the Pfr form of the phytochrome inducing the VLF-photoresponse is unstable disappearing in less than 24 hours. These results reveal the complexity of interactions between the light signal and other environmental factors that control seed germination under natural conditions.

Exploring mechanisms of weed-crop competition (39)

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Most studies on weed-crop competition have focussed on the outcome rather than the process. Simulation models that take an eco-physiological approach can identify gaps in our knowledge about the mechanisms and temporal dynamics of resource capture and utilization. These modelling exercises have tended to emphasize differential resource capture among competing species as influenced by various morphological and physiological traits. The impact of environmental conditions on weed phenology and morphology, and variation within and between weed populations in resource use efficiency are less well understood. The influence of small genetic changes on competitive ability and fitness of herbicide resistant and susceptible biotypes is a fertile area for the study of the eco-physiology of competition. So is the effect of sub-lethal herbicide doses on weed competitive ability and fecundity. A better understanding of weed responses to sub-lethal doses in relation to herbicide mode of action, timing of application, environmental conditions, and crop competition is crucial to the debate on the role of reduced rates in weed management systems.

Ecophysiology of weed-crop competition and dispersion (40)

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Weed ecophysiological studies performed in monocultures help to analyze and understand competition in weed-crop mixtures. Based on this approach, ecophysiological models have provided insight into the weed-crop competition process. However, most of their applications have been biomass-centered and few effort has been invested to link weed ecophysiology to competition and other key processes of population dynamics. This could be done with a simple experimental approach. With this purpose, experiments with *Cynodon dactylon* (L.) Pers. (bermudagrass) were conducted under semi-controlled and field conditions. The growth of 78 cm^2 bermudagrass patches under a range of shadow treatments was studied at the University of Buenos Aires experimental fields. Light regimes explored were 80, 65, 50, 35 and 20% of incident radiation. Biomass and spatial growth were determined periodically. Radiation regimes lower than 65% significantly reduced final biomass of the weed patches. Stolons extension rate and spatial growth were also reduced by shading, though to a lesser extent; spatial growth was reduced with 35 and 20% of incident radiation. A bilinear functional relationship between weed growth rate and spatial growth integrated all the results obtained, pointing out that shading effects on biomass and spatial growth were only partially associated. This suggests a potentially different light competition effect on biomass than on spatial growth of the weed. Field research, set up to evaluate the light interception pattern of various soybean (*Glycine max* (L.) Merr.) and the performance of bermudagrass, confirmed the results. Spatial and temporal design of crops greatly modify the light environment for the weed, thus reducing its biomass and spatial growth, though in a different way. Similar approaches, based on few ecophysiological relationships may contribute to explain particular experimental results and to predict weed performance over a wide range of competition conditions.

Germination and seedling growth of *Glycyrrhiza glabra* L. a noxious weed of Iran's dryland wheat and chickpea fields (41)

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Glycyrrhiza glabra is a deep-rooted perennial weed of Iran's western dryland wheat and chickpea fields. The eco-physiology of this weed is mostly unknown. In this study, cardinal temperatures for germination under different osmotic potentials were investigated under laboratory conditions. Treatments includes twelve temperature regimes (0 to 50°C with 5°C increments) and seven PEG 6000 induced osmotic potentials (0,-3,-8,-9,-12,-15,-18 bar). Experimental design was CRD with four replications. Results showed that minimum, optimum and maximum germination temperature for *G. glabra* were 1 to 3, 25 to 35 and 40 to 45°C respectively. Highest germination rate was recorded in -3 bar. No germination was recorded in -15 bar and lower osmotic potential treatments. Reduced germination rates were recorded in lower temperature and osmotic potential treatments. Phenological stages of *G. glabra* were also recorded. Cotyledon emergence, first, second, third, fourth and fifth leaf stages were recorded at 2, 12, 13, 15, 18, 23, days after planting respectively and, from then on, the plant produced a leaf every 4-5 days. *G. glabra* entered reproductive stage after the 15th leaf appeared.

Competitive potential and return of a glyphosate-tolerant/conventional soybean mix (42)

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Field studies were conducted in 1997 and 1999 to determine the effect of a broadcast seeded Roundup-Ready/conventional soybean cultivar seed mix on soybean seed yield, economic return from weed control, and early-season weed suppression prior to a single glyphosate application. Tests were established by seeding 494 000 Roundup-Ready (DK-5961RR) soybean seed ha^{-1} in combination with 0 to 1 976 000 conventional seed ha^{-1}, incorporating the seed, and rolling the test area. Glyphosate at 1.12 kg a.i. ha^{-1} was applied at the V5 to V6 soybean growth stage to remove all conventional soybean and control emerged weeds. The broadcast planting technique was effective in establishing a soybean stand on a silt loam soil, but ineffective on a silty clay soil. *Sesbania exaltata* and *Ipomoea lacunosa* were controlled 70 to 95% from an additional 988,000 conventional seed ha^{-1} prior to glyphosate application. A trend for increasing yield and return from weed control for dryland and irrigated soybean occurred as conventional seed mix increased from 0 to 247 000 seed ha^{-1} and 0 to 494 000 seed ha^{-1}, respectively. Results were comparable between dryland and irrigated production. A decline in yield at 1 976 000 seed ha^{-1} was attributed to intraspecific interference between the two soybean cultivars prior to removal of the conventional cultivar with glyphosate. This reduction in yield and additional cost incurred from planting a high density of conventional soybean caused a decrease in return from weed control. Thus, the best seeding rate mix, regardless of irrigation level, appears to be approximately 494 000 seed ha^{-1} Roundup Ready plus 494 000 seed ha^{-1} conventional cultivar which increased yield 455 kg ha^{-1} and return from weed control \$87.03 ha^{-1}. Yield increase was attributed to weed suppression and elevated soybean growth rate.

Influence of *Datura stramonium* density on maize seed quality (43)

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Small scale farmers in Africa use produced maize caryopsis (F2 seed) from one season as seed for the next season. Knowledge regarding the influence of weed competition on quality (germination and vigour) of the produced caryopsis of *Zea mays* L. provide information on the degree of interference between the weed and the crop and the influence of weed/crop interference on the quality of the produced grain. Maize was planted in 2.1 m rows with a plant population of 16 000 plants ha^{-1}. *Xanthium strumarium* L. was planted at five densities between the maize. Maize caryopsis, produced at the different weed densities, were harvested at the end of the growing season and subjected to a series of germination and vigour tests. Germination and vigour of the caryopsis decreased with an increase in weed density. This information is important in sustainable agriculture and will also be useful in determining threshold values for more economic weed control.

Competition of *Euphorbia dentata* with soybean (*Glycine max*) (44)

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Competition between soybean and weeds is a complex phenomenon which has been the object of study for many years. This relationship is important for the parameters of crop yield and is the basis for

programming weed control. *Euphorbia dentata* is an annual species with a spring-summer cycle that was detected in Azul Co., Buenos Aires Province, Argentina, in 1983, localized as an isolated focus in soybean plantations. At present it is found as a weed in 85% of cropland with densities ranging between 20 and 200 plants m^{-2}. In the current investigation, field studies were performed over two years to determine the competitive relationship between soybean and *E. dentata*. The effect of different weed densities was evaluated on yield parameters and biomass. Both soybean dry weight and yield gave a significant response related to weed density and biomass, resulting in an 80% reduction in both characters, due to interference starting at a density of 20 plants m^{-2}. It was determined that *E. dentata* strongly influences soybean yield, showing a linear response for the range of densities studied, fitted to a regression equation indicating that seed production decreases 6.73 kg ha^{-1} for each additional plant m^{-2} in *E. dentata*. From the crop yield components, the number of pods per plant was more severely affected by competition producing decreases of 40% with respect to the weed-free treatment. The number of grains per pod and 1000-seed weight were only significantly affected starting at rather high densities of *E. dentata* (55 plants m^{-2}). High correlation levels were found between soybean seed yield, number of pods per plant and 1000 seed weight (98 and 85 % respectively).

Effects of pig slurry on a population of barley and *Lolium rigidum* Gaud. (45)

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The agricultural application of pig slurry for waste disposal and to improve soil quality is a controversial practice considering the environmental problem that this residue poses. Pig slurry contains considerable amount of nitrogen, fundamentally as ammonium, which results in a source of N fertilizer. In a Haploxeralf soil, poor in organic matter (0.82%) and semi-arid conditions of Toledo province (Spain), an experiment was carried out. Pig slurry with 2.4 g N L^{-1} was used on barley infested by the weed *Lolium rigidum*. The mean number of plants m^{-2} were 250 and 510 for barley and *L. rigidum* respectively. The pig slurry doses were 30, 60, 90, 120 and 150 m^3 ha^{-1}, applied 15 days before barley sowing. Also, there was a control without waste application. At barley ripening, crop and weed attributes were measured on 4 micro-plots of 1 m^2. There was a similar response of both species to pig slurry doses. Doses up to 90 m^3 ha^{-1} (216 kg of N ha^{-1}) increased the number of heads and grain yield of barley, and the dry biomass of both species, the response being more marked for the crop than for the weed. With higher doses, these attributes decreased in both species, due to the drought during from April to July period (88 mm of rainfall). The decrease in biomass was more marked in *L. rigidum* than in barley, due the greater competitive ability for N and anticipation of growth of barley compared with *L. rigidum*.

Competitive ability of Argentinean wheat cultivars against Italian ryegrass (*Lolium multiflorum*) (46)

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Argentina has $5x10^6$ ha sown with wheat and at the Southern Pampas ($2.2x10^6$ ha) Italian raygrass (*Lolium multiflorum*) is an important weed. The aim of reducing environmental and economic cost of crop protection has increased interest in utilizing agronomic alternatives such as competitive varieties to diminish the use of herbicide. The objective of the present study was to establish morphophysiological characteristics in wheat varieties that offer competitive ability regarding Italian ryegrass. The studies were carried out in La Plata National University, La Plata (34S, 58W, Argentina) during 1997-1998. Commercial varieties of bread wheat (Klein Cacique and Pro Inta Super (1997) plus Buck Charr·a (1998) were employed. Seeds coming from local ecotype of *Lolium multiflorum* were used. Two weed densities (0 and 100 pl m^{-2}) and 2 levels of nitrogen fertilization (0 and 100 kg ha^{-1}) were used in 1997 and 4 weed densities (0, 50, 100 and

150 pl m^{-2}) and 3 levels of nitrogen fertilization (0, 50 and 100 kg ha^{-1}) were employed during the second year. The determinations were: tiller number, total above ground biomass, yield and components, leaf area index, height, length and width of the flag leaf, height of the penultimate expanded leaf and relative growth rate. The competition was evaluated by means of the Competitive Ability (aggressivity) and Resources Complementarity (relative yield total, RYT). The total above biomass was an interesting characteristic to offer competitive ability in the first year at first node detectable, while in the second year this trend was conditioned by the density of the weed and the fertilizer levels. At anthesis and maturity, we observed that more production in pure crop, major tolerance to the competition, but, as a previous determination, this relationship loses importance due both the increase of the nitrogen level and density of *Lolium multiflorum*. We observed that LAI doesn't appear granting a greater aggressiveness while a positive correlation between the aggressiveness and the height of the penultimate expanded leaf and height, area and length of the flag leaf was obtained. The use of competitive ability appears as an important factor to incorporate as selection criteria in the local breeding programs, given the variability observed in the genotypes evaluated.

Competitive effects of *Setaria parviflora*, Poir, Kerguelen, on alfalfa growth during summer (47)

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Dairy production in the area of Santa Fe (Argentina) is mainly based on rotational grazing systems on alfalfa, which is the most widely grown perennial pasture. Alfalfa varieties are winter active and plant structure is better adapted for hay cutting than for grazing. Persistence is no longer than 3 years. Grass weed invasion in summer is a serious problem, because these weeds severely compete with alfalfa when grazed in subtropical environments. In Santa Fe, the most important grass weed is *Setaria parviflora* (baraval) which is a C4 species. This study was undertaken to determine the relationship between baraval growth and alfalfa persistence regarding the production pattern of stems, leaf area and dry matter yield in summer under a rotational grazing system. In 1994, plots with four treatments were determined in a one year alfalfa pasture, according to the species growing in each: 1) pure alfalfa; 2) alfalfa and baraval; 3) alfalfa and weeds different from baraval and 4) pure baraval. For each species dry matter content, plant height, number of organs and leaf area were determined every 15 days during summer. The experimental design was a randomized complete block with treatments replicated three times. Analysis of covariance was conducted for different populations. In weeded plots, the plant stand of alfalfa was significantly reduced from 22 plants m^2 in weed free plots to 17 in those with baraval. Alfalfa stem and leaf dry matter yields were reduced in weeded plots and so were the number of stems and the leaf area. When weeds were competing and especially when baraval was the main weed, alfalfa plants had fewer stems and leaves and a lower dry matter production. An asymmetric mortality had occurred as described for other species. Baraval was more competitive than other grasses because its strong tillering (almost 200 per plant) and the erect growth of the plant, which reaches a similar height as alfalfa (45 cm) before grazing, thus possibly competing for light.

Effect of bulb depth on the development of *Oxalis latifolia* Kunth (48)

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After consultations carried out during summer 1998 in several guipuzcoan country houses, *Oxalis latifolia*, a widely distributed weed in tropical and temperate climates all around the world, has been identified as the most loathed weed. In prevision and comprehensive fight against *O. latifolia*, its bulbs were planted at 1 and 12 cm under the soil surface. With that, the influence of the depth on the yearly development cycle of *O. latifolia* as well as the importance of a turning over of the arable soil on its removal could be understood. Periodical observations, carried out during the 1999 growing season, have demonstrated that

depth has considerable effects in plant development. Surface individuals are the only ones which develop enlarged roots, one, two or, even, three, used for accumulating water as well as for maintaining the bulb at due depth. Moreover, individuals at the surface develop leaves and second generation bulbs earlier, and in greater number, than those buried more deeply. Besides, these second generation bulbs produced leaves with great precocity. And finally, only shallow bulbs bloomed.

Growth analysis of resistant and susceptible wild poinsettia biotypes to ALS inhibitor herbicides (49)

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All natural weed populations regardless of the application of any weed killer probably contain individual plants (biotypes) which are resistant to herbicides. Persistent herbicide use will expose the weed population to a strong selection pressure which may lead to an increase in the number of surviving resistant individuals in the population. Repeated use of imidazolinone herbicides in continuous no-till soybean selected a herbicide resistant biotype of wild poinsettia (*Euphorbia herophylla*) in Cafelandia county of Parana State, Brazil. A comparative study of growth and development of wild poinsettia resistant and susceptible to ALS (acetolactate synthase) inhibitor herbicides was carried out at Embrapa Soja, Londrina, Parana State, Brazil. The total dry matter, leaf area, shoot dry weight, leaf dry weight, root dry weight and plant height were measured weekly 13 times, starting 14 days after sowing. Data were analyzed with a polynomial exponential function. The response variable for the whole growth period was estimated using 95% confidence interval. Relative growth rate, net assimilation rate, leaf area ratio, leaf weight ratio and specific leaf area decreased with plant ontogeny and behave similarly in both biotypes. The total dry matter of the plants and their organs as well as the leaf area and plant height exhibited similar ranges of variability in both biotypes. There were no significant differences between biotypes for growth and development characteristics.

Compensatory responses to crop shading by *Cynodon dactylon* (L.) Pers. (50)

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It was suggested that for a maximum weed suppression a crop should be planted in a uniform spatial arrangement. An equidistant crop planting delays the beginning of intraspecific competition in crop stands leading to maximum efficiencies in the capture and use of resources by a weed-free crop. But when early competition by weeds can reduce the availability of a limiting soil resource as nitrogen, the advantages of an uniform crop pattern could be lost for the crop. A field experiment was conducted with the objective of analyzing the growth response of *C. dactylon* to maize competition when this crop was planted at three rectangularities and at a constant stand density. Our hypotheses was that an anticipated preemptive capture of the aerial space by the most uniform crop increases its weed suppressing effect in terms of dry matter and N accumulation by *C. dactylon*. A commercial single hybrid of maize was sown at 8 pl m^{-2} in 3.50 x 3.50 m plots according to a completely random design with five replicates. The planting patterns were 0.35 m x 0.35 m, 0.25 m x 0.55 m and 0.18 m x 0.70 m. Photosynthetically active radiation (PAR) transmitted through the crop canopy was measured periodically and integrated for the whole crop cycle. Total biomass and N accumulated by the weed at crop maturity did not differ among crop spatial patterns even though total PAR intercepted by the weed canopy diminished in ca. 20% with crop uniformity. This homeostasis was explained by the increased proportion of aerial biomass which in turn had higher N content than rhizomes. The starting large reserves in rhizomes and a rapid lateral expansion through stolon elongation

supported by a very plastic assimilate allocation make *C. dactylon* able to escape the potential competitive advantages of a more uniform crop pattern.

Weed species contribution to wheat yield loss in Iran (51)

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In order to investigate the effect of wheat yield loss due to weed competition a study was conducted in 1998 in Northern Iran. Twenty-seven plots each with an area of 25 m^2 were randomly selected in a wheat field. Wheat density and their corresponding weed species density were recorded at six wheat growth stages. A regression analysis was used to determine the contribution of each weed species to wheat yield loss. The results were as follows: 1/w + 0.5 = 0.12 + 15 *Convolvulus* + 0.05 *Phleum* + 0.029 *Lathyrus* + 0.028 *Artemisia* + 0.022 *Rapistrum* - 0.0001 *Lolium* - 0.06 *Phalaris* - 0.17 *Stellaria*. Results showed that *Convolvulus* and *Phleum* were responsible for most of the wheat yield loss, whereas no yield losses were caused by other weed species present.

Effect of after-ripening temperature on seed germination of *Echinochloa crus-galli* (L.) Beauv. (52)

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Echinochloa crus-galli is the most important rice weed in Southeast Asia, reducing rice yields by as much as 65 %. *E. crus-galli* is persistent, grows profusely in a wide range of habitat, thus, it is difficult to control. The mature seeds of *E. crus-galli* are innately dormant and need after-ripening. After-ripening is the steady loss of innate dormancy in seeds and it is greatly influenced by the environment. It is essential to understand the after-ripening requirements of *E. crus-galli* to determine the factors that contribute to its persistence. This study assessed the variations in innate dormancy among four *E. crus-galli* populations and determined the effect of temperature during after-ripening and the extent of variations in temperature-dependence of *E. crus-galli* germination. Four populations (Tarlac 1, Tarlac 2, Pangasinan, Laguna) of *E. crus-galli* were collected from three distant provinces in northern Philippines. Seeds were stored under three day/night temperature combinations and tested for germination under fluctuating temperature regimes at different intervals over the ensuing 12 months. Survival analysis showed that the four populations responded differently to both after-ripening and germination temperatures. Laguna had higher survival and censored occurrences than any of the other populations throughout all after-ripening periods. For Tarlac 1, Tarlac 2, and Pangasinan, significant interactions between the effects of after-ripening duration and temperature during after-ripening were observed. The variations in temperature-dependence of *E. crus-galli* germination were more pronounced at shorter than at longer after-ripening duration

Effect of *Cyperus rotundus* on *Saccharum* spp. growth (53)

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Cyperus rotundus (CYPRO) in competition with sugarcane (*Saccharum* spp.) cause losses varying from 25 to 31 %, in Brazilian conditions. However, for any cultivar less tolerant to competition, the losses may

reach 60 %. A trial was carried out in 1999 at Piracicaba, SP, with the purpose to evaluate the tolerance of *Saccharum* spp. cultivar IAC 83-1313 in competition with CYPRO. A randomized block design with four replications was used. The treatments were increasing densities of tubers: 50, 100, 150, 200 and 250 m^{-2}, in combination with *Saccharum* spp. bud stems at 25 m^{-2}, planted in boxes filled with Dark Red Latossol, and compared with a control without CYPRO. Sixty days after sowing, the harvesting of the experiment was done, followed by determination dry matter weight (phytomass). A functional interrelation was found between *Saccharum* spp. phytomass and CYPRO densities, based on significance for quadratic regression ($P < 0.01$). In accordance with the polynomial regression analysis, the coefficient of determination ($R^2 = 0.8906$) giving evidence of high dependence between variables, showing that phytomass of *Saccharum* spp. was reduced in consequence of the density increase of CYPRO starting from 50 plants m^{-2}, reaching the minimum point at 150 plants m^{-2} when the values become stabilized. Results of this research showed that of growth reduction sugar cane was caused by the presence and increase of CYPRO densities.

Wild proso millet (*Panicum miliaceum* L.) growth and competition (54)

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The weedy form of *Panicum miliaceum*, commonly called wild proso millet, has become an important weed in North America. Infestation of this weed has been reported in several regions of the United States. Wild proso millet is weedy in corn causing estimated yield losses of more than $50,000,000 annually in the United States and Canada. To evaluate growth and competitive ability of wild proso millet, experiments were conducted under greenhouse conditions at Colorado State University. Twelve biotypes were grown in 3-L pots. Five destructive harvests were taken over time to compare plant growth rate among biotypes, determined by leaf, stem and root dry weight analyses. Relative growth rate and absolute growth rate were derived using Richards's function. Two biotypes were selected from the results of the first experiment: one with high and the other with low growth rate. Three densities of wild proso millet (1, 3 and 6 plants/pot) were grown in competition with 1 plant of either corn or sugarbeet. The selected wild proso millet biotypes were planted at two time intervals (0 and 14 days after crop planting date). All plants were harvested at 42 days after planting, and leaf area, plant height, and leaf and stem dry weight were recorded. Differences among biotypes were observed. Total dry weight of corn and sugarbeet, in competition with wild proso millet planted at 0-time interval, millet was reduced from 16 to 55% and 50 to 88%, respectively. No differences in competitive ability were observed between the two biotypes studied.

Seed germination of five *Rottboellia exaltata* ecotypes (55)

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The purpose of this research was to evaluate the germination of the seeds of five ecotypes of *Rottboellia exaltata* L.f. from Jujuy (Argentine), Santa Cruz (Bolivia), Piracicaba, Campinas and Junqueira (Brazil). The experiment was performed in the laboratory using two samples of seeds: one composed by caryopsis (nude seeds - NS) and another composed by spikelets with the section of the rachis (covered seeds - CS). Four temperatures were tested 20-30°C (20°C without light during 16 hours, and 30°C for 8 hours with fluorescent white light), 25°C, 27°C and 30°C constant, with light for 12 hours. The statistical analyses were based on completely randomized designs, with four replicates of 100 seeds, and comparisons of means were made with Tukey's test at a 5% probability level. The results showed that for nude seeds, the temperature of 20-30°C was more appropriate, whereas for covered seeds, it varied according to ecotypes. The effects in the germination, of the removal of glumes, lemma and palea that involve the caryopsis varied with the ecotypes and temperatures studied.

Variability in threshold germination temperature in populations of *Phalaris minor* Retz. (56)

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Optimum temperature (17-21°C) for germination of *Phalaris minor* coincides with the prevailing temperatures in last week of November (12°C minimum and 25°C maximum) which is also the time for sowing of wheat in North India. A comparison of the germination response of isoproturon susceptible and resistant populations made under variable temperatures (10-30°C) in Petri-plates in the growth chambers reveals variation with regard to the threshhold germination temperature. Of the two susceptible populations tested one from Panipat showed threshold germination temperature of 15°C and the other from university farms, Karnal of 20°C. All the eight resistant populations that were tested show a threshold germination temperature of 27°C. Even at temperatures of 16°C minimum and 33°C maximum that prevail in the last week of October, some populations showed 40-45% germination. The information could be exploited in planning management strategies, especially if a sufficient percentage could be encouraged to germinate prior to seed bed preparation for wheat.

Morpho-physiological responses of *Euphorbia heterophylla* L. and *Amaranthus dubius* Mart. under recovery from phosphorus stress (57)

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Contrary to many cultivated plants, weeds are known for their ability to survive and their capacity to recover from stress conditions. In order to evaluate recovery potential under P-stress after a period of deficiency, an experiment was conducted under greenhouse conditions with these two dicot weeds. Plants were grown from seed in 950 ml pots filled with sterilized and decarbonated sand regularly irrigated with Hoagland P-sufficient or deficient solutions. Deficiency (0.01 mM P) was applied for 8 days and thereafter plants were irrigated with the P-sufficient solution (1.0 mM P). Control plants were irrigated with 1.0 mM P nutrient solution throughout the experimental period. Three plants per treatment were harvested every third day during the exponential growth phase of each species for dry weights (organs and total), P concentration in the dry matter and morphological studies of the root system. According to the results, *Amaranthus* showed a higher degree of recovering from P-stress as relative growth rates and P-absorption and accumulation indices were higher than those for control plants when plants where under recovery (sufficiency) from P-stress. *Euphorbia* on the other hand had a much lower capacity to recover even though biomass accumulation was 54 % of the control plants as compared to 84 % for *Amaranthus*. A lower shoot-to-root ratio was found for *Euphorbia* but not for *Amaranthus* under P-deficiency.

Ranking weed response to added nitrogen and phosphorus (58)

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Controlled environment studies were conducted to determine the growth response of twenty common weeds of the Canadian Prairies to various levels of nitrogen and phosphorus. Separate experiments were conducted for each soil nutrient. Wheat and canola (*Brassica napus* L.) were included as check species. Plants were grown in a nutrient deficient soil and nutrients were applied at doses approximating field doses of 0 to 240

kg ha^{-1} for nitrogen and 0 to 120 kg ha^{-1} for phosphorus. Other macro- and micro-nutrients were maintained at adequate levels. Shoot and root dry weight of each species was determined after six weeks of growth. Results indicated that weeds varied considerably in their growth response to these nutrients, with many weeds responding more to added nitrogen and phosphorus than wheat and canola. *Sinapis arvensis* L. was among the most responsive species to added nitrogen but was the least responsive to phosphorus. *Amaranthus retroflexus* L. and *Malva pusilla* SM. were highly responsive to both nitrogen and phosphorus. *Salsola iberica* Sennen & Pau was among the least responsive weeds to both nutrients. Differences in crop and weed responses to soil fertility may be exploited by developing agronomic systems that stimulate crop growth over that of weeds.

Influence of livestock manure on the emergence and survival of *Prosopis caldenia* seedlings (59)

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Continuous grazing and over stocking have contributed to the increased abundance of woody species in the temperate semi-arid rangelands of Argentina known commonly as the Caldenal. These infestation reduce the production of desirable range forage plants and interfere with livestock management. *Prosopis caldenia* is one of the dominant woody species in the region. If not consumed by animals, their seeds lies dormant until the seed coat is broken by weathering. Scarification occurs most rapidly under natural conditions when the seeds are passed through the digestive tracts of domestic livestock and wildlife. Our objective was to document the influence of livestock manure in relation to emergency and survival of *P. caldenia* seedlings. The study was conducted at 2 sites with different grazing history in La Pampa province (38°45'S; 63°45'W), an area exposed to long-term continuous grazing (G) or an adjacent, long-term exclosure to domestic livestock (NG). On each experimental site, 20 plots (each 0.1 m^2) with livestock manure and 20 plots without livestock manure were established at random. In October 1995 and 1996, 10 scarified seeds were planted in each plot. Seedling emergence and survival were recorded weekly and every 2 weeks after each planting date, respectively. Above- and below-ground biomass, height, and root lenght of surviving *P. caldenia* seedlings were determinated at end of both growing season. Analysis of emergence data was performed using Kruskall-Wallis test. Survival data were analysed using Chi-square. Emergence and seedling survival were higher ($p < 0.05$) in plots with livestock manure than plots without livestock manure in G and NG sites, in both study periods. Growth of *P. caldenia* seedlings showed a similar response. Results suggest that the microclimate created by the livestock manure would enhanced. at least in part, the establishment of *P. caldenia* seedlings.

Weed community dynamics and sustainable weed management in rice based crops (60)

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Rice based cropping systems in the tropics provide examples of extremely dynamic weed communities in which species responses to management are rapid. Understanding the factors that govern these dynamics is essential to maximize the impact of integrated control practices and to prohibit weed species shifts that threaten crop yield. Case history studies of weed community dynamics in irrigated and rainfed rice are used to discuss current understanding of the nature and processes underlying weed species shifts. It is argued that cultural practices during land preparation act as highly selective switches determining initial weed seedling recruitment, and that subsequent competitive hierarchies of weed species are strongly mediated by early nutrient availability and herbicide applications. The respective roles of studies of theoretical population dynamics, of mechanisms of crop-weed interactions and of the description of multi-species interactions are discussed in the context of underpinning the development of decision support systems for sustainable rice weed management.

Demography of wild oat (*Avena fatua* L.) in barley crops with different strategies of nitrogen fertilisation (61)

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Demographic studies were carried out during 1997-1998, to assess the effect of nitrogen fertilisation on the demography of wild oat (*Avena fatua* L.). The demographic processes assessed were: (i) seedling establishment (ii) seedling survival rate (iii) reproductive performance and (iv) preharvest seed dispersal rate. In addition, we studied the effect of each agronomic practice on the individual growth of the weed and the fate of the seeds during the fallow period. The use of nitrogen fertiliser did not affect the number of seedlings emerged. However, nitrogen fertilisation significantly enhanced different demographic processes that would result in a bigger size of the seed bank at posharvest than that found in control plots. These effects are related to the moment of nitrogen application. When it was applied at crop tillering, nitrogen enhanced the individual fecundity of the weed and the seedling survival rate. Seed production of *A. fatua* was 7287, 5578 and 3035 seed m^{-2} with nitrogen application at tillering, at sowing and without nitrogen application, respectively. However, the preharvest seed dispersal rate was lower when nitrogen was applied than in the control plots. These data indicate that in order to avoid the increase of the size of the *A. fatua* population, it would be advantageous to apply N fertiliser at sowing of the crop. Nevertheless, if nitrogen applications are necessary, it might be recommended not to delay the harvest of the crop.

A multi-species bio-economic model for the management of *Lolium rigidum* and *Raphanus raphanistrum* in Australian dryland agriculture (62)

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Weed infestations in agriculture usually consist of a number of co-existing weed species. In the Western Australian wheatbelt, *Lolium rigidum* and *Raphanus raphanistrum* frequently co-exist and vastly dominate over any other weed species. Both species now widely exhibit herbicide resistance such that farmers no longer can rely solely on herbicides for effective weed control, but rather need to combine a whole range of chemical and non-chemical methods (IWM) to control these weeds. Managing several weeds is a difficult task yet, so far, the use of models capable of considering the management of co-existing weed species has been almost non-existent. Hence, a multi-species version of the bio-economic RIM model has been developed to deal with the complexities involved in the integrated management of *L. rigidum* and *R. raphanistrum* over time. RIM (Ryegrass Integrated Management) is a model that simulates the dynamics of a *L. rigidum* population and accounts for a broad range of weed management strategies over a period of to up to 20 years. The model includes detailed representation of the biology of weed, crops and pasture as well as of the economics of agricultural production and management. Here, we have extended the RIM model to include the dicot weed *R. raphanistrum* as well as a set of extra weed management practices used to control this species. We demonstrate how the multi-species RIM model can be used to evaluate the economic trade-offs between short-term costs and long-term benefits associated with the integrated management of co-existing herbicide resistant *L. rigidum* and *R. raphanistrum*. This is done through

investigating a whole range of herbicide resistance management scenarios in a realistic situation, which considers crucial biological and management interactions of two different weeds infesting the same farming system.

Four approaches to cash grain farming systems: impact on weed communities (63)

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A six-year ''Sustainable Agriculture Project at Chesapeake Farms'' near Chestertown, Maryland, USA, was completed in 1999. This project was designed to compare four cash grain-farming systems relevant to the mid-Atlantic region of the U.S. Each system was intensively sampled for a wide-range of parameters, including soil health, nutrient and agri-chemical movement, economic viability and weed communities. The four systems and their respective approaches to weed management included continuous no-till corn with or without a rye cover crop and pre-planned herbicides were applied based on expected weed infestations (System A). System B was a corn-soybean rotation with conventionally tilled corn and no-tillage soybean, with pre-planned herbicides based on expected weed infestations. System C was a 2-year corn-wheat-soybean rotation with no-till corn, conventionally tilled wheat, and no-till double-cropped soybean, utilizing postemergence herbicide programs based on field scouting. System D was a corn-soybean-wheat rotation with rye and hairy vetch cover crops, with reduced rates of postemergence herbicides used to maintain optimum grain yield. Weeds were counted by species in the spring prior to tillage and herbicide application, and in the fall prior to grain harvest. Weed assessments were made designed to detect weed densities and weed community changes over time within each cropping system. Spring weed counts in 1999 were similar for species richness and diversity indices. Total weed density was lower in system C, presumably since this system often received a spring herbicide application for wheat. For fall 1999 data, differences were observed for species evenness and richness. Species evenness and richness in system C was less than the other three systems, although its crop rotation was more diverse than systems A and B. Fall 1999 assessment also indicated perennial weeds were more prevalent in system A, continuous no-till, than the other three system. Data analyses to date indicate weed communities are quite stable and effective weed management, regardless of how it is achieved, will not result in dramatic changes in the weed community.

Influence of direct-seeded cabbage on upland weed vegetation in Japan (64)

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The Tokachi District in Hokkaido is the most famous field crop production center in Japan. Major upland crops in this area are winter wheat, sugar beet, potato and soybean. However, producers are growing some vegetables because of economic concerns. To clarify influence of direct-seeded cabbage on weed dynamics in upland field, weed community diversity and density were investigated in direct-seeded and transplanted cabbage fields. Weed densities increased in direct seeding and also emergence of *Rorippa islandica* increased in addition to common summer type weeds, *Chenopodium album*, *Persicaria longiseta*, and *Echinochloa crus-galli* etc. During growing season of cabbage, *R. islandica* began flowering and produced many mature seeds. These seeds emerged from late summer to fall and winter survival of fall-emerged seedling influence on following rotational crops. In an attempt to help explain the increasing dominance of *R. islandica*, we clarified three factors as follows: 1.Temperature: Germination test in the labolatory indicated that alternating temperature initiate seed germination of *R. islandica*. Temperature at cabbage planting could promote seedling emergence. 2. Soil management: Seedlings of *R. islandica* distributed in the furrow created by the planter for direct seeding. Disturbance of the soil surface could promote emergence. 3.Herbicide: Although soil-applied herbicide (trifluralin) was successful in the controlling common summer type weeds, it did not control *R. islandica*. Herbicide application may increase the density of *R.islandica* because of releasing competition. Results indicated that *R. islandica* should be considered in weed management system for direct-seeded cabbage production in Tokachi District in Japan.

Impact of fodder crops : *Panicum maximum* and *Brachiaria brizantha* on weeds in certain pastures in the parish of Jacunda, Maraba region, Para, Brazil (65)

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During 1976-1977, small farms were settled on virgin forest land in the parish of Jacunda. After several successful years of fodder crop, *Panicum maximum* pastures were invaded by herbaceous vegetation. This invasion consequently brought about an increasing reduction in the height and above-ground biomass of *Panicum*. The introduction of *Brachiaria brizantha* enabled farmers to regain a considerable increase in fodder crop. Sampling of herbaceous vegetation was carried out in seven *Panicum* pastures and three *Brachiaria* pastures. Species richness was measured in each pasture and an abundance-dominance-cover coefficient of the Braun-Blanquet type was attributed to each species encountered. Seed banks were quantified in two *Panicum* pastures and two *Brachiaria* pastures using the seedling emergence technique. Whereas, on average, the species richness of *Brachiaria* pastures was 10 with all species encountered having a low coefficient, the species richness of *Panicum* pastures was 29 , but with certain species having a high coefficient. The invasion potential of the pastures revealed by the seed banks is 10 times higher in *Panicum* pastures than in those planted with *Brachiaria*. The structure of these two pasture grasses is put forward as an explanation of the relationship between fodder crop and weeds. Finally, the study of two adjacent pastures planted with *Panicum* and *Brachiaria* respectively, which initially were one single pasture of *Panicum*, enables us to deduce that, in the constitution of the seed bank of a pasture and in the future establishment of weeds, the role of weeds in the same pasture is far greater than that of those in surrounding pastures. Consequently, it is in the farmer's interest to suppress weeds on his own land as it has a direct effect on the quality of his pastures, even if neighbours in the immediate vicinity do not have the same concern for weed control.

Demographic quantitative and qualitative study of pasture weeds in Tapalque, Buenos Aires province, Argentina (66)

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A survey of weeds was carried out in a consociated pasture of *Agropyron elongatum* and *Lotus tenuis*, in the four seasons of the year in Tapalquè, Buenos Aires province, Argentina, with the aim of determining the ocurrence of weeds and rank them according to their importance. A list of the present weeds was collated, indicating the number of plants per species. The following quantitative variables were determined: density, relative density, frequency, relative frequency, abundance, relative abundance and the importance index. For the qualitative analysis, the scale of Rhochecouste was used for frequency-abundance, and Braun-Blanquet for abundance-cover. There was a predominance of dicot over monocot weeds in the pasture. The families registering the highest importance index were: Asteraceae (65.8%), Poaceae (51.2%), Lamiaceae (43.7%), Apiaceae (34.6%), Cariophyllaceae (14.4%), Primulaceae (11.4%, Plantaginaceae (11.4%) and Amaranthaceae (4.6%). The most important species are: *Mentha pulegium* L., *Cynodon dactylon* (L.) Pers., *Taraxacum officinale* Web, *Ambrosia tenuifolia* Spreng., *Apium leptophyllum* (Pers.) F. Muell and *Ammi visnaga* (L.). In winter, the principal weeds are: *A. leptophyllum*, *A. visnaga*, *Trifolium*

repens L. and *Medicago arabica* (L.); in spring: *M. pulegium* L. *C. dactylon* L. Oers., *Distichlis spicata* L. Greene, *T. officinale*, *Carduus acanthoides* L. and *Cirsium vulgare* (Sary) Airy-Shaw; in summer: *M. pulegium*, *C. acanthoides* and C. *vulgare*, and in autumn: *M. pulegium* and *C. dactylon*.

Effect of glyphosate doses and soybean row spacing on *Anoda cristata* (L.) Schlecht biomass and seed production (67)

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Information about the efficacy of postemergence applications of glyphosate to control weeds in soybean is lacking due to the recent development of soybean resistant to glyphosate. Utilising reduced herbicide doses, narrowing soybean row spacing, or combining both tactics, may result in reductions in biomass and seed production of the weed species. The aims of this study were to evaluate, in a glyphosate-resistant soybean crop planted at 35 cm (S35) and 70 cm (S70) between rows, the response of *Anoda cristata* to different doses of glyphosate and to crop competition. Field experiments were conducted at Zavalla (33°01' S, 60°53' W), Argentina during 1997 and 1998. *A. cristata* biomass and seed production were significantly reduced when growing in a soybean crop. This reduction was greater in S35 than in S70, probably due to higher initial crop biomass in S35 than S70. Glyphosate at label dose (1440 g a.i. ha^{-1}) gave an excellent control of the weed and a 50% response (in terms of biomass and seed production) was obtained with 170 g a.i. ha^{-1}. The combination of row spacing reduction and reduced herbicide doses decreased even more weed biomass and seed production. No seed production was observed when *A. cristata* biomass was lower than 10 g m^{-2} at crop harvest. The RYT showed full competition between species at 12 weed plants m^{-2} in both row spacings. The highest RYT was obtained with 2 plants. m^{-2} of *A. cristata* in S70. It was concluded that glyphosate used below the label rate is adequate to maintain reliable soybean optimum yield and that weed control can be maximized by combining low doses of herbicide with narrower crop row spacing.

Influence of *Chromolaena* and *Mucuna* fallow on weed growth (68)

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In studies conducted at the Nigerian Institute for Oil Palm Research (NIFOR), Benin City, Nigeria between 1995 and 1998, land was left under three fallow systems namely *Chromolaena*, *Mucuna* and natural bush for varying periods of time before cropping. The natural bush fallow (consisting mainly mixture of grasses e.g. *Brachiaria deflexa*, *Setaria barbata*, and some broadleaf species e.g. *Aspilia africana*, *Triumfetta rhomboidea*, *Hippocratea pallens* and *Ficus exasperata* in that order) The natural bush fallow was slashed back regularly before cropping and after crop harvest each year. This ensured the elimination of volunteer *Chromolaena odorata* in the system. Plots were cropped continuously to maize (*Zea mays*) for 4, 3, 2 and 1 year. Weed species diversity and biomass were taken 3, 8, and 12 weeks after planting during each cropping season. Weed species were more diverse when the plots were continuously cropped than when cropped for lesser period. Presence of weeds in the plots did not become significant until the eighth week in the first year of cropping the plots but became so by three weeks after planting during subsequent cropping. Broadleaf weeds mainly, *Ageratum conyzoides*, *Phyllanthus amarus*, *Tridax procumbens* dominated (about 70% in density and biomass) the *Chromolaena* and *Mucuna* plots while grasses, mainly *Brachiaria deflexa* and *Digitaria horizontalis*, dominated (about 80% in density) the plots of natural bush. In all cases, higher weed biomass was recorded as the plots were cropped longer. Grasses and Commelinaceae (mainly *Commelina benghalensis*) also tended to dominate the plots. Weed diversity and

biomass were significantly (P = 0.05) greater under natural bush fallow system. *Chromolaena odorata* fallow gave lower weed biomass but slightly more diverse weeds than *Mucuna* fallow. Generally there was no significant year by fallow system interaction in weed biomass. This study suggests that as short fallow systems, *Chromolaena odorata* and *Mucuna*, can effectively suppress weed growth and diversity.

Relating cropping history and floristic composition of weed communities (69)

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Several studies, in the Rolling Pampas of Argentina, showed that weed communities were indicative of soil degradation caused by different cropping histories. The objective of this study was to use the information of those studies to develop models to describe the relationship of cropping history and floristic composition of summer weed communities. We used information of surveys carried out in three summers in soybean and maize crops and fitted the data to linear and polynomial equations. These equations related the mean constancy of the two floristic groups used to define the communities (the dominant group DG and the group sensitive to differences in soil degradation IG) with the cropping history. The most troublesome weeds for summer crops are included in DG and minor weeds are included in IG. This group is absent when soil degradation is high. We described the constancy of the DG by a polynomial equation ($y = -0.2098x^2 + 5.078x + 43.486$, $R^2 = 0.54$) and the constancy of the IG by a linear equation ($y = -1.6408x + 48.555$, $R^2 = 0.47$), were y is the calculated constancy, and x is the number of cropping cycles. With these equations we can estimate that with less than 5 cropping cycles after a long-term pasture, average constancy of DG will be low (ca. 55) whereas it will be high (ca. 45) for IG. With 5 to 15 cropping cycles, the average constancy will become high for DG (ca. 70) and low (ca. 30) for IG. Average constancy for both groups will become low after 16 or more cropping cycles.These simple regession models may help characterize site quality when we have identified the weed community in a field or infer the structure of the weed community by the cropping history. We discuss how this information can be used to program pre-sowing and pre-emergence weed control options.

Behind the scenes: considerations of plant-soil-animal interactions (70)

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In an ecological sense, a community is comprised of all the biotic components of an ecosystem. In an agroecosystem, crops, benign or beneficial plants species, and weeds are among the most conspicuous community members. However, soil microorganisms and micro-, meso- and metafauna play a major role in ecosystem function and community dynamics. Likewise in pastures, megafauna (ie. grazing animals) can have a major impact on community structure. In this paper, I will broadly outline the range of community interactions that may directly or indirectly influence weed population dynamics and weed-crop interactions. From my own research, I will focus on post-dispersal granivory, the implications of soil chemical ecology on seed bank dynamics, and the potential effects of soil quality on weed-crop competitiveness.

The "system management approach": a tool and a potential biocontrol solution (71)

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The system management approach (SMA) was proposed to complement the well established classical and bioherbicide approaches of biological weed control. It uses indigenous organisms, like the bioherbicide

approach, and is based on the innate capacity of the natural enemies to reproduce as with the classical approach. The SMA enables the use of indigenous biotrophic fungi, whose host specificity is relatively stable, but that can rarely be cultured on artificial media. Biodiversity is now a major issue in ecology and nature conservation. In the future, agriculture may better contribute to biodiversity conservation by moving away from the clean crop concept towards tolerance of weeds. To find acceptance, the impact of weeds on crop yield would have to be minimised by reducing the competitiveness of weeds without killing them. The SMA takes into account this modern view to weed control by focusing on reduction of competitiveness of weeds. Thus, three criteria are used to select a biocontrol agent suitable for the SMA, (1) an indigenous, host-specific natural enemy, (2) an organism with an innate capacity to reproduce and spread relatively easily, and (3) a natural enemy that reduces the competitiveness of its host without killing it. The rust fungus *Puccinia lagenophorae*,infecting the annual weed *Senecio vulgaris*,met these three criteria and we have used it to develop the SMA. The experimental analysis of epidemics, caused by the reproduction and spread of pathogens such as rust fungi, and its impact on crop-weed competition, are the major topics presently being studied. Basic knowledge of the mechanisms underlying these weed-antagonist interactions may also serve as a tool to optimize weed biocontrol programs using the classical or bioherbicide approach.

Progress in rice allelopathy research (72)

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Over the last decade, several scientist around the world have been working on utilization of allelopathy in rice as a tool for integrated weed management. Understanding of the role of allelopathy in the plant to plant competition complex is essential to be able to optimize modern crops for weed suppression. Around 3.5% of rice accessions are allelopathic against one or more weeds. Experimentation to prove the importance of allelopathy in rice have included a range of laboratory, greenhouse, field experiments, chemical identification of allelochemicals and finally genetic studies to reveal the genetics of allelopathy. In the field, 34% of the variation in weed suppressing ability can be accounted for by allelopathy. Allelopathy in rice is not correlated with any morphological characteristics in rice and are expressed in both traditional and modern rice cultivars. This means that there are no genetics links to plant features that will determine yield, and as such allelopathy have insignificant physiological costs. Four QTLs correlated with allelopathic potential in rice has been located on three different chromosomes. Identification of allelochemicals using bioassay guided isolation has been started and, so far, yielded in 24 fractions of putative allelochemicals. Studies on mechanisms of allelopathy have also been started and results show that allelopathy increase with plant age. This means that cultivars that are allelopathic enough early in the season might only need limited input from other weed management action to be successful. Future work on allelopathy should include a thorough understanding of allelopathy mechanisms as well as identification of allelochemicals and genes of rice allelopathy. Furthermore, it is important to state that, before release of allelopathic rice cultivars, ecotoxicological studies must have been done to ensure us from new environmental problems. Finally, going hand in hand with plant competition studies, allelopathy can prove to be the missing link in understanding of plant interactions.

Allelopathy in rice as a weed control strategy (73)

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More than 50 weed species infest direct-seeded rice (*Oryza sativa* L.) and cause major losses in U.S. rice production. Annual losses due to weeds in rice have been estimated at about 17% of the total production.

Barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], a weed that is found primarily in dry-seeded rice fields can cause almost total loss of field yields and is the most frequently reported weed in rice. Ducksalad [*Heterantheia limosa* (Sw.) Willd.], an aquatic weed that can reduce rice yields by 30% when competing with rice in a water-seeded culture, is second to barnyardgrass as the most frequently reported weed in rice. Allelopathic activity is believed to be the joint action of several secondary metabolites that may act synergistically. Cultivars of rice with allelopathic activity to major weed species could reduce the loss of field yields due to weeds and reduce herbicide costs. We evaluated the USDA-ARS rice collection and identified accessions or varieties with apparent allelopathic properties to weed species, prevalent in either water-seeded or dry-seeded culture, that can be used in variety development programs. A total of 412 rice accessions were identified in field tests in 1988, 1989 and 1990 that had a radius of activity τ10 cm to ducksalad and 145 accessions that had the same radius of activity to redstem (*Ammannia sp.*). In 1994, a total of 94 accessions demonstrated apparent allelopathic activity to barnyardgrass in field tests. In barnyardgrass infested plots, the grain yield reduction of rice accessions that demonstrated apparent allelopathic activity was 37% as compared to a 68% reduction in grain yield of non-allelopathic accessions. Field and greenhouse trials have shown a reduced number and size of both ducksalad and barnyardgrass plants when grown in the presence of apparent allelopathic rice versus non-allelopathic rice. Chromatograms of allelopathic and non-allelopathic accessions fall into two types, one which is represented by the allelopathic accession PI 312777 and the other by the non-allelopathic cultivar ‘‘Rexmont’’.

Effects of four weed extracts on lettuce (74)

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Aqueous and hydro-alcoholic extracts of *Cenchrus echinatus* L., *Commelina benghalensis* L., *Cyperus rotundus* L. and *Indigofera hirsuta* L. were prepared with whole plants and applied on lettuce to verify the possible allellopathic effects. Also, dry matter residues of these especies were mixed with soil, in pots to verify the effects on lettuce plants. The weeds were harvested, dried at 60 C for 72 h, ground in a mill with sieves less than 1 mm^2. One g was weighed and mixed with 10 ml water for aqueous extracts and 50% alcohol + 50% water for hydro-alcoholic extracts. After resting during 10 hours, they were filtered, pasteurized and maintained in refrigerator. To verify the possible allellopathic effects on lettuce, experiments were carried in the greenhouse, where lettuce plants were cultivated with Hoagland nutritive solution and added weed extracts (0, 0.25%; 0.5% and 1%). Data was collected for above ground and root dry matter. No significant differences were observed between treatments using aqueous extracts but there was increased reduction with 1% concentration by *C. rotundus*, *C. echinatus* and *C. bengalensis*, using hydro-alcoholic extracts. Addition of weed dry matter at 3.0% concentration, the number of leaves in lettuce plants was increased by 28.02% in presence of *I. hirsuta* dry matter, reduced 43.94% by *C. echinatus*, reduced 64.4% by *C. rotundus* and reduced 100% by *C. bengalensis*. It was concluded that only hydro-alcoholic extracts presented possible allellopathic effects.

An eudesmanolide isolated from *Hyaloseris salicifolia* Griseb. with herbicidal activity in *Brassica campestris* L. (75)

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Some species of Asteraceae are characterized for the production of secondary metabolites with varying biological activity, inducing an inhibitory effect on germination and growth. In this work, a lactone from *Hyaloseris salicifolia* Griseb. was used. It was identified by espectroscopic methods as ivasperin (eudesmanolide1-hydroxialantolactone) The objective of this work is to study the effect produced by ivasperin on the germination and growth of *Brassica campestris* L. Germination percentage, radicle and hypocotyl length, conductivity of the cellular efflux and mitotic index in tip roots were determined. Seeds of *B. campestris* began to germinate with different concentration of the ivasperin (300, 600 and 1000 ppm) using bidistillated water and chloroform as control. After 96 h, number of the germinated seeds, radicles and hypocotyl length was determined. Then, radicles were placed in 5 ml. of bidistillated water during 15 h at 25C, in order to obtain conductivity of cellular eflux value. Also, dry matter was determined. For mitotic index, tip roots were fixed in 3:1 ethylic alcohol: glacial acetic acid. They were hydrolized in hydrochloric acid at 58C and then colored with 2% hematoxiline. Data were statistically processed. Results showed that the number of germinated seed was not affected by ivasperin, but a decrease in the radicle and hypocotyl length was observed, with significant differences between control and 300 and 600 ppm, and presence of abnormalities in the radicle morphology. Conductivity showed a decrease to 300 ppm but without statistical differences among treatments. As for the mitotic index, we also detected a decrease in the cellular division rhythm as the ivasperin concentration increased, particularly at 600 and 1000 ppm. It is possible to establish a relationship between decrease of the mitotic index and decrease of the radicle and hypocotyl length. These results should be kept in mind in future investigations searching for natural herbicidal products.

Weed phytotoxicity: an ecological perspective (76)

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Allelopathy has been suggested as a potential mechanism to explain weed phytotoxicity. Allelopathy, however, can not be implicated in many studies on weed interference due to less realization of substratum ecology and natural ecological factors. Significance of ecological factors will be discussed by taking examples of two arable perennial weeds, *Pluchea lanceolata* and *Artemisia vulgaris* (Asteraceae), and a boreal forest understory shrub, *Kalmia angustifolia* (Ericaceae). Nature is too dynamic to be explained by one mechanism of interference. In natural settings, interference mechanisms, e.g., resource competition, allelopathy, microbial nutrient immobilization, mycorrhizal activity and microbial nutrition competition may operate in parallel, and synergistic activities of these mechanisms can better explain weed interference. To demonstrate allelopathy, weed and its substratum have to be taken in totality as a unit. Allelopathy studies should be designed by taking multifaceted approach encompassing different facets of substratum. It is almost impossible to demonstrate that allelopathy is solely responsible for observed plant growth inhibition. We can only demonstrate the possibility of allelopathy as one of the potential mechanism of weed interference.

Allelopathic effects of *Brachiaria brizantha* (Hochst.) Stapf on seed germination of pasture weeds and tropical forage species (77)

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Effects of *Brachiaria brizantha* (pasture) allelochemicals on seedbanks has been observed in Brazil. Two experiments were carried out in Sao Paulo State University-Brazil, one with a sandy soil (87% sand) and another with a clay soil (56% clay). Soil solution from pasture soils with *B. brizantha* stands three years or older was sampled with the objective of evaluating the allelopathic effects on seed germination percentage, dormancy, mortality, abnormal seedling, germination rate and seedling growth of pasture weeds and tropical forage species: *Cassia tora* L., *Peschiera fuchsiaefolia* Miers, *Sida rhombifolia* L., *Brachiaria plantaginea* (LINK) Withc., *B. brizantha*, *B.decumbens* Stapf., and *Panicum maximum* Jacq. cv. Tanzania and Mombasa. There was also a control with *Latuca sativa* L. cv. Great Lakes 366. The treatments were the same for both soils: soil solution from the *B. brizantha* pasture, soil solution from the forest (situated nearby with the

same soil), water distillate and PEG solution. The soil solution from *B. brizantha* showed inhibitory effects on roots of *S. rhombifolia* in sandy soil, and on germination percentage of *P. maximum* cv. Tanzania in clay soil.

Relationship between sorgoleone production in the laboratory and the field, and effect on weed density and growth (78)

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Sorgoleone, a long chain hydroquinone exuded by sorghum roots, exhibits allelopathic potential against weeds. The objectives of this work were: to assess sorgoleone production in the field on three sorghum genotypes with different sorgoleone production potential in the lab; and to relate the sorgoleone production in the field with weed density and growth. In the experiment conducted in laboratory, fifteen seeds from BR 304, RS 11 and BR 601 sorghum genotypes were placed in petri dishes and lined with moistened filter paper, and were germinated in germination chamber at 29 C for 5 days in the dark. Two hundred seedling roots for each genotype were excised and dipped in methylene chloride plus 1% glacial acetic acid to extract sorgoleone. In the field experiment, conducted in randomized complete block with four replicates, the same sorghum genotypes used in laboratory were assessed, plus a pearl millet crop and a check without crop. Sorgoleone production in the field was extracted excising roots from plants in 0.5 m row, washing them with water to remove soil, and dipping them in the same solution and conditions an in the laboratory experiment. Overall, the quantity of sorgoleone produced per dry matter of roots in laboratory was seven fold higher than in the field. There was little variation in sorgoleone production per dry matter of roots among sorghum genotypes in laboratory. However, in the field, sorghum BR 304 yielded more sorgoleone per root dry mass than BR 601. Compared with soil without cover crop, either sorghum or pearl millet reduced weed dry mass by 75%, weed density by 41%, and weed size by 51%. BR 601 sorghum genotype was less efficient in decreasing weed dry matter than pearl millet. Overall, weed density and growth in the field were not different on plots with either sorghum or pearl millet. The weak relationship between sorgoleone production and weed density and growth in the field suggests no sorgoleone allelopathic effect in the field.

Allelopathic effects of *Brachiaria decumbens* on annual crops (79)

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The present research consisted of eleven experiments divided in four stages. The experiments were carried out in FCA/UNESP, Botucatu, SP, Brazil. In the first stage, the effects of *Brachiaria decumbens* collected in different seasons on the initial growth of corn, rice, wheat, soybean, bean, cotton and *B. decumbens* were evaluated. Among the seven tested crops, *B. decumbens* was the most sensitive to the effects of its own dry matter. The inhibitory effects were more intense for *B. decumbens* collected in the rainy season. In the second and third stages, effects of increasing concentrations and decomposition periods of ground dry matter of *B. decumbens* on the initial growth of corn plants were evaluated . The lowest concentration that reduced the growth of the corn plants was 1.5% (w/w). The inhibitory effects were noticeable up to 105 days after the incorporation of the dry matter into the soil. In the fourth stage, the strengh and duration of inhibitory effects as affected by the size of the dry matter particles were compared. Larger fragments, compared to ground material, produced less intense and longer lasting effects. If the dry matter in large

fragments (3 cm) was kept at the soil surface, inhibitory effects on corn plants were not detected. The dry matter of *B. decumbens* reduced significantly the amounts of nitrate in the soil in all the studies, independently of the concentration, decomposition periods, size of the fragments and position in the soil.

Allelopathic potential of coffee (*C.arabica*) and rice (*O. sativa*) rusks on seed germination and intital growth of *Amaranthus viridis* (80)

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The differentiation of allelopathy and competition using plant residues as mulching for weed control is difficult. A greenhouse study was stablished to determine allelopathic effects promoted by coffee and rice husks on *Amaranthus viridis*. Husks were placed on top, in the seed layer, and below seed layer, attempting to distiguish the effects on seed germination and seedling growth in pots. Coffee and rice husks inhibited seed germination and stimulated growth of *A. viridis*. Rice husks showed lower germination rate index and percentage of germination than coffee husks. Coffee husks placed at the surface allowed greater plant height and dry matter content than any other treatment, and was followed by the same mulch when incorporated into the seed layer.

Reproduction biology and allelopathic effect of *Reseda lutea* L. (81)

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Reseda lutea is indigenous to the Mediterranean Basin and Asia minor, but it has been spread widely around the world. In Hungary, it is one of the difficult to control weeds in onion fields. Between 1997 and 1999, examinations were carried out in four replicates under laboratory and field conditions to study the biology of the weed. The primary dormancy of the weed seeds ceased 8 weeks after ripening. The optimum temperature for germination was 24 C. Light seemed to inhibit germination. Both stratification and gibbererellic acid treatment enhanced the germination rate. The seeds of *R. lutea* emerged from the upper 3 cm layer of soil. The maximum value of emergence (6%) occurred at 0.5 cm. Field emergence of *R. lutea* started at beginning of May, with the increase in temperature. In the two-year average the 6.8% of the seeds germinated from May until the beginning of June. In 1996, there was no emergence in the further part of the year, while in 1997 at the end of July, the degree of the germination was 1.5 %. The vegetative reproduction of *R. lutea* is important. The weeds can regenerate from primary as well as secondary root fragments. The roots of *R. lutea* are in a dormant state from June until September. The water extracts of its fresh roots and shoots did not influence the germination of wheat, maize, sugarbeet and rape. The alcoholic extract of roots and shoots significantly reduced the germination of wheat. The germination of sunflower was inhibited by alcoholic extract of roots. *R. lutea* is a serious weed because of its ability to reproduce by seeds as well as root fragments. The study of its biology is the first step to work out the integrated weed control against this weed.

Use of jack bean [*Canavalia ensiformis* (L.) DC] for purple nutsedge (*Cyperus rotundus* L.) control (82)

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Purple nutsedge is a perennial weed that resists most common control measures, mainly, due to its propagation mode. Under central pivot area, there is not hydric stress so purple nutsedge finds ideal conditions for growth and fast multiplication In Brazil, the organic agriculture associations recommend the use of jack bean for the efficient control of purple nutsedge due to its allelopathic properties. The literature report several cases about it. Considering this information, the sowing density effect (0, 7, 14 and 21 seeds m^{-2}), plant cutting times (at growth, bloom and pod filling stage and total cycle) and plant material incorporation (without and with incorporation) of jack bean on the development of purple nutsedge, in field conditions was studied in Ribeirao Preto, Sao Paulo State, Brazil. The treatments were combined factorially, placed in bands under central pivot, with four replications during two years. Before the experiment installation and until the end of the cycle plant,, purple nutsedge plants were counted and height was measured monthly. In the first year, we observed a linear increase in the purple nutsedge number when the sowing density of jack bean was increased. It didn't occur in the second year. For the plant cutting times, the purple nutsedge number decreased in both years occurring the lowest purple nutsedge number when jack bean plants remained till the end of the cycle. From the jack bean bloom stage till the end of plant cycle, the purple nutsedge height remained the same in the different treatments. In the first year, the purple nutsedge number was lower in the plots with the incorporation of the plant material. The opposite occurred for the purple nutsedge height. In both years, purple nutsedge number was reduced according to a second degree equation. The smaller value of purple nutsedge number was observed at 89 and 125 days, respectively, for the first and second years. The same occurred to purple nutsedge height in the first year but the lowest value was observed at 124 days. In the second year, purple nutsedge height showed a linear decrease.

Seedling recruitment of *Echinochloa crus-galli* in relation to rice establishment method and companion cultivar (83)

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This glasshouse study investigated the seedling emergence of *Echinochloa crus-galli* L. Beauv. in the presence of rice in relation to crop establishment method (dry-seeding versus wet-seeding), and timing and placement of weed seeds [surface seeding at crop establishment, surface seeding 10 days later, and seeds incorporated into the topsoil, (max 3 cm) at crop establishment]. Four different rice cultivars were used: AC1423, AUS257, (allelopathic in laboratory study) AUS 196, and IR72 (non-allelopathic in laboratory study). Pre-soaked seeds of rice and weed were planted separately into moist soil (dry seeding) and fully saturated soil (wet seeding) in large buckets in the glasshouse. Weed emergence was then observed at 2, 4, 6, 8 and 10 DAS. Number and weight of all surviving *E. crus-galli* plants were recorded 30 DAS. Rice was then grown to maturity and cut at soil surface. At either 4 or 8 weeks after harvest of rice, dry topsoil and remaining rice stubble was mixed and pots re-sown with *E. crus-galli* to evaluate potential cultivar residual effects on weed seedling recruitment. Wet seeding substantially reduced both the rate of weed emergence and the total number of emerging weeds. Furthermore, burial of weed seeds reduced the total emergence. There was a significant differential cultivar effect on the emergence and subsequent size (shoot and root biomass) of *E. crus-galli* when re-seeded into incorporated rice stubble. This effect was more pronounced 4 weeks after rice harvest.

Succession and evolution in weed communities: future challenges (84)

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Farmers have historically used practices such as weed eradication, control, and management to reduce weed problems. Succession and evolution in weed communities have continually curtailed the achievement of the specific goals to which each of these practices was aimed. Despite the large existing body of empirical information on succession and evolution, theory on these processes is seldom used to design weed control or management practices. Only recently, after the worldwide occurrence of herbicide resistant weeds, evolution became an important issue when designing control strategies. My purpose is to present information on changes in landscape and weed communities related to land-use, and to use this information to discuss how ecological and genetic theory could be used to understand changes in weed communities and to improve weed management practices.

Impacts of forest management on unwanted plant species (85)

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Most forest ecosystems are characterized by some level of periodic disturbances, which range in severity from stand replacement events to relatively small changes in tree canopy opening. Although some of these disturbances are natural in origin, increasingly major effects to both forest over- and under-story species are human-caused. It is, thus, quite possible that changes in species abundance and composition are the result of human activities and not the normal course of succession. Three models of succession have been proposed to account for such shifts in species dominance and longevity. The most commonly accepted model is that of competition or inhibition. However, adherence to this model of succession almost always requires a further level of human manipulation-sometimes advancing succession to a more advanced stage but often creating a more simplified forest structure which exacerbates the occurrence of unwanted, weedy vegetation. This paper considers that other models for succession following disturbance exist than competition, which may be more relevant for many managed and unmanaged forest ecosystems. Further, we suggest that biological thresholds be adopted when the competition model is employed to improve species diversity and reduce management costs.

Eco-processes in shrub invasion of tropical woodlands (86)

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At least ten exotic shrub species are serious invaders of northern Australian tropical woodlands and grasslands. They are heterogeneously distributed at national, regional and landscapes scales. These patterns reflect the history of invasion, the disturbance regimes and habitat variability. Many of the invasive species grow most densely in riparian zones and other relatively low-lying parts of the landscape. They drastically alter the structure of the communities they invade, often forming monospecific stands and sequestering a large proportion of the available resources. There are important links between invasive shrubs in northern Australia and the cattle industry that, historically, has dominated the region. Most of the invasive shrub species were deliberately introduced to benefit the cattle industry, by providing forage and/or shade. Cattle (along with other native and introduced herbivores) have played a major role in the dispersal of invasive shrubs. Cattle are also important in the disturbance regime of modern northern Australian rangelands with

the impacts of cattle being greater in riparian zones. Many of the dominant perennial tussock grasses are susceptible to the grazing regimes that have been imposed, and their decline may have facilitated the establishment of grazing-tolerant shrubs. In many areas, grazing has reduced fire frequency and intensity by affecting fuel dynamics. This has probably facilitated the proliferation of native and exotic woody species. Some shrubs species are highly susceptible to fire.

Weed community diversity and cropping systems: concepts and applications (87)

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Diversity is a measure of heterogeneity in a community. Diversity indices account for species richness, the number of species in a community, weighted by species evenness, the relative importance of species within the community. The concept of diversity lies on the assumptions that: all individuals of any species are equal; all species are equally different; samples used in calculations are large enough to represent the community adequately. In natural vegetation communities, diversity generally increases over the early successessional stages and decreases in the later seral stages. In the early seral stages, diversity increases as disturbance decreases. By analogy, it is thought that the adoption of zero-tillage should create conditions favourable to higher weed diversity in the agroecosystem. However, contrary to intuitive belief, conservation tillage practices applied in different forms to various soil types did not cause major increases in weed diversity. Reduction or absence of soil disturbance has little effect on weed diversity compared to that of other crop management factors. Overall, the selection pressure imposed by level and effectiveness of herbicide input has the largest impact on weed diversity, regardless of tillage. Herbicides also have the greatest impact on density/biomass relationships, as captured by *K*-dominance curves. Cropping systems with intensive tillage and weed management show density curves above that of biomass, a relationship that is indicative of stressed environments. Less intensively managed cropping systems show overlapping density/biomass curves but also biomass curves lying above that of density curves, suggesting environments more favourable to the development of weeds. Diversity indices and dominance-diversity curves are useful in grasping part of the complexity of weed communities but must be interpreted with care, given that fundamental assumptions are only partially met.

Shift in weed flora in rainfed wheat under moisture stress in Punjab, Pakistan (88)

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Vegetation shift is an important ecological phenomenon. In order to develop weed management technology, it is important to know about shifts in weed flora composition and species dominance value from time to time. The shift could be caused by invasion, crop management practices, or a change in the ecological factors. The weed flora of the study area was analyzed for weed species, density, frequency, weed biomass and weed moisture. Over a period of ten years, two observations were made: 1986-87 and 1996-97. The comparison of the data reveals that there was an appreciable shift in terms of weed species encountered, their density and all other parameters measured in this regard. Nine weeds invaded the area whereas one weed disappeared during the period of ten years. Three other weeds which have been reported in between these ten years, were also found missing in 1996-97. A shift in the importance value of weeds, calculated on the basis of density, frequency, biomass and moisture, was also observed.

Rubus niveus (Thunb.): the worst weed in the Galapagos Islands? (89)

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Rubus niveus is a serious weed because of successful biological traits; native plant and animal communities are threatened; it renders agricultural land useless and; is extremely difficult to control. The aim of this paper is to discuss some biological characteristics of *R. niveus*, its threats to the fragile Galapagos ecosystem and methods of integrated control. *Rubus niveus* was first recorded in the Galapagos Islands on San Cristobal in 1983, Santa Cruz in 1985 and Isabela in 1989. It invades national park and farmland in the humid highlands where plant endemism is high. Much of these area have already been altered by agricultural activity. Native plant communities such as those dominated by *Scalesia pedunculata* (Hook. f.) are threatened because dense infestations of *R. niveus* prevent regeneration. Furthermore, there is a huge threat of it spreading to some of the pristine islands. *Rubus niveus* has many successful biological traits. It can produce seeds continuously throughout the year depending on rainfall and temperature. In November of 1999, 20,780,250 potentially viable seeds m^{-2} were produced. Long distance dispersal is primarily by birds, four of Darwin's finches have been observed feeding on the fruit. It has a large long-lived seedbank and seed dormancy mechanisms. Of seeds buried for 7 months, 46% were potentially viable. Compared to untreated seeds, those buried in ground for more than 3 months or treated with hydrochloric acid germinated. Vegetative reproduction is also common. Depending on its distribution we have taken two management approaches. On Isabela, where it is still limited, we are attempting complete eradication with a combination of chemical and manual methods. On San Cristobal and Santa Cruz, where it is widespread, we are developing plans which integrate various chemical and manual methods with novel approaches such as grazing with high densities of goats.

Shifts of species groups in crop-weed communities of the Pampas during 1926 to 1999 (90)

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Agricultural activities fragment the habitat of native grassland species, but they also relax competition by reducing plant density, and affecting soil nutrient mineralization. We hypothesized that community composition should vary in relation to the increase in crop area since agricultural activities affect the availability of propagules, nutrients and physical space, favoring the establishment of different species. Our objective was to compare cropland and grassland communities, and analyze their floristic and functional structures to relate them to the expansion of agricultural activity. To compare grassland (1930 and 1995) and crop communities (1926, 1960 and 1999), we used historical data and new phyto-sociological surveys. Crop surveys were carried out in wheat, flax, corn and soybean in the Rolling Pampas (Argentina). Cluster analysis was used for species. Changes in species origin, morphotype and life cycles were also studied. The crop communities for 1926, 1960 and 1999 and the grassland communities shared 48%, 52% and 60% of their species. Species (387) were classified into 15 groups and related to the increase in cropped area. There was a persistent group of species in the cropped fields that was characterized by exotic annual-dicotyledoneous species. In the 1995 grassland surveys, a group that was characterized by native annual-dicotyledoneous species was lost. In the 1926-99 period, 30 species were incorporated to the cropped-land and grassland communities. Almost all of the new species were exotic dicots. Similarity between the grassland and crop communities increased over time. Persistence, loss and incorporation of species groups may be an indication that species in each group share similar adaptative traits fitted to determined levels of agricultural stress.

Dominance structural index for *Sicyos polyacanthus* Cogn. in sugarcane (91)

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Sicyos polyacanthus Cogn. predominance on other harmful sugarcane weeds is structurally analyzed in five localities in the central region of Tucuman piedmont zone (Argentina). The index used is based on modifications of Simpson's index and it takes into account: species number, height or length, and dry biomass in relation to number and total biomass. All sugarcane weeds exceed *Sicyos* in number (density) but it is essential to know the population structure of this species in strict relation with growth habits to determine the predominant one. As a result of this study, we set a predominance pattern with maximum, medium and minimum values. Values found for all localities and different varieties neither surpassed maximum theorical index nor were under the minimum. In some localities, *Sicyos* predominance structural index surpasses that of other species, except that for *Sorghum halepense*. *Sicyos* dry biomass index surpassed that of other weed species, except *Cynodon dactylon* at one locality.

Weed communities associated with wheat and pea crops in the Rolling Pampas (92)

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Wheat (*Triticum aestivum* L.) is the most important winter crop grown in the Rolling Pampas while pea (*Pisum sativum* L.) have limited distribution. Pea is a feasible crop alternative in this region and its sown area may increase, affecting winter weed communities function and composition. In order to evaluate the extent of the differences between pea and wheat weed communities the floristic composition of field crops was described and compared. Eighteen pea and four wheat fields were surveyed during 1999. A set of 32 wheat fields surveyed in 1996 was also included in the analysis, since they did not significantly differed from the recent wheat surveys. In each field, species presence was recorded and their abundance determined by ground cover estimations. Floristic composition was studied by multivariate analysis, considering only species with constancy greater than 10%. Cluster analysis was used to define species groups, and reciprocal averaging was applied to define fields ordering. Total and mean number of species surveyed were 71 and 20, and 60 and 13 in pea and wheat fields, respectively. Species diversity and constancy were greater in pea fields. Eigenvalues obtained were 0.51, 0.37, and 0.28 for Axes 1, 2, and 3, respectively. Axis 1 clearly represented the contrast between pea and wheat fields. When abundance values were plotted against Axis 1, *Cotula australis* (Sieb.) Hook (constancy = 79%) was associated to pea fields and a group of winter annuals to wheat fields [*Bowlesia incana* Ruiz et Pav., *Stellaria media* (L.) Vill., *Coronopus didymus* (L.) Smith, *Carduus acanthoides* L.], despite the fact that they were present in pea fields but with higher constancy and lower abundance. In both wheat and pea fields, *Glycine max* L., and *Zea mays* L. were present as volunteer crops; however, wheat plants were observed only in pea crops.

Early biomass production and composition after breaking up of an old-field. Seed bank or environmental constraints? (93)

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Our main goal is to determine what factors are controlling the early production and composition of an old-field submitted to a severe perturbation such as intense ploughing. In which extent production and

composition are controlled either by soil seed bank composition or by environmental constraints. With this in mind, we have carried out an experiment on a sporadically grazed old-field located near Vitoria (Basque Country). This site is located in the submediterranean region. First of all, the sample site was fenced and then, three environmetal factors controlling emergence and plant growth, such as light, water availability and nutrient status were manipulated in our experimental design (one degree of freedom for treatment). Each of the eight treatments were replicated five times for a total of 40 randomly arranged plots. The following treatments were conducted after breaking up the experimental site in January: U) addition of 6 g m^{-2} of urea in February of 1999; S) shading mesh 50%, 1 m above soil; W) 6.2 L m^{-2} water addition fortnightly during June and July. In March, we took 3 soil samples per plot, mixed them up and let them germinate to estimate the soil seed bank ready to grow in each plot. In the second week of July 1999, each plot was harvested by clipping the plants of an area of 50 x 50 cm at ground level. The material was separated by species in the laboratory and the dry weights were obtained for each species. Preliminary results suggest that the most productive combination of treatments was that with urea and no shade. On the other hand, annual plants (like *Sinapis arvensis*, *Anagallis arvensis*, and others) are more abundant in no shading treatments whereas perennial grasses (*Agropyron repens*, *Arrhenatherum bulbosum*, and others) dominate in those with shading mesh.

Positive vs. negative interactions in *Picris hieracioides* L. over secondary succession in Mediterranean old fields (94)

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Picris hieracioides (Compositae) is an annual or biannual herbaceous plant that colonises the early and mid-stages of post-cultivation succession in the Mediterranean region. We report on an investigation of the responses of *P. hieracioides* populations in two old field communities of differing ages. A reciprocal transplant experiment among populations and stages was performed to compare survivorship, growth and reproductive patterns of populations and stages of abandonment. In addition, individual performances were evaluated in each stage with respect to: (1) competition with neighbours (tested with a weeding treatment) and (2) resource availability (tested with nutrient and water addition) in an effort to investigate some of the ecological factors influencing the performance of *P. hieracioides* in Mediterranean old fields. The results suggest that the mechanism allowing the persistence of Picris populations is the high individual phenotypic plasticity rather than a population response to directional selection during succession. Our results demonstrate that the interactions between *Picris hieracioides* and the other plants of the community are the result of two kinds of process.: The first is the positive interaction or facilitation effect, which is mainly apparent during recruitment because of the decrease in seedling mortality, vegetation reduces the impact of predation by wireworms of genus *Agriotes* and protects seedlings from desiccation. The second is the negative interaction or competition effect, which becomes dominant later in the life cycle and appears through lower growth and reproduction. The addition of resources does not change the strength of the facilitation effect on survivorship pattern either in the young or in the old fields. However, growth and reproduction of established plants are facilitated by resource addition.

Species composition and spread of weed flora in Belarus (95)

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Itinerary inspection of barley weed infestation in fields of Belarus was done in two rounds, the first one from 1981 to 1985, and the second round from 1996 to 1999. The inspection provided an opportunity to determine the species composition of weeds and their spread in barley field agrocoenosis. By the results of the received information, an opportunity was created to follow the tendencies of weed spread in agroclimatic oblasts of the Republic. As a result of itinerary and field research in barley, about 70 weed plant species were found, the most widely spread and harmful include approximately 17 species, among them: *Elytrigia repens* L. (32%), *Echinochloa crus-galli* L. (26), *Stellaria media* L. (4), *Sonchus arvensis* L. (4), *Viola arvensis* Murr. (3), *Matricaria inodora* L.(3), *Chenopodium album* L.(2), *Poa annua* L.(2), *Galeopsis* spp. (2), *Polygonum scabrum* Moench. (2), *Polygonum convolvulus* L. (1), *Spergula arvensis* L.(1), *Equisetum arvense* L.(1%) and others. A majority of weed species grow to an equal degree throughout the Republic, with the exception of *E. crus-galli* which prevails in barley in the Southern agroclimatic oblast of Belarus (80-122 weed plants m^{-2}) and *Agropyron repens* (75-87 weed plants m^{-2}). In the Northern agroclimatic zone, there is at present a tendency in increase for *A. repens*, *E. crus-galli*, *S. arvensis* and of a certain decrease of such resistant species as *S. media*, *M. inodora*, *Viola*, *Polygonum*, *Galeopsis* spp.

Field studies to determine weed associations in tree fruit at the Maracaibo plateau, Zulia state, Venezuela (96)

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This work was conducted, in order to determine weed associations in four species of tree fruit, located at Mara municipality, Zulia state, Venezuela. The area is classified as a very dry tropical forest, with a sandy loam soil, Typic haplargids. The study was based on a floristic survey of weeds on four stratified sample for each four species of tree fruit: grape (*Vitis vinifera* L.), citrus (*Citrus* spp.), guava (*Psidium guajava* L.) and sapotilla [*Manilkara zapota* (L.) Royen]. The dominance of the different species was considered according to their frecuency and density, as well as a taxonomic and agronomic aproach of the main weeds. The results show weeds with a relative dominant index (RDI): *Cynodon dactylon* (L) Pers, *Boerhavia decumbens* Vahl, *B. erecta* L, *Digitaria sanguinalis* (L) Britton, *Melochia fasciculata* Benth, *Cenchrus echinatus* L, *C. ciliaris* L and *Eleusine indica* (L) Gaerth, as the most relevant weeds associated with the crops tested.

Changes of weed population in Hungarian fields based on four country-wide weed surveys (97)

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Knowledge on weed populations in agricultural areas is essential from biological, crop production and weed control viewpoints both for professionals and farmers. In Hungary it was first realized by Újvárosi who started research in 1947. Principles of survey were outlined and the first national weed survey was conducted in 1949 and 1950. It was followed by three other surveys: in 1969-1971, 1986-1987 and 1996-1997, conducted by the herbologists of the county plant protection stations trained by him. Weed population characteristic of cereals is richest in winter wheat, that of row crops is best developed in maize. If data recorded at a site surveying wheat and maize fields as well as wheat stubbles are summed up, weed population for three seasons characteristic of the particular area will be almost completely obtained. Locations and number of sites were determined to ensure that particular regions and soil types characteristic for field crops be represented according to their national importance (202 locations, 17 soil types). Surveys were made in two consecutive years in winter wheat and maize, two times a year, at 10 sites per location. Surveyed areas were herbicide-free. It was concluded that significant changes occurred both in ranking of weed species and proportion of area covered by them. Significant breakthrough was observed with *Ambrosia artemisiifolia* L., *Datura stramonium* L., *Xanthium strumarium* L. and among annual monocot weeds e.g. *Panicum miliaceum* L. Unfortunately among perennial weeds tendency is similar with *Cirsium arvense* Scop., *Sorghum halepense* Pers. and *Elymus repens* Gould. Furthermore, it was conspicuous that the listed species have not only ranked up but their cover % also doubled compared to previous survey period. An especially big problem is caused by the fact that the trend in decreasing cover of perennial weeds since 1950 stopped, and even began to increase.

The role of weeds in the reduction of fertilizer leaching in a banana crop in the humic tropic (98)

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Banana production in the humid tropics of Central America is characterized by excessive rates of inorganic fertilizer applications. The objective of this work was to analyze the role of weeds in reducing the leaching of fertilizer applied to banana plantations. Six experimental plots of 150 m^2 were kept for three years on a sandy loam soil with the following percentages of weed covers: 0, 20, 40, 60 and 70. Visual evaluation of weed cover in each plot was made weekly to determine control measures. To avoid fluctuations of the above levels of weed cover and to minimize specie's dominance, chopping and rotation of herbicide applications were the methods used to regulate weed populations. At the end of three years, concentrations of nitrate-nitrogen (NO_3-N), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}) in the soil were obtained and measurements made on water samples from lysimeters installed at 40 and 90 cm depths. Three weeds cover populations: (0, 40 and 70%) were selected from the range available. In three replications of each plot, lysimeters were installed to determine the amount of nutrient in the leacheated water at the root system level and below. Water samples were analyzed weekly after installing lysimeters. Values obtained for the nutrients studied indicated that K+ concentrations were high for the selected levels of weed population, at depths of 40 and 90 cm. No significant differences were found among potassium concentrations of leacheates of weed population plots. Higher concentrations of Ca^{2+}, Mg^{2+} and NO_3-N at 40 and 90-cm depths were found in weedless plots rather than in those with weeds. As weed population density increased, the concentrations of the above-mentioned nutrients diminished, at the depths evaluated. At the end of three years, growth and foliar analysis of banana plants in plots with the three levels of weed cover were determined. Regarding the nutrient status of the banana plants in plots of the weed populations studied, there were no significant statistical differences among weed cover plots. However, there was a tendency for higher nutritional values in the banana plants growing on plots with weed cover than on those without weeds. The lower nutrient concentration in the plots with zero and 40% weed cover may be due to loss of nutrients from the soil in the water leached. However, none of the treatments showed foliar deficiencies of the analyzed elements (K+, Ca^{2+} Mg^{2+} and NO_3-N). In the study of banana plant growth, no significant differences were found in plant height or in stem diameter.

Using molecular systematics to study weed biology (99)

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Because pest management starts with accurate identification of the pest, plant taxonomy has always been central to weed science. There now exist numerous molecular techniques for exploring taxonomic questions. These techniques are being used increasingly to study the biology and evolution of weedy plant species. One of the first molecular techniques used widely for taxonomic studies was based on polymorphisms of protein isozymes. Subsequent to isozyme analysis, the RFLP technique was developed, in which variability among individuals is measured from DNA restriction fragment length polymorphisms. More recent techniques for molecular systematics utilize the polymerase chain reaction (PCR) to detect DNA polymorphisms. Such techniques include AFLP (amplified fragment length polymorphisms), RAPD (random amplification of polymorphic DNA), SSR (simple sequence repeats) and ISSR (inter simple sequence repeats). In my laboratory, ISSR is being used to aid investigations of variability of weediness traits in *Xanthium strumarium* L. *X. strumarium* is known to be a variable species based on previous morphological studies, but the impact of the species variability on its weediness is unknown. Seventeen ISSR-generated DNA fragments were scored for their presence or absence for each of 198 accessions from 12 of the United States, and the resultant data set subjected to cluster analysis. The 198 accessions were separated into 95 genotypes, confirming high variability within the species. Weediness traits among the most dissimilar accessions are being compared. A second application of molecular systematics in my laboratory is using AFLP to generate molecular fingerprints of weedy *Amaranthus* species. Our interest is in determining if hybridization among these species provides a route for spreading herbicide resistance. Other researchers have used molecular systematics to study the evolution of herbicide resistance among weed populations. Such studies are providing information useful for devising strategies to limit the future spread of herbicide resistance.

The Brazilian weed flora: taxonomy and general aspects (100)

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There are approximately more than 500 plant species in the Brazilian territory that can be called ‘‘weeds’’ according to the definition of ‘‘plants growing where not desired’’. Among them, 80% are indigenous to the country and the introduced ones are mainly from the temperate world. Only a few exotic species came from the Tropics. Our weed flora belongs to 75 different botanical families, the Compositae being the most important with 76 species, followed by Gramineae with 64 species, Leguminosae with 44 species, Cyperaceae with 22 species and Convolvulaceae with 18 species. The scientific names of our weed species changed very much since the first complete Brazilian taxonomic work was published in 1843 (Flora Brasiliensis by Von Martius). Even today, more than 150 years later, there are not complete agreement on many species names due to the lack of botanical review of many families or genus, the most confusing one being the Convolvulaceae. Names continue to change as new botanical reviews appear. The first book related to weeds in Brazil was published 1950 and mentioned only some dozens of species. In 1970, came out a more complete work on weeds of the State of Sao Paulo. A complete book on Brazilian weeds named ‘‘Plantas Daninhas no Brasil’’ was published in 1982. The correct identification turned out to be very important for the control of some weeds considered initially as the same species. For instance, the differential behavior of some herbicides over *Bidens pilosa* was explained when the resistant biotype was identified as being a different species (*Bidens subalternans*). The diversity of the weed flora is much more related to the agricultural crop than to the geographical situation. For instance, the species infesting soybean crops are somewhat the same in the deep South as in the Central-Western regions of the country located 2000 km apart. The most striking difference on the weed situation observed, however, is related to time. In the last 25 years, the weed flora of the main annual crops changed very much, both qualitative and quantitatively. The most important weed species of the main annual crops of today are not the same as of 25 years ago. *Euphorbia heterophylla*, for instance, evolved from a common plant to the most important weed of the soybean crop. Weed control management is the main factor responsible for these changes. On the other hand, some species absent in the beginning are now very important weeds, such as with *Melampodium perforatum*, for instance.

Taxonomy of weedy *Cyperus* species (101)

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Cyperus is a large (ca. 650 species), taxonomically complex genus widely distributed throughout tropical and warm temperate regions of the world. Many of the species are weedy and four (*C. difformis* L., *C. esculentus* L., *C. iria* L., and *C. rotundus* L.) are ranked among the world's worst 32 weeds. We will present an overview of the traditional morphologically based systematics of *Cyperus*, including a synopsis of infrageneric taxonomy and a discussion of the systematic relationships and geographical origins of selected weedy species. We will explore reasons for inconsistencies in nomenclature and circumscriptions of weedy species and possible solutions and potential problems for new research.

Analysis of genetic variation in *Cyperus rotundus* accessions using molecular markers (102)

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DNA-based molecular markers may offer a tool to quantify genetic diversity in native and introduced populations of weed species. The objective of this study was to evaluate *Cyperus rotundus* accessions for genetic variability using random amplified polymorphic DNA (RAPD) markers. A collection of *C. rotundus* accessions was done in Brazil on a countrywide basis. Morphological and physiological studies indicated the presence of distinctive intraspecific biotypes in the Brazilian *C. rotundus* population. Tubers of 66 *C. rotundus* accessions from Brazil, three from Florida, two from Hawaii, one from Mexico and one from Israel were imported into and maintained in a quarantine greenhouse in Gainesville. Based on individual plant analysis, forty-three oligonucleotide primers were used to assess the extent of genetic variation among the accessions. A high level of genetic variability was observed among the accessions tested, suggesting the existence of different clones at different locations. Similarity among accessions was greater for geographically closer clones. The molecular relationships provide new insights into the genetics of Brazilian *C. rotundus* and indicate the possible role of gene flow and/or sexual reproduction in the development of distinctive intraspecific biotypes. Genetic variability of *C. rotundus* should be considered as an important factor in integrated weed management programs.

Identification of purple nutsedge (*Cyperus rotundus* L.) biotypes by isoenzymes (103)

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Purple nutsedge (*Cyperus rotundus* L.) is the most widespread weed in the world. The species reduces tremendously the productivity of crops because it is very aggressive and difficult to control. The objective of this study was to identify and map the distribution of the species with isoenzymes. The isoenzyme analysis constitutes a viable technique to identify purple nutsedge biotypes. The enzymes were extracted of leaf tissues and the electrophoresis was based on horizontal starch gel. The morpholine-citrate (MC) gel/ electrode buffer distinguished different biotypes efficiently. Weed populations were sampled in 66 sites all around Sao Paulo State (Brazil). We observed polymorphism in six out of fourteen isoenzyme systems evaluated (Alfa-EST, Beta-EST, ACP, IDH, MDH and SKDH). Based on information of the six polymorphic isoenzymes, it was possible to identify 10 different biotypes of *C. rotundus* and three other species (*C. flavus*, *C. iria*, and *C. esculentus*). Two biotypes were the most dominant, occurring in 48.5% and 21.2% of the sampled sites.

Identification of different species of *Brachiaria* by isoenzymes (104)

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Seed contamination with species of the same genus *Brachiaria* is very common in commercial seed lots in Brazil. For that reason, it is important to know about their seed quality to establish appropriate pastures. Morphologically, *Brachiaria* species present seeds very similar and hard to distinguish each other. Therefore, the objective of this research was to identify *Brachiaria brizantha* cv. Marand·, *B. decumbens*, *B. humidicula* and *B. plantaginea* by isoenzyme patterns. The enzymes of 50 plants per species were extracted from leaves of seedlings germinated in the dark condition, at 30 C temperature. Vertical polyacrylamide gels from 7.0 to 7.5% concentration were used in electrophoresis procedures. The -esterase and the -esterase showed different isoenzyme patterns for all species studied. Glutamate dehydrogenase and glucose-6-phosphate dehydrogenase separated the species *B. humidicula* and *B. plantaginea* from the others, but presented the same isoenzyme patterns for *B. brizantha* and *B. decumbens*. The isoenzyme technique was efficient in identifying the main species of *Brachiaria* used in Brazilian pastures.

Isoenzymatic characterization of *Eryngium elegans* Cham. et Schlecht populations of Tucuman province, Argentina (105)

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The *Eryngium* genus has about 230 species distributed in temperate and subtropical zones of Europe and America. In South America, the genus is present in Bolivia, Paraguay, Uruguay, Brasil and Argentina. In the northwest of Argentina and especially in Tucuman province, *Eryngium elegans* Cham. et Schlecht is an aggressive weed which affects economically important crops like sugarcane, and pasture areas. *Eryngium elegans* is a diploid species, with regular meiosis and a great fertile seed production, so that it can colonize different ecological areas. Moreover, this species has a remarkable phenotypical variation in natural populations from different localities of the province. So it is interesting to determine if this variation comes from a genetic variability or from environmental factors related to each locality. The objective of this work was to identify the different populations through their isoenzymatic patterns of esterases and peroxidases. The material came from the following Tucuman localities: El Manantial (Dpto. Lules), San Javier (Dpto. Tafi Viejo), Las Talas (Dpto. Leales), Garcia Fernandez (Dpto. Leales), Campo de Herrera (Dpto. Famailla) y Bella Vista (Dpto. Leales). Discontinuous vertical polyacrylamide gel electrophoresis were conducted. In peroxidases, populations showed a characteristic and distinct isoenzymatic phenotype in all samples, that explains in part, the phenotypic variation. In esterases, a common wide band of different intensity according to the locality was observed. In these populations, it was possible to determine intra specific variations, so the samples can be characterized by peroxidase patterns. In the future, populations of different origins will be kept in the same ambient conditions to determine possible action of environmental factors, in addition to the genetic variation observed.

Identification and characterization of itchgrass accessions (106)

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Itchgrass (*Rottboellia exaltata*) was introduced in Brazil from different parts of the world, from India to Central America. The main objective of this research was to search and describe itchgrass accessions. Seeds were collected in different countries in Sao Paulo State, like us Dumont, Campinas, Aramina, Ribeirao Preto, Igarapava e Jaboticabal. Germination rate and percentage were studied in the itchgrass accessions. The husk (article) and stomata were quantified and measured. Number and length of chromosomes were studied in the Dumont, Campinas, Ribeirao Preto, Aramina and Jaboticabal accessions. Six accessions were characterized by molecular markers (PCR). All the accession were evaluated for response to light periods of 10, 12, 14 and 16 h. Sixty days after sowing, the accessions were evaluated for emergence percentage, plant height, leaf number and relative chlorophyll content. One hundred and twenty days after sowing, the accessions were evaluated for inflorescence/plant, leaf insertion angle, leaf area, dry biomass of stem, leaf and roots, 100-article weight, total production, glume and husk length and width. The Ribeirao Preto accession had higher germination and emergence rates. Its husks were longer and thinner than the other accession. The flower stigmas were not exposed during the blooming. The Ribeirao Preto accession is diploid (2n = 20) and the others are polyploid with smaller chromosomes. This biotype was confirmed by molecular differentiation technique (cluster analysis).

Identification of morphotypes of field bindweed (*Convolvulus arvensis* L.) (107)

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Field bindweed is a perennial weed of major importance in temperate regions. Its deep root system and large capacity for vegetative reproduction make it difficult to control by cultural practices or with herbicides. In USA, biotypes of field bindweed phenotypically distintict with respect to their growth, reproduction and sensitivity to glyphosate have been identified. With the objective of detecting variation between clones and their affinity, a collection of fourteen introductions of *C. arvensis*, coming from different regions of Argentina were studied. Thirty-three morphological characters in leaves (4th, 5th and 6th) and six in flowers in ramifications, with at least eight unfolded leaves, were recorded in plants growing in the same environment for the third generation. Data originated from four replications. Cluster analysis using taxonomic distance coefficient (TD) and principal component analysis (PCA) based on Pearson's coefficient, were performed. Within a cluster and at TD=1.25 was observed that a group of eight clones (G1) and another of four (G2) were formed and that clones G and L were isolated. PCA indicated that 81,1% of the variation were explained by the first three components (PC1, PC2, PC3) and the first of them contributed with 45%. Clones from G1 exhibited an intermediate leaf size and pubescence, those from G2 showed larger leaves and obtuse apex, clone G had intermediate sized leaves and high pubescence and clone L had the smallest leaves. PC3 contributed to clone differentiation through flower characters. Owing to registered characters, we established the existence of *C. arvensis* morphotypes between collected clones. No relation between morphotype and place of collection was detected, because some clones from the same area were placed in different groups.

RAPD markers to identify *Phalaris minor* and *Lolium rigidum* biotypes resistant to ACCase inhibitors (108)

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Random amplified polymorphic DNA (RAPD) analysis is a molecular technique used to evaluate genetic variation among and within plant species. The technique involves the amplification of small sequences of target DNA using random primers. The aims of this study were to develop a RAPD analysis that would assist us in detecting grass weeds resistant (R) to ACCase inhibitors and to explore the mode of inheritance of the resistance trait. Plants were grown from seeds of R and S (susceptible) biotypes of *Phalaris minor* and *Lolium rigidum*. Genomic DNA was extracted from leaf tissue and amplified by polymerase chain reaction (PCR) in a thermal-cycler. One hundred and forty primers (AB and UBC) were used in amplification reactions and the amplification products separated by electrophoresis. Few primers were found to consistently amplify the DNA resulting in consistent diagnostic bands. Some of these bands were shared by both species some were unique to *P. minor* and other to *L. rigidum*. At least one of the bands was unique to R biotype of *P. minor*. Additional primers are being tested with R and S DNA to find specific markers for ACCase resistance.

The value of alternative strategies for weed management (109)

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Herbicides represent the primary weed management tactic in most crops. Often, alternative weed management strategies are avoided or ignored. In the United States, the competitiveness of the herbicide industry has changed attitudes such that growers no longer provide supplemental weed management strategies. While the trend of herbicide use displacing alternative weed management strategies is primarily demonstrated in developed countries, it can be argued that there is a loss of alternative weed management strategies in developing countries also. Hand-weeding and mechanical tactics predominate in developing countries and potentially problems in weed management will reflect the lack of alternative strategies. The most prevalent problem that occurs when weed management strategies are narrowly focused is shifts in weed populations to species that no longer respond to the strategy. These weed population shifts may be to more competitive adapted species, tolerant species, or herbicide resistant biotypes. The latter has be a consistent problem where herbicides are the primary or sole weed management strategy. By using alternative strategies such as mechanical and cultural tactics, in the case of maize production in the USA, or the judicious use of herbicides, in the case of maize production in developing countries, weed population shifts can be avoided. This will likely result in more efficient food production and less environmental impact from weed management programs.

Central America experiences: tillage and pests (110)

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All pests, including weeds, are affected by the production system utilized. The tillage system used has a particularly significant effect on pest behavior. Several long-term studies have been conducted in Zamorano, Honduras, to determine the effect of no tillage (NT) and conventional tillage (CT) on pests of corn and dry beans. Zamorano is located at 800 m above sea level, has an annual average temperature of 22 C, a rainy season that lasts from May to November, and average annual rainfall of 1,100 mm. One study initiated in 1986 and another in 1987 lasted eight and seven years, respectively. Purple nutsedge (*Cyperus rotundus*)

population was successfully controlled (1 plants m^{-2}) under NT when glyphosate was used; under CT population remained at more than 300 plants m^{-2}. The NT systems increased grassy weeds, compared to CT. The diversity index of the weed complex and the number of species decreased under CT. Purple nutsedge, Johnsongrass (*Sorghum halepense*), Bermuda grass (*Cynodon dactylon*) and mayflower (*Commelina diffusa*) were introduced and propagated by tillage implements. Under CT, fall armyworm (*Spodoptera frugiperda*) and bean pod weevil (*Apion godmani*) were more prevalent than under NT. Under NT, bean slug (*Sarasinula plebeia*), grass looper (*Mocis latipes*), and ear rot (*Stenocarpella maydis*) infestation were higher. It is probable that grass looper infestation was greater because of higher grass infestation. White grubs (*Phyllophaga* spp.) were more prevalent under NT the first two years, but thereafter were more prevalent under CT, probably due to the establishment of a natural enemy in NT soil. Earthworms (*Lumbricus terrestris*) were more prevalent under NT.

No-tillage in a cool and humid climate: weed populations and weed control (111)

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In sustainable cropping systems, there is a tendency to reduce tillage intensity in order to decrease soil erosion, leaching of pesticides and nitrate, and production costs. These changes in tillage practices are expected to markedly alter the efficiency of weed control and, thus, weed populations. There is a lack of information on how reduced tillage systems, especially no-tillage, affect the development of weed populations and the efficiency of weed control under cool and humid climate, which is typical for large parts of Central Europe. An experiment was conducted on a sandy loam and a loamy silt soil in the Swiss midlands to investigate the impact of the time of herbicide application on the development and control of weed populations in different tillage systems. Pre- and post-emergence herbicides were applied in conventional tillage (CT) with mouldboard plough, minimum tillage (MT) with chisel plough, and no-tillage (NT) in a 'winter wheat-oilseed rape-winter wheat-maize' crop rotation. All crop residues were left on the fields and no stubble tillage was done. In winter wheat following maize and winter wheat following oilseed rape, the abundance of weed species was significantly affected by tillage intensity. The rank order of tillage systems in winter wheat following maize and winter wheat following rape was NT $<$ MT $<$ CT and CT $<$ MT $<$ NT, respectively. Perennial weed species were more abundant in NT and MT than in CT. Generally, the efficiency of post-emergence weed control was better than that of pre-emergent herbicide application.

Effect of tillage practices on weed infestations and soil seed banks in wet-seeded rice (112)

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Yields of wet direct-seeded rice are characteristically at risk from weeds that establish concurrently with the crop in contrast to transplanted rice. Land preparation prior to seeding is an essential tool of integrated weed management practised by farmers in Vietnam to reduce weed seed banks and produce a clean seed bed. Typical major weeds that infest direct seeded rice are *Echinochloa crus-galli*, *Leptochloa chinensis*, *Paspalum distichum*, *Cyperus difformis*, *Fimbristylis miliacea* and *Ludwigia octovalvis*. We report the results of a three season trial investigating the effects of seven different land preparation techniques on resulting weed infestations and the size of the soil seed bank in wet-seeded rice. Minimum tillage, wet and dry rotovation with and without prior straw burning were investigated. Work was conducted at the Cuulong

(Mekong) Delta Rice Research Institute experimental farm in three seasons starting from summer-autumn 1998 to winter-spring 1998-1999. Weed communities varied noticeably (size and composition) from season to season in relation to water supply at seeding. Seed bank sizes declined with depth, overall average estimates at 0-5 cm, 5-10 cm and 10-15 cm being 41 790; 26 796 and 14 558 seeds m^{-2} respectively. Surface soil weed seed banks (0-5 cm) were highest under the zero-tillage treatment without straw burning (269 009 seeds m^{-2}), and lowered by dry rotovation (240 606 seeds m^{-2}). Zero- tillage as well as dry rotovation practices resulted in high weed infestations and poor rice yield. Wet rotovation followed by puddling and leveling was most effective at minimising weed infestations at rice establishment.

Effect of nitrogen on critical period of weed control in corn (113)

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The use of nitrogen (N) fertilizer has been linked with high nitrate levels in ground water, creating a negative impact on the public health system. Therefore, restrictions in N fertilizer use are being implemented in Nebraska and elsewhere. This raises the question whether reduced N rates affect weed competitiveness and consequently influence the critical period of weed control (CPWC). CPWC is a period in the crop growth cycle during which weeds must be controlled to prevent yield losses. Determining effects of N on the critical weed free period will aid in optimizing N use and weed control strategies. Recognizing this potential interaction will improve acceptance of integrated weed management practices. Field studies were conducted in 1999, and will be repeated in 2000, at Mead and Concord in eastern Nebraska to determine the effects of three nitrogen rates on the CPWC in dry land corn. Nitrogen rates were 0, 60 and 120 kg ha^{-1}. Experimental design was a split-plot with N rate as the main plot and weed duration as sub-plots. Two sets of 6 subplots each had increasing durations of weed presence and weed absence up to predetermined corn growth stages. The logistic and Gompertz equations were fit to data representing increasing duration of weed presence and weed absence, respectively. The beginning of the CPWC occurred earliest for the lowest nitrogen rate, and coincided with the first and second leaf stage of corn at Mead and Concord, respectively. The beginning of the CPWC occurred latest for the highest nitrogen rate, and coincided with the fourth and fifth leaf stages of corn at Mead and Concord, respectively. The end of the CPWC differed across nitrogen levels and varied across the two sites ranging from the seventh to the 12th leaf stage of corn. Practical implications are that insufficient N can reduce corn tolerance to weeds and it can widen the window of CPWC. Anticipated restrictions on the level of N fertilizer use in corn may require more intensive weed management programs.

Demonstration sites and other integrated weed management extension initiatives in southern Australia (114)

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The combination of changing farmer cropping practices and increasing levels of herbicide resistance in a range of species (particularly *Lolium rigidum* and *Raphanus raphanistrum*) is highlighting the shortcomings of relying on herbicides as the primary means of weed control. Many of the alternative options available either involve the outlay of capital (e.g. the purchase of a seedcatcher) or represent practices perceived to have large disincentives to adoption (e.g. burning). Throughout Australia a number of extension initiatives have been implemented to demonstrate the benefits of utilising an integrated approach to weed management. In Western Australia a series of Integrated Weed Management Research and Demonstration Sites have been established. These sites demonstrate how the use of a combination of weed control

measures can provide an effective and profitable means of depleting weed seed banks and good in-crop weed control. Trial sites are located on farmer properties or Research stations run by Agriculture Western Australia. Plots within each trial are large enough to be established and harvested with farm size machinery. This is to demonstrate to the growers that the options utilised are ones that they can implement on their own properties with minimal impact to current practices. Results presented to farmers from this demonstration approach include yield data, cumulative gross margins, changes in numbers of individual weed species and changes (if any) to the composition of the weed spectrum. The Alma-Tahlee Landcare group, South Australia, has taken an alternative approach where growers monitor the changes in the weed seed bank of *Lolium rigidum* by taking soil samples. These soil cores are collected to a depth of 5 cm and are analysed to estimate the number of seed per m^{-2} that is present. These results are discussed in farmer groups and related back to different management practices that were implemented the previous year.

Effectiveness of water management in relation to herbicides in controlling red rice in rice fields (115)

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Red rice is one of the most troublesome weeds in much of the Italian rice field. The control of the red rice is nowadays obtained with prevention and agronomic practices (rotation, false seeding technique, etc.) and preplant herbicide treatments. In order to improve the red rice control strategies, experiments were carried out at locations near Pavia (Mortara 1996, Velezzo Lomellina 1997, Zeme 1999) over the 1996-1999 period. Two water management conditions were considered: soil submerged and soil saturated after ploughing and harrowing. Three-four weeks later, in both management conditions the red rice (at 3-4 leaves stage) was controlled with herbicide applications in dried soil. The preplant herbicides used in different quantity of a.i. were: cicloxidim, pelargonic acid, quizalofop-ethyl, dalapon, propaquizafop, alossifop-etossietil, setoff, pretilaclor, pretilaclor+dalapon. The experiments were always conducted as a randomised block design with 4 replications. Six-twelve days after these treatments, all the field plots were flooded and three-ten days later an early variety of rice (Loto) was sown. Observations were made on red rice density, percentage of weed control, percentage of soil cover at two, three and four weeks after herbicides applications, selectivity, grain yield, yield of whole and broken rice. Seedling emergence and ground cover of red rice were affected by the water management. In fact, the infestation of red rice before chemical treatments was higher in saturated soil than in flooded soil. The best red rice control was always obtained with cicloxidim (0.400 kg a.i. ha^{-1}), quizalofop-ethyl (0.100 kg a.i. ha^{-1}), ropaquizafop (97 g L^{-1}) 0.078 kg a.i. ha^{-1}.

The influence of wheat row spacing on weed growth and control (116)

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This research, carried out in the 1996-1997 period at the Carmagnola experimental station (N.W. Italy), was aimed at studying the effect of a wheat planting arrangement on weed growth in order to reduce chemical weed control. In this study, the traditional row spacing of 200 mm inter-row (ORS) was compared to a band arrangement characterised by a 500 mm planted band with 5 rows at 100 mm inter-row alternated with 300 mm non-planted bands (PB-NPB). The following treatments were compared: 1) ORS, broadcast chemical weed control; ORS, mechanical weed control; 3) ORS, untreated; 4) PB, chemical weed control + NPB, mechanical weed control; 5) PB, untreated + NPB, mechanical weed control; 6) PB, untreated + NPB, untreated. The chemical weed control was carried out at the end of the tillering stage, by applying triasulfuron+fluroxipyr at 7.5+172 g a.i. ha^{-1}. The mechanical control was performed with a spike-toothed harrow. The main weed species present in the untreated plots were *Papaver rhoeas* L., *Veronica persica*

Poir., and *Stellaria media* (L.) Vill. The assessment carried out at the end of stem elongation showed that the dry biomass and weed density in band-planting were similar and lower (23%), respectively, than those recorded in traditional-planting plots. The weed control with herbicides in traditional-planting plots was similar to that of the plots carried out in bands but was more effective (84%) than that with harrow (36%). The herbicide application was very effective against *V. persica* and *S. media* but was very weak against *P. rhoeas*. The mechanical intervention provided a good control against *S. media* but was ineffective against *V. persica* and *P. rhoeas*. The wheat yield, obtained in band-planting treatments subjected to chemical and mechanical weed control, was not statistically different from that of the corresponding traditional-planting treatments (8.89 t ha^{-1}, on average). The height of the crop, number of spikes m^{-2}, harvest index, and the weight of 1000 seeds were not statistically different for the treatments where weeds were controlled either with herbicides or harrow. The band-planting system, with the herbicide application on the band and the mechanical intervention on the inter-band area, was as effective against weeds as broadcast herbicide weed control in traditional row spacing. This integrated weed management allowed a 37.5% reduction of herbicide spraying.

Weed control in *Vigna unguiculata* L. Walp bean, under agronomic and ecological conditions of the Maracaibo plain, Venezuela (117)

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Maracaibo plain, a region with a surface of 540 000 hectares shows agronomic and ecological conditions appropriate to bean production, this crop possesses special nutritional characteristics that gives it a very promising potential. However, the specific characteristics of these soils besides a deficient handling have been occasioning the loss of its capacity for the agricultural production. Since 1994, several studies have been carried out in relation to the bean production without damaging the soil besides to assuring a significative reduction of production costs. Nevertheless, to obtain a success through this novel technology is essential to control weeds in an effective way. This work summarizes the results of several researches in which were evaluated different methods for its control, from its identification and description. Thus, it was determined the effect of technology on the environment and the structure of the production costs. The results confirm the viability of the direct seeding for the bean production in the plain conditions. Between the differents treatments evaluated set off the application of glyphosate or ghyphosate trimesio 960 g a.i. ha^{-1}. There is the possibility of reducing the application dose of these herbicides until a 30% through the use of coadjuvants.

A weed flora of Mazandaran, Iran (118)

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More than one-third of the pesticides used in Iran are used in the Mazandaran province. Studies were conducted from 1996 through 1999 to: 1) identify the weed flora of Mazandaran; 2) study biology and ecology of dominant species; and 3) determine best control of these species. Dominant weed species included *Abutilon theophrasti*, *Echinochloa crus-galli*, *Cyperus* spp., *Avena fatua*, *Phalaris minor*, *Chenopodium album*, *Amaranthus* spp., *Sorghum halepense*, *Brassica kaber*, and *Xanthium strumarium*. The focus of this report is on *A. theophrasti*, one of the most troublesome species in soybean (*Glycine* max) and cotton (*Gossypium hirsutum*) in Mazandaran. Field studies were conducted at the Main Agricultural Experiment Station, Sari, Mazandaran to evaluate the effect of various *A. theophrasti* densities on cotton growth and yield; and to determine the effect of tillage and split applications of bentazon on *A. theophrasti* population, seed production, and control. In cotton study, the experiment was initiated as a randomized complete block design with four replications. One *A. theophrasti* plant m^{-1} of cotton row caused 23, 28, 32 and 76% reduction in height, number of nodes, canopy width, and dry weight as compared to the cotton alone, respectively. Cotton boll number reductions were 71, 80, 84, 87 and 88% for 1, 2, 3, 6, and 12 *A. theophrasti* plants m^{-1} in the cotton row, respectively. Control treatment produced 2629 kg ha^{-1} seedcotton yield while plots infested with 1, 2, 3, and 6 *A. theophrasti* plants m^{-1} produced 456, 149, 65 and 0 kg ha^{-1}. In bentazon study, the experiment was a split plot with four replications. Tillage (no tillage and conventional tillage) was the main plot. Subplots were bentazon at 1.44 kg ha^{-1} (recommended rate) applied once at 1- to ^{3}-leaf stage of *A. theophrasti*; 0.71 kg ha^{-1} applied at the 1- to 3-leaf stage and repeated 10 days later; and 0.45 kg ha^{-1} applied three times, 1- to 3-leaf stage and repeated 10 days after the first and second application. The no-tillage system reduced Abutilon theophrasti population, dry weight, and seed production τ90% compared to conventional tillage. In tillage plots, population was reduced 81, 97, and 99%; dry weight was reduced 53, 87, and 95%; and seed production was reduced 26, 87, and 94% for 1.44, 0.71, and 0.45 kg ha^{-1} compared to untreated plots. The first application at 1.44, 0.71, and 0.45 kg ha^{-1} controlled Abutilon theophrasti 87, 79, and 69%, respectively, 9 days after application. Abutilon theophrasti control was 83, 90, and 84% (at 1.44, 0.71, and 0.45 kg ha^{-1}), 10 days after the second application timing. Control after the third timing was 78, 85, and 84% for 1.44, 0.71, and 0.45 kg ha^{-1} of bentazon, respectively.

Weed control in Florida citrus (119)

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Citrus is one of the most important agricultural crops in Florida, comprising 845,260 acres with an on-tree value of 1.15 billion for the 1998-99 crop year. Control of weeds is a major economic cost, estimated at $172.8 million or 25% of annual production budget. Florida's favorable climate allows for weed germination and year-round growth. Weeds compete with citrus trees for nutrients, water, light and harbor insects and rodents that attack citrus trees. Additionally, weeds increase cold damage from radiation freezes, increase the incidence of *Phytophthora* foot rot, impede harvesting of citrus crops, interfere with low volume irrigation systems and intercept soil-applied chemicals. Thus, the objective of today's citrus weed management program is the suppression of weed populations to a level that minimizes economic losses. Herbicides used in groves are divided into two groups: soil-applied preemergence, and foliar-applied postemergence. The postemergence herbicides can be further divided into systemic or contact. Postemergence herbicides include non selective paraquat and glyphosate, and selective grass control herbicides are fluazifop-p-butyl, and sethoxydim. Commonly used preemergence herbicides for the control of grasses include: bromacil, norflurazon, oryzalin, and thiazopyr. Preemergence herbicides for the control of broadleaf weeds include: diuron, oxyfluorfen, and simazine. Soon to be released azafenidin controls both broadleaf and grass weeds. Control of specific weeds are product and rate dependent. For the effective control of all weed species combinations of products may be necessary.

Interactions between narrow row spacing and low dosages of atrazine on weed control in grain sorghum (*Sorghum bicolor*) in La Pampa, Argentina (120)

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Interactions between row spacing (0.35; 0.52 and 0.70 m) and low dosages of atrazine applied at pre-emergence (0, 250, 500 and 750 g a.i. ha^{-1}) on grain sorghum (*Sorghum bicolor*) yield under conventional tillage and weed control have been evaluated during 1996/97; 97/98 and 98/99. These treatments have been compared with hand weeded plots. *Chenopodium album*, *Digitaria sanguinalis*, *Panicum capillare* and *Hirschfeldia incana* were the major weeds during the three years of research. Low herbicide dosages (250 g a.i. ha^{-1}) combined with narrow row spacing (0.35 m) produced similar yields than thehighest herbicide dosages combined with normal row spacing (0.70 m) when weed levels were lower than 2.9 DM ton ha^{-1} at crop flowering. When weed levels were between 2.9 and 6.0 DM ton ha^{-1}, only herbicide dosage showed significant effects on crop yield; row spacing had no significant effects on this variable. Number and size of heads were yield components most affected by weed interference.

Control of *Eryngium paniculatum* with different management alternatives in a grassland in Entre Ríos, Argentina (121)

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The natural fields of the province of Entre Ríos cover 70% of its surface and produce quality forage. The increase of undesirable invasive species as the ‘‘caraguata’’ (*Eryngium paniculatum*) are carrying these communities in a regression process, characterized by the presence of forage species of smaller value. The objective of the work was to evaluate during 3 years the control of the ‘‘caraguata’’ in a grassland field with different management alternatives, to increase the productivity of the grassland. The trial was established in San Gustavo site (W 59°39’: S 31°37’), dedicated to the sheepherding of bovine. The experimental layout was a RCBD in plot of 70 x 25 m, with three replicates. The treatments were: T1: untreated control (fenced); T2: chemical and mechanical control without sheepherding; T3: chemical and mechanical control with sheepherding; T4: sheepherding. Two applications were made (November ’96 and July ’97) of picloran + 2,4-D in dose of 256 g a.e. ha^{-1} + 960 g a.e. ha^{-1} , and three cuts (May ’97; November ’97; May ’98). Bimonthly, control of the weed was determined by estimating density, cover, and above- and underground biomass; and abundance-cover and biomass of the grassland. The initial density (August’96) was 42 700 plants ha^{-1} and 9% of coverage of ‘‘caraguata’’. At the end (July ’99), T3 presented less than 1,000 plants ha^{-1} and coverage near to 0 %. The rhizome biomass per m^2 showed significative differences between treatments; (T1=240 g T2=20 g; T3=6 g; T4=217 g). Significative differences to the 5% (Tukey test) were found among the T3 and the remaining treatments for density of the ‘‘caraguata’’; and among T3 and T2 versus T1 and T4 for coverage and biomass. Reduction of the cover of the weed and biomass of the rhizomes were achieved with the integrated control, improving the production of the grassland.

The use of mineral oil with post-emergence application of metamitron in strawberries (122)

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Strawberries are grown in Poland on the acreage of 50-60 thousand hectares. The most adequate method of weed control on big plantations has been herbicide use. In 1998-1999 in Skierniewice (Central Poland) the possibility of metamitron (as Goltix 70 WG and 90 WG of Bayer AG) use at the low rates with mineral oil (as Olbras 88 EC containing 88% of post-refining fatty acids) was evaluated. The aim of rate reduction was to minimize both expenses of herbicide application and environmental pollution. The experiment was carried out under field conditions in a plantation of cv. Senga Sengana, which has good tolerance of the tested herbicide and is the most popular one in Poland. Metamitron was applied as the double (split) application, at two rates: 0.6 and 0.9 kg a.i. per ha with adjuvant at the rate of 1.5 L ha^{-1} as well as at the full dose of 2.75 kg a.i. ha^{-1}. The herbicide was applied in spring, before strawberry flowering when annual

weeds were between the cotyledon and two leaf stage. The efficiency of weed control and strawberry yield were evaluated. The seedling control was estimated one week after the treatment. It was similiar to the application with adjuvant at both rates and herbicide at the full rate alone.The fruit yield on the plots treated with metamitron and oil was as good as on ones treated with the full herbicide dose, though the soil effectiveness of reduced doses was poorer. Selectivity of tested herbicide for strawberry plant used with the adjuvant was satisfactory.

Investigations into the weed infestations, seedbanks and tea growth in relation to different weed management methods in a young tea (*Camellia sinensis* [L.] Kuntz) plantation (123)

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An experiment was conducted in the Low-Country of Sri Lanka, during the period of 1994 to 1995 to investigate the weed seedbank density in soil and severity of weed infestation and growth of tea in relation to the present weed management methods during early establishment of tea. Manual weeding at various intervals was compared with the use of herbicides, with or without mulching. Weed control by herbicides was superior to that with manual weeding. Manual weeding every six weeks and herbicide treatments affected tea growth similarly but the former was not cost effective. Neither agronomic nor economic advantage was achieved with clean manual weeding every two weeks. Plots allowed to remain weedy for 12 weeks or more adversely affected tea growth. Application of oxyfluorfen at 0.29 kg a.i. ha^{-1} followed by paraquat at 0.17 kg a.i. ha^{-1} and glyphosate at 0.99 kg a.i. ha^{-1} was more cost effective and superior than manual weeding every six weeks incurring minimum weed infestation. Weed seedbanks determined 12 months after treatments were reduced slightly with the use of these herbicides but increased slightly when manual weeding was less frequent than every six weeks. Glufosinate ammonium at 0.2 kg a.i. ha^{-1} and 2, 4-D at 0.94 kg a.i. ha^{-1} followed by paraquat at 0.17 kg a.i. ha^{-1} were less effective in weed control and had little influence on reducing the seedbank density. Mulching tea inter-rows with grasses was more beneficial for tea than not mulching whilst the live mulch of weeds suppressed tea growth. A combination of chemical followed by manual weeding every 10 weeks and continuous mulching would be the most appropriate integrated weed management system in tea new clearing.

Mapping *Phalaris minor* in the rice-wheat cropping system of different agro-ecological regions of Nepal (124)

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Changes in the population, biotypes, and weed flora in the wheat crop of the intensively cultivated rice-wheat cropping system of South Asia have been alarming. The phenotypic similarities between wheat and *Phalaris minor*, especially during the early part of the crop season has added to the difficulties in controlling the weed. The Terai region of Nepal has been the breadbasket in terms of production and productivity of rice and wheat for the country. Wheat is the pre-dominant winter crop and more than one-third of the total rice area is followed by wheat. Weed infestation in the wheat crop of Nepal reduces yield from 15% to 70%. Use of 2,4-D to control broadleaf weeds and isoproturon to control grass weeds is common along the Terai of Nepal. Due to the lack of quantitative information regarding the spread of *P. minor* in Nepal, a survey was planned during the 1997/98 wheat season in the nine districts with different agroecological regions. Altogether 58 weed species were recorded during this survey, of which 54 weed

species belong to 20 families. Of these 54 species, 43 species were broadleaf and 11 species were grass weeds. Among these, some of the important broadleaf and grass weeds were *Chenopodium album*, *Soliva anthemifolia*, *Anagalis arvensis*, *Vicia* sp., *Medicago denticulata Lathyrus aphaca*, *Polygonum plebijum*, *Gnaphalium* sp., *Rumex* sp., *Alopecurus* sp, *Oxalis corniculata*, *Fumaria parviflora*, *Melilotus parviflora*, *Stellaria media*, *Polygonum* sp., and *Poa annua*, *Phalaris. minor*, *Polypogon fugox* and *Phalaris minor* respectively. Weeds like *P. minor*, *C. album*, *Alopecurus* sp., and *Vicia* sp. were recorded from all the surveyed districts indicating their adaptation to the terai, inner terai and the mid-hills region of Nepal. Farmers reported yield losses in wheat due to weed infestation to be 10 to 50 percent. *Phalaris minor* has spread in almost all the surveyed districts with different intensity. The population pressure of *P. minor* also differed according to the districts. The farmers in almost all the surveyed districts realized the increasing trend of weeds in the wheat crop but due to some constraints weeding is generally not practiced. Factors farmers cited were *P. minor* in its vegetative stage mimics the wheat crop therefore the difficulty in distinguishing it from the wheat plants especially in broadcast seeding. Cutting of *P. minor* and other associated weeds is generally done for the livestock feeding only in the heading stage when *P. minor* is easily distinguished from the wheat plants but where the chances of crop damage will be high. Future strategies that need to be focus include awareness and identification of *P. minor* among the wheat growers. Preventative measure should be taken to prevent the spread of this weed in the future. Frequent monitoring of weeds in different tillage and weed management practices should be done as well as research on the new tillage technologies such as surface seeding, reduced tillage, and bed planting should be practised.

Baccharis coridifolia **integrated control in natural pastures** (125)

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In Uruguay, natural pastures are the most important grazing resource, occupying 85% of the area dedicated to cattle raising. *Baccharis coridifolia* is one of the most widespread weeds, presenting toxicological problems for cattle. There are chemical alternatives, which are effective and specific for the weed, avoiding any harmful effect to gramineous species. However, their persistence prevents the establishment of legumes for one year. The objective of this experiment was to evaluate the effect of a localized chemical control of *B. coridifolia*, using glyphosate treatments with a rope type applicator, under three sheep grazing situations, and with the introduction of *Lotus subbiflorus* to a natural pasture. The experiment was established in a silty Mollisol, with a pH (H_2O) of 6.1 and an organic C content of 1.9%. The initial infestation level was 2 plants m^{-2}. In the fall, 5 kg ha^{-1} of *Lotus subbiflorus* cv. El Rincon, was seeded into the natural pasture. Grazing systems used were continuous and non-continuous, the latter one with two defoliation intensities of 2 and 10 cm grass remainder height. Glyphosate was applied in the fall with two water concentrations, 0.06 and 0.24 kg a.i. L^{-1}. A check treatment without herbicide was included in each grazing treatment. A rope type applicator was used for the localized applications of the herbicide. Control index was determined as the difference between the initial number of plants and the plants that reappeared in the next fall. A year after fall applications, total grass production of the 2 cm defoliation intensity treatment duplicated the production obtained under continuous grazing, while in the 10 cm, intensity the production was triplicated. No significant differences were detected in forage yield due to the weed control. The response in grass production due to the different grazing resulted in higher degrees of competitiveness against *B. coridifolia* which complemented the chemical control. Under continuous grazing, control index was 20% and 60% for the lowest and highest concentration of herbicide respectively. This 60% value did not differ from those obtained under the non-continuous grazing system for both defoliation intensities and both gliphosate concentrations.

International standards for environmental weed management (126)

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In an era of escalating environmental concern and global marketing, the need for internationally recognized standards to assure consumers that Best Management Practices have been employed in food production is increasing. The International Organization for Standardization (ISO) has taken the lead in providing the basis for such guarantees with its ISO 14000 initiative. Although response to implementing ISO 14001 in agricultural operations has been slower than it has in other industries (e.g. chemical and electronic), it has been adopted in several countries. If interest in using ISO 14001 in the agri-food sector continues, it will have implications for several important issues including: product identification, segregation, and traceability; non-tariff barriers to trade; and changing the structure of agriculture in ways that favour large-scale capital intensive operations. This paper provides an overview of the ISO 14001 standard in light of its relevance for these implications.

Have gains in yielding ability compromised weed competitiveness of modern wheat cultivars? (127)

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There is a perception among weed scientists and farmers that the development of short-stature high yielding cultivars has reduced the capacity of wheat to compete with weeds. To test this hypothesis, a field experiment was undertaken to study the variation in weed competitiveness among 14 wheat cultivars released and widely grown in South Australia over the last 100 years. Various morphological traits of wheat cultivars were measured over the season and at the end of the growing season, assessments were also made on plant height, weed biomass, grain yield and harvest index. The gains in yielding ability through improvements in harvest index over time were clearly evident in this study. However, there was no consistent trend between the year of the release of a cultivar and its competitive ability with *Lolium rigidum*. Purple Straw, the oldest cultivar examined, was able to maintain its yield in the presence of weeds. Its competitiveness or tolerance to weed competition appears to be related to its good early vigour and tall growth habit (89 cm). However, other older cultivars such as Federation, Insignia and Warigal were found to be poor competitors with weeds. Shorter statured (75 cm) more recent cultivars, Frame and Spear were good competitors with weeds and maintained their yield advantage over the older cultivars even in the presence of *L. rigidum*. Correlation analysis of plant traits and competitive ability indicated that traits contributing to early vigour (size of first two leaves) and light interception (height and flag leaf size) enhance the competitive ability of wheat against weeds. This preliminary study did not show any systematic decline in weed competitiveness of modern wheat cultivars. It appears that selection based on traits that improve early vigour and light interception could be used to further enhance the weed competitiveness of Australian wheat cultivars.

IWM - A concept now put into practice to control broadleaf pasture weeds (128)

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Carduus nutans, *Onopordum* spp. and *Echium plantagineum* are major weeds of pasture in southern Australia. In the past, implementations of single control techniques have not achieved adequate long term

control. An Integrated Weed Management (IWM) program, currently under way in high rainfall grazing areas in south-eastern Australia looks at a combination of control methods, which is put into practice in an extensive field trial, and is pioneering work of its kind. Biological control, various combinations of light and heavy sheep grazing and deferments, competitive species, spray grazing (sub-lethal herbicide rate and heavy grazing), and a one-off herbicide application are integrated. The impact of grazing and herbicide treatments on the weed and biocontrol agents, as well as on pasture composition, is being investigated. Demography of biocontrol agents and target weeds, as well as pasture composition, is being monitored. First results of grazing treatments are now available. In the short term, the spray-grazing treatment is showing promise in reducing the weed population. The long-term value of the different grazing treatments and compatibility with biocotrol agents remain to be investigated. This study looks at a long-term solution and takes a holistic approach and a sustainable solution to the problem of broadleaf weeds in pasture.

Some physical and biological effects of three tillage systems and two herbicides on sorghum [*Sorghum bicolor* (L.) Moenth] in Venezuela (129)

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An experiment was carried out around Maracaibo lake, in the very dry tropical forest life zone, to evaluate the performace of sorghum crop under three different tillage systems conventional (LC), reduced (LR) and zero (L0) and two herbicides types: systemic (glyphosate) and contact (paraquat) and their effects on some physical properties of a coarse loam Aridisol,. For that purpose, two statistical designs were used, one a complete ramdomized block to evaluate the effect of tillage on soil physical propieties, and the other, an split plot in time to evaluate the biological effects of herbicides on soil physical properties. The soil physical properties analized were bulk density (Da), total porosity (Pt) and macroporosity. The biological variables were pacicle number (NP), panicle weight (PP), grain yield (R) and dry weight of weed (PCM). The results showed that was significatively higher for LR followed by LC and L0. Pt did not show statistical differences between tillage systems. Macroporosity showed statistical differences ($P<0.05$) between sampling and not between tillage systems. PCM was significatively lower for L0 plus systemic herbicide, than for any other combination of tillage and herbicide. (R) showed statistical differences ($P<0.05$) between tillage systems and was significantly higher for the reduced tillage which showed greater panicle number and panicle weight followed by LC and L0. These results put in evidence that soil roturation is necessary in order to improve the soil physical properties and grain yield. These results are preliminary and observations beyond 6 months are required to observe positive effects of no tillage systems.

Diversifying cropping systems for weed management - where to from here? (130)

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Diversification of conventional cropping systems through rotation, intercropping, and cover cropping reduces weed density and biomass and improves crop production in many agroecosystems. Better use of innovative cropping practices for weed management requires better knowledge of relevant ecological and physiological mechanisms. Three factors are especially important for determining the impacts of crop diversification on weeds: (1) the timing of weed seedling emergence relative to crop-specific management activities; (2) the degree to which crops utilize available resources; and (3) changes in soil characteristics created by crop residue additions. Large differences exist among weed species with regard to emergence timing. Thus, weed community composition can be manipulated by planting crops that fill particular temporal niches and stress weeds at vulnerable life stages. Weed scientists need to collaborate with

vegetation ecologists and agronomists to predict changes in weed communities due to crop production practices, and to design cropping systems that defuse challenges posed by invasive weed species. Weeds can be suppressed by planting mixtures of crops that use resources more effectively than sole crops. Cooperative work by crop physiologists, crop breeders, and weed scientists is needed to develop cultivars that avoid resource competition with each other while maximizing competitive suppression of weeds. Enhancing crop growth by using long rotation sequences to improve soil and pest conditions should also improve the ability of crops to compete against weeds. Collaboration between soil scientists, agronomists and weed scientists could facilitate the design of optimum crop sequences. Crop residues containing phytotoxic compounds may be used to suppress small seeded weeds without diminishing the performance of large seeded crops. Selection and breeding of cover crops and grain crops for greater concentrations of weed-suppressive compounds seem feasible. As environmental and economic pressures on agricultural producers intensify, participation of weed scientists on teams developing new cropping systems is highly desirable.

Evaluation of different weed control methods for two weed species: cattails (*Typha* spp.) and giant bulrush (*Scirpus californicus* C.A. Meyer) stand on German grass (*Echinochloa polystachia*) pasture in the surrounding areas of the Limon River region (131)

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In order to evaluate the effect of the different methods of weed control of cattails (*Typha* spp.) and giant bulrush (*Scirpus californicus*) in german grass pasture. The experiment was conducted at the Don Bosco Agricultural Training Center located in Paèz county, Zulia state. The life zone in classified as dry tropical forest with a rainfall of 800 mm year^{-1}, average annual temperature of 28°C and a relative humidity of 76%. A statistics randomized block design with nine treatments and four replications was used. The treatments were dicamba, (2,4-D 1.50 and benzoic acid 0.44 kg a.i. ha^{-1}); 2,4-D ester 2.81 kg a.i. ha^{-1}; 2,4-D 2.39 plus 2,4-DP 2.34 kg a.i. ha^{-1}; picloram, (picloram 0.96 plus 2,4-D 10.192 plus metsulfuron methyl 0.012 kg a.i. ha^{-1}; mechanical control (machete) and an absolute check. The experimental plot unit for cattails trail was 10 m by 15 m equal to 150 m^2 with and effective total area 5400 m^2; and for the giant bulrush was 5 m^2 by 10 m^2 equal to 50 m^2 for a total area of 1800 m^2; all the plot were cut and the chemical treatments were applied after three weeks. A 60 DAT, a weed control evaluation was made and weight samples of cattails, giant bulrush and German grass were taken. The statistical analysis showed significant differences ($P<0.05$) between chemical treatments and the mechanical control gave the best results: For cattails control, dicamba 95%; 2,4-D plus 2,4-D plus 2,4-DP 93%; picloram 92%; picloram plus metsulfuron methyl 91% and commercial mechanical check 30% for giant bulrush, picloram 93%; dicamba 91%; 2,4-D plus 2,4-DP 90%; glyphosate 81%. Also there were significant differences in the yield of the German grass. All the chemical treatments were better than the absolute check, but only picloran, dicamba and 2,4-DP were better than the commercial check.

The influence of chemical weed control timing on the yield of winter cereals in Slovenia (132)

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The results of fourteen experiments in winter wheat and barley conducted between 1992 and 1999, at different locations in Slovenia are presented. Soil and foliar acting herbicides were used at different times, in early and late autumn, and early and late spring to evaluate the herbicide efficacy and yield due to different application timing. Only the most effective herbicide combinations with at least 95 % of herbicide efficacy were included in yield comparison. From the results, it can be concluded that early autumn application gave, on average, the best herbicide efficacy as well as highest yields which were up to 600 kg higher in comparison to late spring application. Nevertheless, it is very hard to foresee the justified application time due to many factors which influence the herbicide efficacy and yield, among them especially weather conditions, sowing date, density of the cereals, the type of weed species and their density.

Effect of weed control on two genotypes of cowpea [*Vigna unguiculata* (L.) Walp] under direct planting in the Maracaibo plateau, Venezuela (133)

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An assay was carried out to evaluate different methods of weed control in two genotypes of cowpea in direct planting systems, at the experimental farm ''Ana Maria Campos'', located in the San Francisco municipality, state of Zulia. The ecological area belongs to a very dry tropical forest, with a sandy loam soil with a subsuperficial argilic horizon and pH of 5.0-5.6. The stastical design used was a randomized split plot desing. The genotype factor was the primary plot and the weed control methods were in the secondary plot. We evaluated sixteen treatments with five replications. The experimental unit was a plot with 4 rows of 5 m long and 0.6 m between rows. The statistical analysis showed highly significant differences ($P < 0.01$) for herbicide effect, coadjuvants and cover for the variables: number of pods/plant, yield ha^{-1} and control weed. The results showed no significant differences ($P < 0.05$) for the two factor interaction. Significant differences were detected for genotypes and herbicides for the variables number of pods/plant, number of grain/pod, weight of 100 seed, yield ha^{-1} and weed control, but only for the genotypes. Glyphosate trimesio gives the major economic profit (Bs ha^{-1}). The ON - 30(6) mutant provides the higher grain yield.

Effects of three tillage systems and two herbicide over some physical and chemical soil properties of a sandy loam Typic haplargid and cowpea yield [*Vigna unguiculata* (L.) Walp] in the Maracaibo plain, Venezuela (134)

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The experiment was carried out on a sandy loam Typic haplargid in the Maracaibo plain, located at the experimental field ''Ana Maria Campos'' of the Zulia University, Venezuela. To evaluate the effect of two tillage systems over some physical a chemical proporties at two depth (0-10 cm and 10-20 cm), aqnd over the yield of cowpea (*Vigna unguiculata* L. Walp). A randomized block design with a split plot arrangement was used, the tillage treatments were: no tillage, reduced tillage and conventional tillage; the herbicide treatments were glyphosate 1% and 1.5%. The results showed that physical soil properties changed significantly and chemical properties and crop yield did not change with tillage treatment. There were no differences in weed control between herbicide doses. Finally, it was observed that there is no soil constraint for the establishment of sustainable systems using no tillage.

Performance of CGA362 622 post emergence on broadleaf weeds in cotton (135)

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CGA362 622, is a new Novartis sulfonylurea herbicide selective in cotton and sugarcane. It is a systemic post-emergence compound, with some residual activity. This field study had the objective to evaluate efficacy and crop safety of CGA 362 622, when applied early post-emergence in cotton. During the season 1998/99, 13 trials were conducted, in the principal cotton regions of mid-west Brazil. Layout of the trials was a randomised block design, with 4 replicates and a plot size of 15 m^2. Application was done by a CO_2 backpack sprayer, and a water volume of 300 L ha^{-1}. Tested treatments, rates in a.i. ha^{-1}: CGA362 622 at 5.0, 7.5, 10 and 15 g and pyrithiobac sodium (standard treatment) at 70 and 140 g ha^{-1}. Extravon was added to all treatments, at rate of 200 ml /100 L of water. Application was done at a stage of 1-4 leaves of cotton and 2-6 leaves of broadleaf weeds. CGA362 622 at all tested rates presented good selectivity, similar to pyrithiobac sodium, when applied at 3-4 leaf stage of cotton. Excellent efficacy, comparable to pyrithiobac sodium, was achieved with 5.0 g a.i. ha^{-1} of CGA 362 622 on *Acanthospermum hispidum* and *Bidens pilosa*, 7.5 g a.i. ha^{-1} of CGA 362 622 provided $>$ 90% control of *Ipomoea grandifolia* and *Euphorbia heterophylla*, (equal or superior to pyrithiobac sodium). CGA 362 622 at 10 g a.i. ha^{-1} gave $>$ 90% on *Tridax procumbens*, *Senna obtusifolia* and *Alternanthera tenella*, species which were not controlled by pyrithiobac sodium. CGA 362 622 did not show sufficient activity on *Amaranthus spinosus* and *Commelina benghalensis*. Based on these results, it can be concluded that CGA 362 622 is an effective solution for a selective post emergence control of the most important broadleaf weeds in cotton.

CGA 362 622: a new selective herbicide for use in sugar cane (136)

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CGA 362 622 is a new selective sulfonylurea herbicide in sugar cane and cotton, discovered by Novartis, and has the proposed chemical name trifloxysulfuron sodium. This product has systemic action, and, therefore, it is more active in postemergence application, although it has good soil activity. CGA 362 622 was tested in sugar cane in mixture with ametryn. The commercial product, formulated as water dispersible granules, contains 750 g active ingredient (18.5 g of CGA 362 622 and 731.5 g of ametryn) per kilo. The product was tested in Brazil during the last 3 years. The objective of this paper is to describe the efficacy and selectivity of CGA 362 622+ametryn for the control of the main weed species in sugar cane, in postemergence application. The trials were carried out as complete randomised blocks with 4 replicates, plot size of 20 m^2. Products were sprayed with hand held sprayer, boom with 6 Teejet 110 03 nozzles, pressurised by CO_2 at 40 psi in 200 L water per ha. Products tested were: CGA 362 622+ametryn 750 WG at 1125 g, 1500 g and 1725 g a.i. ha^{-1}, ametryn 500 SC at 3000g a.i. ha^{-1} and hexazinone+diuron 600 WG at 1500 g a.i. ha^{-1}. All CGA 362 622+ametryn treatments were sprayed with surfactant (Extravon 0.2 %). Treatments were sprayed postemergence on sugar cane at 20-40 cm height, and on weeds at 4-10 leaves. The results at 60 days after application (DAA), at canopy closure, show that CGA 362 622+ametryn at rates of 1500 g and 1725 g a.i. ha^{-1} give excellent control $>$ 90 % of *Brachiaria decumbens* with 2 tillers, *B. plantaginea* with 2-3 tillers, *Digitaria horizontalis* with 3 leaves, *Acanthospermum hispidum* with 2-8 leaves, *Commelina benghalensis* with 2-6 leaves, *Richardia brasiliensis*, *Amaranthus viridis*, *Sida rombifolia*, *Euphorbia heterophylla*, with 2-8 leaves. With this high level of control, CGA 362 622 + ametryn was similar or better compared to the standard ametryn solo and hexazinone+diuron for the control of these species. CGA 362 622+ametryn has shown acceptable control of *Cyperus rotundus* (80 %) at 45 DAA, and it was clearly superior to the standards which did not control *Cyperus* at all. CGA 362 622+ametryn has shown good selectivity to the sugar cane varieties RB 76 3710, RB 89 2575, SP 801842, SP 81 32 50, RB 72454, RB 85 5536. CGA 362 622+ametryn 750 WG provides excellent control of the

main grass species, broad leaf weeds and *C. rotundus* in sugar cane and this product can be used for a weed management in this crop.

Control of *Cyperus rotundus* in sugar cane with CGA 362 622 (137)

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Cyperus rotundus is one of most important weeds in sugar cane because it spreads easily and competes strongly with the crop. The control of this species is difficult and there are only a few products which can reduce its population. CGA 362 622 is a new herbicide discovered by Novartis, which has shown excellent control of several weed species in sugar cane and it has shown good activity for *C. rotundus*. CGA 362 622 is formulated in mixture with ametryn as 750 WG and the proposed commercial name is Krismat. The objective of this work was to determine the efficacy and selectivity of CGA 362 622 750 WG and CGA 362 622+ametryn 750 WG for the control of *C. rotundus* in single application and sequential applications. The experimental design was a complete randomised blocks with 3 replicates, and about 500 weeds m^{-2}. The treatments used were: CGA 362 622 750 WG at 50 g a.i. ha^{-1}, CGA 362 622+ametryn 750 WG at 1500 g a.i. ha^{-1} alone and in mixture with 2,4-D at 360 g a.i. ha^{-1} and a sequential application of CGA 362 622+ametryn at 1500 g a.i. ha^{-1} followed by CGA 362 622 at 15 g a.i. ha^{-1} , applied 21 days later. Extravon at 0.2 % was added to all treatments. The standard used for comparison was halosulfuron at 112.5 g a.i. ha^{-1}, plus the surfactant Aterbane at 0.5%. Treatments were sprayed with a hand held sprayer, boom with 6 Teejet 110 02 nozzles, pressurised by CO_2 at 45 psi and 250 L water per ha. Sugar cane, variety SP 80 1842, was 20-40 cm height and *Cyperus* 10-15 cm. Assessments were made at 15, 28 and 52 days after application. After 52 DAA (canopy closure), CGA 362 622+ametryn as single application at 1500 g a.i. ha^{-1} gave 63% control while this rate in mixture with a small amount of 2,4-D (360 g a.i. ha^{-1}) gave 73%. CGA 362 622 alone at 50 g a.i. ha^{-1} gave excellent control of *Cyperus* (95%) and was superior to halosulfuron which gave 82% control. The sequential application CGA 362 622+ametryn followed by a low rate of CGA 362 622 (15 g a.i. ha^{-1}) applied 21 days later gave also excellent control (93%). All treatments were well tolerated by the crop. To verify the viability of *Cyperus* tubers remaining in the soil after application, 6 soil samples per treatment (15x15x15 cm) were taken from the plots at 52 DAA and checked for viability in the laboratory. At 98 days after soil sampling, CGA 362 622 reduced the germination of the remaining *Cyperus* tubers by 54%, halosulfuron by 58% and the sequential CGA 362 622+ametryn followed by CGA 362 622 by 62%. The results confirmed the good activity of CGA 362 622 for *C. rotundus* and indicated that the product can reduce *Cyperus* population in the field. The sequential application of CGA 362 622+ametryn plus CGA 362 622 is also an excellent alternative for the control of this species with the benefit of controlling others grasses and broadleaf weeds.

Environmental impact of herbicides under no-till system in Brazil (138)

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The intensive use of agricultural machinery during the early 1960's and the subsidised soybean export market led to the expansion of the cropped area in Brazil. Farmers moved from a diversified cropping system to conventionally tilled intensive wheat - soybean system. Annual soil erosion losses under this system averaged 12.8 t ha^{-1}. Watersheds contamination by pesticides followed soil erosion and run-off. No-till system was introduced as an alternate to conventional tillage with an objective to reduce production costs and soil erosion. Since its introduction in the 1970's, more than 10 million hectares in southern Brazil were under no-till system in 1999. This system not only conserves water and soil but also reduces herbicide use and run-off. The cropping system in southern Brazil comprises of two crops per year: winter cereals are sown in May-June followed by soybean or corn in October-November. Farmers in Brazil are including cover crops in their cropping sequences for weed suppression. Inclusion of cover crops in no-till systems can reduce herbicide use and cost by about 50%. Direct-seeding of corn and soybean can be done into the crop residue or cover crop without using desiccant herbicides. In addition, post-emergence herbicides have contributed to the rational use of herbicides. Improved water quality is a major benefit that results from reduced pesticide use. This process is facilitated by no-till systems because most of the pesticides are tightly bound to the soil particles. A decrease in soil erosion and pesticide run off from no-tilled fields hence results in a reduction of water contamination in reservoirs.

Integrated weed management system in coffee (*Coffea arabica*) with herbicides (139)

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Herbicide rotation is well known as a good procedure for weed control in crop and non-crop lands to avoid development of herbicide resitant populations. The purpose of this research was to identify the best post-emergence herbicide sequences for *Eleusine indica*, *Cenchrus echinatus*, and *Commelina benghalensis* control in coffee (*C. arabica*) under field conditions. *Eleusine indica* and *C. echinatus* were efficiently controlled by the sequences sulfosate, (paraquat+diuron), sulfosate and sulfosate, (paraquat+diuron), (paraquat+diuron) applied in November, January, and March, respectively. Best results could be obtained if sulfosate and glyphosate were sprayed at shorter than 60-day intervals in the sequence, except in March applications when all sequences tested were efficient for 60-day period for *Eleusine indica* and sulfosate, (paraquat+diuron), sulfosate and sulfosate, (paraquat+diuron), (paraquat+diuron) for *C. echinatus*. The species *C. benghalensis* required (paraquat+diuron) in the sequence for better control. Also, sulfosate, even showing only 60% control, was better than glyphosate. Sulfosate application in March following (paraquat+diuron) applied in January gave 84% control at 15 daa. Therefore, sulfosate, (paraquat+diuron), sulfosate and sulfosate, (paraquat+diuron), (paraquat+diuron) sequences provided the best control for the three species.

Effect of planting density and weed control on cassava (*Manihot esculenta* Crantz) in the Sucre municipality, Zulia state, Venezuela (140)

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This experiment was carried at sector the Marias located in Sucre municipality sudeste area of Zulia state, Venezuela. The objetive of this study was to compare different plant densities and distinct weed control methods effects on cassava. The experimental design was factorial 3 x 5 in split plots with five replications. Three plant densities (10 000, 12 500 and 15 625 plants per hectarea), and five treatments were evaluated (fomesafen 187.5 g a.i. ha^{-1} + fluazifop-p-butyl 175 g a.i. ha^{-1}, oxyfluorfen 480 g a.i. ha^{-1}, linuron 500 g a.i. ha^{-1} + alachlor 960 g a.i. ha^{-1}, hand weeding, and the control). The statical analysis showed significant differences for the variable number of roots per plant and weed control percentage with respect to plant densities, it showed significant differences for the variable percentage of weed control. The treatment fomesafen + fluazifop-p-butyl obtained the highest yield, 21 800 kg of root ha^{-1}. The plant densities 12 500 plants per hectare with 22 438 kg ha^{-1} obtained the highest yield.

Effect of two herbicides on weed control in corn (*Zea mays* L.) under a minimum tillage system in Venezuela (141)

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An essay was conducted on an Inceptisol soil with a subequatorial and continental climate, a dry tropical wood, situated in Turèn, Portuguesa state, Venezuela. The effect of paraquat 400 g a.i. ha^{-1} and glyphosate 960 g a.i. ha^{-1} on weed control in corn under a minimum tillage system was evaluated. The experimental design was a factorial 2 x 2x 3 with *Rottboellia exaltata* L. and *Cyperus rotundus* L., being predominant the latest. Weed appearance was evaluated 35 days after sowing, the best control was observed with the application of glyphosate. In relation to the effect of weeds on some variables of the crop, no significative differences were found; however, the trend of the effect was better where glyphosate was used.

Integrated control of *Chrysanthemoides monilifera* ssp. *monilifera* (T. Norlich) in temperate natural ecosystems in Southern Australia (142)

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Chrysanthemoides monilifera ssp. *Monilifera* (boneseed) is an invasive woody weed in temperate Australia. The species has naturalised in Mediterranean type climatic zones in open grassy woodlands, dry schlerophyl forests and closed eucalypt forests. Control of *C. monilifera* using fire, herbicides and the seeding of competitive native grasses was undertaken in a species rich (>20 species m^{-2}) Eucalyptus viminalis-dominated natural ecosystem. The site was located in the Mornington Peninsula State Park, c. 100 km southeast of Melbourne, Australia. A prescribed autumn burn was directly followed by handbroadcasting of the native C3 grass *Poa sieberiana* var. *sieberia*na (Spreng.). The following spring the C4 grass *Themeda australis* (R. Br.) Stapf. was broadcast onto plots. Spraying of glyphosate and metsulfuron-methyl occurred at 5 or 17 months after burning to control *C. monilifera* seedlings. Almost complete *C. monilifera* control occurred in plots which received methsulfuron-methyl treatments. These plots had abundant regeneration of native grasses. Glyphosate initially controlled *C. monilifera*; however after one year, very little grass had re-established and new *C. monilifera* seedlings had germinated. A low cover of planted *P. sieberiana* var. *sieberiana* failed to outcompete boneseed seedlings, while plots with 100% *P. sieberiana* var. *sieberiana* cover appeared to reduce seedling survival, although not completely. As gaps will always be present in distributed grass, sowing grass for simultaneous control and revegetation of *C. monilifera* infested areas would need to be integrated with other control methods. In conclusion, the integration of fire, metsulfuron-methyl application and competitive grass cover can effectively control *C. monilifera*.

Weeds in food legumes and their control in the Middle East (143)

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The objective of the study was to compare the efficacy of different methods of weed control applied to food legumes grown in warm and arid areas of the Middle East. Weeds are the major growth-restricting factor in those regions. The trials conducted in Northern Syria in the years 1981-1985 were set up on private farms and on experiment stations operated by the International Center for Agricultural Research in the Dry Areas (ICARDA). All the major food legumes of the region, faba bean, lentil and chickpea were included in the trials. Two approaches, one being an integrated method which involved tillage, nitrogen

fertilization and the use of chemicals, and the other consisting in the use of chemicals alone, were used for controlling the parasitic weed *Orobanche* sp. Since cultivation is ineffective in controlling weeds in food legumes the use of herbicides is essential. Cyanazine, mixture of cyanazine with pronamid and fluazifop-butyl gave the best control of weeds in lentil. Chickpea-infesting dicots were well controlled by chlorbromuron, terbutryne, cyanazine and by the mixture of cyanazine with pronamid or with methabenzthiazuron. Fluazifop-p-butyl and dinoseb-acetate were the best choice for postemergence control of monocots. The highest weed-killing efficiency in faba bean was achieved by the use of such postemergence herbicides such as chlorbromuron, methabenzthiazuron and terbutryne. Threefold sprays with glyphosate formula at a rate of 0.08 kg a.i. ha^{-1} gave the best control of the parasite *Orobanche* sp. in faba bean and lentil. Under arid conditions weed control must be made integral part of improved crop production technologies since it is only with the use of weed control that full benefits of irrigation and fertilization can be achieved.

Ipomea **spp. control in cotton** (144)

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Field studies were conducted from 1997 to 1999 to evaluate weed control efficacy and the tolerance of herbicides applied post directed at layby on 22.86-30.48 cm cotton. *Ipomea* spp. is difficult to control with existing cultural and herbicide programs in cotton. The objectives of these studies in 1997 and 1999 were to evaluate increasing rates of pyrithiobac-sodium, tank mixes of pyrithiobac-sodium with UN-32, tank mixes of pyrithiobac-sodium with MSMA, increasing rates of flumioxazin, tank mixes of flumioxazin with glyphosate, and tank mixes of flumioxazin with MSMA. In 1997 all rates of pyrithiobac-sodium + Agridex gave partial control of emerged *Ipomea* spp. in Acala cotton. The addition of 18.92 liter of UN-32 fertilizer to pyrithiobac-sodium increased control in all rates of pyrithiobac-sodium. UN-32 fertilizer alone gave some control. Cotton injury was slight for 14 days following treatments. The addition of UN-32 to cyanazine gave better control of *Ipomea* spp. than the cyanazine + Agridex, however cotton injury increased. In 1999 flumioxazin + Agridex gave excellent control of emerged *Ipomea* spp. and *Cyperus rotundus*, however cotton injury was severe almost killing most plants. The tank mixes of flumioxazin + MSMA and flumioxazin + glyphosate also gave excellent control of *Ipomea* spp. The addition of glyphosate, the tank mixes of glyphosate with cyanazine and oxyfluorfen also gave excellent control of *Ipomea* spp. and *Solanum nigrum* in glyphosate tolerant cotton.

Annual weed control in field corn with tank-mix combinations of isoxaflutole (145)

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Isoxaflutole (RPA 201772) is a systemic preemergence herbicide for broad-spectrum weed control. Field experiments were conducted to evaluate the effectiveness of tank-mix combinations of isoxaflutole and acetochlor, alachlor or metolachlor in controlling annual grass and broadleaf weeds in conventional tillage corn (*Zea mays* L.). Treatments were replicated three times in a randomized complete block design. Corn 'Maximizer 747' and 'Maximizer 21' was planted on May 14, 1996 and May 13, 1997. All preemergence treatments were applied one day after planting using a CO_2-backpack sprayer that delivered 210 L ha^{-1} at 152 kPa. Control of *Setaria lutescens* (Weigel) Hubb. (yellow foxtail), *Digitaria sanguinalis* (L.) Scop. (large crabgrass), *Chenopodium album* L. (common lambsquarters), and *Amaranthus retroflexus* L. (redroot pigweed) was estimated 4, 8, 13 and 15 weeks after treatment (WAT). Corn injury and yields were determined. All isoxaflutole treatments were safe to corn in both years. In 1996, isoxaflutole alone at 80, 105 and 130 g a.i. ha^{-1} controlled *S. lutescens* 60, 53 and 63%, respectively, 4 WAT. Isoxaflutole at 80 g ha^{-1} in combinations with acetochlor, metolachlor or alachlor at 1 kg ha^{-1}, controlled *D. sanguinalis*, *C. album* and *A. retroflexus* over 90% up to 15 WAT in both years. Atrazine in combination with isoxaflutole provided over 90% control only up to 8 WAT, followed by a decline in *S. lutescens* control 13 WAT. Grain and silage yields of corn from all treatment combinations were comparable to the yields from the cultivated check and commercial standards. Tank-mix combination treatments of isoxaflutole have great potential for effective weed control in corn.

Studies on weed management in rainfed chilli and cotton intercropping systems (146)

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Chilli and cotton intercropping is the most popular and remunerative cropping system in northern Karnataka. At present, manual and cultural methods are used for weed control in this cropping system. A field study was carried out for two years at the Main Research Station of the University of Agricultural Sciences, Dharwad. The study involved integrated weed management techniques including chemical and cultural methods. The field experiment consisted of ten treatments replicated thrice in RCBD. The treatments included: pre-emergence application of fluchloralin pendimethalin at 1& 1.25 kg a.i. ha^{-1}, oxyfluorfen at 0.1 and 0.2 kg a.i. ha^{-1} followed by either postemergence application of glyphosate at 1 kg a.i. ha^{-1} or hoeing at 90 days after chilli transplanting; tank mix of pendimethalin (0.5 kg a.i. ha^{-1})+ oxyfluorfen (0.1 kg a.i. ha^{-1}); conventional method-hand weeding (twice) + hoeing (twice). The data indicated the superiority of conventional method followed by pre-plant application of oxyfluorfen at 0.2 kg a.i. ha^{-1} followed by post-emergence directed spray of glyphosate at 1 kg ha^{-1} with weed control efficiency values ranging from 85 to 100 % and 70 to 94% respectively. Significantly higher dry chilli yield was obtained from the plots which were kept weed free through cultural methods throughout the crop growth period than in all other treatments except oxyfluorfen followed by glyphosate. Similarly weed free check plots, that received multiple intercultivation and hand weedings out yielded all other treatments in seed cotton yield. The higher net income and benefit-to-cost ratio was obtained with weed free check, two hand weedings + two hoeing and oxyfluorfen followed by glyphosate.

Will farmers adopt integrated weed management without resistance? (147)

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Integrated weed management (IWM) is currently not adopted by most farmers until they have a herbicide resistance problem. The adoption of preventative IWM may increase in the future, as the threat of resistance and the benefits of IWM are more widely recognised and understood. The reasons why some farmers already adopt preventative IWM are: a) greater awareness of the impact of resistance; b) clearer understanding of how resistance develops and selection pressure; c) an assumption that all farmers using herbicides will eventually get resistance, its just a matter of when; d) farmers are given a simple, clear and consistent message about resistance and are working closely with trusted and well informed advisers; e) farmers are targeting other difficult species and are moving to a multi-species approach to management; f) farmers have come out of the ‘‘resistance denial’’ phase; g) resistance is managed at the whole-farm scale over a longer time-frame to spread risk; h) a participatory extension approach with on-farm monitoring; i) better records of herbicide usage; and h) the herbicide resistance ‘‘threat’’ accelerates IWM adoption through concerns about, lost profits, complicated and long-term management required, loss of herbicides,

penalties for grain contamination, devaluation of land values, not geared up with the necessary equipment, and the need to learn new skills. The challenge is to develop management packages with farmers that include farm-scale, long-term planning within an economic framework, including the probability of success of individual control tactics. It is likely that once farmers get resistance in one field, they are more likely to adopt preventative IWM in the remaining fields to preserve their remaining herbicide options. The rate of adoption of preventive IWM will probably increase but at a slower rate than reactive adoption in response to the development of herbicide resistance.

Decision support for integrated weed management (148)

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Farmers face several difficulties when making decisions about integrated weed management (IWM) strategies: the farmers are inexperienced with some of the control options; impacts of individual treatments within an integrated strategy can be difficult to interpret from field observations; some strategies have indirect, as well as direct, costs and benefits; long-term impacts of multiple control options are difficult to predict; and the number of possible combinations of treatments is vast. Given these difficulties, computerised decision support systems (DDSs) for IWM could be especially valuable to farmers. However, existing DSSs for weed management have focussed primarily on herbicides. One Australian DSS, RIM, does include a comprehensive range of treatment options. RIM simulates ryegrass (*Lolium rigidum*) population dynamics, competition and economic costs and returns for any user-specified IWM strategy over 20 years. It provides a number of insights about the economics and biology of IWM, including the following. Even in the absence of a herbicide resistance threat, the optimal combination of control practices does often include non-chemical methods. After the onset of resistance, the most profitable integrated strategies do include a more diverse range of control methods. Individually these tend to be less effective than selective herbicides, so a greater number of treatments must be employed. The ‘‘optimal’’ strategy with resistance involves only a slightly greater average density of weeds. Thus the economic losses due to resistance are not primarily due to differences in weed density, but to differences in total treatment costs. There appears to be no compelling case for reducing the reliance on herbicides in order to delay the time when they will be lost to resistance. It can sometimes be economically desirable to change the sequence of crops and pastures as part of the management response to herbicide resistance. For full paper see: http://www.general.uwa.edu.au/u/dpannell/dss4iwm.htm

Integrated weed management studies on fenugreek (*Trigonella foenum-graecum* L.) in semi-arid regions of Rajasthan, India (149)

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Different weed control treatments provided effective control of weeds such as *Chenopodium album* L., *C. murale* L.and *Rumex dentatus* L. Hoeing twice at 25 and 45 days after sowing and pre-emergent pendimethalin at 0.5 kg. a.i. ha^{-1} superimposed with one hoeing at 35 days after sowing achieved excellent control of weeds (87.74 and 86.88 %). As a result, these treatments improved periodic crop dry matter yield, crop growth rate, relative growth rate, yield attributes and enhanced seed yield significantly by 42.55 and 41.20% and net return by Rs. 5274 and Rs. 5076 ha^{-1}, respectively over the weedy check. Of the sole herbicides evaluated, pre-emergent pendimethalin at 1.0 kg a.i. ha^{-1} also achieved promising control of weeds (63.19%), improved growth and yield attributes and enhanced seed yield and net return considerably and thus, provide an effective alternative to above treatments. As sufficient literature was lacking on weed management in fenugreek, an important spice crop in the country, a field experiment was conducted to work out appropriate integrated weed management strategy in this crop during the winter seasons of 1996-97 and 1997-98 at Agricultural Research station, Durgapura, India. The experiment comprised nine manual and herbicidal treatments applied alone and in combination in fenugreek grown under three dates of planting and was laid out in split-plot design with four replications.

New automated system for integrated weed management in sugarcane (150)

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A new, computer-based, automated system has been developed on a Windows environment, for integrated weed management in sugarcane. It comprises three interrelated parts: I. A knowledge base, which includes extensive information about the main weed species in Cuban sugarcane fields (including color images of different stages), herbicides and herbicide treatments currently in use, their action on each of the weed species and crop-weed-environment conditions, productivity and costs of all chemical, mechanized and manual weed control operations and spray nozzle specifications; II. An expert system for immediate herbicide treatment decision-making, which recommends best treatments, according to number of weed species controlled or suppressed among those reported as prevalent, treatment costs and prevailing weed-crop-environment conditions.

Integrated alien weed control planning (151)

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In Sappi Forests, invasive alien plants are controlled for business production purposes, for enhanced water production and for biodiversity conservation. Long term programme planning is needed to achieve effective invasive alien plant control. The long term objective is to reduce all areas of plantations to a low cost maintenance level of infestation. Weeding in planted areas is integrated into a single environmental weed programme. Weed infestation levels are quantified in both planted and unplanted areas using a rapid and effective index, referred to as the shifts per hectare method. A system to determine priority areas has been developed. Plantations are subdivided into relatively large Management Units (MUs). Each MU is prioritised primarily according to its relative ease of control. Consideration is also given to ranking habitats according to their status, protection and management urgency. Areas that are lightly infested are normally cleared first. An adaptive management approach is recommended, to allow for a process of continual improvement of the control programmes. All changes to plans are documented and include brief motivations. The poster illustrates the planning procedure and shows how recommendations are made, regarding the determination of appropriate annual budgets.

Effects of weed interference on maize hybrid grain yield in relation to crop density (152)

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Grain yield achievement of maize (*Zea mays* L.) hybrids is frequently limited by weed interference. Plant and row spacing, crop, and crop cultivar competitiveness are cropping-system factors in IWM and are used in order to reduce herbicide use in maize weed control. Determination of competitive effects of different crop densities of two maize hybrids on decreasing weed interference on maize grain yield was the objective of this research. Effects of three different maize densities on dry weight of weeds and plant height and

grain yield of two maize hybrids were studied under conditions with and without herbicide application. Two hybrids of different FAO maturity groups (H1 - ZPSC 42A and H2 - ZPSC 704) were grown in a three factorial randomised complete block design experiment with four replications on sandy loam soil at Zemun Polje in 1996 and 1997. The planting densities were: D1: 40 816 plants ha^{-1}, D2: 69 686 plants ha^{-1} and D3: 98 522 plants ha^{-1}. Herbicide combination of atrazine + metolachlore was applied preemergence in the amount of 1.0 and 2.88 L ha^{-1} a.i. Check plot was untreated. The weed dry weight (g/m2), and maize height (cm) were measured at maize flowering stage. Maize grain yield (t ha^{-1}) was measured at the end of vegetation season. Obtained results show that decrease of weed dry weight from the lowest (D1) to the highest (D3) planting density was significant (41.2% and 36.7% for both years, respectively). Also, weed dry weight significantly was lower on treated variant in relation to the check. In respect to this, grain yield of maize was higher in both years in the treated variant, higher planting density D3, and hybrid H2. Coefficients of correlation between dry weight of weeds and maize plant height and maize grain yield were negative and statistically significant for investigated densities and hybrids.

Modelling interactions: developments and applications (153)

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Quantitative knowledge on crop-weed interactions and population dynamics is required to design preventive measures, to develop long-term and short-term strategies for weed management, to assist in decision making to determine if, when, where and how weeds should be controlled and to identify new opportunities for weed control and increase the precision of weed control. Significant improvements have been made with respect to the quantitative understanding of crop-weed interactions with eco-physiological simulation models. Eco-physiological models for interplant competition were first developed in the early 1980's to obtain a better understanding of the harmful effect of weeds on crop productivity. The models were developed from simulation models of monoculture crops, which were then linked by additional routines to account for the distribution of resources over competing species. Initially the models were used for the construction of more robust damage relationships to support rational decision making on the use of herbicides such as the relative leaf area model. At present, apart from a need to reduce the use of herbicides, the design of weed management systems with a reduced reliance on herbicides is advocated. As a result the weed problem should be envisaged in a different perspective. Rather than only focusing on detrimental effects in current crops, main emphasis should shift towards the management of weed populations and weed management itself should become an integrated component of crop management. That resulted in a shift in emphasis from effects of the weeds on the crop to studies on the effect of the crop on the weeds with emphasis on weed seed production. For the development of these alternative management systems specifically improvements with respect to prevention, alternative control technology and decision making seems promising. The new challenges for modeling crop-weed interactions and prerequisites for crop-weed competition models that follow from these developments are discussed.

Modeling crop-weed interactions for management decisions (154)

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Weed management decisions are frequently made before planting or very early in the growing season, long before yield loss associated with the weed complex present in a particular field can be predicted with any certainty. Many experiments have concentrated on quantifying the reduction in final yield which can be attributed to a particular weed population density, without regard to the mechanisms through which that yield reduction occurred. A number of studies have shown that crop yield increases as distance from a weed increases, indicating that weed spatial distribution is important. Studies have also quantified the

importance of duration of competition, and weed versus crop emergence date. Other factors that have been demonstrated to be of importance include crop variety, crop stand density, planting date, row width, geographic location, and rainfall patterns. Because weed control decisions can be very complex, a number of computerized decision aids have been developed to help pest managers decide if herbicides or other control measures are necessary, and if so, which treatment to use. To date, the decision models consider only a small subset of the factors that may affect crop yield loss. In this paper we look at relatively simple ways to model the effect of these factors on final yield. We will also explore the sensitivity of recommendations made by HADSS, a weed management decision support system for field crops, to variations in these factors. Information from the literature and from simulation experiments will be used to define reasonable ranges for each factor. From a management perspective, inaccuracies in predicting yield losses due to weeds are only important insofar as they result in less than optimal decisions. Uncertainties in early-season yield loss predictions cannot be totally eliminated because of inherent uncertainty about future weather patterns, etc. However, accounting for differences in row spacing, crop and weed emergence times, planting date, weed spatial distribution, and other factors that are known at the time of decision has the potential to improve weed management decision-making.

CROPSIM - A mechanistic simulation model of multispecies competition (155)

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CROPSIM is a generic mechanistic model of multispecies competition that can be adapted for any number of weed-crop combinations. The model dynamically simulates competition based on knowledge of the underlying physiological processes governing leaf area development, photosynthesis, transpiration, nutrient accumulation, and phenological development. The model simulates competition for irradiance, moisture and nitrogen. The model is modular in structure and follows ICASA input standards and formats. It is structured with separate sections for initialization of rate and state variables, calculation of rate variables, and updating of state variables. Phenological development, growth, soil and environmental data was collected over the season for a competition study conducted in 1998 between wheat and annual ryegrass under irrigated and dryland conditions. Simulated and observed results are compared. The ability and limitations of using a mechanistic model such as CROPSIM to explain observed results from field competition experiments will be discussed.

***Rottboellia cochinchinensis* (LOUR.) Clayton competition with sugar cane** (156)

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Field experiments were conducted to examine the effects of different densities of *Rottboellia cochinchinensis* on sugar cane yield during the initial and subsequent years following grass establishment and to study changes in populations of *R. cochinchinensis* in the years after establishment. In the year of *R. cochinchinensis* establishment, the rectangular hyperbola accurately portrayed the response of cane yield to increasing densities of the grass weed. The predicted cane yield losses were 64 and 43% in plant and ratoon cane respectively. In the year following the weed establishment (in the second ratoon cane crop), although at two months after ratooning the populations of *R. cochinchinensis* showed increase with increasing initial density, but at 5 months after ratooning they were similar for all initial densities. Likewise the biomass of *R. cochinchinensis* and cane yield losses (67-70%) were similar for all initial densities of *R. cochinchinensis*.

Prediction of *Phaseolus vulgaris* L. yield loss based on density or relative leaf area of *Panicum maximum* Jacq. (157)

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Mathematical models to predict crop yield losses caused by weed interference are important farmers' tools for rational use of herbicides, that will reduce production costs, development of herbicide resistant weed biotypes, environmental pollution and human health risks. Parana is the major producer State of *Phaseolus vulgaris* in Brazil, and *Panicum maximum*, one of the most important weeds especially in areas previously occupied by pastures cultivated with this grass. However, there is no literature information about the yield losses caused by *P. maximum* in the crop. Therefore this study was undertaken to test and compare the efficiency of a hyperbolic yield loss-weed density model, $YL = a*Nw/(1 + a*Nw/m)$, to a hyperbolic yield loss-weed relative leaf area model, $YL = q*Lw/(1 + ((q/m) - 1)*Lw))$, to predict *Phaseolus vulgaris* yield losses. YL is the relative yield loss (%), Nw is the weed density (plants m^{-2}), Lw is the relative leaf area of the weed and m is the maximum relative yield loss. The parameter ''a'' was calculated with data collected from a glasshouse experiment, and ''q'' parameter, from the glasshouse experiment and a field experiment. In the glasshouse experiment, a replacement series was used at a total density of 16 plants/pot (18.5 cm diameter), and five proportions of *P. vulgaris* to *P. maximum*, 16:0, 12:4, 8:8, 4:12 and 0:16. Three replicates of the treatments were conducted as a randomized block design. In the field experiment, the density of *P. vulgaris* was 25 plants.m^{-2} and treatments were *P. maximum* plant densities at 40, 61, 103 and 138 plants m^{-2}. Three replicates of the treatments were conducted as a randomized block design. Both models have predicted well the yield loss of *P. vulgaris* competing to *P. maximum* when model's curves were compared to real yield losses obtained from the field experiment.

Interference of increasing *Parthenium hysterophorus* L. population densities with tomato (*Lycopersicon esculentum* Mill.) (158)

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Field studies were conducted in the Dominican Republic to determine the extent of *Parthenium hysterophorus* interference with tomato, as influenced by the population density of the weed. A randomized complete block design with 6 treatments (*P. hysterophorus* population densities of 0, 1, 3, 6, 9 and 12 plants per m^2) with four replications was utilized. *Parthenium hysterophorus* from San Cristobal, Dominican Republic, and 'HeatMaster' tomatoes transplanted at the 4-true leaf stage (height of 10 cm) were used. *Parthenium hysterophorus* plants were allowed to interfere season-long with the crop. Other weeds were removed every 4 to 6 days. Tomato plant height, vegetative biomass and fruit yield, and *P. hysterophorus* biomass accumulation were determined. Analysis of variance and regression analysis were performed on the resulting data. Tomato plant height was not significantly influenced by *P. hysterophorus* population density. However, as *P. hysterophorus* density increased, weed biomass accumulation increased, and tomato plant biomass and yield decreased. The relationship between tomato yield loss and weed density was described by a rectangular hyperbola, with tomato yields decreasing drastically as *P. hysterophorus* density increased from 0 to 6 plants per m^2. Maximum tomato yield loss was 63%.

Damage from the weeds and optimal terms for their control in silage corn (159)

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Silage corn takes leading place in the structure of planting areas in Ukraine. Total area of corn sown makes up 1.5 million ha. Meanwhile the productivity of it is not very high. Among many reasons, one of the main is the high weediness of the crops. Modern technologies of planting (because of the difficulties in our economy) are not always able to apply herbicides and often agrotechnical means are not used in due time. That is why they do not fulfill full control of weeds in silage corn. During 1996-1998, we studied weediness of different weeds (different time of germination) and how different time of application influence corn harvesting. To study the harmful effect of the broadleaf weeds, we considered *Sinapis album*. Densities were in the range of 0-100 plants m^{-2}. The results of our investigations showed that weeds in the crops during the first 5-25 days of plant growth lowers yields by 5%. If the weeds are in the crops during 30 days, yield losses make up 23%. There is a strict proportion between duration of weeds in the crops and yield loss. In cases when weeds were in the crops from beginning to end (from emergence till harvest), the yields made up only 42% in comparison with the control plots (crops without weeds during whole vegetative period). Damage from weeds was determined by the time of their appearance in the crops. So, in the experiment, when the weeds had been growing every 5 days after crop emergence, the most harmful were weeds which appeared either before or at corn emergence. They made up to 1864 g m^{-2} of total mass, and yield losses were over 54%. On the plots which were clean from the weeds during first 5 days, before yield the weeds made up 1230 g m^{-2} and yield loss was 52%. If the weeds were absent during 25 days, their mass before harvesting is not over 349 g m^{-2}, and yield loss made up 8%. On the plots which were clean from the crops during 40-50 days, weed mass was in the limit of 47-97 g m^{-2}, and harvesting of the crop made up 98-99% in comparison with the weed-free plots. It was proved that corn is damaged by weeds and the yields are less when there are 2-5 units of Sinapis album on square meter. Mass of *Sinapis album* made up 113-181 g m^{-2}, and yield loss made up 7-21%. This is the evidence that weeds that are similar by their biological cycle to *Sinapis album* are might revival to the crop in agrocenoses of silage corn. So the result is that the weeds in the silage corn crops must be destroyed not longer than 25 days after crops germination. Weeds that appear on the crops in 30 days after their planting do not harm corn yields significantly.

Effect of *Lolium perenne* seeding density on germination and growth of weeds (160)

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In New Zealand pastoral systems growers are concerned that reduced herbicide use will allow weeds to quickly dominate newly planted fields. Research was conducted to determine what effect perennial ryegrass (*Lolium perenne*) seeding density has on the subsequent germination and growth of weeds. The recommended perennial ryegrass sowing rate in New Zealand is 10 to 15 kg ha^{-1}. Fields that are to be planted into a perennial ryegrass/white clover (*Trifolium repens*) mix are typically sprayed with glyphosate at least two weeks before planting and usually followed by a post-emergence application of MCPB. After emergence, perennial ryegrass plants will self-thin to about 200 plants m^{-2}. Research in the greenhouse and field, using perennial ryegrass planting densities of 0, 5, 10, 20, 40, and 80 kg ha^{-1}, determined that increasing the density of perennial ryegrass increases its competitiveness against weeds. Seven troublesome weed species (*Carduus nutans* L., *Cirsium arvense* (L.) Scop., *Cirsium vulgare* (Savi) Ten., *Ranunculus repens* L., *Ranunculus sardous* Crantz, *Senecio jacobeae* L., and *Sisymbrium officinale* (L.) Scop.) were studied. As perennial ryegrass seeding density increased, weed seed germination was slightly reduced and weed size was markedly reduced. Eight weeks after planting, weight per plant of *Sisymbrium officinale* was least affected by increases in ryegrass density whereas *Cirsium vulgare* was most affected. Subsequent growth of the weeds was reduced in plots with increased perennial ryegrass densities. White clover, which was planted at 5 kg ha^{-1}, was also negatively affected by the increased perennial ryegrass planting density, however increases in grazing pressure may allow clover biomass to recover more rapidly. Results of this research are being used to determine the economics of replacing herbicides with additional perennial ryegrass seed at planting. This research will also complement the efforts conducted worldwide towards reducing pesticide use.

Intraspecific competition among annual pasture plants (Donald 1951) and Michaelis und Menten law of constant final yield (161)

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Relations between biomass yield from annual pasture plants and plant density and length of growing season and level of nitrogen fertilization were studied with Michaelis and Menten law of constant final yield and intraspecific competition data where plant type a is *Trifolium subterraneum* and plant type b is *Lolium loliaceum* and plant type c is *Bromus unioloides*. Law of constant final yield may be from de Wit (1960) equation (5.4) where Ya = Ya*sapa/(sapa + 1) and if sa = 1/Kma then Ya = Ya*pa/(pa + Kma). Objectives were to find (a) Ya* and Kma as a f(length of season) and (b) Yb* and Kmb as a f(length of season) and (c) Yc* and Kmc as a f(nitrogen) and (d) Yc as a f(pc, nitrogen). Mean data from Donald (1951) were regressed with Ya = Ya*pa/(pa + Kma) and Yb = Yb*pb/(pb + Kmb) and Yc = Yc*pc/(pc + Kmc). Kma and Kmb decrease with length of growing season and though more variable Ya* and Yb* mostly increase with length of growing season. Yc as a f(pc, nitrogen) may be from Yc = Yc*pc/(pc + Kmc) where Yc = (0.11N + 6.7)pc/(pc + 2.0). Nitrogen may have no effect on Kmc but Yc* may be linearly related to nitrogen up to 700 mg N pot^{-1}. Prairie grass pastures may be nearly fully exploited at pc = 4Kmc where Yc = 0.8Yc*. Here 4Kmc = 8.0. Results may not agree with conclusion of Donald (1951) where he says ‘‘. . . more plants are needed to achieve full exploitation of a more favourable environment than to exploit fully a less favourable environment.’’ Nitrogen may have no effect on Kmc and so no more plants may be needed to exploit fully a more favorable environment than to exploit fully a less favorable environment.

Breeding for competitive cultivars of wheat (162)

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Strongly competitive wheat crops are important for management of herbicide resistant weed species like *Lolium rigidum* Gaud. in Australia. The aim was to enhance competitiveness of wheat by selecting for certain morphological traits as well as maintaining high yield potential. Two populations of wheat were selected from crosses between a high yielding, poorly competitive but locally adapted cultivar (Janz or Sunbri) and a strongly competitive, vigorous, large-leafed cultivar (Katunga or Kharchia). The crosses were Janz x Kharchia and Sunbri x Katunga and these were selected for disease resistance and plant type over two generations. More than 700 genotypes (F2 derived F5) from the two populations were grown in paired plots, with and without a *L. rigidum* density of 200 plants m^{-2}. Grain yield was used as a genetic measure of competitiveness and yields with and without weed constituted two traits. A positive (genetic) correlation between traits was expected, so a regression line of yield with weed on yield without weed was fitted. There was a strong linear dependency between yields in the weedy and weed-free plots (slope = 0.59). Genotypes which were high yielding in the absence of weed were also high yielding when weed was present. A competitive genotype was one which had a large positive deviation above the regression line, while a poorly competitive genotype had a negative deviation below the line. Selecting for weed-free yield identified genotypes with high yielding ability in the presence of weeds. The potential to combine both yield potential and competitiveness was demonstrated. About 80 of the genotypes will be further evaluated for yield, quality and competitiveness to detect a genotype for possible release to growers. The identification of a way to analyse a genetic measure of competitiveness based on wheat yield is a useful tool for breeding strongly competitive wheat.

Response surface analysis of nitrogen rate effects on competition between water-seeded rice and *Echinochloa oryzoides* (Ard.) Fritsch (163)

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Data for nitrogen rate effects on competition between rice and *Echinochloa oryzoides* from experiments in 1981 (exp. 1) and 1985 (exp. 2) in California were reanalyzed using response surface analysis. Urea-N was incorporated at rates of 0, 33, 66, 100, 134 and 168 kg N ha^{-1} in exp. 1, and 0, 56, 112, 168 and 224 kg N ha^{-1} in exp. 2. Rice cultivars grown were the semi-dwarf 'S-201' and tall, closely related 'S-6' in exp. 1, and 'M-202' in exp. 2. At crop maturity, plots were harvested by combine and rice yields and percent moisture were measured. A response surface analysis was done based on the hyperbolic yield-density model, by evaluating N rate effects on three parameters: 1) weed-free yield (Y_{WF}, kg grain ha^{-1}); 2) percent yield loss as weed density nears zero (I, % m^2 $plant^{-1}$); and 3) percent yield loss as weed density becomes very large (A, %). N rate effects were significant in the yield-density-N model for all cultivars ($p < 0.01$). In the best regression, Y_{WF} was an asymptotic f(N), I was an exponential f(N), and A was a logistic f(N) (adjusted-R^2 = 82%, no. parameters = 15, n = 340). Low N rates always increased rice yields over 0 N, but yield losses increased at rates of 100 kg ha^{-1} or more. The relationship between N and I affected rice-*E. oryzoides* competition the most, which was important because weed densities in this system are more likely to be small than very large. Most important, low *E. oryzoides* densities reduced rice yields significantly, especially at high N rates. Optimal N rates decreased as weed density increased. A simple management strategy indicated by the results may be for rice farmers to apply less pre-plant N and top-dress additional N once it is determined that weeds are not present.

Prediction model of *Sicyos polyacanthus* Cogn. populations in sugarcane in Tucuman, Argentina (164)

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Detailed demographic studies were carried out on *Sicyos polyacanthus* Cogn. in the central region of Tucuman Province (26-28° South Lat. and 64-66° West Long.), in: 1) commercial fields of sugarcane crop; 2) natural ecosystems of the region infested by this weed; 3) ruderal zones, abandoned culture areas and roads, river and lake edges. A graphic and very simple mathematical model provided easy calculations without complicated programming. Essential demographic parameters required for calculations are: a) total seed amount per plant; b) germinative power using trays under greenhouse conditions; c) lenghth of time in years during which changes are expected; d) area in which the species is distributed according to the infestation degree; e)density or weed number per square meter; f) seed losses in relation to different estimated factors. Predictions for 1, 3, 7 and 12 years were realized. It was predicted that in twelve years, the weed will reach 109.56 km^2 with an increase of 17.67% (high infestation zone). In a low infestation zone, the weed will reach 194,64 km^2 with an increase of 14.40%. With increased weed population density, there will be less probability that one plant may inhabit new areas.

Challenges for modelling long-term population dynamics of weeds (165)

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After the proliferation of demographic models in the 1980s and early 1990s, in recent years there has not been major break throughs in this area. However, there is still wide room for improvements. The basic models built in the past can be further refined in various ways. Although some of the models available consider the long-term effects of various types of management practices, future models must be more accurate on short-term effects, integrating a better description of crop-weed interactions, factors regulating seed production and dispersal, etc. Demographic ''black box'' models could be improved by substituting the ''boxes'' by mechanistic relationships between variables. Temporal variability in environmental conditions may have a strong impact on long-term population dynamics. In order to take into consideration this variation it is unavoidable to use a mechanistic approach for modelling. The effect of environment on seed germination and emergence, weed growth and competition with the crop and weed reproduction can be modeled using available approaches. However, the need to obtain experimental data on a large number of parameters is a limitation to the use of these models. New, improved methodology is required in order to get reliable estimates of the parameters in an affordable way. Very few population dynamics models have been tested in the field. Validation of models using long-term experimental data presents various theoretical and practical problems difficult to overcome. Integration of population models into broader systems designed specifically for evaluation of weed management programs has been attempted in various cases. Currently available models can not predict quantitatively the dynamics of the populations, but they can give us a qualitative indication of its behaviour in various situations. Consequently, they can tell us which management option is likely to be the best. Further work in this area should yield science-based decision support systems.

Long-term dynamics of weeds: a community-ecology perspective (166)

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Weed communities - as wholes - have occasionally been considered as a unit of analysis in weed science, and properties of weed communities do indeed appear to be important to many practical issues in weed management. First, it is often the total weed community that is of concern in management. Management actions that are focused on a single weed species often have only short-term effectiveness, because of community dynamics - species shifts - that result in return to a higher level of weed abundance. In this situation, it is the dynamic response to management of the community as a whole that is of interest. This response is contingent on community properties such as species composition and on interactions among weed species. These interactions may involve suppression or facilitation of other weeds, which may be desirable or not, depending on the roles of the weeds involved. Secondly, weeds appear to be inevitable in agroecosystems; therefore it can be argued that the objective of management is to have the best weeds possible, i.e., a weed community that is least harmful and most beneficial. Many of the beneficial agroecological functions of weeds are likely to be geared to properties of weed communities. For example, the diversity of weed communities may determine the roles that weeds play in, e.g., maintenance of beneficial organisms, soil quality, and closed nutrient cycling in agroecosystems. In the hope of helping weed science to frame focused, incisive and practically significant questions about weed communities and their dynamics, I will present results from a survey of relevant theories of plant community dynamics. I will address issues such as interference, facilitation, dispersal and response to disturbance.

Population dynamics and decision support for agro-ecosystems (167)

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In order that herbicide usage be reduced for environmental and economic reasons, a knowledge of weed population dynamics is desirable. Consequently, a knowledge of damage and period thresholds is additionally required in order to maintain weeds at acceptable levels. Population dynamics information is dependent on demographic studies based on weed life cycles. Thus, information is required on seed fecundity, seed rain and dispersal, seedbank dynamics, seedling recruitment and mortality. The effects of cultural practices such as tillage, rotation, crop, fertiliser and herbicide use exert considerable selection pressure, yet such information is available for relatively few species in both cool-temperate and warm-season crops. Information is discussed for selected examples including *Avena* spp., *Alopecurus myosuroides*, *Anisantha sterilis*, *Abutilon theophrasti* and *Echinochloa crus-galli*. An area that has received scant attention is that of seed predation and its impact on population dynamics. Consideration is given to genotypic and phenotypic variation amongst weeds in relation to the effects of environment and climate. It is concluded that a knowledge of weed population dynamics is an essential component for effective weed management strategies.

Predicting seed production of *Bromus tectorum* L. using a simple growing degree-day model (168)

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Control of *Bromus tectorum* in dryland winter wheat presents a major constraint to the adoption of conservation tillage systems in the Pacific Northwest United States. Effective control of *B. tectorum* during fallow periods helps deplete seed in the soil and reduces populations in subsequent winter wheat crops. Delaying fallow tillage operations or herbicide applications in the spring increases the risk for production of viable *B. tectorum* seed during the fallow period. In a series of experiments, developing *B. tectorum* panicles were sequentially sampled near Pendleton, Oregon, USA in 1994 through 1997 and at eight locations around the winter wheat growing region of the western USA in 1999. Cumulative growing degree-days (GDD) required for *B. tectorum* to produce seed was determined. An experiment was also established to determine how late *B. tectorum* could be treated with glyphosate to prevent production of viable seed. Climatological data collected at all sites was used to calculate cumulative GDD by using the equation: GDD = (daily max. temp. - daily min. temp.)/2. A base temperature of 0 C, and a biofix point of 1 January was used to determine cumulative GDD required for production of viable *B. tectorum* seed. Viable *B. tectorum* seed was observed after approximately 1050 GDD with a range of 915 GDD at Moscow, Idaho to 1210 GDD at Stillwater, Oklahoma. Application of glyphosate until nearly 100 percent seed head emergence prevented viable seed production at 965 GDD at Pendleton. Timing of fallow tillage or herbicide application before 950 accumulated GDD can prevent *B. tectorum* seed production. An internet based calculator of accumulated GDD for Oregon was developed to disseminate information to facilitate timing of *B. tectorum* control in fallow.

Effects of sugarcane crop residue from mechanical harvest on weed population dynamics and chemical control (169)

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The objective of this research was to compare the effects of two sugarcane harvest systems used by Brazilian sugarcane growers on weed population dynamics and chemical control. The two major harvest

systems are manual harvest where the crop residue is burned prior to harvest, and mechanical harvest where about 12 to 15 ton of crop residue is left on the soil surface after harvest. One experiment was installed in order to evaluate the effects of sugarcane crop residue on the germination percentage of viable weed seeds under greenhouse conditions, comparing the two sugarcane harvest systems. Soil samples collected from plots that had been harvested manually and mechanically for five years where placed in the greenhouse and weed emergence was monitored. The results indicated surprisingly higher weed emergence from the soil collected in the mechanical harvest system, being the major weeds *Portulaca oleraceae*, *Mollugo verticillata*, *Digitaria horizontalis*. The second experiment was installed in a sugarcane ratoon harvested mechanically and seeded to *Brachiaria decumbens*, *Brachiaria plantaginea*, *Digitaria horizontalis*, *Euphorbia heterophylla*, *Panicum maximum*, *Ipomoea aristolochiaefolia*; one half of the area was kept with crop residue. Herbicide treatments were diuron + hexazinone at 0.936 + 0.264, 1.117 + 0.330, and 1.404 + 0.396 kg a.i. ha^{-1} The emergence of the weeds *Euphorbia heterophylla* and *Ipomoea aristolochiaefolia* was not affected by the crop residue, however all the grasses did not emerged through the crop residue. The herbicide diuron + hexazinone controlled effectively all the weeds in the treatments without crop residue and the weeds that emerged through the crop residue. The general conclusion from these experiments is that sugarcane crop residue change considerably the weed population dynamics suppressing the presence of grasses, and can be an additional tool in the weed management in sugarcane.

Sampling size of weed seed banks (170)

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For quantitative studies of weed seed banks, in cultivated and uniformly managed soils, the number of soil samples to be taken to assure a satisfactory estimation of the number of seeds in the area, is crucial. In order to determine the number of soil samples needed for a required precision, experimental plots of 60 m^2 (small plots) and farmers fields of 0.25-0.5 ha (large plots) were sampled and compared. Sets of 506 and 517 seed counts were computed for the small and large plots, respectively. Sampling was conducted using10 sub-samples/sample in small plots and 50 in the large plots. Samples were taken randomly, using a tubular soil sampler of 5 cm diameter, up to a 10 cm soil depth. Soil samples were washed trough an inox sieve of 0.5 mm mesh, floated, and viable weed seeds identified by species and counted. Linear regression equations were established between means and variances of the weed species, allowing to calculate the number of samples needed (n), as a function of the average number of seeds per sample (Xm), for two different precision levels (c.v. = 20% or 40%). The equation nP = ((50712*(Xm)-1,147)/cv2) estimates the number of samples needed in the small experimental plots and nF = ((50759*(Xm)-0,717)/cv2)), the number in the farmers field large plots. It was estimated that for means between 500 and 1000 seeds m^{-2}, taken at soil depth of 10 cm, and c.v. = 20%, a number of 9 to 4 soil samples (10 sub-samples per sample), respectively, are needed for smaller plots. With a lower precision (c.v. = 40%), the number of soil samples needed varied between 2 and 1 samples (20 to 10 sub-samples), respectively. In considering the same number of seeds/soil sample for larger plots, the number of required samples would be about tree times higher.

Population models are essential tools for selecting weed control strategies - *Nassella trichotoma* (Nees.) as an example (171)

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Nassella trichotoma has been a severe problem in New Zealand and Australian grasslands since early last century, invading millions of hectares to the exclusion of more palatable species. Millions of tax-payer dollars have been spent on control programmes in both countries over the last 50 years employing methods such as cultivation, herbicides, destocking, fertilisation, pasture renewal, forestation, burning, grazing with cattle, and in New Zealand, annual digging up of scattered plants. The persistence of this weed, despite these various control strategies, has led to a demand for improved management approaches including biological control. However, relatively little research on its ecology has occurred during this time and as consequence we continue to have a poor understanding of both the intrinsic processes regulating the population dynamics of *N. trichotoma*, and the impacts of control strategies on these processes. As a result it is not possible, currently, to determine the long-term consequences of alternative strategies or to define the requirements of a particular strategy or biological control agent. A study into the population ecology of *N. trichotoma* is therefore long overdue. Such a study, including the development of a population model, will enable any weaknesses in the weed's life history to be identified and potentially exploited in a control strategy. The resulting *N. trichotoma* model could then be used as a predictive tool to ôtestö different control strategies, including various biological control agents, and compare their relative effects on future population sizes. Only in this way can management strategies for *N. trichotoma* be developed that ensure the sustainability of pastoral farming in grassland ecosystems that are prone to invasion by this weed.

The evolution of herbicide resistance evolution models (172)

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Models were developed to predict herbicide resistance evolution starting in 1978 when triazine resistance was identified around the world. The goal of modeling was to increase understanding of the relative importance of different biological processes in determining resistance evolution and to provide a venue for assessing management strategies that would decrease the probability of resistance to herbicides. Simple models were constructed based on plant population genetics theory and refined by including weed population demographics, crop damage functions and economic outputs. The models required input of the initial proportion of resistance in the weed population, a determination or assumption of whether the resistance was a single gene dominant or recessive trait, and some assignment of the relative fitness of the resistant and susceptible biotypes when not in the presence of the herbicide. There have been few formal validations of the resistance evolution models, but casual assessments indicate that they have been generally accurate predictors of the time (weed generations) to reach identifiable resistance. It is not clear if the resistance models have been effective in influencing management of herbicides to decrease the probability of resistance.

Simulated evolution of glyphosate resistance in *Lolium rigidum* (173)

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Until recently, it was widely assumed that the broad spectrum herbicide glyphosate was infallible to the evolution of herbicide resistance. However, it is becoming increasingly clear that this is not the case. In Australia, there are two annual ryegrass (*Lolium rigidum*) populations with documented resistance and other populations under close scrutiny. The imminent introduction of glyphosate resistant crops into Australian cropping systems and the increasing move towards zero and minimum tillage systems, with their increased reliance on knockdown herbicides for pre-seeding weed control, is likely to increase selection pressure for the evolution of resistance to glyphosate and other knockdown herbicides. A two gene simulation model of the population genetics and dynamics of glyphosate and paraquat resistance in *L. rigidum* has been developed. Results are presented from 30 year simulations which predict the rate of glyphosate and paraquat evolution under a range of herbicide use strategies, with and without glyphosate resistant crops in the rotation. Of these strategies, the double knock (sequential pre-seeding applications of both glyphosate and paraquat) is the most effective, preventing resistance evolution to both herbicides over the 30 year simulation timescale. The model is used to demonstrate that the selection pressure imposed by pre-seeding applications of broad spectrum herbicides depends, in the long term, on the efficacy of subsequent control measures and on the intrinsic population dynamics of the population. Where rare resistant survivors are subsequently well controlled by at-seeding tillage and by alternative post-emergence selective herbicides, evolution of resistance is slowed considerably. Where concomitant evolution of resistance to these in-crop selectives is included in the simulation, evolution of resistance to glyphosate is more rapid. The introduction of glyphosate resistant crops into the rotation increases the risk of resistance evolution. Where glyphosate is applied in-crop, resistant survivors are not subject to further non-selective control and hence are able to set seed, considerably increasing gene frequencies for resistance within the population. In conclusion, model simulations predict that the introduction of glyphosate resistant crops has the potential to increase the risk of resistance evolution in populations of *L. rigidum*. However, judicious use of pre-seeding herbicide options and effective tillage and alternative control strategies will considerably reduce this risk.

Exploring methods for proactive management of herbicide resistance in weeds (174)

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The effects of herbicide resistance in weeds can be reduced by the use of any weed control method or methods other than use of the herbicide in question. A modelling study of ryegrass control in a wheat-lupin rotation in Western Australia has indicated that the value of killing a proportion of the weeds by alternative methods is approximately constant whether they are killed early or late in the life of the herbicide. For this reason, the greatest benefit can be achieved by using alternative strategies for the entire useful life to the herbicide. Another potential method for proactive control of resistance is sowing of susceptible weeds into the population being controlled. However, this method would be expected to have minimal effect in practice, because most of the major genes for herbicide resistance are dominant. A third factor that can influence rate of development of resistance is local extinction of resistance genes. A modelling study has indicated that where weeds are being managed in small areas, and where movement of weeds between areas can be controlled, it is often possible to reduce weed populations to the point where resistance genes become locally extinct. In such circumstances, selection for resistance can be greatly reduced. Patterns of herbicide use can have a marked effect on the probability that extinction will occur. ‘‘Double knock’’ strategies, where two highly effective herbicides are used each year, are more effective at achieving local extinction than is ‘‘rotation’’ where the same herbicides are used in alternate years.

Chemical control of a *Conyza albida* biotype resistant to imazapyr (175)

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A biotype of *Conyza albida* from a road continuously treated with imazapyr was found in Seville (Southern Spain). This biotype survived higher imazapyr rates than those used by farmers. Previous ALS in vitro assays had shown that the resistance to imazetapyr and imazapyr in this biotype was due to an altered target site. In pre-emergence growth assays at field doses of imazetapyr, only the R biotype was resistant to this herbicide, while the S biotype was killed, as compared to treatments with chlorsulfuron, triasulfuron, diuron, simazine and terbutilazine+diuron where both biotypes were killed. In post-emergence treatments at field doses of several herbicides belonging to the sulfonylurea and imidazolinone families, the following occurred:a)using bensulfuron, rimsulfuron, tribenuron and triflusulfuron there was no significant reduction in fresh weight in either biotype; b)using nicosulfuron both biotypes were controlled; and c) treatments with imazapyr, imazetapyr and amidosulfuron showed that only the R biotype was resistant while the S biotype was killed. The rest of the chemical families used (clopyralid, 2,4-D, fluroxypir, MCPA, mecoprop, quinclorac, triclopyr) affected both biotypes but did not exercise a good control. Only glyphosate and glufosinate killed both biotypes of *C. albida*.

Simulation modelling for the development of site-specific weed management systems (176)

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Stochastic simulation modelling of weed spatial dynamics in an arable environment has provided some insights into the likely effects of site-specific management techniques. These techniques can be split into two categories, analogous to whole-field economic optimum threshold (EOT) and economic optimum dose (EOD) approaches. Which technique is most appropriate will depend on the level of uncertainty in the management system, the spatial resolution and the spatial discreteness of the weed target. Locally calculated EOT approaches assume the application of full herbicide dose to management units where weed presence is observed or where weed density exceeds a threshold. Simulations show that local economic weed density thresholds are much lower than their whole field equivalents and this is a reflection on the relative efficiency of site specific management. The local EOT approach is more appropriate where the position of weed infestation is accurately known, where spatial resolution is high and where the weed target can be regarded as spatially discrete. An example would be where real time sensors allow the selective treatment of individual weed plants. Simulations have shown that discreteness of weed patches is enhanced by annual variations in herbicide efficacy or when a previous low efficacy application has been made in the current year. This is due to local extinction in weed plant and seed bank population respectively in regions on the periphery of patches, where a long receding 'tail' in the weed density pattern would otherwise be formed. Husbandry practices which encourage this effect may make on/off patch spraying more generally profitable. Local EOD approaches seek to balance yield loss and herbicide costs by adjusting herbicide dose. These approaches are more complex and require a knowledge of herbicide dose:response relationship and weed competitiveness. Simulations have shown that local EOD is more robust than whole field dose reduction when presented with spatial and temporal uncertainty of efficacy and more stable control of weed population is possible. Such management approaches are more effective when operating at lower spatial resolution and the quality of information on weed disposition is relatively poor. An example would be in a management system relying on historical and/or subjective weed maps, where spatial resolution is defined by the length of the spray boom or boom section . Herbicide can be reduced with low risk of current year yield loss by reducing doses only in regions where there is likely to be low weed density. In occasional years this approach will lead to an increased seed return in some regions of the field but over a number of years will result in a reducing whole field weed population. Whilst simulation studies have provided useful information on which to base the design of automated spatial decision support systems there remain several, research topics that must be addressed. We need a better understanding of the competitive relationships between multiple species and the antagonism /synergy relationships between simultaneously applied herbicide products. Work on timely adaptation of dose to conditions is required to aid the minimisation and prediction of uncertainty in efficacy.

Spatial dynamics of multiple competing weed species (177)

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Variability control is a key issue for farming, especially for precision farming. It is the first step to achieve the spatial management, to know the source of variability of field properties such as yield distribution, weed distribution, soil properties. Our final goal is to build up the scheme of spatio-temporal management of

weed-crop systems. A 2-Dimensional Coupled Map Lattice (2D-CML) model is developed to describe spatio-temporal dynamics of the multiple competing plant spices. Lotka-Volterra model is employed as a fundamental function to describe competition among spices. Local interference is also incorporated into the model among neighboring cells. Without any rule to govern a global pattern of the plants community, it generates a global pattern only by a given local dynamics. This is recognized as a kind of emergence from complexity. We also develop the algorithm to identify the local dynamics of multiple competing plant competitions from spatio-temporal data.

Describing linkages between site specific and integrated weed management (178)

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Successful weed management is possible by applying diverse and effective weed control tactics during vulnerable stages in the lifecycle of a weed species. Effective integrated weed management (IWM) should result in reduced numbers of weeds and increased crop tolerance to escaped weeds. IWM systems have been developed without explicitly accounting for the spatial heterogeneity of weed populations. For example, economic thresholds determine whether an application of weed control is warranted and are usually based on mean whole field densities. Clearly, weed populations are patchy and are not represented well by mean field densities. Linking concepts of IWM with site specific weed management (SSWM) should improve weed control of these patchy weed populations. Insights gained from studying the spatial biology of weed populations highlight unique links between IWM and SSWM. In agricultural fields in Nebraska and Iowa, USA, associations between weed species and underlying site properties were identified. The dominant hypothesis was that site property variation interacted with soil applied herbicides to influence extent of weed control and allow for weed populations to develop. An integrated approach would be to vary herbicide doses according to site properties and the presence of the target weed species. The spatial pattern of individual weed patches was characterized in these same fields. Seedling distribution maps had single or multiple focal points of high density that decreased with distance from the focal point. Additionally, patches were elliptical and oriented in the direction of crop rows and field traffic. An integrated approach would be to target control at weed patches and to adjust intensity of weed control according to seedling density distribution within the patch. Spatial aspects of weed populations need to be included in the development of ISSWM programs.

Study and comparison of sampling procedures for assessing weed populations (179)

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The objective of this research was to develop sampling procedures that enable the precise estimation of central tendency and variability measures of weed populations. The experiment was carried out in Botucatu-SP-Brazil, using a population of *Raphanus raphanistrum*, an important weed in the south of the country. Samples (122) were taken from a field highly infested with this species (around 140 plants m^{-2}, using a frame of 1.0 x 1.0 m subdivided in 100 squares of 0.1 x 0.1 m. The number of plants in selected sub-divisions were added to simulate sampling units of 0.2 x 0.2, 0.4 x 0.4, 0.6 x 0.6, 0.8 x 0.8 and 1.0 m x 1.0 m; a cross and a frame of 0.36 m (36 sub-divisions); and a cross and a frame of 0.64 m (64 sub-divisions).We simulated 16 470 surveys, using the different sampling units and replication numbers. Except for the smallest square, if the replication number was properly selected, all sizes and shapes of sampling units provided similar values for mean, mode and median. Variability measures, including variance, were dependent on the type of sampling units. This is an important limitation for the classification of populations according to its variance, the variance / mean ratio or any other variability measure. In some cases, the

same population can be included in different classes depending on the size and shape of the sampling units. Small area, high linear dimensions and high within-plot variance (calculated from the weed densities in each sub-division of 0.1 m x 0.1 m) characterized sampling units well fitted to surveys of this population of *R. raphanistrum*. The within-plot variance was more important than the size of the sampling units to determine the minimum number of replication necessary to achieve pre-fixed precision levels. The results were similar and the conclusions were identical to those obtained in a previous experiment using a population of *Brachiaria plantaginea*, the major grass weed in Brazil. For this grass species, a complementary study showed that different conclusions were achieved when surveys were simulated from data generated by software instead of data obtained in field surveys. This is an important limitation to the use of generated data in this type of study.

Crop spatial arrangement and weed seed production (180)

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In manipulating crop-weed interactions, a longer-term perspective includes minimising returns to the seed bank, rather than focusing only on short-term effects of competition on the crop. The spatial arrangement of grain crop plants can be used to change the local environment that a weed experiences. A more square and dense pattern, achieved by decreasing row spacing and increasing the sowing rate, presents a weed with a more crowded neighbourhood. In systems relying on mechanical control, a trade-off is that narrower row spacing precludes hoeing. Consequently more weeds survive. A first, population level question is what crop spatial arrangement, in combination with associated mechanical weed control results in the lowest returns to the seedbank? A second, individual level question is what is the relation between neighbourhood characteristics, such as nearest crop and other weed distances, and weed survival and seed production. To investigate these questions individual-based experiments in spring wheat were carried out at two sites in 1999. Approximately 50 naturally occurring individuals of each of the target species (*Polygonum persicaria, Polygonum convolvulus,* and *Stellaria media*) were marked and surviving plants harvested in each of the treatment fields consisting of spacings of 10, 20, and 30 cm and sowing densities of 140 and 180 kg ha^{-1}. Mechanical hoeing and harrowing was carried out in the 30 cm spacing only, while the other spacings were harrowed. First results indicate that mean biomass increases with increasing row spacing, and that variation in biomass is higher in the two wider spacings. Due to hoeing, plant survival was lowest in the widest spacing. However, because of relatively high seed numbers per plant in the widest spacing, it appears that average seed production is comparable to or greater than that in the narrowest spacing, even with lower survival. Within treatments, it is unclear how target plant biomass is related to nearest crop distances. In the 30 cm spacing plant survival was strongly related to crop distance.

Models and problem solving in the biological control of weeds (181)

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One of the keys to improving success rates in biological control of weeds is in development of the underlying theory. A review of recent abstracts was carried out to identify the ways and the extent to which models are being used to improve strategy and predictions in the biological control of weeds. The author's own work on population models of *Rottboellia cochinchinensis* [Lour.] W.D. Clayton is also discussed. These have been used to investigate integrated management tactics for this weed including biological control. Models of specific invasive weeds require considerable data, hence their association with large projects. A number of biological control research programs are incorporating a considerable long-term research effort into the ecology of weed and control agents and modelling of various aspects of weed ecology and control is now playing a part in these programs. The most usual application is to predict the effects and time-scale of biocontrol. But in our review of the literature we also found examples of: resolution of conflicts of interest; investigation of the relationship between release size and establishment; and interaction with other controls. The majority of models are spatially homogeneous, concentrating on equilibrium weed densities, however it is becoming clear that a spatial component to models is also important. Spatially explicit models allow the area invaded to be differentiated from the weed population density, and the effects of spatial heterogeneity can be incorporated. General models still have a role to play in the relatively unexplored aspects of the theory of weed biological control including biocontrol with plant pathogens, and identifying general strategies of which the importance of tackling new weed foci is a well known example.

Modelling potential impact of biocontrol of Scotch broom (182)

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The European shrub, Scotch broom, *Cytisus scoparius* Link (Fabaceae), is an invasive introduced weed in many countries and a target of biocontrol programs in New Zealand, Australia and the United States. Simulation and analytical models were developed to explore factors affecting population size and area covered by the weed to predict why it can become such a problem and the potential impact of biocontrol. The simulation model incorporates spatially local density dependent competition, asymmetric competition between seedlings and established plants, a seed bank, local seed dispersal and an age-structured established plant population. The analytical models are simple approximations of the simulation. Using data published on broom demography from studies around the world the models indicate that broom abundance is largely determined by only three parameters: probability of disturbance creating germination microsites, the probability a site becomes suitable for recolonisation immediately following plant death, and the longevity of broom plants. Chronic insect herbivory has been demonstrated to reduce broom longevity in Europe. Insect herbivory might also reduce the probability a site becomes suitable for recolonisation by reducing the size and vigour of broom plants so competing vegetation persists beneath broom stands and smothers emerging seedlings, following the death of the parent stand. The results indicate that prospects for biocontrol of Scotch broom are good if sufficiently damaging and specific agents can be found. Furthermore, the impact of seed-feeding insect herbivores was explored. This analysis suggested that seed-feeding biological control agents might have a substantial impact if the disturbance rate is high, plant fecundity is low, and seedling survival is low. Even herbivores that reduce seed production by only 75% can have a dramatic impact on broom abundance, in contrast to several published predictions.

Exploring integrated weed management using meta-modelling techniques to develop models of weed population dynamics (183)

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Several models of weed population dynamics have been developed within the CRC for Weed Management Systems, including a model for *Chrysanthemoides monilifera* ssp. *rotundata* (DC) T. Norl., and a four-species temperate pasture model. A meta-modelling methodology was adopted in these two cases. This involved a series of short-duration workshops where weed biology/ecology experts and those involved in weed management specified the model structures, identified the functional relationships used to drive the population dynamics, and specified the different forms of control that the model would have to simulate. The experts identified the sources of ‘‘hard’’ data used to define the functional relationships. The DYMEX population modelling package was used to develop the models ‘‘on-the-fly’’. This meant that the experts received some immediate feedback from the model. Inevitably, some functions and parameters had to be guessed. The models were used to highlight inappropriate guesses, refine estimates, and identify and prioritise research needed to make the models sufficiently reliable. By using the modelling framework to integrate available knowledge on each weeds' behaviour, we were able to develop an understanding of the areas of its population dynamics that are relatively robust, and those that are relatively weak. We could then consider what techniques might be employed to attack the more vulnerable lifestages, and the level of control needed to reduce the population to desired levels. The results of applying the meta-modelling technique and using a generic population dynamics modelling package are very rewarding - model development time is comparatively short, and the modelling process is opened up to the community of weed experts, who are then able to take collective ownership of the model. Current modelling efforts have focussed on weed ecology and physical control techniques. Attention will now be turned to developing and integrating population dynamics models of proposed biological control agents.

Biocontrol strategies for *Avena fatua* using crown rust (*Puccinia coronata* f. sp. *avenae*) (184)

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Biocontrol of wild oat (*Avena fatua* L.), one of the world's most serious weeds in small grain crops, is largely unexplored. We investigated crown rust disease (*Puccinia coronata* f. sp. *avenae*) as a potential control agent for wild oat. San Clemente Island, California, has been subjected to large scale grazing disturbance and subsequent wild oat infestation (*A. fatua* and *A. barbata*). Endemic populations of crown rust were described on the island in 1994. The natural infection cycle on San Clemente occurs too late in the season to cause significant damage to emerging oat plants. We hypothesized that earlier infection would result in lower wild oat reproductive rates. Field trials of isolates collected from the island were conducted during the winter season of 1997 and 1998. Artificial infections were successfully established in inoculated plots in both years. The artificial infections preceeded the onset of natural infections by two weeks, but only in one of these years. Analysis of reproductive output from these plots showed that reproductive biomass and seed number were significantly lower ($P < 0.05$) in inoculated plots as compared to control plots. Although the results show promise for reducing wild oat populations over time, we believe there is potential for improvement. Some strategies that may improve control levels include co-application with oat smut (*Ustilago avenae*), and selection for higher virulence.

Biological aspects of multiple seeded cocklebur (*Xanthium strumarium* L.) and its control (185)

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Common cocklebur is an important weed with many biotypes. Multiple seeded cocklebur (MSC) has up to 25 seeds per bur usually producing up to nine seedlings, whereas normal common cocklebur (NCC) has two seeds per bur which usually produce only one seedling, MSC burs are large, round, covered with hairy spines or pickles, and flattened on one end. Apomixis occurs with MSC but not with NCC. MSC produces increased numbers of seedlings which increases the difficulty in controlling common cocklebur. MSC was noted in the field to be more competitive in soybean than NCC. The purpose of this paper is to present an overview of biological aspects of MSC and its response to various control agents. In greenhouse tests the fungal pathogen *Alternaria helianthi* was shown to cause 100% mortality on 5 to 7 leaf stage plants, when sprayed to run-off with a 4 to 6 hr dew period at 4×10^4 conidia/ ml of 0.2 Silwet L-77 with at least an 8 hr dew period. Symptoms started with soft necrotic lesions on leaf surface and stems, which spread to the entire plant resulting in death within 1 wk. *Pseudomonas syrinae* pv. *tagetis* (PST) at 1 x 10 ^{9} cell/ ml in 0.2 Silwet l-77 caused severe damage on MSC and NCC at the 2 leaf stage. Plant damage included apical chlorosis, necrosis, stunting and mortality. The herbicides 5g/A of chlorimuron, 7g/A of imazaquin, 113g/A of MSMA, and 7g/A of Pursuit caused mortality on MSC. MSC did not show resistance to the herbicides used in these studies, although some of the NCC biotypes were resistant. MSC was killed by lower rates of conventional herbicides than recommended for NCC. These studies showed that *A. helianthi* and PST as well as commercial herbicides have potential to control MSC.

Predicting environmental fate and behavior: uses and limitations of models (186)

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The role of modeling in predicting the environmental fate of pesticides has expanded dramatically over the last few years. A wide range of models are now used in discovery and comparison of new lead areas, in regulatory evaluation of the fate and behavior of new products and in stewardship review of registered products. The types of environmental fate models which are currently in use include relatively simple screening models, more mechanistic regulatory models and various types of research models including fuzzy logic and neural network approaches. A relatively recent trend has been the development of prescribed modeling scenarios for the evaluation of potential herbicide concentrations in soil, surface water, sediment and groundwater likely to be present in various geographic settings. In addition, there have been a number of recent advances in the use of probabilistic modeling to provide estimates of the likelihood of observing specific concentrations in various environmental compartments. This presentation will focus on reviewing screening and regulatory models as well as modeling scenarios which are currently being used in the USA and Europe for the discovery and registration of plant protection products

Simulation of picloram movement in loamy soil under field conditions using MACRO-DB model (187)

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The aim of this study is to evaluate MACRO-DB model (Jarvis et al., 1997) on herbicide transport in a macroporous soil wide spread in Russia. The 2-year field experiment was carried out in the Moscow region on a silty loam. Three plots were treated twice with picloram (2.0 kg a.i. ha^{-1}). Soil samples were taken from different depths (0-100 cm) and analysed for herbicide concentration. All plots were fallow. At the end of the experiment picloram leached to the depth of 80 cm, however, its maximum concentration remained in the upper 5-cm soil layer throughout the study period. There was preferential flow which does not significantly affect the movement of the herbicide inside the micropores in the topsoil. The groundwater recharge value calculated by the MACRO-DB model (160 mm year^{-1}) was similar to the value (150 mm year^{-1}) reported by Pashkowskiy (1990) in a study estimating water fluxes through the soil profile for the same area. In the ‘‘blind’’ test the model calculated picloram parameters automatically from the DAOA database. Herbicide residual mass was four times overestimated by the model. In general, the predicted curve for picloram distribution in the soil was similar to the observed one. Then, the field data on the herbicide half-life at average soil temperature and new sorption coefficient were used. Calculated picloram content in the soil profile was close to the experimental data. Predicted curve of picloram distribution in soil was similar to observed one. The MACRO-DB model showed good correspondence of the observed and simulated drainflow as well as picloram distribution in the soil profile. It is necessary to note the

striking over-prediction of the herbicide persistence in the soil. The simulated flux concentrations of picloram showed that more than 1% of the applied dose (at concentrations 12.4 $\mu g\ L^{-1}$) was predicted to leach deeper than 1 m depth in the field.

Sorption of acidic herbicides in variable-charge soils (188)

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Current models for estimating sorption of acidic compounds as a function of pH are based on some assumptions that may be unfounded. In this study a model of acidic herbicide sorption in soils was developed, considering initially a combination of a strongly acidic compound and a variable-charge soil with high clay content. At low pH levels where acidic herbicides exist largely in neutral form, the soil sorbed much more 2,4-D than at high pH levels, where the herbicide is mostly in anionic form. Sorption of the acidic form is expected to decrease with increasing pH because the net negative charge on the soil minerals increases and ion-pair formation effects appear to be negligible. Contribution of 2,4-D anionic-form sorption was small when compared with its overall sorption. Therefore, the further modeling work of this study did not take into account the contribution of ionic interactions and data sets used from the literature were not restricted to variable-charge soils. Dissociation of 2,4-D was not sufficient to explain the variation in Kd as a function of pH. Accessibility of soil organic functional groups able to interact with the herbicide (conformational changes) as a function of organic matter dissociation was proposed to explain the observed differences in sorption. Experimental 2,4-D sorption data adequately fit the model presented, which explained a majority of the variation observed in the experimental data set. The model also accurately estimated Koc values for flumetsulam and sulfentrazone in several soils. Therefore, it is apparent that anionic-form sorption has been overstated, and the effect of organic matter dissociation due to pH changes has been overlooked in previous studies.

Aspects of the variability in herbicide behaviour in soils (189)

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An important environmental concern with herbicides is their potential to affect soil or water quality. This potential will be controlled to a large extent by the persistence and mobility of the compounds in the soil. A number of mathematical models have been developed to simulate or predict persistence and mobility of residues in the field. Major input parameters required are the physical and chemical characteristics of the soil plus appropriate weather data. The main driving forces for most of these models, however, are data concerning the degradation rate and sorption partition coefficient of the chemical, and accurate estimation of these parameters is essential. Recent research at HRI Wellesbourne has examined the spatial variability in sorption and degradation parameters for the herbicide isoproturon (and some other pesticides) at a number of field sites. In the largest experiment, 30 soil samples were removed on a grid pattern at 50-m intersections from a field with nominally uniform soil characteristics. There were considerable differences between the samples in the kinetics of isoproturon degradation and the overall DT_{50} varied from 6.5 to 30 days. The sorption distribution coefficient also varied with a minimum of 0.99 and a maximum of 1.44. The range of observed input parameters was used in combination with weather data for a 10-year period in a probabilistic leaching assessment using the LEACHP model. Depending upon the combinations of input parameters, the model predicted that leaching below a depth of 50 cm would vary from about 0.5 g to over 80 g ha^{-1}. The cumulative probability distribution indicated that the 50th percentile for leaching below 50 cm depth was 0.34% of the applied dose; the 90th and 99th percentiles were 1.40% and 2.95%, respectively. These data strongly suggest that single value average data for sorption and degradation parameters will give a misleading prediction of potential leaching risk, and that some form of probability assessment using all available information is essential.

Degradation study in Andalusian soils from olive groves of two herbicides: oxyfluorfen and simazine (190)

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In the Mediterranean basin, olives are grown in over 9 million ha, accounting for 97% of the total world area. In Spain olives are grown in about 2.3 millions ha., 60% of which is in Andalusia (southern Spain). Weed control in olive groves is required to obtain profitable yields and, in general, the use of residual herbicides (and non-tillage) in olives increases crop yield and reduces costs and soil erosion. Oxyfluorfen and simazine are the preemergence herbicides most used in olive trees to control annual broadleaf weeds and grasses. Simazine is a selective systemic herbicide, which acts as a photosynthetic electron transport inhibitor, whereas oxyfluorfen is an inhibitor of protoporphyrinogen oxidase. The rate of simazine degradation in soil gave ranges of DT_{50} (time for 50% loss or half-life) values from 27 to 102 days, while little published information on oxyfluorfen is available. The degradation of oxyfluorfen and simazine was investigated at two depths (0-5 and 5-15 cm) in alkaline soils (mean pH 8.4) with low organic matter levels (0.2-1.4 % o.m.), and ECC (equivalent content carbonate) between 65.46 and 77.4% and a different history of treatment and doses for both. The application doses were 0.36 kg a.i. ha^{-1} and 1.5 kg a.i. ha^{-1} of oxyfluorfen and simazine, respectively, using high-performance liquid chromatography (HPLC) as a separation system and diode array as a detection system. Degradation data for the two herbicides followed experimentally a first-order kinetics, and DT_{50} (time for 50% of loss or half-time) values observed in surface and subsurface soils ranged from 21 to 103 days and from 12 to 16 days for oxyfluorfen and simazine, respectively. It is to be expected that the repeated application of simazine in the next few years may cause the appearance in the soil of microorganisms which are more specialized in degrading the herbicide. However, the same soils treated with oxifluorfen showed a similar degradation without any real evidence of previous treatments.

Fuzzy logic to assess herbicide use impact on farm sustainability (191)

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The evaluation of the impact of herbicide use on sustainability at field-year scales involves the consideration of multiple factors, which are difficult to integrate in a systematic way. In order to overcome this difficulty, we have developed a system based on fuzzy logic to evaluate herbicide use impact on farm sustainability. All the assumptions, rules of inference and decision criteria are mathematically defined in the system. System inputs include five characteristics to describe herbicide applications during a cropping cycle: application rate, mammal toxicity, insect toxicity, human toxicity and half-life in the soil. First, the system calculates mammal, insect and human impact indexes for each application. In a second step, these indexes are integrated by a fuzzy membership function to calculate similar indexes for the whole cropping cycle. Finally, the former indexes are integrated by a Sugeno's inference rule to assemble a final sustainability index (ranging from 0 = unsustainable to 1 = sustainable). In order to verify the system, we analysed typical maize cropping management practices which contrasted in toxicity and doses levels. The system discriminated among the typical cropping management pratices in accordance with the toxicity input gradient. Then, we applied the system to analyse a subset of 20 maize fields with different tillage system from a large data set of Inland Pampa farms (Argentina). A large heterogeneity was found in the sustainability index, ranging from low sustainability (0.12) to medium sustainability (0.56). When sustainability of herbicide use was analysed for fields under conventional and non-tillage systems, we found that the average index was 0.38 for conventional tillage and 0.28 for non-tillage. This difference was significant ($P = 0.02$). We concluded that the explicit architecture of the system could be a good framework to discuss the development of sustainability indicators in a systematic manner.

Persistence and leaching of atrazine and metolachlor in soil under corn (192)

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The soil persistence and the leaching of atrazine and metolachlor was investigate under field conditions of Campinas, SP, Brazil, in a loamy podzol red-yellow soil planted with corn crop. Herbicides were applied at the rate of 1.6 kg ha^{-1} (atrazine) and 2.4 kg ha^{-1} (metolachlor) after corn planting and pre-emergence of weeds on 14 January 1992. Gas chromatography analyses of soil samples collected in five depth (0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm and 40-50 cm) eight times after herbicide application over a year showed that the greatest atrazine and metolachlor concentrations stayed at the 0-10 cm layer; atrazine and metolachlor residues were not found under 20 and 30 cm soil depth, respectively, and persistence curve of the herbicides was accounted for a second degree regression. Atrazine residues were found up to 184 days (0.06 mg kg^{-1}). Metolachlor residues (0,11 mg kg^{-1}) were found in the soil 380 days after treatment.

Influence of drying processes in the leaching potential of imazaquin in two Brazilian soils (193)

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Imazaquin is a herbicide widely used for weed control in soybean. This molecule presents slow mineralization in soils, so it can be leached in soil by rainfall. This research aimed to study the leaching potential of ^{14}C-imazaquin using 300x50 mm glass columns filled with two different soils: Acric Oxisoil and Rhodudalf soil. This study was carried out at Laboratorio de Ecotoxicologia of Centro de Energia Nuclear na Agricultura (CENA-USP), Piracicaba, SP, Brazil. The statistical design adopted for the experiment was a factorial 2 x 3 (soils and soil drying condition), in triplicate. In the first treatment the herbicide was applied to the soils at 100% field capacity, and water was added to the columns in amount corresponding to a 400 mm rainfall within 96 h. In the second treatment, imazaquin was applied to dry soils and the same amount of water applied as in treatment 1 but within 24 h. In the last one, the herbicide was applied to soils at 100 % field capacity, and then dried for 30 days. After that, water was added in the same amount as in the two other treatments. The radioactive used was 70 Bq g^{-1}. The herbicide soil residue was extracted with methanol and characterized by TLC/radio-scanner. The detection of residual radioactivity in the soils was made in LSC counter after extraction and oxidation in biological oxidizer. The leaching potential of imazaquin was observed in both soils, being higher in Oxisoil than Rhodudalf. In both soils, there was a reduction in the leaching with the increase of the drying period. The results showed no occurrence of metabolites in the leaching and in the soil. A considerable fraction of imazaquin was found as soil-bound residues, mainly in Rhodudalf soil.

Oxasulfuron degradation under controlled and outdoor conditions (194)

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Oxasulfuron is a new postemergent sulfonylurea herbicide recently registered in Brazil by Novartis Biosciences mainly for broadleaf weed control in soybean. The aim of this research was to evaluate degradation of formulated oxasulfuron under controlled (flasks placed in a semi-dark room at 25°C) and outdoor (flasks digged down into a soil field between soybean rows) conditions. Oxasulfuron [phenyl-U-^{14}C

labeled] was applied at rate of 2.3 mg a.i. kg^{-1} (3 times the recommended field rate) to fifteen flasks containing 100 g of a Typic Hapludox soil. The amount of ^{14}C-CO_2 mineralized was measured weekly. At 0, 7, 17, 38, 59, 80 and 108 days of incubation, soil samples were taken in order to evaluate extraction, metabolites, and soil bound residues. The residues bound to the soil organic matter were further fractionated. Oxasulfuron degradation was not affected by incubation condition. For both conditions, oxasulfuron showed high mineralization rate ($>$ 50% after 59 days of incubation). Sooner after application, 99% of applied radioactivity was extractable (92% was oxasulfuron). This fraction was reduced to $<$ 4% after 59 days. Detectable oxasulfuron dropped to only 26% and $<$ 4% after 17 and 7 days, respectively. The major metabolite found was saccharin. The amount of soil bound residues increased continuously up to 38 days, reaching 30% of applied radioactivity. Most of the radioactivity bound to soil was found in the fulvic acid. In conclusion, oxasulfuron shows fast turnover rate behaving like an environmentally safe molecule.

Constraints in bioeconomic decision-making models and possible improvements (195)

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Bioeconomic decision-making models for weed control differ depending on the time scale considered (single or multi-year) and on the number of factors considered for identifying the best management option. A basic model should consider weed competitiveness, herbicide efficacy towards the different weed species and some parameters to convert yield losses into economic variables (weed free-yield, grain price). With this information, it is possible to obtain a first approximation, single-year suggestion for weed control. Experiments conducted in different environments and crops show that such a system can give interesting information even if the assessment of weed competitiveness is not very precise. Practical applications of these models have in fact been quite limited. At field level, the major drawback can be related to the scouting procedure (i.e. analytical assessment of the weed population) which requires a considerable amount of work within a short time-window. Furthermore, this approach fails to account for some important biological aspects such as the age structure of the weed population, which is largely determined by the emergence pattern. Important improvements of these decision-making tools can therefore only be obtained explicitly considering the pattern of weed emergence. This type of information can be used to improve the estimation of yield loss, as well as to identify the best weed control application time. Modelling of weed emergence would allow the coupling of traditional bioeconomic decision-making models with those relating weed age to herbicide efficacy and weed seed production. This approach would also lead to an improvement in the overall model performance for the current year as well as providing the background for a multi-year approach. It is our view that the knowledge of weed emergence patterns would provide the background for a more practical determination of the weed competitive-load.

The impact of decision models on integrated weed management (196)

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Arable practices continuously require decisions. Experience, advice and ‘‘copying the fittest neighbour’’ facilitate decisions, sometimes to a degree that the spirit of free decisions is almost buried. Moving from spraying herbicides against weeds to integrated weed management means to combine various instruments, like indirect methods of plant husbandry and direct methods of control. Obviously all methods are to further evaluate, how they compete with other farming goals (economic result, man power demand etc.). For those who pass this gate, the environmental effect should additionally influence the ranking of alternatives. Thus, integrated weed management can be very exacting in the level of the information required for decisions. However, the number of components and the degree of complexity of the information vary between situations. Decision models claim to support complex decisions on the base of input variables either observed by human, electronic or sensor power. They are built by components of modeling (e.g. the effects of competition between crops and weeds on actual yield, the population development of weeds, the influence of weed development on herbicide performance) and decision rules (e.g. time of control, mechanical versus chemical control, type of herbicide). Some examples for approaches focussing cereal production in Mid-Europe are given. However, none of the examples fulfill the demand to be a relevant tool neither in integrated weed management nor in weed control in arable practice anyway. Reasons for the difference between the theoretical ability of decision models and their practical relevance are seen together in the very restricted practical demand and in the diffuse supply by either individual, often scientific persons or small, often short-living enterprises. An optimistic view into the future identifies both, demand and supply, as changing - simultaneously with an increasing importance of other tools in agriculture (precision agriculture, environment and quality management etc.).

The use of decision support systems in weed science (197)

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In weed science, decision support systems are traditionally used for operational decision making on weed control options in farmer's fields. The nature of these decision support systems varies ranging from simple flow charts to fully computerized quantitative multicriteria optimalization programmes. At present a new role and a larger application domain for decision support systems in weed science seems to evolve. Weed science will increasingly have to provide transparent, structured guidance in the support of technical decisions by both farmers and policymakers. We will increasingly face ever more complex discussions on issues that require an integration of all aspects of weed science like biology, control methods, control economy, non-target effects, environment and transgenic crops. Development and use of decision trees may facilitate both discussion and decision-making. A decision tree is a logically ranked chain of hierarchical questions leading to predetermined answers, whereas a flow chart is a graphic representation of a decision tree. Decision trees and flow charts have been used by authorities for many years in taking administrative decisions. Use of these tools in weed science is limited to expert decision support systems for farmers; very few examples exist for use in support of policy-makers. The present paper discusses the construction and possible uses of decision support systems in weed science and compares the simple decision tree-approach with truly quantitative approaches. Practical examples will be shown to demonstrate the current use of decision support systems in weed science. Special attention will be given to the limitations in working with decision support systems and to the necessity of conveying both possibilities and limitations to users

An expert system software to explore short and long term effect of cropping systems on crop-weed interactions (198)

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Ecological studies have provided many models that explain short and long term effects of cropping systems on crop-weed interactions. In order to integrate them we developed an expert system software (http://www.ifeva.edu.ar/yuyos). The software is based on a dynamic model described by two functions for each cropping practice-weed combination: 1) a function that describes the effect of weed infestation level on yield, 2) a second function describes the effect of a cropping practice cycle on the future infestation level

of the weed. Function shapes and parameters may be defined by the user, therefore weed models can be tested. The software integrates these functions in a ''breadth-first'' algorithm. Given the initial conditions of a field, the algorithm explores possible rotations using heuristics to dynamically select the best ones. Finally, the software ranks the rotations using a sustainability approach weighting yields and final field infestation levels. To verify software integrity and to evaluate its potential use, we tested it against expert opinions in the analysis of field situations. A panel of weed specialists conducted a blind evaluation of the rotations recommended by a group of 20 agronomists, 60 advanced students and the software to deal with three different field situations involving infestation with important weeds. The software not only recommended acceptable rotations but was ranked 2nd in order of merit by the panel. The software has been used in undergraduate Ecology and Crop Production courses and in the Weed Ecology graduate course. It was applied to relate classical population dynamics theory to cropping systems in teaching the Ecology course. Students used it to synthesize their knowledge about cropping practices and to design cropping systems during the Crop Production course. During the Weed Ecology course it was used as a tool to explore the effect of management practices on weed communities.

Modelling glyphosate use in Roundup Ready soybean (199)

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Crop yield can be expressed as a function of the maximum yield of the crop kept weed-free, the weed competitive load and time of weed emergence and removal. These factors determine the variation over time of the financial advantage of a herbicide application. Knowing the weed population and its emergence pattern, an optimum application time that maximises net return can be identified. With herbicide resistant crops, this aspect is of particular interest because the focus shifts from herbicide choice to the identification of the best time window for spraying the crop. The relationships between Roundup Ready soybean yield and time of weed control have been studied at the Experimental Farm of the University of Padova (Italy) over three years. Natural weed populations were treated at 7 different times, from 2 to 49 days after soybean emergence, with glyphosate (2 L ha^{-1} of Roundup Bioflow). Each year the weed emergence evolution was assessed and yields measured. The three years were well differentiated both in terms of infestation levels and weed emergence patterns; the final weed densities in untreated plots were 247, 131 and 423 plants m^{-2} in 1997, 1998 and 1999 respectively, and the percentage of weeds emerged at soybean emergence were 61%, 17% and 75%. Crop yield loss as a function of time of weed emergence and removal, as well as of total weed density, was simulated with a bioeconomic model developed at our Centre. Despite some discrepancies, ascribable to differences in the weed flora composition in the three years, the model gave an acceptable description of the observed yield losses. The model indicates a good flexibility of glyphosate use; in spite of different weed emergence dynamics soybean yield is not affected if glyphosate is applied from 50-80 to 250-300 degree-days after crop emergence, corresponding to a time window of about 20 days.

Bioeconomic methods and decision-making models for herbicide use in Russian agriculture (200)

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The prospects of herbicide application in Russia provide three aspects: potential yield losses due to weeds, losses prevented by herbicide application and economic effect of herbicide use in 1990-2000. The data issued by Russian Academy of Agricultural Sciences on areas with different degrees of weediness and data on harmfulness of weeds for grain crops, flax, sugar beets, potatoes, vegetables, fruits (from the results of experiments) were used to estimate potential yield losses. The data were represented in the form of Yx =Y0 * a x , where Yx - the yield on plot with an x degree of weediness,Y0 - the yield on weed-free plots, x- the degree of weediness ; a- coefficient of resistance crops to competing weeds. Potential yield losses (YL) calculated by the formula : YL = Y0 - Yx = Y0* (1- a x) for areas with different degrees of weediness. Total potential yield losses due to weeds was determined for 1990-1999 period in Russia (arable area - 126 million ha) and constituted 45 million t of grain equivalent per year (17 % of the actual yield). The additional yield due to application of herbicides (6 million t) was determined using the areas treated with herbicides -15 million ha per year with different degrees of weediness and the yield increase factors (Ypyl) by the formula: Ypyl = k*Y0*(1-a x), where k- was the herbicide technical effectiveness coefficient in %. To evaluate the economic effect of herbicides the monetary value of the additional yield was compared with the additional expenditure on weed control. Considering the effectiveness of herbicides (the profitability - 115 %), the needs for increasing the treated areas and the amount of herbicide for 2001-2005 period it were determined (twice greater than that obtained in 1990-1999 period).

Are physical methods of weed management appropriate in a chemical age? (201)

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Physical methods of weed control have been largely superceded by chemical technology in the past two decades over much of the world. Problems of herbicide resistance, groundwater residues and cost of technology are real issue for the continued use of this approach to weed management. Physical methods of weed control have been practiced for centuries and still have the potential to play a significant role in weed management. Physical methods of weed control are available for dealing with weeds in all phases of the weed life cycle. That the technology is available is often overlooked by many weed managers, and deemed not to have a role in their weed management programs. Yet integrated weed management strategies call for such methods to be incorporated into most weed management programs. The range of methods available is considerable, and novel approaches are increasingly being considered as countries adopt pesticide reduction programs. Cultivation (including for example mouldboard ploughing, harrowing, inter-row brush weeders), mowing (hay making, seed head topping), green manuring, seed catching at harvest and flaming are all considered viable options to include in systems approaches to managing weeds. Novel techniques such as electroporation, and new approaches to understanding the efficacy of physical methods of weed control offer exciting new avenues of research for this weed management area. The use of models such as the Ryegrass Integrated Management model (RIM) has shown that physical methods of weed control are valuable tools for managing weeds in cropping systems. Further development of physical weed control methods is likely to rely upon new modelling tools to enhance their use as system tools.

What does physical weed control really do to weeds? (202)

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Few data are available on how physical control methods kill weeds. The usual approach to research on physical weed control is to apply particular implements, mulch materials etc. to a field and assess subsequent weed populations. This is a reasonable approach for comparing efficacy of different machines or methods, but often has low sensitivity. This is illustrated by a comparison of high residue cultivators: differences in weed control were mostly nonsignificant even though some machines obviously did not work as intended. Some recent research has taken a dose-response approach, in which weed density is studied as a function of propane consumption, number of harrow passes, or other parameters. This allows quantitative modeling. This approach is illustrated by a study with varying mulch rates, in which it was found that emergence relative to a bare control, E, follows the formula, $E = \exp(-b * MAI * V^c)$, where MAI is the surface area index of the mulch, V is the fraction of volume occupied by solid, and b and c are fitted constants dependent on weed species. The formula allows prediction of how much mulch is needed to achieve a given level of weed control. Neither of these basic approaches, however, reveals mechanisms of weed mortality. For a particular cultivator, is burial of shoots or exposure of roots to desiccation more important in killing weeds? To what extent does mulch inhibit germination versus interfere with emergence? Why does weed density differ in till and no-till systems? The answer to the last question appears to depend on the interaction between seed burial, variation in seed mortality with depth and probability of emergence from different depths. These and similar questions will challenge scientific investigation of physical weed control in the coming century. Understanding mechanisms could improve physical weed control methods.

Comparison of different strategies for reducing seed production and regeneration of *Vulpia* in pastures (203)

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Vulpia is a short-season annual grass that occurs in pastures of southern temperate Australia. Its increasing presence in pastures means that more desirable species are progressively excluded and livestock productivity is reduced. Previously, the solution to remedying degraded pastures was to replace them by cultivation and resowing. With current returns and costs associated with the sheep and cattle industries, this approach is now largely uneconomic. The alternative approach to restoring/maintaining high levels of pasture productivity has depended heavily on herbicide use and a number of strategies have been developed commercially [eg. spraytopping where a low rate of non-selective herbicide (paraquat, glyphosate) is applied to elongating *Vulpia* inflorescences in spring, inhibiting seed production]. More recently however, it has become apparent that herbicide use only provides short-term control, with *Vulpia* densities returning to similar pre-herbicide levels within 18 months of application. Further, for a variety of reasons, the landholder may prefer not to use herbicide in particular paddocks. The landholder clearly requires other options for reducing seed production of *Vulpia* in pastures. This paper describes experiments where a range of different methods for reducing seed production of *Vulpia* were compared annually over a three-year period. These included herbicides (paraquat, simazine), targeted grazings, grazing rests, hay and silage cuts, and fertiliser application. The results indicate that comparative effectiveness varied from year to year according to rainfall and growth conditions, and that herbicide application was not always the best option. Absolute effectiveness, however, was always well below 100%, and the need to integrate strategies is emphasised.

The physical properties of mulches contributing to weed suppression (204)

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Mulches on the soil surface are known to suppress weed emergence but there is little research that describes the quantitative relationships between emergence and mulch properties. Data from experiments determining the emergence of four annual weed species through seven mulch materials applied at six rates were fitted to various measures of mulch physical characteristics. Mulch materials, in order from lowest to highest surface area to mass ratio, were bark chips, corn (*Zea mays* L.) stalks, rye (*Secale cereale* L.), crimson clover (*Trifolium incarnatum* L.), hairy vetch (*Vicia villosa* Roth), oak (*Quercus* spp.) leaves, and landscape fabric strips. Weed emergence was successfully predicted by models based on mulch properties alone regardless of mulch material suggesting the fundamental importance of these properties for determining weed emergence. The best fitting models included the properties ‘‘mulch area index’’ and ‘‘solid volume fraction’’. Mulch area index, defined as the projected area of mulch elements per unit soil area (analogous to leaf area index), was a pivotal property for understanding weed emergence through

mulches and for quantitatively defining mulch properties. Solid volume fraction, defined as the fraction of mulch space filled by mulch material, also contributed significantly to models defining seedling emergence through mulches. The order of weed species sensitivity to mulches (*Amaranthus retroflexus* L. > *Chenopodium album* L. > *Setaria faberi* Herrm. > *Abutilon theophrasti* Medicus) inversely correlated with the order of seed size suggesting that the capacity of seedlings to grow through empty mulch space before exhausting seed reserves was an important factor contributing to emergence success.

Solarization and chemical control of weeds in orchard nurseries (205)

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Orchard nurseries in Argentina are infested by weeds that are problem when fruit plants are small and with a reduced root system and thus compete for water and nutrients. Weed control is necessary to produce good quality plants with an adequate size so as to obtain good sale prices. The aim of the study was to determine the efficacy of different control methods (chemical control and solarized soil in nurseries of peach trees, and seedbeds of citrus) on fruit plant size and weed emergence. Experiments were conducted in the University of Rosario at Zavalla (33°01' S, 60°53' W), Argentina in 1999 in peach and citrus trees. Two separated experiments were conducted for each species and were laid out using a complete randomized block design with 3 replications. Treatments were the same in both experiments: (T1) weedy check, (T2) herbicide control with terbacil WP 80% at a rate of 1.6 kg a.i. ha^{-1}, and (T3) solarized soil using mulching 100 μ thick, previous to weed germination. Evaluations were done on diameter and height of the rootstock when plants were removed for sale. Distribution of weed seedling emergence throughout the year was determined in all treatments. Data were analyzed using ANOVA and LSD ($P < 0.05$) to separate means. For both fruit species, T3 showed the greatest plant height and stem diameter. Fruit plant emergence was also more rapid in T3. Four months after citrus planting and seven months after peach tree planting the density of weeds was low for T2 and T3. In the weedy check, emergence of weeds increased with time in both experiments, especially for perennial weeds as *Cynodon dactylon* (L.) Pers. and *Cyperus rotundus* (L.).

Solarization as a tool to predict control of *Digitaria sanguinalis* (L.) Scop in no-till corn and soybean (206)

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Methods based on soil sampling have been tested to predict weed seedlings in crops, but they represent a very small area. More simple, faster and lower-cost methods should be tested. The objective of this study was to evaluate if weed control decisions, based on results achieved in solarizated areas prior to crop planting are coincident with those taken when weeds are counted after crop and weed emergence. In four farms of the SE of Buenos Aires Province, Argentina, 64 plastic sheets of $1m^2$ and 100 μm thick were placed in eleven fields in which no-till corn or soybean were to be planted 30 days later. Forty-eight were located in plots that had been sprayed with 2.5 L ha^{-1} of glyphosate, after wheat harvest and before weed maturity, and 16 in places without post-harvest weed control. The limit to decide weed control was set at six or more *Digitaria* plants m^{-2} competing with the crop. Since the number of individuals of *Digitaria* sp. germinated under the plastic was generally higher than those competing with the crop, the limit for decision of weed control for this case was 8 plants m^{-2}. This number was calculated as the ratio between the total number of individuals germinated under the plastic and the total number m^{-2} in places close to the plastic after crop emergence. A Chi-square test for proportion homogeneity showed that the proportion of coincident decisions about weed control (89%) based in weeds under the plastic or close to it is different

from proportion of non-coincident decisions (6% spray when it is not necessary and 5% not spray when needed) (P = 0.001). It is important to emphasize that concordance existed between decisions of *Digitaria* sp. control, suggested by solarization and those advised through general scouting of the sampled area.

Electroporation: a new physical weed control technique (207)

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Today we experience a general demand for pesticide reduction in crop production. This emphazises the need for new and efficient physical weed control methods. Currently, a method using electroporation to control weed seeds is investigated at the Swedish University of Agricultural Sciences. Electroporation is a well-known technique to incorporate specific genes into cells. Exposing the cell to high-intensity electric field pulses temporarily destabilize the cell membrane making it highly permeable to exogenous molecules. An increase in the electric field strength will however result in permanent pores in the cell membrane which are lethal to the cell. This effect can then be used as a weed control method. In the present project, weed and crop seeds have been exposed to electric fields of 3-5 kV cm^{-1}. The electric field has been obtain with exponential pulses of 1 ms. The seeds have either been treated in peat soil, natural soil or in cuvettes filled with tap-water. Survey experiments with weed seeds treated in cuvettes showed control effects of 80-100 %. *Thlaspi arvense* L., *Descurainia sophia* (L.) Prantl. and *Achillea millefolium* L. were all controlled to 99-100 % at a field strength of 5.2 kV cm^{-1}. Experiments in natural soil obtained from vegetable fields have shown a less pronounced weed control effect compared to the laboratory trials. About 40 % weed reduction has been achieved in soils with a flora of *Urtica urens*, *Capsella bursa-pastoris* and *Chenopodium album*. In these trials two series of each 50 pulses were given using 3kV cm^{-1} and 4 kV cm^{-1}. The results of the treatments in natural soil show a potential to use the method for weed control in e.g. vegetable crops. However, additional work must be carried out in order to evaluate the effects of electroporation in field experiments and possible negative impact on soil microflora.

Future trends in weed management (208)

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There are likely to be more changes in agriculture and weed management in the next 20 years than we have ever seen before. Our approach to weed management is already changing and driven by a number of factors that will have a major impact. *Economic:* World population growth will put increasing pressure on productivity, with a desire for overall improvement in diet quality. Industrialization in developing countries will continue to take labor from the land and land out of food production and, with the significant downward trend in world crop (commodity) prices, there will be increasing pressure on the price of herbicides and competitiveness within the industry. *Social:* The public is demanding high quality food without risk, which at the moment particularly manifests itself as concerns about genetically enhanced ingredients. Concomitant regulatory pressure continues to raise the hurdles for both existing and new herbicides as well as for genetically enhanced organisms. *Technical:* We have already seen the significant impact of herbicide tolerant crop technology on production of soybean in the last three years and its impact in other crops such as maize, cotton and canola can already be seen. The adoption of other biotechnology enhancements, especially for modification of output traits, will continue to drive change in agriculture. Bundling of technologies, combining output traits, weed, fungal and insect management, will have an important part to play. *Agronomic:* There has been a significant resurgence in interest in weed ecology, brought on by the increasing occurrence of resistance and the anticipation of weed population shifts following continuous use of the same or similar herbicides. The next big change, especially in developed agriculture, will be the ‘‘Knowledge Revolution’’. Site specific technology will become the norm. However, the farmer will have to balance cheap, broad spectrum weed control against investment in information gathering, mapping weeds and mixing and matching products. *Industry:* Many of the current major herbicides have already, or will in the next 5 years, come off patent and there will inevitably be an increase in the presence of generics. Nevertheless, in recent years, the introduction of new active ingredients has been a major factor in promoting growth in proprietary products. However, the industry is long overdue a new mode of action. With the creation of new businesses and partnerships through the integration of chemical and bio-technology the future of weed management looks very bright.

The world of off-patent herbicides: their appeal, utility and impact in weed management (209)

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Off-patent agrochemical products are of two types: ‘‘commodity’’ manufactured by the discovery company and ‘‘generic’’ from other manufacturers. In 1997, $17.4 billion of the $26.3 billion in agrochemical sales were off-patent products (66.3%), of which 73% were commodity and 27% were generic. Off-patent herbicides represented 62.1% ($8.3 billion) of the herbicide market in 1997, which is a smaller percentage of total sales than for off-patent fungicides or insecticides. Whereas commodity products are widely accepted and represent the bulk of off-patent agrochemical sales, generic products are also an important component, due at least in part to lower market entry costs when compared to new proprietary products. Even though the sales growth for generic agrochemicals is expected to increase slowly over the next few years (2% per annum), the appeal of generic products is often their favorable price to farmers and ability to provide added value to the distribution network, including the potential for branded products. To have utility, a generic product must consistently contain a high quality active ingredient and be formulated so that efficacy is comparable to the corresponding commodity product. For generic postemergence herbicides, formulation is key for optimum performance and should be assessed for attributes such as spreading and adhesion to leaf surfaces and for absorption through plant cuticles. Glyphosate will represent a major off-patent herbicide and will include a spectrum of commodity and generic products. Favorable prices coupled with a wide array of uses for weed control in genetically modified crops, as well as in conventional crops, and in non-crop areas may lead to use patterns which could be detrimental to its long term utility. Whilst the incidences of selecting weed populations resistant to glyphosate will remain low, shifts in weed populations to species less well controlled by glyphosate will occur if used as the sole product for weed control over multiple years. Opportunities exist for favorably priced premixes of off-patent glyphosate with proprietary herbicides, and commercial acceptance of such formulations will facilitate the long-term utility of this herbicide.

BAS 625 H: a new post-emergence herbicide for grass weed control in rice (210)

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BAS 625 H is a new post-emergence herbicide for control of annual grass weeds in seeded and transplanted rice. BAS 625 controls grass weeds through inhibition of acetyl CoA carboxylase (ACCase). Rice selectivity is due to the differential uptake, metabolism and translocation of BAS 625 H in rice versus susceptible grass weeds. The active ingredient of BAS 625 H has a favorable toxicological and environmental profile. BAS 625 H has demonstrated good to excellent control of the following grass weeds: *Brachiaria plantaginea, Brachiaria platyphylla, Cenchrus echinatus , Digitaria species, Echinochloa colonum, Echinochloa crus-galli , Eleusine indica, Eriochloa species, Ischaemum rugosum, Leptochloa chinensis, Leptochloa filiformis, Leptochloa panicoides, Panicum species, Rottboellia exaltata, Setaria* spp. An outstanding feature of BAS

625 H is the flexible control of grass weeds over a wide range of growth stages. With proper application rates, BAS 625 H controls *Echinochloa* species beginning at the 1 leaf stage up to the beginning of panicle exertion stage of growth. BAS 625 H provides control of many grass weeds which are difficult to control with other herbicides including control of propanil resistant *Echinochloa* biotypes. Dependent on grass weed spectrum, rice growing systems and region, the application rates of BAS 625 H will be within the following ranges: S-America: 150 - 200 g a.i. ha^{-1} BAS 625 H (plus 0.5 % Dash HC™); N-America: 75 - 150 g a.i. ha^{-1} BAS 625 H (plus 1 % crop oil concentrate); Europe 100 - 150 g a.i. ha^{-1} BAS 625 H (plus 0.25 - 0.5 % Dash HC™); Asia 50 - 125 g a.i. ha^{-1} BAS 625 H (as additive containing formulation). Two formulations of BAS 625 H have been developed: a 200 g a.i. L^{-1} EC formulation (trade name AURA™) for use in tank mixtures with recommended additives such as Dash HC™ or crop oil concentrate; a 75 g a.i. l^{-1} EC additive containing formulation (trade name TETRIS™) which was developed for use in Asia. BAS 625 H has been granted registration in most South and Central American countries, as well as in Thailand, with additional registrations to follow in Asia, Europe and North America.

Evaluation of the herbicidal activity and crop selectivity of dimethenamid-p in corn under Brazilian conditions (211)

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Dimethenamid-p is the herbicidally active isomer of dimethenamid, (tradenames:“Frontier”, “Zeta 900”), and is currently under development for pre- and early postemergence weed control in corn and other crops. During the growing season 1998/1999, a series of trials were conducted in Brazil to evaluate dimethenamid-p for weed control in corn. The experiments were laid out on medium textured soils with a clay content of 28-40%) in a randomized block design with 3 replicates. Applications were made with a pressurized knapsack sprayer at a spray volume of 200 liters ha^{-1}. Dimethenamid-p was applied preemergence alone at rates of 0.58, 0.72 and 0.87 kg a.i. ha^{-1} and in tankmixture with atrazine (1.5 kg a.i. ha^{-1}) to moist soils. Evaluations of herbicidal activity and crop selectivity were made after crop emergence and 21 as well as 42 days later using the standard 0-100% evaluation scale. Dimethenamid- p alone and in mixture with atrazine showed excellent corn selectivity at all rates tested. Preemergence applications of dimethenamid-p at the rate of 0.72 kg a.i. ha^{-1} provided over 90% control of *Digitaria sanguinalis*, *Eleusine indica*, *Commelina benghalensis*, *Amaranthus viridis*, *Spermacoce latifolia* and *Galinsoga parviflora*. The tankmixture of dimethenamid-p (0.72 kg a.i. ha^{-1}) with atrazine (1.5 kg a.i. ha^{-1}) improved the weed spectrum of dimethenamid-p by providing additional control of *Ageratum conyzoides*, *Bidens pilosa*, *Euphorbia heterophylla*, *Nicandra physaloides*, *Emilia sonchifolia* and *Richardia brasiliensis*. In summary, dimethenamid-p applied at rates of 60% of the active ingredient of the racemic dimethenamid achieved weed control and selectivity levels comparable to the respective full recommended application rates of dimethenamid. Dimethenamid-p is currently in the registration process in Brazil and is planned to be introduced following registration approval.

Activity and selectivity of the new post-emergence graminicide BAS 620 H (tepraloxydim) in broadleaf crops of Brazil (212)

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Competition between weeds and commercial crops is one of the main factors of yield loss. Farmers have many options to control weeds, particularly grass weeds in broadleaf crops. Pre-emergence herbicides provide residual broad spectrum grass control but fail under dry soil moisture conditions and are not sufficiently active on volunteer small grains and volunteer corn. BAS 620 H is a new cyclohexenone graminicide of Nisso BASF Agro Ltd,. developed for grass control in broadleaf crops. In order to evaluate the activity and selectivity of BAS 620 H, a series of trials were conducted in cotton, dry beans and soybean in different agricultural regions of Brazil during the years 1995-1999. A randomized block design was used in all trials. All treatments were replicated 3-4 times. Plot size in each trial was 20 m. Applications were made post-emergence to grass weeds ranging from three leaf stage to four tillers. The 200 g L^{-1} EC formulation was used in all trials with either Dash (0.5 % v/v) or Assist (1.0 % v/v) as adjuvant. The following treatments and rates were used: BAS 620 H + Dash at 50, 75 and 100 g a.i. ha^{-1}; BAS 620 H + Assist at 75 and 100 g a.i. ha^{-1}; sethoxydim + Assist at 184 g a.i. ha^{-1}. BAS 620 H (tepraloxydim) at rates up to 100 g a.i. ha^{-1} provided excellent selectivity in cotton, dry beans and soybean independent of test location, climatical conditions and growth stage of the treated crops. Applied at 75 g a.i. ha^{-1} either with Dash or Assist, BAS 620 H achieved control levels above 95 % on economically important annual grass weeds such as *Brachiaria plantaginea* (Link) Hitchc., *Cenchrus echinatus* L., *Digitaria horizontalis* Willd, *Eleusine indica* (L.) Gaertn and *Pennisetum setosum* (Sw.) Rich. The 75 g a.i. ha^{-1} rate of BAS 620 H was also very effective in controlling volunteer small grains and volunteer corn. BAS 620 H demonstrated in the majority of trials excellent timing flexibility, however, under dry conditions and with growth stages exceeding mid tillering, 100 g a.i. ha^{-1} + Dash were needed to control *D. sanguinalis* (L.) Scop. Under these conditions, the use of an effective adjuvant was important.

Grass weed control in Brazilian rice fields using BAS 625 H, a new post-emergence herbicide (213)

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Grass weed infestations which occur in rice crops cause reductions in rice yield, quality, and often lower the efficiency and speed of rice harvest. Herbicides which control grass weeds in rice are therefore important tools for efficient rice production. BAS 625 H is a new cyclohexenone herbicide for selective post-emergence grass weed control in rice developed by BASF. During the years 1995-1999, trials were conducted in the rice growing regions of Brazil under both flooded and upland conditions. In all trials, randomized block designs with four replications and a plot size of 20 m were used. The treatments were applied post-emergence to the crops and the grass weeds, with application timings ranging from the four leaf stage to the four tiller stage of the grass weeds. The 200 g L^{-1} EC formulation of BAS 625 H (AURA) was applied in combination with an additive (Dash 0.5 % or Assist 1 %) in all trials. The following treatments and rates were used: BAS 625 H + Dash (0.5 %) at 150 and 175 g a.i. ha^{-1} and BAS 625 H + Assist (1%) 150 and 175 g a.i. ha^{-1}. Herbicidal activity and crop selectivity was assessed at regular intervals using the standard 0 - 100% scale. BAS 625 H treated rice sometimes exhibited temporary chlorotic symptoms after application which quickly grew out and caused no negative effect on rice yield. Applied on flooded rice paddies at rates of 175 g a.i. ha^{-1} + Dash at 0.5% v/v, BAS 625 H provides very effective control of *Echinochloa crus-galli* (L.) Beauv., *Echinochloa colonum* (L.) Link., *Brachiaria plantaginea* (Link) Hitchc., *Eleusine indica* (L.) Gaertn, *Digitaria sanguinalis* (L.) Scop, *Digitaria horizontalis* Willd, and *Ischaemum rugosum* Salisb. Under the conditions of upland rice production, 150 g a.i. ha^{-1} of BAS 625 H + Assist at 1% v/v controlled the most important grass weeds such as *B. decumbens* Stapt, *B. plantaginea*, *E. indica*, *D. horizontalis* and *Cenchrus echinatus* L. while providing good rice selectivity.

BAS 620 H: a new graminicide for post-emergence grass control in broadleaf crops (214)

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BAS 620 H is a new cyclohexenone herbicide of Nisso BASF Agro Ltd. containing the new active ingredient tepraloxydim (proposed ISO common name). BAS 620 H is developed for broad spectrum post-

emergence grass weed control in broadleaf crops. BAS 620 H is an inhibitor of the acetyl-CoA carboxylase (ACCase), which is responsible for the formation of lipids required for cell growth. The broadleaf crop selectivity is based largely on the lack of activity of BAS 620 H on this target site. Worldwide extensive field research confirmed the excellent selectivity of BAS 620 H in all major broadleaf crops and vegetables at herbicidal use rates. At a use rate of 50-75 g a.i. ha^{-1}, BAS 620 H controls very well all economically important annual grasses (e.g. *Avena fatua*, *Brachiaria plantaginea*, *Digitaria sanguinalis*, *Echinochloa crus-galli*) as well as volunteer small grains. BAS 620 H, at 75-100 g a.i. ha^{-1}, is particularly strong on *Poa annua* and volunteer corn. At 100 g a.i. ha^{-1}, BAS 620 H controls perennial grasses such as *Sorghum halepense* and *Agropyron repens* and suppresses *Cynodon dactylon*. Investigations showed that some annual grass biotypes with metabolism based ACCase inhibitor resistance are still sensitive to BAS 620 H. Graminicidal activity of BAS 620 00 H on economic important grass weeds in field trials were conducted world wide 1990-1998. The standard formulation of BAS 620 H is a 200 g/litre EC formulation for use with an additive (e. g. DASH HC™, oil concentrate) in soybean, cotton, canola, peas, beans, mustard and flax. An adjuvant built-in formulation is under development in Europe for use in winter oil seed rape, sugarbeet, potatoes, cole and pulse crops. BAS 620 H has a favorable environmental and toxicological profile. First registrations of BAS 620 H (tradename: ARAMO™) were granted in 1999 with the worldwide market introduction planned from 2000 onwards.

MKH 3586: a new low rate, broad spectrum, preemergence herbicide in sugarcane (215)

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MKH 3586 (Bayer), formulated as 80 WDG, was assessed in sugarcane from 1997 to 1999 in replicated, small plot and large scale, on farm demonstration trials, in Santiago de Cuba province, on fertile Cambisol soils, under rainy season conditions. Initially, treatments of MKH alone at 0.4 and 0.8 kg a.i. ha^{-1}, as well as mixtures of the same rates plus 1.6 kg a.i. ha^{-1} atrazine, were compared to 4.8 kg a.i. ha^{-1} diuron, both in preemergence and postemergence (15-20 cm) of weeds. Predominant species were: *Echinochloa colona* (L.) Link, *Rottboellia cochinchinensis* ssp. *cochinchinensis* (Lour.) Clayton, *Brachiaria fasciculata* (Sw.) Blake, *Leptochloa panicea* (Retz.) Ohwi, *Euphorbia heterophylla* L., *E. hirta* L, *Ipomoea* spp. and *Boerhavia erecta* L.. The lower rate of MKH showed significantly lower control than the standard. On the contrary, 0.8 kg a.i. ha^{-1} was slightly better than the standard in preemergence and equivalent to it in postemergence. The former time of application showed better control than the latter.

The response of grass weeds to graminicides (216)

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Grass weeds, especially *Echinochloa crus-galli* and *Elymus repens*, commonly infest vegetable crops in Poland and often become a serious problem. The introduction of post-emergence grass herbicides offers good possibilities for the prevention of yield losses caused by weed competition in onion. The aim of this experiment, conducted in 1997-1998, was to determine the effect of some graminicides, at rates adjusted for *E. crus-galli* and *E. repens* control in drilled onion. Quizalofop-P-tefuryl (40 g.l-1), quizalofop-P-ethyl (5%) and fluazifop-P-butyl (12.5%) were applied at 4-6 leaves stage of *E. crus-galli* and 6-8 leaves up to tillering of *E. repens* as a single treatment, and 2-4 leaves and 4-6 leaves respectively (1st of split-application). The second application was done 10-14 days later. The action of graminicides was evaluated 1, 2, 3, 4 weeks after application. The results showed that the single application of graminicides for *E. crus-galli* control presented higher efficacy and faster action compared to split-application methods. The only split-application of fluazifop-P-butyl (50 + 50 g ha-1) showed a similar effect of *E. crus-galli* control. Otherwise, split-application of quizalofop-P-ethyl (37.5 + 50 g L-1) and fluazifop-P-butyl (125 + 187.5 g L-1) presented practically the same level of *E. repens* control as the use of quizalofop-P-tefuryl alone (70 or 80 g L-1). The differences of control level between those two species probably depended on different time of emergence, spread and periods of germination. No regrowth of *E. repens* was noticed after both herbicide treatments and slightly more *E. crus-galli* cover, with split-application methods, before onion harvest. Phytotoxicity symptoms on onion plants were not observed. Graminicides in all treatments positively influenced onion yield.

Weed control in golf turf (217)

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Technology for weed control in golf turf is based on the study conducted during 1986-1992 in Jiangsu Province. CaoPingNing(CPN), a program which consists of 4 pre-emergence and 3 post-emergence herbicides, specially designed for weed control in golf turf. In bermudagrass (*Cynodon* spp.), Zoysiagrass (*Zoysia* spp.) and bluegrass (*Poa* spp.), broadleaf weeds and annual grasses can be controlled by CPN 1# (chlosulfuron+metsulfuron) as pre- & early post- emergence herbicide. Sedges and broad-leaved weeds can be controlled by CPN 4# (bensulfuron) as pre-emergence herbicide. Sedges and broad-leaved weeds also can be controlled by CPN 7# (bentazon+MCPA) as post-emergence herbicide. Broadleaf weeds can be controlled by CPN 10#(dicamba+MCPA) as post-emergence herbicide. To avoid injury to flowers and young trees, CPN 5# (oxadiazon+pendimethlin) or CPN 9# (oxyfluorfen+pendimethelin) can be broadcast by mixing with sand under young trees or near by the flowers as a pre-emergence herbicide. In ryegrass (*Lolium perenne*) and tall fescue (*Festuca arundinaceae*, some broadleaf weeds and annual grasses can be controlled by CPN2# (quinclorac) as an early post-emergence herbicide. Sedges and broad-leaved weeds also can be controlled by CPN 7# (bentazon+MCPA) as a post-emergence herbicide. Broad-leaved weeds can be controlled by CPN 10# (dicamba+MCPA) as post-emergence herbicide. CPN has no passive influence on water, air, soil and human body.

Strategies for use of plant-derived natural products in weed management (218)

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Natural products are a vast repository of compounds with the potential for use in weed management. There have been only three natural products used in their natural form as commercial herbicides (bialaphos, phosphinothricin, and pelargonic acid). Two herbicides are analogues of plant-derived products. The triketones were derived from leptospermone, and cinmethylin is an analogue of 1,4-cineole. Success in the utilization of natural products as herbicides has been very limited compared to uses as fungicides and insecticides. Nevertheless, these compounds have modes of action that are largely unique. So far, most of the emphasis in natural product-based herbicide discovery has been on microbial products. However, plants possess many highly phytotoxic compounds that could be used in the native form or in analogue form as a herbicide, or indirectly as an allelochemical for interference with weeds. There are two primary strategies that can be employed in finding highly phytotoxic compounds from plants. Bioassay-directed isolation of compounds that appear to be allelopathic is an approach that has been used historically. The other approach is to isolate compounds that are sequestered or rapidly exuded by plants. One reason that such compounds are sequestered or exuded soon after synthesis might be to avoid autotoxicity. Examples of sequestration are hypericin and various sesquiterpenes such as artemisinin. Sorgoleone and its analogues will be discussed as an example of rapid exudation from root hairs. The use of modern tandem separation/chemical characterization instrumentation (e.g., LC/MS) facilitates these strategies. Biotechnological advances provide the opportunity to manipulate the crop to produce weed-fighting levels of allelochemicals. This can be done by increasing the production of allelochemicals already present or by introducing transgenes to produce new compounds. The use of functional genomics techniques to identify structural and regulatory genes to accomplish this will be discussed.

New herbicides from screening microbes (219)

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Although natural products have been an excellent source of novel chemistries with unique modes of action, few have served as templates for the design of commercial herbicides. The difficulties in using natural products as starting points in herbicide discovery include their chemical complexity, narrow spectrum of weed control, and generally poor physio-chemical properties. Recently, two microbial phytotoxins were discovered in our program that are new natural products but are known by synthesis. The compounds were found in novel strains of soil actinomycetes. Both compounds are highly water soluble, readily translocated to meristems of plants, and broad-spectrum in activity. The herbicidal activity of these compounds has not been previously described. The first of these, an adenyl oxetane, was discovered in shake-flask fermentations of *Streptomyces albus* strain LW030448. Bioassay directed fractionation resulted in identification of two related phytotoxic factors that induce intense chlorosis in a number of grass and broadleaf weeds. While the onset of symptoms is slow, lethality following postemergence applications was observed at rates as low as 100 g ha^{-1}. A ribose triazolone was identified as the principal phytotoxic component of a fermentation broth derived from *Actinomadura* sp. LW189365. Pre and post-emergence herbicidal activity was demonstrated in greenhouse tests. Metabolite reversal studies suggested the target site was adenylosuccinate synthetase, which was confirmed by direct measurement of the activity of the 5'-phosphorylated derivative on the isolated enzyme. It is the second reported compound that must be bioactivated by phosphorylation in order to inhibit the activity of AdSS.

Selected sesquiterpene lactones inhibit the growth of two problematic atrazine resistant weeds (220)

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Control of atrazine-resistant weeds is an important and serious problem affecting many grain crops. *Solanum nigrum* is one of the first maize weed species developing resistance to triazine herbicides, while *Abutilon theophrasti* is one of the latest triazine-resistant species reported. *Solanum nigrum* mechanism of resistance is based on mutation of the D_1 protein, while *A. theophrasti* resistance mechanism is due to conjugation of glutathione and atrazine. Allelopathic studies offer a different approach to solve this problem and plant natural products constitute a large reservoir of bioactive compounds used for many different purposes, chemical defence among them. Based on our previous results and our on-going systematic study of allelopathic agents as new herbicide models, we have selected the sesquiterpene lactones (SL): parthenolide, a natural compounds isolated from many species with allelopathic properties, and 11β,13-dihydro-13-hydroxy-dehydrocostuslactone, a synthetic derivative of the natural SL dehydrocostuslactone, for further studies. Herein, we report the results of a dose-response experiment with different concentrations of these SL on the resistant (R) and sensitive (S) biotypes of *S. nigrum* and *A. theophrasti*. Compounds have been tested at 1000, 500, and 125 μM and the results compared with a parallel set of atrazine treatments at 100, 50, and 5 μM. The results show that both compounds exert a phytotoxic effect on the two biotypes of

each weed species, affecting mainly the radicle growth. At the higher dose (1mM), parthenolide treated roots of *A. theophrasti* biotypes show almost 100% inhibition, while the effect is slightly lower with the two *S. nigrum* biotypes. There is no phytotoxic effect at 125 μM. The phytotoxic effect can be observed earlier in the treatments with the SL than in the treatments with atrazine on the S biotypes. These results suggest that the target site of these compounds is different from that of atrazine, since the sesquiterpene lactones are able to overcome the resistance mechanism of the R biotypes.

Inhibition of asparagine synthetase, the key to the mode of action of cinmethylin (221)

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The mechanism of action of cinmethylin was elucidated in a study contrasting the effect of this herbicide and its structurally related natural analog 1,4-cineole. Both cinmethylin and 1,4-cineole were potent growth inhibitors. Phytotoxicity caused by either cinmethylin or 1,4-cineole was reversed in a dose-dependent manner by supplying asparagine to the treated seedlings. Furthermore, root uptake of radiolabeled asparagine was increased in the treated plants relative to the control plants, suggesting that the physiological pool of this amino acid may be altered in the presence of the inhibitors. An assay was developed to measure the enzymatic activity of asparagine synthetase, the key enzyme involved in asparagine biosynthesis. The method (using HPLC radiochemical detection) was developed to measure enzyme activity in crude plant extracts. The effect of cinmethylin and several monoterpene cineoles was tested on asparagine synthetase extracted from several weed and crop species. *In vivo* data suggested that these compounds targeted the same biosynthetic pathway. However, *in vitro* assay of asparagine synthetase showed that cinmethylin did not inhibit this target site, whereas 1,4-cineole monoterpenes were potent inhibitors. We conclude that the herbicide must be metabolically bioactivated by cleavage of the benzyl ether moiety to yield a natural product-like 1,4-cineole toxophore, in order to be active on this novel molecular target site.

Herbicide selectivity: mechanisms and future importance (222)

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The main reason for the considerable success of modern herbicides is their selective phytotoxic action and weed management in major crops has been mostly dependent on selective herbicides. Selectivity of new herbicides might become more important in future. In the quest for new herbicides in the coming century, we need higher selectivity as well as novel mechanisms of action which maximize efficacy while minimizing environmental and non-target effects. Mode of action studies greatly aid, and in many cases, totally explain the selectivity shown by many herbicides. Although absorption, translocation of herbicides and sensitivity at target sites are involved in the selectivity mechanism in some cases, the selectivity based upon differential herbicide metabolism by tolerant crops compared with susceptible weeds is the basis for the majority of herbicides. Herbicide metabolism and detoxification in plants is generally a multi-phase process involving oxidation, hydrolysis, conjugation and compartmentation into vacuoles or extracellular compartments. Glutathione S-transferases (GSTs) and cytochrome P450 monooxygenases (P450s) are the most significant plant enzyme systems involved in the initial herbicide metabolism. Hence, the substrate specificity of these enzymes determines the tolerance of plants towards many herbicides. Differential metabolism will remain important to new herbicide discovery. More information on enzyme regulation of herbicide metabolism, role of their isoforms, substrate specificity and induction mechanism by safeners should be accumulated. Improvement of herbicide metabolism by transgenic plants expressing animal P450

enzymes has been reported recently. These transgenic plants are useful not only for investigating the function of P450s but for phytoremediation of pesticide residues.

Dissecting herbicide-metabolizing cytochromes P450 systems in maize (223)

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Cytochromes P450 (P450s) are established as one of the most important enzymes systems for the selective detoxification of herbicides in plants. However, questions concerning the number and selectivity of herbicide metabolizing P450s plus their regulation, particularly induction by safeners, remain. We used genetic studies and in-vitro microsomal assays to separate the activities of two genes (BEN1 and BEN2) for herbicide-metabolizing P450s in maize. The BEN1 gene is associated with P450 activity capable of metabolizing a range of herbicides and other pesticides. In contrast, the BEN2 gene is related to P450 activity with a more restricted herbicide substrate range. Further, the BEN1 activity is inducible by safeners while the BEN2 activity is not. However, since the maize microsomes contain a number of P450 activities, it is difficult to assign the metabolism of a herbicide to a particular P450. To overcome this limitation, we undertook a project to clone and heterologously express P450 genes from maize. Using PCR primers designed to conserved regions of known P450 sequences to generate partial P450 clones followed by screening a cDNA library prepared from maize shoots grown from naphthalic anhydride-treated seed, we isolated several P450 cDNA sequences. We demonstrated metabolism of several herbicides and insecticide (malathion) by two of the P450s. Thus, we have shown the presence of multiple P450s capable of metabolizing multiple pesticide substrates in maize.

Selective induction of glutathione S-transferase subunits in acifluorfen-treated wheat plants (224)

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The glutathione S-transferase (GST) isoenzyme family has important roles in detoxification reactions in plants. These enzymes are homo- or heterodimeric combinations of different subunits. GST isoenzymes catalyze the conjugation of glutathione (GSH) to various xenobiotics (including numerous herbicides) and their electrophilic metabolites to produce less toxic and more water-soluble thioether conjugates. They are also capable of catalyzing the breakdown of toxic lipid hydroperoxides and thereby contribute to the protection of plants against oxidative membrane damage. The nitrodiphenylether herbicide, acifluorfen (5-[2-chloro-4-(trifluoromethyl)-phenoxy]-2-nitrobenzoic acid), is known to induce photooxidative membrane damage and, ultimately, plant cell death. Acifluorfen and other nitrodiphenyl ether herbicides are metabolized via GSH-conjugation in plants, and their selective action is primarily due to differences in herbicide detoxification rates. GST activities were measured in shoot and root tissues of wheat spectrophotometrically at 340 nm by using 1-chloro-2,4-dichlorobenzene as substrate. The total GST complement was purified from shoots by affinity chromatography on GSH-agarose gel and the subunit composition was investigated by reversed-phase HPLC. Exposure of wheat seedlings to 50 mM acifluorfen caused slight phytotoxic symptoms. Acifluorfen treatments led to the marked induction of GST activities, particularly in the shoots but did not result in the appearance of any new subunits. However, the amounts of several constitutively expressed subunits were markedly increased by acifluorfen. Levels of two major subunits were selectively induced while concentrations of the other major subunits were unchanged or only slightly modified by acifluorfen. Our findings suggest that the wheat GST subunits induced by acifluorfen treatment could participate rather in the detoxification of acifluorfen than in the protection against the oxidative stress caused by the herbicide.

Comparative properties of glutathione transferases in plants (225)

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Conjugation to glutathione assisted by the action of glutathione transferases (GSTs) is well established to form the basis of crop selectivity of many well-known herbicides. GSTs are encoded by multiple gene families in plants and are characterised by heterogeneity in their sequence and dimer organisation and regulation. Isozymes able to attack electrophilic herbicides are typically present in greater amounts in tolerant crop varieties than in susceptible weed species. Herbicide safeners can induce the appearance of certain GSTs in crops; the mechanisms of transcriptional regulation underlying this have not been well characterised. However it is clear that promoters from such safener-inducible genes may find use in a variety of biotechnological applications. Recent evidence suggests that the glutathione peroxidase functions of some GSTs may have significance in the ability of plants to withstand a range of herbicide types. Building adequate selectivity margins into new herbicides is a pressing challenge for the agrochemical industry. To this end, rapid and miniaturised metabolism screens based on recombinant enzymes such as GSTs can be used to develop structure-activity rules and guide synthesis of new compounds having improved selectivities. It is expected that understanding compound binding by three-dimensional analysis and site-directed mutagenesis will complement this approach. Genomics and bioinformatics are having a revolutionary impact in the identification, sorting and analysis of plant GSTs. This will accelerate our ability to use molecular approaches to optimise selectivity of new herbicides and also to confer new selectivities through modified plant expression of GSTs. On the other hand, genomic tools such as plant knock-out libraries and microarray analysis will help to define the hitherto largely refractory roles of GSTs in plant physiology and function.

Differential tolerance of selected weed species to glufosinate (226)

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Field studies were conducted at Plymouth and Kinston, NC (USA), to evaluate the tolerance of selected weed species to glufosinate. Three times of application (20, 30, and 40 days after seeding) and three rates of glufosinate (0.18, 0.36, and 0.73 kg a.i. ha^{-1}) were tested in each location. At Plymouth, the data indicated that *Datura stramonium* and *Desmodium tortuosum* were the most susceptible weed species, *Xanthium strumarium*, *Senna obtusifolia*, *Amaranthus albus* and *Chenopodium album* the intermediate group in order of susceptibility, and *Ipomoea purpurea*, *Digitaria sanguinalis*, *Brachiaria platyphylla*, *Amaranthus hybridus*, and *Sida spinosa* the most tolerant species tested. At Kinston, *D. stramonium* and *D. tortuosum* were also the most susceptible species, *C. album*, *I. purpurea* and *S. obtusifolia* the second group most susceptible, and *A. albus*, *S. spinosa*, *D. sanguinalis* and *A. hybridus* the most tolerant group. At Plymouth, a rainfall of 5.6 mm three hours after the first time of application affected the control level in some species. *D. stramonium*, *D. tortuosum*, *X. strumarium*, *S. obtusifolia* and *C. album* were not affected by the rain. *I. purpurea, A. albus, D. sanguinalis, B. platyphylla, S. spinosa* and *A. hybridus* were poorly controlled indicating the adverse rainfall effect on control of these species. In a second study at Plymouth, with three rates of glufosinate (0.18, 0.36, and 0.73 kg a.i. ha^{-1}) and one time of application (20 days), *B. platyphylla, Eclipta alba, Ipomoea hederacea, Amaranthus retroflexus* and *Acalypha virginica* were completely controlled with glufosinate at 0.18 kg a.i. ha^{-1}, while *Commelina diffusa* required glufosinate at 0.73 kg a.i. ha^{-1} for control.

Herbicidal selectivity of dimethenamid on different potato (*Solanum tuberosum* L.) cultivars (227)

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The selectivity of dimethenamid was evaluated in four experiments, side by side, with four different potato cultivars: Bintje, Monalisa, Atlantic and Achat. The trials were carried out at the BASF Agricultural Experimental Station in Sao Paulo state in Brazil on a Dark Red Latosoil of medium texture. A randomized block experimental design was used in all trials with a plot size of 21 m and five replications. The following treatments were applied: Hand weeding, dimethenamid at dose rates of 0.75, 1.50 and 3.00 kg a.i. ha^{-1}, metribuzin at 0.48 and 0.72 kg a.i. ha^{-1} and linuron at 1.50 and 2.00 kg a.i. ha^{-1}. All herbicides were applied pre-emergence to the weeds, one day after planting of the crop. Three visual assessments of selectivity were made at 25, 32 and 43 days after planting. Also, the yield of the cultivars, the dry matter content of the potato tubers, the number of primary stems emerged from the seed tubers and the classification of the potato tubers according to different size classes were evaluated. The severity of crop injury in the different cultivars was directly correlated with the herbicide, the dose rates and the potato cultivars. In spite of some initial visual symptoms of phytotoxicity, the cultivars recovered and none of the herbicidal treatments interfered negatively with the number of emerged primary stems, the yield, the dry matter content of the potato tubers and the final size of the potato tubers. Therefore, it can be concluded that dimethenamid as well as metribuzin or linuron can be safely used for chemical weed control in the tested potato cultivars.

Response of corn varieties to trifluralin (228)

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Corn is sown as a catch crop in the Cukurova Region of Turkey following loss of cotton crops in early stages, due to unfavorable weather conditions. However, trifluralin is commonly applied for preemergence weed control in cotton, and the trifluralin label prohibits use of corn as a catch crop. In earlier literature, it is stated that corn response to trifluralin depends on varieties. Pot experiments were conducted in 1999 to determine response of 20 common corn varieties in the Cukurova Region to trifluralin. For comparisons, root and total dry weights of a corn plant were used. Data obtained from three experiments were subjected to variance and regression analyses, and varieties were compared at 10, 30 and 50 % growth reduction points. TREBBIA, LG.2777, SELE, DK 626, P.32K61, and TTM.815 varieties performed the best while C.6127 and T.1595 varieties were the worst. The best performing varieties generally showed 50% growth reduction at greater than 4 times the recommended rate of trifluralin, 0.96 kg a.i. ha^{-1}. No variety showed 30 % growth reduction with the recommended rate of trifluralin in cotton. The herbicide rate causing 10 % growth reduction was calculated to be 0.2-0.4 times the recommended rate, depending on variety. Although results suggest that most varieties can be sown after cotton with no or little crop loss, further studies including field experiments are needed to give more precise recommendations to farmers.

Azafenidin: a new herbicide for weed control in *Eucalyptus camaldulensis* (229)

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A field experiment was conducted at Presidente Castelo Branco, PR, Brazil, to evaluate the selectivity of the new herbicide azafenidin to *Eucalyptus camaldulensis*, as well as its efficacy to control some important

weeds in this crop. Azafenidin was applied at rates of 300, 400, 500 600 and 800 g ha^{-1}. Additional treatments including oxyfluorfen (720 g ha^{-1}), a hand-hoed check and weeded check were also included. Both azafenidin and oxyfluorfen caused crop symptoms of phytotoxicity, and for azafenidin, injuries were more intense for rates greater than 600 g ha^{-1}. In relation to weed control, rates of azafenidin of 500 g ha^{-1} or higher were very effective to control *Brachiaria decumbens*, *Commelina benghalensis*, *Richardia brasiliensis* and *Sida santaremnensis,* even after 180 days after application. Lower rates of azafenidin provided enough control of most weeds, but with shorter residual effect.

Weed control in corn in the Cukurova Region of Turkey (230)

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Corn producing areas in the Cukurova Region of Turkey have been increasing as main and second crop production since 1982. Weeds are one of the main problems in the second crop corn. Chemical options and mechanical weed control (hand hoeing) in corn were studied in 1992, 1993, and 1994. Metolachlor plus atrazine (1.5 plus 1 kg a.i. ha^{-1}) and pendimethalin (1.65 kg ha^{-1}) were applied all three years. Paraquat (0.6 kg ha^{-1}), rimsulfuron (12.5 g ha^{-1}), a tank mix of atrazine (1 kg ha^{-1}) and alachlor (1.44 kg ha^{-1}), and a tank mix of 2,4-D amine salt (0.5 kg ha^{-1}) and dicamba (48 g ha^{-1}) were studied for two years. Atrazine plus alachlor (1.44 plus 3.36 kg ha^{-1}), nicosulfuron (50 g ha^{-1}), bentazon (1.44 kg ha^{-1}), and 2,4-D amine salt (1 kg ha^{-1}) were used one year. Natural weed populations were used. *Amaranthus retroflexus*, *Echinochloa colona* and *Portulaca oleracea* were identified in experimental sites every year. *Hibiscus trionum*, *Xanthium strumarium*, *Euphorbia prostrata*, *Corchorus olitorius*, *Sorghum halepense*, *Cyperus rotundus*, *Convovulus arvensis* and *Digitaria sanguinalis* were other weeds in the experiments. All herbicides controlled *A. retroflexus*. The control range of metolachlor plus atrazine was broader than pendimethalin for the given weeds. Although directed application of paraquat was effective on most weeds, up to 10% phytotoxicity on corn was observed. Rimsulfuron showed 2.5% phytotoxicity. Hand hoeing was as effective as chemical weed control. Yields were significantly different in 1993 and 1994. In 1994, hand hoeing gave the highest yield, possibly due to hoeing twice. Also, yields in other years were higher with hoeing than with most herbicide applications. However, metolachlor plus atrazine gave one of the highest yields all three years. It is suggested that hand hoeing can be used for weed control in the second crop corn. When chemical control is used, herbicides with a wider control range are preferred.

Efficacy of the herbicide CGA 362-622 + ametryne in post-emergence control of *Digitaria horizontalis* in sugarcane (231)

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Sugarcane is one of the most important crops grown in Brazil for sugar export and alcohol as fuel for cars. Extensive areas are cultivated with the crop (5 million ha), 50% being in Sao Paulo State. Among the factors that influence crop yield, the weeds certainly play an important role. Weeds that infest sugarcane in Brazil are mostly from the botanical family Poaceae, and the weed *Digitaria horizontalis* is the most frequent in sugarcane fields. An experiment was conducted in Piracicaba, Sao Paulo State, Brazil in a sandy-clay soil, using the sugarcane cultivar RB 85 5113 planted in April 1999, in an area where the weed *D. horizontalis* was the major weed (130 pl m^{-2}), in early post-emergence. The experimental design of the experiment was a randomized complete design with four replications and eight treatments: CGA 362 622 + ametryne at 1097.25 + 27.75; 1463 + 37,0; 1828,75 + 46,25 g a.i. ha^{-1} respectively, ametryne + diuron at 1500 + 1500 g a.i. ha^{-1}; tebuthiuron + ametryne at 1000 + 1500 g a.i. ha^{-1}; isoxaflutole + ametryne at 75 +

1500 g a.i. ha^{-1} and clomazone + ametryne at 1000 + 1500 g a.i. ha^{-1}, and the check plot. Herbicide applications were made using a CO_2 backpack sprayer, fitted with 110.03XR nozzles, 200 KPa, 250 liters ha^{-1} application volume, at the weed stage of two pair of leaves. Phytotoxicity symptoms was observed 28 DAT in the treatments with CGA 362 622. However, this was acceptable in a production field. In the following evaluation, no injury symptoms caused by CGA 362 622 were observed. Phytotoxicity observed in the treatment with the mixture of clomazone + ametryne was more severe than with the mixture of CGA 362 622 + ametryne. *D. horizontalis* was controlled efficiently by all treatments with the mixture of CGA 362 622 + ametryne, except by the lower rate (1097.25 + 27.75). As general conclusion of the research, it can be inferred that CGA 362 622 in mixture with ametryne can be an alternative for the control of *D. horizontalis* in sugarcane.

Isoxaflutole selectivity to sugarcane varieties applied in pre-crop emergence (232)

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The herbicide isoxaflutole is registered in Brazil for pre- and early post emergence use in sugarcane and corn to control *Amaranthus deflexus, A. retroflexus, Brachiaria plantaginea, Cencrhus echinatus, Digitaria horizontalis, Eleusine indica, Panicum maximum* and *B. decumbens*. For weed control in sugarcane grown in the southern part of the country, it is recommended at doses of 75 and 112.5 g a.i. ha^{-1} during the dry and wet season respectively. In corn, the herbicide can not be used on sandy soil, because of lack of selectivity in the crop, however in other textural classes of soil, it is applied at 60 g a.i. ha^{-1}. Isoxaflutole has been introduced as a new herbicide for weed control in sugarcane in Brazil because of its excellent potential for grass and broadleaf weed control. The inhibition of carotene biosynthesis by isoxaflutole is a new mechanism of action for this crop, preventing and managing weed herbicide resistance. However, isoxaflutole has caused severe bleaching symptoms and, in certain sugarcane varieties, in such intensity during the earlier stages of the crop, that those growers were concerned about possible effects on crop yield. Therefore, an experiment was conducted in a sugarcane production field in Sao Paulo State, Brazil, with the objective of evaluating isoxaflutole selectivity to five major sugarcane varieties. The results on sugarcane height, stand, and phytotoxicity revealed that isoxaflutole caused high initial injury symptoms, after sugarcane sprouting, such that some sugarcane varieties were graded as phytotoxicity 4, on a scale of 0 to 10, where 0 represents no phytotoxicity symptoms, and 10 plant death. However, in the subsequent assessments, the injury disappeared, showing that this herbicide was selective to all sugarcane varieties tested in these experiments with the yield of none of the varieties affected by the herbicide compared to check plot. It can be concluded from this research that isoxaflutole is safe and selective in sugarcane. The major varieties planted in Brazil are tolerant to the product, even though severe symptoms of phytotoxicity can occur during the early development stages of the crop.

Postemergence chemical control of rush skeleton weed (*Chondrilla juncea L.*) in wheat (233)

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Rush skeleton weed (*Chondrilla juncea*) has become the most important perennial weed in several crops of the SW of the Buenos Aires province, Argentina. The aim of this study was to evaluate the effects of several herbicides of the aryloxyalkanoic and pyridine acid groups on the population density and biomass of rush skeleton weed in wheat crops. The experiment included 11 treatments (12 x 3 m plots) in a randomized block design with 3 replicates. Herbicide applications were made in October 1998 and 1999, when the weed was at the full rosette stage. Treatments involved the application of clopyralid (90 and 135 g a.i. ha^{-1}), triclopyr (240 and 480 g a.i. ha^{-1}) and fluroxypyr (200 and 300 g a.i. ha^{-1}), and their mixtures at low rates with 2,4-D ester (395 g a.i. ha^{-1}). A mixture of clopyralid (90 g a.i. ha^{-1}) and picloram (24 g a.i. ha^{-1}) was also tested. In both seasons, all the chemical treatments were effective in terms of plant density and biomass reduction in relation to the untreated plots, but no difference were found among herbicides ($p<0.05$). The mixture of clopyralid and picloram produced the most important damage but differences were not significative ($p<0.05$). Due to differences in crop management and environmental conditions between the two seasons, immediately before wheat harvesting the untreated plots had different degrees of rush skeleton weed density and biomass, being 77.0 plants m^{-2} in 1998 and 34.3 plants m^{-2} in 1999, and 89 g DW m^{-2} in 1998 and 58 g DW m^{-2} in 1999, respectively. Despite this, ranges of density and biomass plant reduction caused by the herbicides were very similar in both years, and ranged between 60% and 92 % . It is concluded that the herbicides and mixtures studied were effective in the reduction of the infestation of rush skeleton weed in the crop, and are potential tools to be used in wheat.

The role of extracellular esterases in herbicide metabolism (234)

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Plants encounter a wide range of xenobiotic organic compounds such as herbicides, which may or may not have a deleterious effect. To have a herbicidal effect, a compound must enter plant cells by penetrating the hydrophobic layers at the plant surface. Therefore herbicides that are active as carboxylic acid anions are often formulated as uncharged carboxylesters, in order to enhance uptake. The localization of specific esterases in the apoplast, (one of the first points of contact between the plant and a xenobiotic) capable of de-esterifying herbicides will consequently influence the whole plant uptake and activity of the compound. Apoplastic proteins were extracted by vacuum infiltration, and analyzed by 2D electrophoresis, with isoelectric focusing in the first dimension and native separation in the second dimension. By activity staining fourteen esterases were identified in apoplastic extracts from seven-day-old wheat seedlings. Reverse HPLC analysis has shown that these extracts were capable of hydrolysing herbicide esters such as fenoxaprop-ethyl and diclofop-methyl to the active acid form. Using the model ester substrate 2-nitrophenyl acetate, the induction of wheat esterases in response to treatment with fenoxaprop-ethyl and the safener fenchlorazole-ethyl was investigated. The implications of esterases on biodelivery and metabolism of herbicides and other xenobiotics will be presented.

Selectivity of some herbicides for controlling grass weeds in turfgrass (235)

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Unwanted grass species on turfgrass cause big problems, because they lower the quality of turf and are very difficult to be selectively controlled. The aim of this study was to assess the selectivity to turfgrass of some herbicides which could be used to control grass weeds. Five different turfgrass species were sown on 24/09/1998, i.e. *Festuca arundinacea* (cv. Barbizon), *Festuca rubra* ssp *rubra* (cv. Boreal), *Festuca rubra* ssp *commutata* (cv. Tatjana), *Lolium perenne* (cv. Numan) and *Poa pratensis* (cv. Baron). When swards had uniformly established, each plot was splitted into five subplots to accommodate five different herbicide treatments, i.e. pendimethalin (1000 g a.i. ha^{-1}), pendimethalin (1500 g a.i. ha^{-1}), fenoxaprop-p-ethyl (98 g a.i. ha^{-1}), fenoxaprop-p-ethyl (196 g a.i. ha^{-1}) and untreated control. The resulting experimental design was a

split-plot with three replicates, with turfgrass species as main plots and herbicide treatments as sub-plots. Herbicides were sprayed on 3/05/99 (pendimethalin) and 9/06/99 (fenoxaprop-p-ethyl). No weed species emerged and thus herbicide selectivity was evaluated by measuring fresh and dry weigh of turfgrass biomass at each mowing time (nine times for pendimethalin and seven times for fenoxaprop-p-ethyl). Results showed that pendimethalin did not cause any apparent damage to none of the five turfgrass species. A slight decrease in weight of treated swards was observed with all species and both doses, but differences were never statistically significant. Fenoxaprop-p-ethyl did not cause any phytotoxicity on *Lolium perenne* and *Festuca rubra* (both subspecies). Otherwise, *Poa pratensis* and *Festuca arundinacea* were damaged by both doses of fenoxaprop-p-ethyl, even though symptoms were transitory and swards recovered 50 (*Poa pratensis*) and 30 (*Festuca arundinacea*) days after treatment. In conclusion, pendimethalin seems a suitable choice whenever it is necessary to prevent the emergence of grass weeds in turfgrass. On the other hand, fenoxaprop-p-ethyl can be used to control emerged weeds, even though same care is necessary when spraying *Poa pratensis* and *Festuca arundinacea*, because the selectivity of the treatment may not be perfect.

Tolerance of direct-seeded paprika pepper (*Capsicum annuum*) to clomazone applied preemergence (236)

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Field experiments were carried out during three years at Ejea and one year at Valdegon (Spain) to study the tolerance of direct-seeded pepper to clomazone alone or in combination with linuron, napropamide or pendimethalin. Weed control at 6 weeks after sowing was also evaluated. Paprika cultivar ‘‘Agridulce’’ was direct-seeded on late March or early April on a loamy (Ejea) and silt loamy (Valdegon) soil. Emergence, visual injury, dry weight of plants, yield and pigment content of paprika were recorded. Pepper was tolerant to clomazone applied at 0.18 kg a.i. ha^{-1} but weed control was unsatisfactory ($<$ 77%). Clomazone applied at 0.36 kg ha^{-1} was selective for pepper and controlled weeds by more than 85%. Clomazone at higher rates resulted in visual injury of pepper 6 weeks after sowing but plants recovered and the dry weight, yield and pigment content of paprika was not affected. Napropamide at 2.025 kg ha^{-1} used in combination of clomazone was selective and improved the control of *Diplotaxis erucoides* L. (Beauv.). Pendimethalin at 0.247 kg ha^{-1} used in combination of clomazone increased pepper injury and did not increase weed control. Linuron at 0.075-0.100 kg ha^{-1} used in combination of clomazone provided complete weed control but resulted in the highest pepper injury (33-88%) and reduced pepper stand by 50% in one year. Pepper yield and pigment content were not affected by any treatment.

Formulation and adjuvant technology: an overview (237)

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Agriculture has been defined as ‘‘a controversy with weeds’’. Herbicides continue to be the most powerful tool for weed management in most advanced agricultural systems. They represent approximately one-half of an estimated $30 billion worldwide crop protection chemicals market. However, herbicides are rarely if ever applied alone as pure active ingredients. Formulation additives (adjuvants) are included to enhance certain desired physicochemical properties and/or practical end use results. Spray adjuvants also are used extensively as tank mixtures to enhance herbicide performance under field conditions. The total worldwide adjuvant market is estimated to be $1 billion. Herbicides are formulated to (a) make them easier to mix,

handle, and apply, (b) increase their field effectiveness, (c) increase safety of use, (d) ensure more even distribution on the plant, and (e) reduce drift. Chemists change formulations to affect solubility, volatility, specific gravity, corrosiveness, shelf life, compatibility with other products, and post-application characteristics such as spreading and penetration. Activator adjuvants or blends thereof may enhance herbicide activity by increasing droplet spread and absorption, providing rainfastness, and/or decreasing photo-inactivation of the herbicide. Utility adjuvants can improve herbicide efficacy by functioning as compatibility, deposition, drift control, or water conditioning agents (relating to pH, buffering, and herbicide-ion interaction). As herbicide formulations change and environmental concerns become more of an issue, the need for different, perhaps more function-specific, adjuvants increases. How adjuvants modify the characteristics of spray solutions is fairly well known. However, greater understanding of mechanisms whereby adjuvants enhance cuticular and/or stomatal penetration is needed; also, how best to relate known physicochemical properties to practical use efficacy to enhance herbicide performance. Providing adjuvant solutions for the many diverse, sometimes unique, global weed problems, e.g. in tropical situations, constitutes a promising (albeit somewhat formidable) challenge for the future.

Using adjuvant physicochemical properties to improve herbicide performance (238)

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Adjuvants are clearly essential for postemergence herbicides to perform at economical rates under the wide array of commercial delivery systems and application conditions. In most cases, the physicochemical properties of an adjuvant determine the herbicidal activity. Optimizing these adjuvant properties can be complex and dependent on many factors including the physicochemical properties of the herbicide, its mode of action, the targeted weed species and their growth stage, application system, and environmental conditions. Weed science and the weed control industry are still evolving their approaches to adjuvant optimization. Approaches that are more systematic and based on our growing understanding of adjuvant properties are continually being developed. Better optimization is essential as users expect excellent weed control and economic and regulatory pressures are forcing this performance be achieved with less herbicide. The higher cost and longer times needed to register new herbicides has slowed the introduction of new actives and emphasized the improvement of existing products with formulation and adjuvants. Improving herbicide performance with adjuvants is directly dependent on the adjuvant physicochemical properties. This paper reviews our current understanding of adjuvant physicochemical properties and issues associated with optimizing these properties to improve herbicide performance and minimize use rates.

Adjuvant solutions to global weed problems (239)

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Adjuvants are defined by the American Society of Testing and Materials (ASTM) as any material added to a tank mix to aid or modify the actions of an agrichemical, or the physical characteristics of the mixture. Adjuvants have proven to be very useful in resolving many agrichemical application and performance problems. Worldwide, the agrichemical market is estimated to have a value of about 40 billion U.S. dollars. Herbicides are estimated to represent about 50% of the total value. Postemergent herbicide applications in developed countries are estimated to represent about 50% of the total herbicide value in those countries. This makes the postemergent herbicide market the single largest market for adjuvants. Worldwide, the total value of the adjuvant market is estimated to be about one billion U.S. dollars. Adjuvants have successfully been used with herbicides to reduce, minimize, or eliminate many of the variables negatively affecting spray application and to positively enhance the biological effect of the herbicide while not negatively affecting crop response. With the imminent increase in global populations, more pressure will be put on the efficient production of food and fiber. Weed management will play a major role in this process. Regarding the management of the world's most troublesome weeds in the most important food and fiber crops, adjuvants will provide one of the most cost effective and environmentally responsible solutions. Solutions presented by the selection of the correct type of adjuvant and the use of the best product within the type and in combination with the appropriate agrichemical will result in: improvements in biological activity at full and lower labelled use rates, more biological activity on a wider variety of weeds as listed on the agrichemical label, fewer sequential treatments, less impact on the environment, less impact on crop response, more economic benefits and more efficient use of agrichemical and application resources and other benefits.

Effect of glyphosate formulation on Brazil pusley (*Richardia brasiliensis* (Moq.) Gomez.) control in Florida citrus (240)

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Glyphosate has marginal effects of *Richardia brasiliensis* control; therefore, the effects of combinations of glyphosate and 2,4-D (surfactant) on *R. brasiliensis* were investigated. Actively growing *R. brasiliensis* (4 to 6 inch tall) transplanted into plastic pots in Candler fine sand, were kept in a greenhouse maintained at 25/16 ^{o}C (0.5) day/night and 70% (0.5) relative humidity. The herbicide formulations were glyphosate as Roundup Ultra (0.68 lb a.i./A), 2,4-D as Weedar (0.15 to 0.6 lb a.i./A), Landmaster II (product containing glyphosate, 2,4-D and inert matter)(1 - 2 qts product/A) and tank mix (glyphosate and 2,4-D). Herbicides were applied alone and with adjuvants Induce (0.25%) a nonionic, L-77 (0.1%) an organosilicone, and Kinetic (0.25%) a blend of nonionic and organosilicone. Landmaster II or tank mix treatments killed all *R. brasiliensis* without adjuvants. Therefore, to differentiate between the effects of surfactants on either Landmaster or tank mixture, reduced rates of herbicides were used. The effects of combinations of glyphosate + 2,4-D (surfacant) on *R. brasiliensis* control were studied. Typical 2,4-D symptoms on plants were observed within 2 to 3 days after treatment. Application of glyphosate controlled only 14% plants but addition of Induce significantly increased percent control to 83% and reduced the fresh weight by 68%. Application of Landmaster or tank mix (surfactant) controlled 96 to 100% of the plants. The treatment with 2,4-D alone, with Induce, and L-77 resulted in 84, 90 and 100% control of test plants, respectively. Significantly very low fresh weight of *R. brasiliensis* was recorded when 2,4-D (+ Induce/L-77), Landmaster II (surfactant) and tank mix (surfactants), were applied. In the regrowth studies, the shoot weight was greater in glyphosate (L-77/Kinetic) treatments. The fresh weight of regrown shoots, obtained with 2,4-D, Landmaster (surfactants) was very low except with Kinetic in Landmaster. No regrowth of the shoots occurred in tank mix treatment. Similar observations were recorded for roots. There was no regrowth from 2,4-D treated plants. These results suggest that 2,4-D was the main component of either formulation, which accelerated synergistic effect of the glyphosate to the target site and hence effectively controlled *R. brasiliensis*. Therefore, 2,4-D could be used either as a component of the formulation or a tank mix product with glyphosate to control this difficult to control weed, *R. brasiliensis*.

Phytotoxicity of different ghyphosate formulations in *Conium maculatum* L (241)

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Glyphosate phytotoxicity is greatly influenced by the type of surfactants in the spray solution. It is possible to find important differences between glyphosate formulations. Values of ED_{50} (doses causing 50%

reduction in shoot fresh weight) of five glyphosate formulations (Sting SE, Roundup N, Roundup Plus, Roundup SEC and Roundup 400 Presiembra) were calculated for Conium maculatum. The order of herbicide efficacy was: Sting SE and Roundup 400 Presiembra > Roundup N > Roundup Plus and Roundup SEC. ED_{50} values changed from 86 (Sting SE) to 257 g a.i. ha^{-1} (Roundup SEC). Stock solutions of ^{14}C-glyphosate were prepared by mixing ^{14}C-glyphosate with the different glyphosate formulations for penetration and translocation studies. Formulation Roundup N showed the most penetration and translocation (18.18 % ^{14}C-glyphosate recovered), 48 hours after treatment. The order of ^{14}C-glyphosate penetrated was: Roundup N and Sting SE > Roundup 400 Presiembra and Roundup Plus > Roundup SEC. There is no total correlation between ED_{50} values and penetration values. Other parameters such as herbicide retention could play an important role for explaining the phytotoxicity of different formulations.

Oxo-alcohol acetate esters as adjuvants for herbicides (242)

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The activity of certain herbicides (clethodim, sethoxydim, nicosulfuron, imazethapyr) is known to be significantly increased by the use of adjuvants like paraffinic oils and methyl esters of fatty acids. These adjuvants, although they improve activity, possess deficiencies; for example, compatibility problems, product consistency, peroxide formation due to presence of oxidizable functionalities, and hydrolytic stability (vegetable oil esters). This poster will describe a new class of phytobland esters which possess good adjuvancy without many of the above deficiencies. Exxate™ Fluids are a family of acetate esters of primary oxo alcohols that are registered for agricultural chemical use in the U.S. under 40CFR 180.1001(d). Selected members of the family have been field tested as tank mix adjuvants in combination with commercial herbicides (Accent, Lightning, Select) for the control of a broad spectrum of weed species in corn and soybean. The field trials demonstrated that the Exxate Fluids were phytobland and as effective as paraffinic oil and methylated vegetable oil controls in providing needed adjuvancy to the herbicide. No differentiation was observed among the various Exxate grades studied. The poster will describe the Exxate Fluids and compare them to control paraffinic oil and methylated soybean oil. Details of the field trial and specific results will be described.

Improved rainfastness of post emergent herbicides with the tankmix adjuvant Break-Thru™ S240 (243)

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Rainfall shortly after application can reduce the effectiveness of many agricultural chemicals. This is particularly true of slow acting post-emergent herbicides. It restricts the use of some herbicides in areas of the world where rains are frequent. Susceptibility to rain can present a potentially expensive dilemma for a farmer. When an unexpected rain falls soon after application the farmer can either re-treat with the herbicide, and so double the cost, or risk having unacceptable weed control later. Even a small amount of rain (2 mm simulated) one hour after application can reduce the effectiveness of these herbicides. The organomodified trisiloxane tank-mix adjuvant, Break-Thru S240 (Goldschmidt Chemical) has now been shown to be very effective in enhancing the rainfastness of post-emergent herbicides. Simulated rain within 60 minutes of application of the halosulfuron significantly reduced its performance on *Cyperus rotundus* such that the treatment was no longer commercially viable. However, the rain had no effect on weed control when Break-Thru S240 was included in the spray solution at rates of 0.1% (v/v) or higher. Break-Thru S240 also enhanced the performance of glyphosate in both the presence and absence of rain. Without rain the glyphosate rate used did not give commercial control (85%) of perennial *Brachiaria decumbens*.

Simulated rain substantially reduced the performance of glyphosate alone. However, with the addition of Break-Thru S240 to the spray tank, commercial control was provided both in the presence and absence of simulated rainfall. Similar results were obtained with broadleaf weeds. Likewise, the degradation in performance of the turf herbicides, Trimec (mixture of the dimethylamine salt of 2,4-D, dimethylamine salt of mecoprop and dimethylamine salt of dicamba) and Confront (mixture of triethylamine salt of triclopyr and triethylamine salt of clopyralid), by artificial rain 60 minutes after spraying was corrected by the use of Break-Thru S240.

The ambiguity of herbicide interactions (244)

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For most agricultural scientists the term interaction is related to the design and analysis of variance of multi-factorial experiments. As such, interaction is a statistical term that usually complicates interpretation and precludes generalisation of how mixtures of herbicides or adjuvants affect each other's action. Interaction will inevitably occur if the dose range of herbicides is wide enough because of the shape of the dose-response curve. At very low doses the responses approach the untreated control, and at very high doses the test plant is either killed or its biomass reaches a lower limit. Consequently, interactions close to those limits are of little biological relevance. Analysis of variance is a common method to assess differences of effects of herbicides at pre-set doses. The analysis is independent of the dose-response relationship. Another way of comparing the efficacy is to compare the doses of herbicides at pre-set response levels. This assessment requires use of dose-response relationships with regression models to interpolate and find the desired response levels. In fact, comparison of dose-response curves answers the question farmers frequently ask: ''How much of herbicide B do I need to obtain the same result as with a dose of x kg ha^{-1} of herbicide A''. The different ways, analysis of variance or regression, used to summarise the results of experiments with herbicide mixtures are often confusing the additivity or multiplicativity of effects and the additivity of doses. Herbicide research and development is based on dose-response curves, and the success in finding effective herbicides speaks for itself. However, the research and development of herbicide mixtures has, in most cases, been based on factorial analysis of variance and not on dose-response curves. This has severe consequences if we wish to generalise from our research.

Optimising herbicide mixtures according to weed flora (245)

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Herbicide mixtures are widely used to control diverse weed floras with species of varying susceptibility to the individual herbicides. Farmers are well aware of the benefits of herbicide mixtures and particularly the potential of reducing the costs of application. Several mixture models have been used in the literature to assess the joint action of herbicide mixtures. One of the models is the Additive Dose Model (ADM). The ADM assumes additivity of doses; i.e. one herbicide can be replaced, wholly or in part, by another herbicide at equivalent doses. If a herbicide mixture follows the ADM and the required dose to produce a given effect of the herbicides applied alone is known, then equivalent doses can be calculated easily and herbicide mixtures producing a similar effect as the individual herbicides can be designed. The Danish decision support system for weed control, named 'Plant Protection', contains information on the dose response curve of any relevant combination of herbicide and weed species. The dose required to produce a given effect can therefore easily be calculated. An extensive study on the performance of herbicide mixtures has revealed that the majority of the herbicide mixtures used by Danish farmers to control weeds in small grain cereals follow the ADM. Hence, it was possible to incorporate an ADM module in 'Plant Protection' optimising the composition and doses of mixtures of cereal herbicides according to the prevailing weed flora. Herbicide mixtures can be optimised either to minimise the costs of treatment or to minimise the Treatment Frequency Index (TFI) which is a measure of the intensity of pesticide use. A large number of validation trials showed that the implementation of the ADM module reduced the costs of treatment by 18% in spring barley and 24% in winter wheat and the TFI by 27% in spring barley and 29% in winter wheat compared to the previous version of the decision support system. Applying the principles of ADM makes it possible to fully exploit the strong points of the individual herbicides, be it a high activity on specific weed species or a low price.

Metabolic complementarity explains PSII and carotenoid inhibitors synergism (246)

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Herbicide inhibitors of photosystem II (PSII) yield chlorophyll free radicals which promote an oxidative stress and destroy chloroplast membranes and, consequetly, promotes the death of the weeds. Plant mechanisms to avoid chloroplast oxidative stress involve carotenoids, which dissipate chlorophyll energy in the form of heat. However, when susceptible plants are treated with PSII, the amount of chlorophyll free radicals produced overcomes the protective capacity of the plants. We hypothesized that the simultaneous application on plants of carotenoid inhibitors and PSII inhibitors can have a synergistic effect, allowing the reduction of herbicide rates. The objective of this work was to demonstrate the synergism for the mixture between PSII and carotenoid inhibitors. Two field experiments were conducted, one with soybean and the other with corn. Both experiments used a factorial experimental design. The soybean experiment, conducted in Brazil, included all possible combination of the PSII inhibitor metribuzin at 0 and 280 g ha^{-1} and the carotenoid inhibitor clomazone at 0 and 560 g ha^{-1}. The corn experiment, conducted in the USA, included all possible combination of the PSII inhibitor atrazine at 0 and 840 g ha^{-1} and the carotenoid inhibitor isoxaflutole at 0 and 50 g ha^{-1}. The inhibitors where sprayed on the soil after the crop was planted. In the soybean experiment, *Bidens pilosa* control was highest with the mixture of metribuzin and clomazone. Colby's method to test for synergism indicated that all treatments with herbicide mixtures gave superior results than the expected from the sum of the individual treatments. For instance, control of *Bidens pilosa* by the mixture of metribuzin and clomazone was 85%, whereas each herbicide applied alone controle the weed only 45%. Likewise, in the corn experiment, *Amaranthus retroflexus* density was smallest with the herbicide mixture. These results confirm the hypothesis that the simultaneous application on plants of carotenoids and PSII inhibitors have a synergistic effect.

Herbicide efficiency in maize and their impact on microbiological activity in soil (247)

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Various herbicides and herbicide combinations have been applied for weed control in maize. The following weed species were present in this trial: *Amaranthus retroflexus*, *Chenopodium album*, *Datura stramonium*, *Echinochloa crus-galli*, *Hibiscus trionum*, *Polygonum lapathifolium* and *Setaria viridis*. Atrazine at a rate of

3 L ha^{-1} has shown high efficiency on broadleaf weeds. Atrazine and alachlor had different impact on number and dehydrogenase activity of microorganisms in soil with maize. The objective of the study was to observe the changes with respect to the number of groups of microorganisms and dehydrogenase activity in soil under maize after the application of two herbicides. For the study, the following herbicides were used: atrazine 2 L ha^{-1}, atrazine 3 L ha^{-1}, alachlor 4 L ha^{-1}, alachlor 5 L ha^{-1}. A trial with maize hybrid NSSK/606 was established on calcareous chernozem on loess. During the maize growth period, the soil was sampled three times. The effect of the herbicides depended upon herbicide and its dosage, microorganism species and the period of the herbicide action. Both hrbicides reduced the total number of bacteria, number of ammonifiers, azotobacter and dehydrogenase activity, and increased the number of fungi and actinomycetes. Alachlor had higher average inhibitory effect than atrazine. Expanded herbicide quantities increased its inhibitory effect that was most noticeable at the beginning of the growing period.

Influence of rainfall on the weed control efficacy of sulfentrazone and carfentrazone tank mixtures with glyphosate (248)

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An experiment was conducted in Sao Paulo State, Bariri in order to test the efficacy of tank mixtures of sulfentrazone and carfentrazone with glyphosate, with a 6 mm rainfall simulation, two hours after herbicide application. Five weeds were seeded in order to get good infestation: *Cenchrus echinatus*, *Commelina benghalensis*, *Senna obtusifolia*, *Bidens pilosa* and *Ipomoea grandifolia*. The plots were sprayed at the 2 to 4 leaf stage. The experimental design was RCB with eight treatments and four replications, and two rainfall simulation, 6 mm at 2 h after herbicide application and 20 mm one day after application (normal rainfall occurred). The treatments were sulfentrazone + glyphosate (150 + 960 and 200 + 960 g a.i. ha^{-1}), carfentrazone + glyphosate (18 + 960, 30 + 960 and 42 + 960 g a.i. ha^{-1}) and 2,4-D + glyphosate at 670 + 960 g a.i. ha^{-1} and 2,4-D at 1 005 g a.e. ha^{-1} as patterns, and the check plot without herbicide. Mineral oil at 0.05 % v/v was added to all herbicide treatments. Number of weeds/l.m. and height were assessed at 0, 7, 14 and 30 DAT and weed control efficacy at 7, 14 and 30 DAT. For the treatment where the rainfall occurred one day after herbicide treatment (normal field situation), the tank mixture of sulfentrazone + glyphosate and carfentrazone + glyphosate gave more 90% control of *C. echinatus*, *C. benghalensis*, *B. pilosa* and *I. grandifolia*. For *S. obtusifolia* the control level was higher than 90% up to 14 DAT; however at 30 DAT the lowest rate of carfentrazone + glyphosate gave best results followed by the intermediate and highest rates. 2,4-D alone did not control *C. echinatus*. The rainfall simulated two hours after treatments did not affect the efficacy of the tank mixture of sulfentrazone + glyphosate and carfentrazone + glyphosate on *C. echinatus*, *C. benghalensis*, *B. pilosa* and *I. grandifolia*. However, for *S. obtusifolia* the control was better for the mixtures at 7 and 14 DAT, and worse for 2,4-D, but at 30 DAT the reverse was true, 2,4-D being a better treatment.

Relationship between rice cultivar tolerance to iron and photosystem I inhibitor (249)

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Tolerance to toxic iron is an important characteristic of rice cultivars. The water inundation and high levels of iron in the soil can be toxic to some rice cultivars and decrease plant growth and grain yield. Iron toxicity to rice plants can be a direct effect due the high absorption of this mineral, or an indirect effect when it is caused by oxidation of iron on root surface and decreased absorption of other minerals. Iron ions accumulate in the chloroplasts producing free radicals that promote chlorophyll and membrane lipid oxidation. The bipyridylium herbicides are reduced in the photosystem I and react with molecular oxygen, producing free radicals and the same effects in membranes and chlorophyll as iron toxicity. The aim of this experiment was to investigate the relationship of tolerance of rice cultivars to iron toxicity and their susceptibility to herbicide inhibitor of photosystem I. An experiment was conducted in pots in the greenhouse using a completely randomized design, with four replicates. The treatments were rice cultivars EPAGRI 108 and EPAGRI 109 (iron toxicity resistant) and BR IRGA 409 and IRGA 417 (susceptible) and paraquat herbicide at rates of 0, 15, 30, 60, 120 and 320 g a.i. ha^{-1}. The herbicide was sprayed when rice plants presented four leaves. The leaf chlorophyll concentration was estimated through handheld chlorophyll meter and evaluated by SPAD readings. Visual injury one day after application (DAA) was higher on iron susceptible cultivars, mainly at 100 g a.i. ha^{-1} of paraquat. At 8 and 16 DAA, only the cultivar IRGA 417 was more sensitive than the other genotypes. The SPAD readings showed the same effects of paraquat among cultivars. However, for three cultivars, at one DAA, SPAD readings were higher on plants sprayed with paraquat at 20 g a.i.ha^{-1} than the untreated plants. This can be due to a stimulus on chlorophyll synthesis caused in the beginning of action of a low herbicide rate. Dry matter at 16 DAA presented different results than visual injury and SPAD readings, probably due to different growth rate of the cultivars. The chlorophyll readings showed a linear relation with visual injury; therefore, these could be used to evaluate a large range of herbicide effects.

Efficacy of imazapyr and its mixtures against weeds under rubber (250)

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Isopropylamine salt of imazapyr is effective against several weeds in rubber plantations but is relatively expensive. Lower rates of imazapyr were therefore evaluated in mixtures with other herbicides to determine whether improved weed control can be obtained. Trials were conducted along planting strips of rubber of about five years old against weeds comprising mainly of *Ottochloa nodosa* (Kunth) Dandy, *Paspalum conjugatum* Berg., *Axonopus compressus* (Swartz.) Beauv., *Borreria latifolia* (Aubl.) Schum. and *Asystasia gangetica* (L.).T. Anders. Imazapyr required at least 0.2 kg a.e. ha^{-1} for effective weed control while rates of 0.1 kg a.e. ha^{-1} and 0.15 kg a.e. ha^{-1} provided less effective weed control. Mixtures of imazapyr at 0.15 kg a.e. ha^{-1} with dimethylamine salt of 2,4-D (1.08 or 2.16 kg a.e. ha^{-1}) or glufosinate ammonium (0.225 or 0.45 kg a.i. ha^{-1}) showed decreased weed control. Its mixtures with ametryn (0.5 or 1.0 kg a.i. ha^{-1}) provided more persistent weed control than with diuron (0.5 or 1.0 kg a.i. ha^{-1}) which showed almost comparable weed control. Mixtures of imazapyr with metsulfuron methyl at 0.015 kg a.i. ha^{-1} or with premixed isopropylamine salt of glyphosate + isopropylamine salt of dicamba at 0.18 + 0.09, 0.36 + 0.18 or 0.54 + 0.27 kg a.e. ha^{-1} improved weed control. Addition of alachlor (0.48 or 0.96 kg a.e. ha^{-1}), metolachlor (0.36 or 0.72 kg a.e. ha^{-1}) or oxyfluorfen (0.12 or 0.24 kg a.e. ha^{-1}) to imazapyr at 0.25 kg a.e. ha^{-1} showed comparable control. Imazapyr therefore is compatible with the herbicides tested except with 2,4-D or glufosinate ammonium which provided reduced weed control.

The current status of herbicide target sites (251)

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This paper reviews the current status and knowledge of herbicide target sites and discusses their characteristics and the prospects for future target site discovery. Empirical glasshouse screening processes employed by agrochemical companies have resulted in the discovery of 270 herbicides. However, to date only 17 known modes of action have been established, with only 11 target sites identified. These include the enzymes enoyl pyruvyl shikimate phosphate synthase (EPSPS), glutamate synthase and dihydropteroate synthase which only have one commercialized herbicidal inhibitor each, i.e. glyphosate, glufosinate and

asulam respectively. Whereas photosystem two (PS11), acetolactate synthase (ALS) and protoporphyrinogen oxidase (protox) are targeted by over 50% of commercialized herbicides. There are also 28 commercialized herbicides whose sites of action are still unknown. Molecules that target ALS and protox have dominated herbicide introductions in the last ten years, comprising two-thirds of the 66 most recent announcements. In this period only two new target sites have been identified, namely 4-hydroxyphenylpyruvate dioxygenase (HPPD) and auxin transport inhibition. This lack of new target sites may be a consequence of the chemical synthesis programmes and associated glasshouse screening procedures of the agrochemical companies used for the discovery of new molecules. These procedures are undergoing change, due to the development of high throughput biochemical screens (HTBS), in which large numbers of molecules derived from combinatorial chemistry are screened on isolated enzymes. The choice of target site in new screens is between the few known but proven targets, or new but unproven or speculative enzymes. The essential role in plant metabolism is a key characteristic for the success of a herbicide target. This raises the question; why are there so few herbicide targets, as analysis of plant genomes indicates in excess of 20,000 genes. The vast majority of these are essential for plant growth and development. Phytotoxic secondary effects resulting from the interaction of the herbicide with its primary target are associated with the effectiveness or lethality of most, if not all the proven modes of action of commercial herbicides. It can be speculated that the large number of essential plant genes not targeted by herbicides may not be associated with rapid development of secondary phytotoxic events.

Are there "good" and "bad" sites for herbicide action? (252)

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Successful discovery of herbicides via in vitro screening will require judicious choice of targets. In principle, a sustained blockade of the activities of any number of essential enzymes and proteins involved, for example, in primary biosynthesis might be expected to disrupt metabolism and lead to a lethal effect. However, while many hundreds of sites appear to exist in principle (being valid, for example, on the basis of functional genomic criteria), only a relative few have been demonstrated in practice and yet fewer have proven important commercially. The question arises as to whether the few demonstrated sites are somehow different from the many which have, thus far, remained potential. Here, the relationship between intrinsic activity and herbicidal efficacy is explored for hydroxyphenylpyruvate dioxygenase, acetolactate synthase, and a number other enzymes involved in amino acid biosynthesis. Initial studies created the impression that, generally, it might only be necessary for inhibitors to have in vitro activity in the tens of nM range in order to exert potent herbicidal effects. However, reexamination of the enzyme kinetics often reveals herbicides to be far more potent than this in vitro. Here, it is argued that rates of enzyme/ inhibitor (EI) complex formation greater than 105 M s^{-1} coupled with rates of EI dissociation slower than 105 s^{-1} and Ki values in the pM range are more likely the rule than the exception. Thus, while targets such as acetolactate synthase may genuinely be special, many other well known sites of herbicide action may have no distinguishing feature other than to have been turned up as the fortuitous subjects of inhibition by molecules able to combine such a remarkable level of potency with the many other characteristics needed for herbicidal efficacy.

***p*-hydroxyphenyl pyruvate, the target enzyme of new bleaching herbicides** (253)

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p-Hydroxyphenylpyruvate dioxygenase catalyses the transformation of *p*-hydroxyphenylpyruvate into homogentisate. In photosynthetic organisms, this enzyme plays a specific and crucial role. This is because the product of the reaction, homogentisate, is the aromatic precursor of all plastoquinones and tocopherols, which are essential elements of the photosynthetic electron transfer chain, and of the antioxidative systems, respectively. Plant HPPD is also involved, as in other organisms, in the degradation of tyrosine. The importance of this enzymatic activity in plants was recently demonstrated by the lethality of its inhibition by sulcotrione, and isoxazoles, members of new families of bleaching herbicides. In order to engage a detail characterization of this new herbicide target, we have isolated the carrot HPPD cDNA, overproduced the corresponding protein in *E. coli* and purified the enzyme to homogenity. Carrot HPPD behaves as an homodimer with 48 kDa subunits. A Km of 7 μM for *p*-Hydroxyphenylpyruvate, and a Vm of 2 μmol of homogentisate formed per min per mg of protein were determined. The nature of its inhibition by the diketonitrile of isoxaflutol (DKN) was investigated on the purified recombinant plant HPPD by inhibition kinetics and binding studies. We observed that DKN acts as a slow tight binding inhibitor for carrot HPPD (kon= 1.5×10^4 M^{-1} s^{-1}), and is competitive with respect to HPP. Moreover, we have demonstrated that HPPD shows only a half site-reactivity versus DKN. Modification of one active site by DKN is sufficient to inactivate the dimeric enzyme. The dual involvement of plant HPPD in both tyrosine catabolism, and prenylquinone synthesis, raised the question of the existence of several isoforms. We have thus examined the subcellular localisation of the carrot HPPD either by following its biochemical activity, or by immunological analysis. With both methods we found only one pool of HPPD associated with the cytosolic compartment

Mode of action of chloroacetamides and functionally related structures (254)

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In short-term experiments, labelled malonate or stearate have been incorporated into fatty acids of seedlings of cucumber, leek and other plant species. While the formation of fatty acids (up to C-18) was not influenced, phytotoxic chloroacetamides strongly inhibited the synthesis of very-long-chain fatty acids (VLCFAs; C-20,-22,-24) with I_{50}-values of 10-100 nM. Inhibition depends on the amide structure and on stereospecificity. Also compounds of structures different from chloroacetamides like cafenstrole or recently developed tetrazolinones and phosphosulfonates were found active to inhibit fatty-acid elongation. Only the S-enantiomer of dimethenamid or metolachlor, not the R-forms, showed inhibition as is the case with their herbicidal action in the field. Using *Scenedesmus*, it could be shown that inhibition of VLCFA biosynthesis corresponds to growth inhibition. Subsequently, a cell-free elongase assay was developed using microsomes from leek (*Allium porrum)*, with ^{14}C-malonate and C-18, C-20, or C-22 acyl-CoA as primer substrates present. All elongase steps were strongly affected by those phytotoxic herbicides which were found active *in vivo*. Apparently, the inhibitors form a tight-binding complex with the enzyme which develops with time and lowers the I_{50}-values markedly. Due to the low I_{50} values, we assume that impaired VLCFA-formation is the primary phytotoxic impact of chloroacetamides and functionally related structures.

The structure-activity relationships of fungal toxins that disrupt sphingolipid biosynthesis in plant and animal systems (255)

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The fumonisins consist of several series of structurally analogous mycotoxins produced by economically important *Fusarium* species. Fumonisins were initially identified as the cause of mammalian toxicity, but subsequent studies have shown them to be phytotoxic as well. Fumonisin B_1 (FB_1) exhibits primarily contact phytotoxicity and its mode of action is consistent with inhibition of ceramide synthase, an important enzyme in the sphingolipid biosynthesis pathway. AAL-toxin, a structurally-related mycotoxin produced by *Alternaria alternata*, lacks the C-1 terminal methyl group. It is also a strong inhibitor of ceramide synthase. FB_1 and AAL-toxin were tested for phytotoxicity with various plants and found to have relatively similar effects on tomato lines and a variety of other plant species. Australifungin, a toxin produced by *Sporomiella australis*, also inhibits ceramide synthase, although it is not structurally analogous to FB_1 and AAL-toxin. It has proven a useful research tool to establish inhibition of ceramide synthase as a novel phytotoxic mechanism. Because the known mammalian toxicity of FB_1 makes it unsuitable for direct use as a herbicide, structure-activity relationship studies have been carried out on synthetic and semi-synthetic analogs to investigate differential toxicity in plant and animal *in vitro* bioassays. Although FB_1 analogs with a degree of selectivity for plant toxicity were identified, fundamentally the same structure-activity relationships of fumonisins were observed in plant and animal systems.

Glyphosate-induced increase in glutathione-*S*-transferase activity and glutathione content in groundnut (256)

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There is paucity of information discussing the metabolic fate of glyphosate in higher plants and very little is known about whether glyphosate becomes conjugated with natural metabolites. A significant increase in the activity of the glutathione-*S*-transferase (GST, E 2.5.1.18) and glutathione (GSH) content was observed in the three groundnut cultivars (*Arachis hypogaea* L. cv. JL24, CO2 and TMV2) upon glyphosate application. The increase in specific activity of GST, although proportional to the herbicide concentration, was however, not correlated to the sensitivity of these cultivars to glyphosate. The glyphosate induced increase in the enzyme activity was maximum (5- to 10-fold) in the foliar explants of all the three cultivars. Interestingly, the groundnut cv. JL24 (the most sensitive amongst the three cultivars tested) could achieve comparably high GST activity at 0.3 mM glyphosate (LD_{50} value), but it failed to maintain the enhanced enzyme activity at higher concentrations of glyphosate. The data indicate that the differences in the sensitivity of these groundnut cultivars to glyphosate were not due to differential EPSP synthase levels, and may thus be dependent upon differential rates of herbicide metabolism and intrinsic physiological adaptations to herbicide stress. Glyphosate tolerant cell lines of groundnut (*A. hypogaea* cv. JL24) selected *in vitro*, also showed significantly higher GST activity (1.2- to 1.5-fold) as opposed to the glyphosate sensitive cell line, accompanied by an increase in the non-protein thiol content. In the glyphosate sensitive cell line, herbicide treatment resulted in rapid but transient elevation of specific activity of GST and non-protein thiol content. The glyphosate induced increase in GST activity could be prevented by cycloheximide and actinomycin D. The enhanced GSH metabolism accelerated by glyphosate stress may have a possible role in the mode of action and/or detoxification of this herbicide in groundnut.

Comparison of time of application of herbicides for the control of *Sorghum halepense* (257)

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A correlation between two methods to determine the best moment to apply postemergence herbicides to control *Sorghum halepense* L. (Pers.) in soybean was done. This essay was carried out in Tandil, Buenos

Aires province, Argentina during the 1997/1998 season. Treatments were: T0: control, with weeds; T1: haloxyfop- R-methyl (CE 3%) 2 L p.f. ha^{-1}, at 252,76 C-day; T2: fluazifop-P-butyl (CE 15%) 1 L p.f. ha^{-1} at 252,76C-day; T3: fluazifop-P-butyl (CE 15%) 1 L p.f. ha^{-1}, sorghum height 40 cm; T4: haloxyfop-R-methyl (CE 3%) 2 L p.f. ha^{-1}, sorghum height 40 cm; T5: imazethapyr (CE 10%) 1l p.f. ha^{-1}, 21 days after the soybean was sown. The herbicides were broadcast with a manual sprayer, at 40 psi pressure, nozzle 8002 with 120 L ha^{-1} of water volume. A completely randomized block design with four replications was used. Tillers per plot were counted before the imazetaphyr application and at 15 to 30 days after the other treatments, and weed control percentage and yield were determined. There are significant differences in *S. halepense* control among the different treatments, T1, T3 and T4 do not differ among them but with T0, T2 and T5 that do differ between them. There are no significant differences between the two parameters considered to determine the moment for the application of the herbicides. Yields differ significantly between control without treatments and plots treated but no among them. Best results in weed control were obtained with haloxyfop-R-methyl 3, and fluazifop-P-butyl 15 at 30 days from the application. None of the treatments were phytotoxic to soybean.

Selective mechanism of cyhalofop-butyl ester between rice (*Oryza sativa* L.) and barnyardgrass (*Echinochloa crus-galli*) (258)

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This experiment was conducted to determine the selective mechanism of cyhalofop-butyl ester on uptake, translocation, and metabolism of the herbicide in both rice and barnyardgrass. Uptake and translocation of ^{14}C-cyhalofop-butyl ester was higher in barnyardgrass than rice when treated to shoot. ^{14}C-uptake by barnyardgrass roots increased rapidly at 30 minutes after treatment and reached a maximum at 12 hours after treatment. After that, uptake leveled off. Uptake pattern in rice root was not significantly affected by the duration of herbicide treatment. In barnyardgrass, the absorbed ^{14}C-cyhalofop-butyl ester seemed to be rapidly metabolized into free acid and the content of modified free acid was higher than in rice.

Ethylene involvement on highly selectivity herbicidal action of 2,4-D between monocot and dicot plant callus tissues (259)

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It is known that 2,4-D, an auxin-type plant growth regulator, has the distinctly selective herbicidal activity for dicot plants without damaging monocots. 2,4-D has been used as a selective herbicide to control the dicot weeds in paddy and upland fields in the world. However, the mode of action of 2,4-D on the selectivity between dicot and monocot plants is not so clear, yet. We conducted to throw light on this problem by using dedifferentiated callus tissues derived from the seed and/or seedling stem of dicot and monocot plant species. Modified MS medium with 2,4-D or IBA (indole butyric acid) as the auxin and benzylaminopurine (BAP) as the cytokinin produced callus under light (7 000 lux) and dark conditions. After several subcultures monthly, callus tissues were used for detection of ethylene production with measurement of fresh and dry weight. Gas samples were withdrawn from the head space of the 100 ml glass flask cultured callus tissues with 1 ml tuberculin syringe. Ethylene was assayed using a FID gas chromatograph and a stainless steel column packed with Porapak Q. Dependent on the increase of 2,4-D concentrations, the growth of dicot callus was suppressed, and the ethylene production from that remarkably promoted. In the case of monocot plant callus tissues, however, there was no response to 2,4-D, that is, 2,4-D had no effect on monocot callus growth and ethylene production. It is suggested that ACC-synthase has different sensitivity to 2,4-D between dicot and monocot plant tissues.

Biokinetic profiling: what it takes to get to the site of action (260)

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Target site activity without delivery to the site of action is of no practical value from a weed control perspective. The systemic properties of a compound can thus spell the difference between an interesting disrupter of a plant biochemical process, and a blockbuster herbicide. Consequently, an understanding of the physico-chemical features that characterize systemic xenobiotics can aid in both the design and discovery of new herbicides. Useful rules for assessing the systemic potential of xenobiotics have been inferred by several research groups. These rules are usually stated in terms of the physical properties of the xenobiotics. Thus, systemic behavior has often been related via both empirical and mechanical models to various measures of molecular lipophilicity, size, and degree of dissociation. Exceptional behavior not accounted for by these baseline models may arise as a result of chemical properties including instability and specific binding to cellular components. Rules for predicting reactivity can be formulated in terms of sub-structural features commonly present in unstable compounds, and incorporated into expert systems that anticipate the exceptional cases. The biokinetic profile of a compound typically includes an assessment of its potential for uptake, transport and metabolism. If sample and analytical resources are available, the profile can be produced experimentally. When sample or resources are limiting, profiles can be produced computationally using mathematical models and expert systems. Computer assisted biokinetic profiling can be an aid in discovering new herbicides in a collection of available compounds by identifying those substances with desirable biokinetic properties. Of course, such profiling is not limited to compounds for which samples exist. Individual hypothetical molecules or even large virtual libraries can be processed for the purpose of prioritizing compounds for synthesis.

Structural and physicochemical requirements for systemicity of herbicides (261)

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Many herbicides require transport within the plant to their site of action. Long-distance transport occurs *via* the phloem and/or xylem, the pattern of herbicide transport being determined by the physicochemical properties of the compound. Lipophilicity determines movement across membranes, with penetration being optimal at intermediate lipophilicity for non-ionised compounds. Herbicides with this property are able to enter and move freely in the xylem. Transport *via* phloem is more difficult. Though the phloem vessels are accessible to herbicides, a compound moving freely between phloem and xylem in the vascular bundles will be moved upwards with the xylem sap given its greater flow rate. Only compounds that can enter the phloem sieve tubes and yet not escape rapidly will be able to move long distances therein, this concept underlying the 'intermediate permeability theory' for phloem transport. Acids are a special case within this theory, for they can cross membranes rapidly as the undissociated form, whereas the anion, being both negatively charged and much more polar, will generally cross membranes only slowly. The slight alkalinity of the phloem sap allows acids to be both accumulated in the sieve tubes and then transported over long distances. Of about 50 acidic herbicides and analogues, Bromilow *et al* found that glyphosate was the best transported in phloem using a system based on the castor bean plant (*Ricinus communis*). This behaviour of glyphosate is difficult to accommodate within the simple theories of phloem transport, for it is a tribasic acid and a strong base, so that it must be crossing membranes as a charged species. An analogue with similar ionisable functionality was also well transported, though others with fewer ionisable groups were less so. Whilst there was no evidence for carrier loading, the excellent retention of glyphosate within phloem and its sinks appeared due to the combination of ionisable functionality.

CGA 362622 uptake, translocation and metabolism in cotton and sugarcane (262)

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CGA 362622 is a new Novartis sulfonylurea herbicide for post-emergence weed control in cotton and sugarcane. It controls a wide spectrum of important dicot and monocot weeds, and sedges. In cotton, CGA 362622 is especially active on *Acanthospermum* spp., *Bidens pilosa*, *Cyperus* spp., *Desmodium tortuosum*, *Euphorbia* spp., *Ipomoea* spp., *Senna* spp. and *Xanthium* spp. In addition to the weeds controlled in cotton, troublesome weeds such as *Brachiaria* spp., *Rottboellia exaltata* and other grasses are controlled in sugarcane in mixture with ametryn. The use rates of CGA 362622 are extremely low and vary between 5-15 g a.i. ha^{-1} in cotton and 15-50 g a.i. ha^{-1} in sugarcane. Laboratory experiments with ^{14}C radiolabelled product show that CGA 362622 applied post-emergence to sensitive weeds penetrates rapidly into the leaves and is well translocated. In Xanthium canadense, 35% of the post-emergence applied herbicide was taken up 24 hours after application. Crop tolerance in cotton and sugarcane is based on 2 mechanisms; enhanced metabolism of the active ingredient compared to sensitive weeds and extremely low translocation out of the treated leaves. Six hours after application only 50% non-metabolized CGA 362622 is found in cotton compared with 95% in *Xanthium canadense*. One week after application 600 fold more radiolabelled products are found in the growing point and young leaves of *X. canadense* than in cotton.

Glutathione mediated metabolism of acetochlor in weeds (263)

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Acetochlor is an effective herbicide controlling monocot weeds and to a lesser extent dicots in maize. It has been shown that crops detoxify acetochlor via glutathione (GSH) conjugation. Endogenous levels of GSH and glutathione S-transferases (GSTs) were found to be the major factors in acetochlor detoxication. By contrast, the biochemical basis for the differential level of response of monocot and dicot weeds to this herbicide has not been established. This study examined the components of acetochlor detoxication (uptake, translocation, metabolism, GSH and GST levels) in weeds. Roots of 12-day-old monocot (*Avena fatua*, *Bromus secalinus*, *Echinochloa crus-galli*) and dicot (*Abutilon theophrasti*, *Amaranthus retroflexus*, *Xanthium strumarium*) seedlings were exposed to ^{14}C-acetochlor for 24-h. GSH levels and GST(acetochlor) activities were studied using 6-day-old etiolated seedlings. Effect of GSH and cysteine conjugates of acetochlor on catalytic activities of weed GSTs was also evaluated. In general, dicot seedlings absorbed about twice as much acetochlor than monocots. The only exception was *X. strumarium* which absorbed less herbicide than monocot species. The translocation pattern was similar in all seedlings. About 30% of the herbicide absorbed by roots moved to shoots. All plants except *X. strumarium* metabolized major part (70-92%) of the absorbed herbicide via GSH conjugation to water-soluble metabolites. *X. strumarium* transformed only 47% of the absorbed radioactivity to water-soluble form. No correlation between GSH contents of various weed species and their acetochlor sensitivity was observed. The ratios of GSH contents to the amount of acetochlor absorbed ranged from 2 to 50. GST activities using acetochlor substrate were comparable for all seedlings except for *A. theophrasti* and were much less expressed than in maize. Extractable GSTs of *A. theophrasti* did not show specificity for acetochlor even though this weed was able to metabolize 92% of acetochlor absorbed to water-soluble form. GSH conjugate and to a lesser extent cysteine conjugate were inhibitory to GSTs from *A. fatua* and *E. crus-galli*. The inhibitory action of conjugates is unlikely to be a major selectivity factor because similar levels of inhibition were obtained for the maize and weeds. Our results suggest that acetochlor metabolism in weed species can take place primarily via non-enzymatic GSH conjugation.

Comparative absorption, translocation, and metabolism of foliar-applied oxyfluorfen in wheat and barley (264)

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Wheat is known to be relatively tolerant to diphenyl ether herbicides. Absorption, translocation, and metabolism of foliar-applied oxyfluorfen in wheat were examined in comparison with those of oxyfluorfen-susceptible barley. Epicuticular wax contents in the first fully expanded leaves were similar in wheat and barley, but the wheat leaves exhibited 1.73-fold higher cuticle content than the barley leaves. The absorption of ^{14}C-oxyfluorfen was slightly higher in barley than in wheat leaves. However, most of the radioactivity remained in epicuticular wax. Little translocation of the herbicide out of the treated leaf was observed in either species. Although slightly more translocation of ^{14}C-oxyfluorfen to shoot other than the treated leaf or to roots was found in barley than in wheat leaves, there were no statistically significant differences in the amount of ^{14}C-oxyfluorfen translocation between the two species. Autoradiographs of the ^{14}C-oxyfluorfen-treated leaves of both species also showed that the radioactivity was distributed mainly in the treated site. Thin-layer chromatographic analysis of leaf extracts revealed that oxyfluorfen metabolism did not occur in intact leaves of both species. These results indicate that the differential susceptibilities of wheat and barley to oxyfluorfen are not due to the consequence of differential absorption, translocation, and metabolism of the herbicide.

Bioavailability of triasulfuron and metsulfuron-methyl in soils derived from volcanics ashes from south of Chile (265)

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Soil capacity to maintain a certain herbicide concentration in the soil solution or bioavailability, is a desirable characteristic to know, and reflects the capacity of degradation and adsorption of a given soil. The objective of this study was to determine the bioavailability of metsulfuron-methyl and triasulfuron in six agricultural soils of the south of Chile, through bioassay and, their relation with some physical and chemical characteristics of the soils. Soils used were: two Dystrandept soils, series Malihue and Valdivia; two Palehumults, series Fresia and Cudico; and two Placandepts, series Frutillar and Lanco. An inert sand quartz (0.2-0.7 mm) substrate was used as control. Samples were taken from the upper 10 cm of soil, placed in plastic pots, to which 11 concentrations of each of the herbicides were applied. In each pot, pea seeds (*Pisum sativum* L.) were sown, and after 8 days, root length was measured. The values were fitted to a logistic model and the herbicide concentration that inhibited 50% of the root growth (IC_{50}) was determined. The bioavailability of each herbicide, in each soil, corresponded to the proportion of the IC_{50} obtained in the quartz substrate on the IC_{50} obtained for each soil. Results determined that the concentration of herbicide in the soil solution that causes the same toxic effect on the test species was always greater for triasulfuron than for metsulfuron-methyl in all soils. The percentage of herbicide bioavailability in the soil solution was always superior for metsulfuron-methyl (14.9- 68.5%) than for triasulfuron (6.9-22.2%), and was negatively associated to the content of organic matter of the soil, mainly for triasulfuron, but when these contents of organic matter were high the relation was more dependent on the type than on the amount of organic matter of the soil. There was no association between the bioavailability of both herbicides with any of the other physical and chemical soil characteristics.

Glyphosate residues in transgenic RR soybean plants and grains (266)

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Chemical weed control in soybean prevents yield losses. Transgenic varieties with glyphosate (N-[phosphonomethyl]glycine) resistance (RR cultivars) are employed in 80% of soybean cultivated area in Argentina. In this area, glyphosate is sprayed twice or three times during the crop cycle, to avoid weed's emergence and growth. This herbicide is non selective and no residues are observed in soils. However, there is a lack of information on glyphosate or its metabolite, AMPA (amino-methyl-phosphonic-acid) persistence in soybean leaves and stems and in grains. This work was undertaken to detect glyphosate and AMPA residues in soybean plants and grains. In 1997 and 1998, six fields with RR soybean varieties were selected to determine the evolution of herbicide residues in different growing periods. Glyphosate was sprayed from one to three times with recomended doses (09.96 to 1.92 kg a.i. ha^{-1}) along the crop cycle. Fifteen plants were cut twice in vegetative stage, (V2 and V8), once in flowering stage and again during harvest. Glyphosate extraction in these plants, was done with organic solvents and buffers, agitation, centrifugation and clean-up with different adsorbents. Identification of glyphosate and AMPA was done by HPLC with an ionic exclusion column, post column derivation and fluorescence detection. In both years, glyphosate residues were observed in plant samples during the whole soybean cycle, with the highest values near spraying dates. Residue values were between 0.10 and 9.4 ppm. Glyphosate residues were also detected in grains when herbicide was sprayed in flowering stage or later. The values were between 0.1 and 3.30 ppm. AMPA residues were observed in very low concentrations in those samples where glyphosate was detected. Even when there is no information on human toxicity of glyphosate, it should be considered the influence of the presence of its residues in grains on commercial barriers that could be established for this crop.

Atrazine phytotoxicity and degradation in grass rhizosphere (267)

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A study was conducted to determine the tolerance of potential filter strips grasses (*Alopecurus arundinceus* Poir., *Dactylis glomerata* L., *Festuca arundinacea* Schreb., and *Panicum dichotomiflorum* Michx.) to atrazine and herbicide degradation in a grass rhizosphere. Atrazine was applied at 0, 0.14, 0.28, 0.56 and 1.12 kg a.i. ha^{-1} to Emporia loamy sand soil and the weights of the grasses were measured four weeks after planting. Tolerance of the grasses to atrazine was compared using GR_{50} values: the rate of atrazine that causes 50% reduction in the weight of each species compared to the untreated control. Degradation of atrazine in Emporia soil with and without *P. dichotomiflorum* was determined at 0, 7, 14, 21, 28, and 42 days after planting. *Panicum dichotomiflorum* (GR_{50} = 0.71 kg ha^{-1}) was the most tolerant followed by *F. arundinacea* (GR_{50} = 0.4 kg ha^{-1}), *A. arundinceus* (GR_{50} = 0.14 kg ha^{-1}), and *D. glomerata* (GR_{50} = 0.07 kg kg ha^{-1}). The concentration of atrazine declined at a faster rate in Emporia soil with *P. dichotomiflorum* than without, indicating that the grass can contribute to dissipation of the herbicide in nontarget areas. The exhibited tolerance of *P. dichotomiflorum* makes it a suitable filter strip grass in areas where atrazine is in runoff or carry-over.

Behaviour of molinate and thiobencarb in the Albufera Natural Park, Valencia, Spain (268)

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The two main residual herbicides used in the rice area of the Albufera Natural Park (ANP), Spain are molinate and thiobencarb. Both herbicides control grass and broadleaf weeds in rice fields, being especially useful to prevent *Echinochloa* spp. infestations. Two experiments were conducted in order to understand the behaviour of the mentioned chemicals in water and soil. Several water samplings were done in the irrigation and drainage canals of the rice fields in the ANP; it was found that the concentration of molinate was very site variable, in the mg/l levels, not only immediately after the main month of treatment (May), but even through the entire crop season. The other experiment consisted in the application of both herbicides to 8 m^2 subplots simulating the rice crop. We observed a rapid dissipation of the herbicides in water and a great accumulation in soil of thiobencarb, always more strongly adsorbed than molinate. In an experimental field of the ANP, a commercial granular form containing both chemicals (4.5% a.i. each) was applied in May at 60 kg ha^{-1}. Four months after this treatment, molinate and thiobencarb were still detected at levels of a few ppm, at 0-30 cm of soil depth.

Effect of haloxyfop-methyl on some soil biological parameters (269)

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Although haloxyfop-methyl is recommended for use in soybean, which is an important Brazilian agricultural product, nothing is known on its behaviour in Brazilian soil conditions. Soil biological activity is the consequence of continuous microbial activity related with soil fertility and short-lived effects of pesticide applications. First data on the influence of haloxyfop-methyl on soil biological activity were obtained after application of 1.06 g g^{-1} soil. The studied soil (clayish Dusky-Red Latosol; collected at 0-20 cm of soil profile; pH: 5.3, and 32.0 g dm^{-3} of organic matter) was previously remoistened to 55% WMHC five days before the herbicide treatment, and kept at 25 C. These conditions were mantained during all the experimental time together with an untreated soil sample, used as control. The studied soil biological parameters were the respiratory quotient (RQ) measured by the substrate (glucose) induced respiration and the dehydrogenase activity (DHA), which were evaluated 1, 3, 7, 14, 23 and 64 days after the herbicide treatment. They were measured, respectively, by the CO_2 production (from 3 x 50 g soil subsamples) during 2 days, and formazan production immediately after the (at least 3 x 3 g) subsamplings. Although variations were detected also in the untreated soil sample, the RQ was very inhibitted and stimulated on day 1 and 64, respectively. On the other hand, only inhibitory effects were detected on DHA, from day 14 and increasing until day 64. As it is stated that the haloxyfop-methyl is rapidly degraded to the acid form (haloxyfop), it seems that the haloxyfop-methyl had a direct effect on soil respiration in the first day, and then, the hydrolized product haloxyfop had a stimulatory effect on respiration, but inhibitory effect on DHA.

HPLC determination of the herbicide haloxyfop in a Dusky-red latosol (270)

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A reversed-phase high-performance liquid chromatographic method has been developed for the determination of haloxyfop in a dusky-red latosol from São Paulo State, Brazil. The extraction solution of

methanol:1*M* hydrochloridric acid (9:1) was added to spiked soil samples at 10 $\mu g\ g^{-1}$ and the mixture was shaken for 30 min, then centrifuged at 2500 rpm for 5 min. The entire procedure was repeated three times on the same soil sample. The extracts were pooled and after filtration, 15 ml of HCl was added until pH 1-2, diluted in 60 ml of water and extracted three times with dichloromethane (50 ml). The organic phase, dried by filtration over anhydrous sodium sulphate, was rotoevaporated to about 1 ml and dried with a gentle nitrogen stream. The residue was resuspended in 2 ml of pure water, filtered and injected. The concentration range studied varied from 0.5 to 40.0 $\mu g\ ml^{-1}$ and quantitative recoveries of 79.56% (6.22) were obtained of the theoretical value (15.35 $\mu g\ ml^{-1}$) for three replicates in the presence of coextracted constituents of soil.

Simultaneous detection in soil of two herbicide residues: oxyfluorfen and simazine (271)

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The present paper proposes an HPLC method for the simultaneous determination of two herbicides: oxifluorfen and simazine. The proposed method considerably shortens the analysis for the two herbicides. A study of the chromatograms obtained permitted the finding of the suitable wavelength to perform the analysis, simazine (l = 230 nm) and oxifluorfen (l = 206 nm). Both compounds exhibited a really excellent linearity in the range of concentrations studied. This method was experimentally contrasted by the methanol extraction of the above herbicides from agricultural olive grove soils previously treated with both herbicides at field doses. The recovery percentages of both herbicides were also obtained and the amounts were quantified by means of an HPLC analysis. These percentages changed with the time, but the means were practically the same for both herbicides, approximately, i.e. 70%.

Environmental fate of oxasulfuron under tropical condition (272)

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Oxasulfuron is a new postemergence sulfonylurea herbicide developed by Novartis Crop Protection AG, Basel, Switzerland for broadleaf weed control in soybean. At present, little is known about its environmental fate under climatic, cropping, and soil conditions in the tropics. This research was conducted in order to evaluate the fate of oxasulfuron under realistic environmental Brazilian conditions, using lysimeters as experimental tool. Soybean was planted on 6 November 1997. Formulated (phenyl-U-^{14}C) oxasulfuron was applied on 27 November, at 177.3 g ha^{-1} to two lysimeters (1 m^2 of surface and 1.1 m of depth) containing soil cores of a Typic Hapludox (pH = 6.0, 20 g dm^{-3} OM, 71 % sand, 8 % silt, and 21 % clay). In order to determine the presence of either oxasulfuron or its metabolites in the leachate, water samples (2 L) were periodically collected. Black-oat was planted on 5 May 1998. Immediately after harvest of both soybean and black-oat crops, samples of the upper (0-20 cm) soil layer were collected to evaluate desorption, extractability, and formation of bound residues. As typical for a tropical region, the average maximum air temperature was 28oC and the accumulated precipitation was 1558 mm during the first year of the experiment (Nov. 97-Oct. 98). The accumulated volume of drained water and radioactivity found in the leachates of lysimeters 1 and 2 amounted to 642 and 729 L and 0.37 and 0.23% of applied radioactivity, respectively, corresponding to a concentration of 0.103 and 0.056 mg L^{-1} oxasulfuron equivalent. After rainfall, the maximum concentration of oxasulfuron found in the leachates (0.065 and 0.031 mg L^{-1} in lysimeters 1 and 2, respectively) were below the limit established for drinking water in Brazil. The total amounts of residual radioactivity found in the plants were low. The equivalent

concentration of oxasulfuron corresponded to about 0.012 and 0.002 mg g^{-1} of grains for soybean and black-oat, respectively. After both soybean and black-oat harvests, only about 10% of the radioactivity found in the upper soil layer (0-20 cm) were desorbed and extracted (it corresponded to about 3.9 and 2.2% of applied radioactivity, respectively). At about 32 and 16% of the applied radioactivity were bound to the same soil layer after soybean and black-oat harvests, respectively. Taking into account the very small amount of residues found in the leachate, and despite the extreme conditions (high rate, high precipitation, and sandy soil), it can be concluded that oxasulfuron does not present a risk to groundwater.

Monitoring of glyphosate and sulfosate in foliar washoff water (273)

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The washoff of herbicides from leaves is influenced by factors related both to plants and to the environment. Environmental factors such as soil moisture and rain may interfere with herbicide performance, therefore the perception of this interference is primordial to understand the action of these chemicals in weed management. The purpose of this paper was to monitor and to quantify residues of glyphosate and sulfosate in washoff water, after a 53 mm h^{-1} of rainfall simulation on *Brachiaria brizantha* plants grown with or without soil water deficit. Tomato (*Lycopersicon esculentum*) 'Santa Clara' was used as bioindicator. Root lenght was the most suitable and sensitive characteristic to evidence plant response to herbicide rates, and tomato was more sensitive to glyphosate than to sulfosate. The lowest root length detection limit (I_{50}) obtained from the standard curve was 324.12 and 407.86 μg L^{-1}, respectively for glyphosate and sulfosate. I_{50} was lower when herbicides were applied to plants grown under soil water deficit.

Study on the degradation of herbicides in soil with respect to ecological risk assessment (274)

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The residues of herbicides in soil are considered to be among the main factors responsible for water pollution and global migration of contaminants. The aim of the work was to develop an approach for fast preliminary evaluation of the persistence in soil and to propose a system for classification with respect to the risk of environmental pollution of new herbicides. The degradation kinetics in soil of herbicides belonging to four different chemical groups: asymmetric triazines (metribuzine), acetamides (metolachlor), and dinitroanilines (pendimethaline), diphenyl ethers (oxyfluorfen) were studied in field experiments and under controlled laboratory conditions. The experiments were carried out with two soil types of different organic matter content and under different moisture and temperature conditions. Gas chromatography with electron capture detector was used for determination of herbicide residues in soil. Although the calculated half-life values (T_{50}) differed significantly under the various conditions, the order of the compounds according to their T_{50} values remained constant in all experiments. This fact gave us reason to propose a comparative approach for fast preliminary assessment of the persistence in soil of new compounds by matching their T_{50} values with those of well investigated compounds, determined under the same laboratory conditions. A classification, based on T_{50} values, was proposed for environmental pollution risk assessment of new herbicides.

Control of *Cyperus esculentus* and *C. rotundus* with methyl bromide alternatives in tomato (275)

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A three-year soilborne pest control study with fall tomato was initiated in 1998 to investigate the long term potential of the most likely chemical replacement for methyl bromide, 1,3-dichloropropene (1,3-D) + chloropicrin, combined with pebulate, and the most promising nonchemical alternative, soil solarization. Treatments consisted of 1) a nontreated control, 2) methyl bromide and chloropicrin (67/33 %, respectively) at 392 kg ha^{-1}, 3) 327 L ha^{-1} of a mixture of 1,3-D and chloropicrin (83/17%, respectively) with pebulate herbicide (4.5 kg ha^{-1}) soil incorporated prior to fumigant application, and 4) 8 weeks of soil solarization. Tomato plants were more vigorous in fall 1998 in soil treated with methyl bromide and 1,3-D + chloropicrin + pebulate than in soil which received no chemical treatment. Plants were no more vigorous with soil solarization than with no fumigant. Prior to planting the tomatoes, *Cyperus esculentus* and *C. rotundus* had begun to emerge and penetrate the mulch in all of the plots, but there were more plants in the nontreated and solarization plots than in the fumigant plots, necessitating an application of paraquat to desicate the foliage. Both fumigants and soil solarization reduced *C. esculentus* and *C. rotundus* compared to the nontreated throughout the season and there was no statistically significant difference in the number of nutsedge plants between either fumigant or between the fumigants and soil solarization, due in large part to the early dessication of nutsedge in solarization plots. Methyl bromide and 1,3-D + chloropicrin + pebulate produced more fruit in each size grade and total with no differences between the two treatments. Yields of all sizes and grades were highest with the fumigant treatments, intermediate with soil solarization and lowest where no soil treatment was applied.

Applicability of soil solarization for weed control in tomato and strawberry (276)

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With the phaseout of methyl bromide (MB) scheduled for 2005 and few herbicides labeled for use within the plant bed, alternative weed management practices are critically needed for polyethylene-mulched vegetables and strawberry. Recent evaluations of soil solarization as an alternative to MB were aimed at enhancing its efficacy by use of improved solarization films and implementation as an integrated management tool together with alternative fumigants. Whereas cool-season soil solarization during the period from December to March was ineffective for weed control for spring production of tomato, summer soil solarization for a fall crop provided effective control of annual weed species. However, *Cyperus rotundus* L. and *C. esculentus* L. were more difficult to control. Incubation of *Cyperus* spp. tubers with oscillating soil temperatures indicated that temperature regimes with a maximum of 50 C resulted in 100 % tuber mortality. In the field, soil temperatures lethal to nutsedge tubers occurred only within 10 cm of the soil surface. Tubers not exposed to lethal soil temperatures also were amenable to management with soil solarization. Emerging rhizomes of sprouting tubers undergo morphogenesis in response to light, promoting

leaf expansion that results in the trapping and foliar scorching of nutsedge shoots beneath the clear solarization film. The duration of solarization should be extended to at least six weeks to promote tuber depletion. Higher soil temperatures were obtained with thermal infrared-absorbing solarization film than with low density polyethylene film under fair and adverse weather conditions and, therefore, may be more appropriate for use where environmental conditions can limit the effectiveness of solarization. Soil solarization from late summer to early fall for strawberry production provided inadequate weed control. Painting the clear film black after solarization suppressed weeds under the mulch film, but weeds were still a problem in the plant holes. Prolific weed regrowth occurred under unpainted film, which either eliminated or greatly reduced fruit yield.

Screening new herbicides for potential use in irrigated vegetable crop production systems (277)

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Most herbicides are initially discovered, developed, and registered for use in major crops such as corn, soybean, cereal grains, cotton, and sugar beets. Very little, if any herbicide screening effort is directed toward high value vegetable crops. In the desert southwest United States, melons (*Cucumis melo* and *Citrullus lanatus*), lettuce (*Lactuca sativa*), and cole crops (*Brassica oleracea*) are produced with a limited number of herbicides. Heavy reliance is placed on crop rotation, mechanical tillage, cultivation, and hand-hoeing for weed control. Several field tests were initiated and conducted to evaluate seventeen newly introduced corn, soybean, and cereal grain herbicides for potential use in melons, lettuces, and broccoli. In a preemergence herbicide screening test, flumioxazin, dimethenamid, halosulfuron, and s-metolachlor demonstrated melon crop safety at rates higher than rates for needed effective weed control. In a postemergence screening test, halosulfuron and rimsulfuron gave acceptable weed control with adequate melon crop safety. Flumetsulam and thifensulfuron appeared to offer acceptable weed control with a very narrow margin of melon crop safety. Herbicides that did not offer adequate melon crop safety or acceptable weed control in the screening tests were carfentrazone, sulfentrazone, cloransulam, flumiclorac, fluthiamide/ metribuzin, imazamox, isoxaflutole, triflusulfuron, primisulfuron/prosulfuron, and clomazone. In lettuce, preemergence testing demonstrated that carfentrazone, flumetsulam, and imazamox offered selective weed control. In postemergence testing, flumetsulam, imazamox, and thifensulfuron safely controlled weeds in lettuce. None of the herbicides tested demonstrated safe weed control for use in cole crops. Plant-back tests are also being conducted to evaluate and determine the effect of preemergence and postemergence herbicide residues on rotational crops. Herbicides demonstrating crop selectivity and weed control efficacy will advance to further testing to evaluate potential use on specific crops and weeds.

Control of *Orobanche* spp. in potato (278)

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Orobanche aegyptiaca, *O. ramosa* and *O. cernua* are obligate root parasites that attack many crops, ornamentals and weeds in Israel and the neighboring countries. Potato (*Solanum tuberosum* L.) is one of the most susceptible hosts to these *Orobanche* spp, and is parasitized in winter, early spring and autumn along the Mediterranean coast. *Orobanche* was effectively controlled in potato infested fields by foliar split applications of the herbicide rimsulfuron (12.5 and 25.0 g ha^{-1}), sprayed at first two weeks after potato shoots emergence and twice more at 14 days intervals. This treatment selectively controlled *Orobanche* and did not reduce tuber quality. However, split foliar application of imazapic (4.5 g ha^{-1} each) following the same time schedule, prevented Orobanche emergence but caused increased crop vegetation followed by tuber deformation. A single application of 7.5 g ha^{-1} triasulfuron sprayed on potato foliage, severely damaged the crop. Our studies on Orobanche control with sulfonylurea herbicides clearly indicate that the herbicide activity is through the soil solution. Sprinkler irrigation following rimsulfuron application in potato fields activates the herbicide in the soil, thus facilitating the control of *Orobanche*.

Alternative fumigants for controlling *Cynodon* sp. in turfgrass systems (279)

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Methyl bromide (MB) has been the predominant broad-spectrum soil fumigant used in turfgrass systems for controlling troublesome pests including undesirable common *Cynodon sp.* and off-type bermudagrass hybrids. Because of its prolific seed production and rapid growth rate, common *Cynodon sp.* contamination is a pervasive problem in hybrid bermudagrass turf systems. Without an effective fumigant, these perennial weeds overtake vegetatively propagated fields. Furthermore, no herbicides are available which select between common *Cynodon sp.* and hybrid bermudagrass, thus exacerbating the problem. Because of environmental concerns, MB has been targeted for removal, leaving the turfgrass industry vulnerable to contamination and genetically impure turfgrasses. One objective of this research was to evaluate alternative fumigants for their efficacy in controlling common *Cynodon sp.* and off-type bermudagrass hybrids. This study was conducted at three locations: the West Florida Research and Education Center, Jay, FL, and on two turfgrass sod farms, one near Punta Gorda, FL and the other in Sylvania, GA. Treatments included: untreated control, MB, oxidiazon/1,3-dichloropropene (1,3-D), dazomet, dazomet/chloropicrin, dazomet/1,3-D, methyl iodide (MI), metham sodium (MS), MS/chloropicrin (tarped and not tarped), MS/1,3-D, and two experimental compounds (MBA#200 and MBA #300). MB and MI provided 98% control of common *Cynodon sp.* and off-type bermudagrass hybrids when compared to the untreated. MBA #200 and MBA #300 provided 90% and 94% control, respectively. When covered with a tarpaulin, MS/chloropicrin provided control similar to MB. Dazomet combinations and oxidiazon/1,3-D did not provide acceptable control of common *Cynodon sp.* and off-type bermudagrass hybrids.

Herbicides as fungicides, PGRs, and bioherbicide synergists (280)

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Bioassay systems using various plant species and/or tissues in herbicide (synthetic or natural product) discovery programs have inherently restricted detection of most other possible biological activities. Nevertheless, some herbicides possess other uses. Bialaphos (discovered in 1971) is a tripeptide containing the unique amino acid L-2-amino-4-[hydroxy (methyl)phosphinyl]butyrate, called phosphinothricin; PPT). Antimicrobial activity of bialaphos was attributed to PPT. PPT also exhibited potent inhibition of glutamine synthetase in *Escherichia coli* and later (1977) was found to be herbicidal. Synthesis of the PPT ammonium salt (glufosinate) has led to a global market for this herbicide. In transgenic crops resistant to glufosinate, PPT can control weeds and fungal diseases, e.g., sheath blight and blast disease in transgenic rice. Furthermore, fungi (*Cercospora* sp., and *Cochliobolus* sp.), transformed with bacterial genes for resistance to PPT, are being used to elucidate biosynthetic pathways important in developing crops resistant to pathogens. Some herbicides provide additive and/or synergistic effects when applied with bioherbicides (plant pathogens for weed control). Such combinations can reduce herbicide and pathogen usage rates required for weed control. Examples include, glyphosate-*Alternaia cassiae* synergy on the weed *Cassia*

obtusifolia L., and synergy of acifluorfen or bentazon combined with *A. cassiae*, *Colletotrichum coccoides*, *C. truncatum*, or *Fusarium lateritium*, applied to their respective weed hosts. Detrimental effects are also caused by herbicide interactions with some bioherbicides, and herbicides can increase diseases in crops. Sub-lethal concentrations of some herbicides (e.g., chlorophenoxys, triazines, etc.), reportedly illicit PGR effects. Whether these effects are due to chemical-plant-microbial interactions or plant physiological responses, awaits further study. Myriad alternative uses of herbicides may exist, but much innovative research and development will be needed to discover those that are beneficial to man and the environment.

Herbicides as harvest aids (281)

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The presence of weeds at harvest can cause problems such as slowing the speed of harvest and blocking combine operation. To overcome these problems, preharvest application of herbicides may be used. Besides helping the harvesting process, the use of herbicides as harvesting aids can be useful in producing better quality seeds by allowing harvesting at the most appropriate time. Herbicides help the desiccation of crops with indeterminate growth such as some soybean varieties, reduces weed populations and decreases weed seed production, and allows the use of crops as forage in temperate weather zones when planted too late to reach maturity before a killing frost. In the latter case the crop could be used to feed livestock rather than harvested for grain. Another implication of using this process is related to tropical regions where the crop can be harvested earlier, allowing the production of another crop. This is what is happening in large areas of central Brazil where the farmers are able to harvest soybean with the help of a desiccant and to sow corn immediately afterward in no-tillage systems. On the other hand, some problems can be associated with the use of this process. The quality of crop seeds can be affected by the herbicides, depending on their mode of action and also on the maturity stage of the crop seeds. Herbicide residues can be present in the harvested material, and, when found in crops that will be used for grazing or haying, restrictions are applied to herbicides and timing for grazing. The use of herbicides as harvest aids is an important tool for the farmers, and, when done in proper way, can improve yields and seed quality, decrease weed populations, and, in some cases in the tropics, allow more than one crop in a single season.

Herbicide seed dressing of corn as an appropriate treatment for *Striga* control while allowing intercropping (282)

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Herbicide spray applications control parasitic weeds on crops bearing target site-resistance to the herbicides. Such technologies are inappropriate for subsistence farmers, as they are too expensive, do not fully protect the crop from yield losses, and preclude intercropping. Seed dressings were tested as appropriate, cost-effective procedures for preventing damage from the parasitic witchweeds *Striga hermonthica* (Del.) Benth. in Kenya, and *S. asiatica* in Malawi. Corn (*Zea mays* L.) genotypes with acetolactate synthase (ALS) target site-resistance allow application of locally high herbicide levels needed. Mg-imazapyr and Na-pyrithiobac had the least phytotoxicity and the longest persistence among ALS inhibitors. Seeds were dressed with herbicide by priming and planting either wet or dry or as seed coatings with polyvinylpyrillidone (PVP) or in insecticide+fungicide dust. Intercropping with bean (*Phaseolus vulgaris* L.) and cowpea (*Vigna ungiculata* L.) was done at intervals from 0 to 30 cm from corn hills. There was hardly any *Striga* emergence for three months after planting primed Pioneer 3245-IR hybrid corn with any seed dressing containing at least on 30 g a.e. imazapyr or 21g a.e. pyrithiobac per ha. Few *Striga* that flowered on seed-dressed corn formed no seed by harvest. *Striga* was nearly suppressed by >30 imazapyr per ha in dust or PVP coating. Herbicides were safe to herbicide-susceptible intercrops planted at least 15-cm from treated corn hills, but were sometimes phytotoxic to the legume at shorter distances. Seed dressing with both imazapyr and pyrithiobac coupled with pulling rare *Striga* escapes can reduce damage and deplete the *Striga* seed bank. This technology has potential to reduce the *Striga* problem on small-scale farms in Africa where intercropping is also widely practised. This technology may have value in developed countries to provide an early season weed-free zone around the crop seed and replace pre-emergence spraying with their concomitant monetary and environmental costs.

Herbicides as pharmaceuticals (283)

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There are a number of experimental herbicides and plant growth regulators that have potential use as pharmaceuticals. Among these are fungal secondary metabolites. Some specific examples include trichodermin which has delayed herbicidal action, like Roundup, and which has very low mammalian toxicity, an exception among the 12, 13-epoxytrichothecenes. Its mode of action appears to be through intercalation into DNA. However, it was also under investigation by pharmaceutical companies as a marketable fungicidal agent. Another example is brefeldin A, or decumbin, which has plant growth regulatory activity. It is a structural congener of prostaglandin E1; the latter being an important medicinal for use in the treatment of erectile dysfunction, or impotence. A third example is cytochalasin H which has marked plant growth regulatory activity and has been substantially evaluated as an antineoplastic agent. Its mode of action is through tubulin inhibition. Moniloformin, which has been found to inhibit c-metaphase, much like colchicine, in onion root tips was extensively evaluated by Ciba Geigy and derivatives were patented for herbicide use. Perhaps the most examined class of practical herbicides are the sulfonylurea congeners which have found use as hypoglycemic agents in lowering serum blood glucose for diabetic patients. The latter include glipizide, glyburide, and tolbutamide. Examination of the pharmaceutical literature indicates that there are numbers of structures which may have useful agronomic and horticulture application. An earlier example of this includes the chlorinated aryl herbicides such as 2,4-D and the later development of serum lipid lowering agents such as clofibrate and fibric acid. Essentially, there theoretically exists a bridge between the chemistry and practical use of herbicides and pharmaceuticals.

Herbicide alternatives for 2,4-D in no-till cropping systems (284)

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The mixture of 2,4-D with other herbicides such as glyphosate, sulfosate or paraquat is a common practice all over the country in Brazil. The objective is to enhance the efficiency of control of broadleaf weeds and to reduce costs in no-till crop systems. However, many problems have been registered due to drifts of 2,4-D over economic crops as cotton, grapes and vegetables. In the State of Parana, about 40 counties have forbidden its use because of damage caused to neighbouring crops. In order to find herbicide alternatives for 2,4-D in risk areas, one experiment was conducted in Londrina, Parana State, Brazil, in small plots having weed species such as *Commelina benghalensis* L., *Bidens* spp. and *Euphorbia heterophylla* L.. The treatments consisted of glyphosate alone and mistures with 2,4-D, flumioxazin, sulfentrazone, glufosinate-ammonium or chlorimuron-ethyl. Paraquat plus diuron was also used in tank mix with diquat, 2,4-D, or flumioxazin, besides flumioxazin alone and an untreated check. The experiment was conducted in a block design, with plots of 2 m x 5 m, with four replications. Application was made with a CO_2 equipment, using

207 kPa of pressure, nozzles 110.015-BD and spray volume of 160 L ha^{-1}. Weed control evaluations were made at 8 and 15 DAA (days after application) and for *C. benghalensis*, also at 33 DAA. For this species, at 15 DAA, treatments with paraquat + diuron in mixture with 2,4-D, diquat or with flumioxazin were not statistically different from glyphosate + 2,4-D (check). At 33 DAA, those and glyphosate + flumioxazin (1.44 + 0.025 kg ha^{-1}) presented the same behaviour. All substitutive treatments were efficient to control the other two weed species.

Metribuzin + diuron or ametryn mixtures: an effective and viable option for weed control in sugarcane (285)

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In numerous small plot and large scale commercial trials, metribuzin + diuron, ametryn or atrazine mixtures, as well as metribuzin alone, preemergence and postemergence treatments were assessed over a range of weed, soil and crop conditions. In all these, both preemergent and postemergent (the latter plus 0.25 l.ha^{-1} surfactant), 0.7 kg a.i.ha^{-1} metribuzin + 2.4 kg a.i.ha^{-1} diuron or ametryn mixtures (slightly best on black Vertisol and red Ferralsol soils, respectively), and well as preemergent 1.4 and 2.1 kg a.i.ha^{-1} metribuzin alone, showed similar to greater weed control as compared to standards: preemergent 4.8 kg a.i.ha^{-1} diuron and postemergent 4 kg a.i.ha^{-1} diuron + 1.6 kg a.i.ha^{-1} ametryn or 0.3 kg a.i.ha-1 paraquat + 0.25 l.ha^{-1} surfactant. Effective control was generally from 60 to 90 days. However, in postemergence of weeds, over 5 cm high, general weed control by metribuzin alone was unsatisfactory. At present prices 2.1 kg a.i.ha^{-1} metribuzin is not economically viable, but the 0.7 + 2.4 kg a.i.ha^{-1} diuron or ametryn mixtures, and 1.4 kg a.i.ha^{-1} metribuzin alone are. Among annuals well controlled by these treatments were *Rottboellia cochinchinensis* (Lour.) Clayton, *Echinochloa colona* (L.) Link, *Eleusine indica* L., *Echinochloa crus-galli* (L.) Beauv., *Brachiaria fasciculata* (Sw.) Blake, *Leptochloa panicea* (Retz.) Ohwi, *Digitaria adscendens* (Kunth) Henr., *Cenchrus echinatus* L., *Ipomoea* spp., *Rhynchosia minima* (L.) D.C, *Croton lobatus* L., *Euphorbia heterophylla* L., *Cassia obtusifolia* L. and *Commelina diffusa* Burm. Additionally, perennials *Dichanthium* spp., *Panicum maximum* Jacq., *Cynodon nlemfluensis* Vanderyt, *Hyparhenia rufa* Ander. and *Brachiaria mutica* (Forsk.) Stapfz showed good control through their seeds. Conversely, perennials *Sorghum halepense* (L.) Pers. and *Cyperus rotundus* L. showed poor control, while *Cynodon dactylon* (L.) Pers. showed variable results. On the other hand, metribuzin 0.7 kg a.i.ha^{-1} + atrazine 2.4 kg a.i.ha^{-1} , both in preemergence and early postemergence (+surfactant) always showed unsatisfactory weed control. Tolerance of all sugarcane cultivars to metribuzin treatments was very significant.

Evaluation of efficiency of acetochlor in corn (286)

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The production potential of corn is being affected to the extent of 33-50% due to seed borne weed menace in irrigated production areas. Hence, a field experiment was carried out for two seasons at ARS, Arabhavi on medium black soil to evaluate the bio-efficacy of acetachlor (MON- 8435) against grass and broadleaf weeds and its phytotoxic effect on corn under irrigated conditions. The trial consisted of nine treatments replicated thrice in RCBD. The treatments consisted five levels of pre emergence application of acetachlor at 1.0, 1.5, 2.0, 3.0 and 4.0 kg a.i. ha^{-1} in comparison with the check atrazine at 2.5 kg a.i. ha^{-1}, cultural practice of 2 hand weedings and 2 inter cultivations, untreated control and weed free check. The results indicated that acetachlor at 3.0 kg a.i. ha^{-1} recorded higher corn yield, fodder yield due to higher weed control efficiency and lower weed count as well as weed dry biomass with least phytotoxicity. Increase in the level of Acetachlor beyond 3.0 kg a.i. ha^{-1} had phytotoxic effect on corn, which resulted in lower corn yield. The net returns and benefit to cost ratio were higher with the application of Acetachlor at 3.0 kg a.i.

ha^{-1} which were on par with the check Atrazine and weed free check. Acetachlor did not have any residual effect on germination, growth and yield of the succeeding wheat crop. Therefore, acetachlor can be used as an alternative and safe herbicide in corn production.

Proper use of cyhalofop butyl for weed control in direct seeded rice in Vietnam (287)

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Clincher 10EC (10 % cyhalofop butyl) developed by Dow AgroSciences, has been introduced recently into Vietnam for controlling grass weeds in rice. Clincher 10EC is a very effective grass herbicide in dry- and wet- seeded rice with high selectivity and a wide application window of 7-25 days after seeding. However, the disadvantage of this herbicide is that it is unable to control sedges and broadleaf weeds. In order to overcome this limitation, some other herbicides have been tested to find out the best combination with cyhalofop butyl to broaden weed spectrum of control. Results from experiments conducted in the Mekong delta of Vietnam revealed that the tank mix between cyhalofop butyl at 60-80 g.a.i. ha^{-1} and ethoxysulfuron (Sunrice 15 WDG) at 12 g.a.i. ha^{-1} can be used safely at 7-16 days after sowing (DAS) and the mixture provided a high control against all common weeds such as: *Echinochloa crus-galli*, *E. colona*, *Leptochloa chinensis*, *Cyperus difformis*, *Fimbristylis miliacea*, *Ludwigia octovalvis*, *L.adscendens*, *Marsilea minuta* present in rice fields. The cost of this mixture at rates proposed is expected to be acceptable to farmers. On the other hand, cyhalofop butyl has been used properly by farmers in this country in accordance with current farming practices to control tough weeds such as *L. chinensis* infesting dry pocket areas. These have proven resistant to many common rice herbicides. In particular, a high dose of 160-200 g.a.i. ha^{-1} cyhalofop-butyl applied late post emergence (15-25 DAS) can also be spot applied to effectively control patches of perennial *Paspalum distichum* and *Echinochloa stagnina* colonized from stem cuttings with no phytotoxicity symptom observed in rice at any tested rates. Cyhalofop butyl and its mixture have contributed a new option for farmers to chose for controlling rice weeds in Vietnam.

Post emergence control of *Cuscuta pentagona* in alfalfa hay (288)

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Cuscuta pentagona (field dodder) is a major weed species populating alfalfa hay and alfalfa seed producing fields in California. Currently, only non-selective measures are used to control emerged *Cuscuta* that result in loss of crop yield and plant population. The non-selective control measures include sulfuric acid based liquid fertilizers or flame burning using propane gas. Field research in a new alfalfa hay planting was conducted to evaluate effectiveness of herbicide imazethapyr, imazamox and pendimethalin. Efficacy data was collected for herbicide rates, timing interaction and herbicide combinations. Measurements were based on reduction of length and biomass of Cuscuta and forage yield. Ninety three and 80% of *Cuscuta* was controlled with imazethapyr at the rate of 94 g ha^{-1} of active ingredient at twenty six and forty nine days following application. Imazamox applied at the rate of 48 g ha^{-1} provided 86% and 77% control respectively. Imazethapyr and pendimethalin applied at 94 and 3992 g ha^{-1} as a tank mix application produced the best control of *Cuscuta* obtaining 98% and 88% for the two evaluation dates. The sulfuric acid fertilizer burn down provided only temporary suppression of 43% and 15% control. The thirty day delayed timing treatment with 94 g ha^{-1} imazethapyr followed the second alfalfa harvest. *Cuscuta* size had increased two fold, had begun flowering and developed extensive attachment to the alfalfa plant. Control reached 97% reduction in *Cuscuta* length twenty days after application. Alfalfa yield and biomass weights on a 90% dry matter basis were significant at the 5% level ranging from 1237 kg ha^{-1} with the non-selective fertilizer treatment to 1999 kg ha^{-1} with the selective imazethapyr treatment. Crude protein of forage ranged from 18% for the untreated control to 27% in the herbicide treatment.

New problems and new resistance mechanisms (289)

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Herbicide resistant weed biotypes continue to be selected throughout the world. In the last 10 years work on documenting new cases of resistance as well as on the mechanisms of resistance has dramatically increased. This information provides us new insights on the conditions that can result in the selection of herbicide resistant biotypes. The development of new technologies, such as herbicide tolerant crops and application techniques, may have an impact on the selection of resistance. The documentation of weed populations that are resistant to multiple herbicides has risen in the last few years. While many cases of resistance are due to selection of an altered form of the target site of the herbicide, there are an increasing number of cases where resistance is due to alterations in metabolism or to uptake of the herbicide. The ways in which we manage herbicide resistance need to be examined in light of this new information in order to determine if we need to change our approaches and recommendations.

Relationships between agronomic practices and the development of herbicide-resistance (290)

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At the turn of this century, the International Survey of Herbicide-Resistant Weeds recorded 232 herbicide resistant weed biotypes (150 unique species) found in 47 countries (see http://www.weedscience.com for more details). Agronomic practices play a large role in the rate of development of herbicide-resistant weeds. The intensive agriculture practiced by developed countries has, understandably, led these countries to select the greatest number of herbicide-resistant weeds (>90%). Crop monoculture and reliance on the same herbicide or herbicide mode of action in the absence of other weed control practices has been responsible for the overwhelming number of herbicide-resistance cases identified to date. Short of avoiding the use of herbicides entirely, the rotation of herbicide-modes of action is the single most effective strategy that growers can use to delay the appearance of herbicide-resistant weeds. Similar results may also be achieved by use of herbicide mixtures or sequential treatments of herbicides having a different mode of action where they are active on the same target weeds. Rotation of herbicide modes of action in combination with cultural controls will further delay the appearance of resistance. Most cultural weed control practices do not provide acceptable weed control alone. However, they reduce population numbers without exerting a chemical selection pressure. Cultural weed control strategies available to growers include crop rotation, cultivation, competitive crops, burning, stale seedbeds, hand weeding, post harvest grazing, hay crops, fallow, and delayed seeding. Many of these cultural controls have severe economic and environmental drawbacks and may not be a viable option for growers. Crop rotations are often the most viable option as they allow different herbicide modes of action to be used. Crops may differ in sowing times or require different seedbed preparation allowing control of problem species. Certain crops may just be more competitive against problem weeds.

Mechanisms of resistance in *Alopecurus myosuroides* and *Avena* spp. (291)

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Herbicides can damage plant cells in a variety of ways and intuitively there are several heritable mechanisms by which plants could protect themselves from this damage. For example: (a) modification of a herbicide-sensitive site (target site), (b) conversion of the compound to an inactive form by (enhanced) metabolism, (c) compartmentation of the active compound, (d) increased efflux and/or decreased influx of the active compound, (e) alternative pathways to bypass the inhibited reaction (f) increased production of herbicide-sensitive enzymes, (g) increase in the amount of an enzyme's substrate (i.e. to compete with the herbicide), (h) decreased requirement for the product of the inhibited reaction, and (i) failure to activate the herbicide. The imposition of selection by herbicides for one or more of these traits in a population of weeds, can lead ultimately to the evolution of resistant populations. The challenge facing us when we try to understand the biochemistry and physiology of herbicide rsistance in weeds is to determine which of these various mechanisms operate in a particular plant or population. We have investigated the biochemical mechanisms that confer resistance to aryloxyphenoxypropionate and cyclohexanedione herbicides in a range of European field populations of the grass weed *A. myosuroides* (black-grass) and in UK populations of *Avena* spp. (wild oat). Our results suggests that at least three mechanisms are responsible for resistance to fenoxaprop in the populations of *A. myosuroides* and that both target-site and enhanced metabolism mechanisms are responsible for resistance to the herbicides in UK populations of wild oat. We conclude that before selection was imposed by the herbicides, the populations possessed the appropriate genetic variance for some of the mechanisms highlighted above.

Resistant weed biotypes in Hungary (292)

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Every unconsidered, drastic intervention in the creative order of nature leads to ecological changes unfavourable for human being. In Hungary such a deadlock was formed in chemical weed control by growing maize based on the principle of ''monoculture-monoherbicide''. Long-term use of the same type of herbicides for over twenty years have naturally provoked appearance of herbicide resistant weed biotypes. Up to now more than 200 resistant weed biotypes have been recorded in the world. In the last decades the appearance rate of new resistant biotypes has been almost constant: on average, nine new names are added to the global list annually. During the period of 1975-2000, herbicide resistant biotype(s) of nine weed species were found in Hungary: *Amaranthus retroflexus* L., *A. blitoides* Watson, *A. chlorostachys* Willd. and *Chenopodium album* L. to atrazine; *Erigeron* (*Conyza*) *canadensis* L. to atrazine; *Amaranthus bouchonii* Thell. to atrazine; *Cirsium arvense* (L.) Scop.to 2,4-D and MCPA; *Chenopodium polyspermum* L. to atrazine and *Ambrosia artemisifolia* L. to atrazine. Resistance of *Conyza canadensis* to other herbicides (paraquat, ureas) was also reported. Solymosi and Nagy described the sulfonylurea-resistant biotype of *Cirsium arvense* in 1997-1998. Since 1992, studies have been regularly conducted in all the 19 counties of Hungary to monitor weed resistance. Maize growing in monoculture is a thing of the past. Introduction of crop and herbicide rotations have positively influenced diversity of flora in the fields and reduced frequency of resistant weeds in the last two decades.

Tolerance of *Conium maculatum* L. populations to diuron in olive groves (293)

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Conium maculatum is a weed which can grow in olive groves treated with diuron. ED_{50} values (concentration required for 50 % reduction of fresh weight) were calculated for *C. maculatum* populations collected from olive groves continuously treated with diuron (T) and from adjacent areas never treated with herbicides (NT). There were no differences in ED_{50} values between either population (ED_{50} = 2.1 kg a.i. ha^{-1}). This tolerance was not due to herbicide metabolism or to an altered target site as was shown by fast fluorescence assays with leaves incubated in diuron solution. *Conium maculatum* plants were incubated in an aqueous solution of ^{14}C-diuron for absorption and translocation studies, which showed that diuron was restricted in leaf petioles and could not reach the leaf segments. This lack of transport is proposed to explain the tolerance of *C. maculatum* to diuron.

ACCase isoforms in *Lolium rigidum* resistant to diclofop-methyl (294)

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A biotype of *Lolium rigidum* resistant to diclofop-methyl was found in a monoculture winter wheat field in Lerida (Spain) that had been treated for several years with this herbicide. In this study, partial purification and separation of two multifunctional acetyl-CoA carboxylase did not reveal any differences between resistant (R) and wild (S) biotypes of *L. rigidum* in terms of purification, activity, elution profile in TMAE (trimethylaminoethyl) anion exchange column, and molecular mass of ACCase subunits. ACCase I and ACCase II were eluted from a TMAE anion exchange column at approximately 250 and 210 mM KCl, respectively. Both isoforms were composed of subunits of 200 kDa. ACCase I represented about 90% of the total activity recovered from the TMAE column. Diclofop-acid concentrations to inhibit ACCase activity by 50% (I_{50}) were determined for both isoforms of S and R biotypes. ACCase II was highly resistant to diclofop acid in both biotypes (I_{50} of 90-110 mM). In contrast, the I_{50} value for diclofop inhibition of ACCase I was 39-fold greater for the R biotype than for S biotype. It can be concluded that diclofop resistance in the *L. rigidum* biotype from Lerida was due to the presence of a resistant form of the ACCase I isoform.

Identification of *Euphorbia heterophylla* L. biotypes resistant to acetolactate synthase (als/ahas) inhibitors (295)

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The ALS-inhibitor herbicides are the main products employed for controlling *Euphorbia heterophylla* in soybean fields. However, resistant biotypes to these herbicides have already been identified. With the objective of studying the mechanisms involved in the resistance of *E. heterophylla* to ALS inhibitors, studies were carried out with resistant and susceptible biotypes of that species. The results indicate cross resistance to the herbicides inhibitors of the enzyme ALS. The biotypes that acquired resistance started to tolerate doses ten times higher than those recommended. They presented GR_{50} of 531.94 g ha^{-1} for imazapyr and of 1 232.02 g ha^{-1} for the imazethapyr, contrasting with the susceptible biotypes that presented GR_{50} of 10 g ha^{-1} for imazapyr and 13 g ha^{-1} for the imazethapyr. The studies with the ALS enzyme demonstrated that the herbicides inhibitors of this enzyme presents reduced effect on its activity, being the I_{50} superior to 3 000 μM for the imazapyr and 2 000 μM for the imazethapyr. On the other hand, ALS of susceptible plants presented I_{50} of 2 μM for the imazapyr and 0.7 μM for the imazethapyr. In this way, the insensitivity of the ALS of the resistant plants to the herbicides inhibiting it can be considered the main responsible for the resistance of the *E. heterophylla* biotypes.

Resistance of *Monochoria vaginalis* to sulfonylurea herbicides in rice fields in the southern part of Korea (296)

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A biotype of *Monochoria vaginalis* from a rice field in the southern part of Korea, in which sulfonylurea herbicides had been used for the past 8 years, failed to be controlled by label recommended rates. This biotype which was evaluated under the greenhouse condition, exhibited resistance to two sulfonylurea herbicides: imazosulfuron and pyrazosulfuron-ethyl. The susceptible biotypes were completely controlled at the recommended dose for each herbicide tested. However, the resistant biotypes survived at different rates, ranging from 24 to 40% even at 8 times the recommended dose of the respective herbicide. Further, GR_{50} of resistant biotypes (fresh weight) against sulfonylurea herbicides was 108 times for pyrazosulfuron-ethyl and 212 times for imazosulfuron compared to the susceptible biotypes. A resistant biotype was susceptible to other commonly used broad-spectrum herbicides such as pyrazolate, simetryn, bentazone+2,4-D and pyrazolate+butachlor mixtures.

Resistance *Echinochloa crus-galli* L. to quinclorac in flooded rice in Southern Brazil (297)

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In Rio Grande do Sul State, South Brazil, roughly one million ha of flooded rice are cultivated annually. Quinclorac is used in about 300,000 ha. With the continued use of this herbicide in some areas since 1990, problems of control of *Echinochloa crus-galli* (ECHCG) have been reported in the last two years. The purposes of this study were to evaluate the resistance of ECHCG to quinclorac and to estimate the level of resistance in the seedbank population. Seeds of this weed were collected in uncontrolled plants, as well as in the soil in four rice fields from regions where growers reported of herbicide failures. Two experiments were conducted in a greenhouse. One with seeds harvested from the plants and other with seeds from the soils. In both trials, a check was included with seeds collected from plants susceptible to quinclorac. When plants were at three-leaves stage, quinclorac was applied in rates of 0; 187.5; 375; 562.5; 750; 1,125 and 1,500 g ha^{-1}. The lowest rate killed all susceptible plants. However, the biotypes from fields showing quinclorac resistance survived at all the rates tested. Only with the highest rate, was there a reduction of about 20 % of shoot fresh weight. In the second trial, 85 % of ECHCG plants from seeds collected in problem areas showed resistance to twice the recommended rate of quinclorac (750 g ha^{-1}). The ECHCG biotypes studied are resistant to quinclorac and approximately 85% of the seedbank population from the fields evaluated are not controlled by the herbicide anymore.

Comparative studies on ACCase in herbicide-resistant and -susceptible littleseed canarygrass (*Phalaris minor*) (298)

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Herbicide-resistant weeds are widely spread all over the world. At present, hundreds of weed species evolved resistance to almost all herbicide groups. This is mostly due to monoculture, lack of herbicide rotation and reduced soil cultivation. Recently, a population of littleseed canarygrass (*Phalaris minor*) was

discovered which confer resistance to herbicides inhibiting the acetyl coenzyme A carboxylase (ACCase). We investigated in laboratory and field trials the possibility that the resistance to ACCase inhibitors is associated with reduced growth and low ecological fitness. We also examined in vitro the sensitivity of the plant and the target enzyme (ACCase) to various inhibitors. Greenhouse and field experiments with both biotypes (R/S) were planted at different proportions and densities. Various vegetative (shoot number and biomass) and reproductive (spike number and weight) parameters were determined. Resistant (R) and susceptible (S) biotypes of *P. minor* yielded comparable inflorescence number and fresh weight, shoot number, and fresh and dry weight. We concluded that resistance to ACCase inhibitors is not associated with reduced ecological fitness or competitiveness. The relative frequency of herbicide-resistant plants in a population may not change in the absence of herbicide selection pressure. Laboratory experiments conducted in petri dish have shown that the roots of *P. minor* were affected by fenoxaprop more than the shoots in both, R and S biotypes. These data indicate that more than one form of ACCase is present in *P. minor*. However, no differences were observed for the response of the ACCase activity between the shoots and the roots of the same biotype. These data indicate that another mechanism is responsible for the differences in root and shoot response of *P. minor*.

Mechanism of resistance and sensitivity of *Brachiaria plantaginea* (Link) Hitchc. to ACCase inhibitor herbicides (299)

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One biotype of *Brachiaria plantaginea* resistant to ACCase inhibitor herbicides from soybean areas of Parana State, Brazil, and a susceptible biotype were tested in a growth chamber with the objective of evaluate the sensitivity of these biotypes 'in vivo', to sethoxydim and tepraloxydim. Laboratory experiments were also conducted in order to test the absorption and translocation of the resistant plant compared to the susceptible, and tests the isolated ACCase from both biotypes to compare the activity of the enzyme in the presence of ACCase inhibitors. From the results obtained in the growth chamber, it was concluded that even though the tepraloxydim presented better results than sethoxydim for both biotypes, tepraloxydim and sethoxydim reduced significantly the biomass of the susceptible biotype, however, the resistant biotype did not have any significant effect on the biomass caused by the herbicides. The leaf absorption and translocation of the herbicides were similar for both biotypes. The value of I_{50} for the herbicide sethoxydim was 1.0-2.5 μM and 600 μM for the susceptible and resistant biotypes respectively, and the values of I_{50} for the herbicide tepraloxydim were 0.25-0.5 μM and 4 μM for the resistant and susceptible biotypes, respectively. These data presented the same trend as the one obtained using whole plants. The results from this research allowed the conclusion that the mechanism of resistance of this resistant biotype of *B. plantaginea* is due to an alteration of the ACCase, which in turn is insensitive to the herbicides sethoxydim and tepraloxydim.

Triazine-resistant *Avena barbata*, another threat or a crop? (300)

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Avena barbata Link (2n=28) is widely spread all over the Middle East and may be found also in the Americas, North Africa, Central and South East Europe, Asia and Oceania. A triazine resistant biotype of

A. barbata was found during the winter of 1997/8 along roadside in the Esdraelon Plain, repeatedly treated with atrazine or simazine for the last 20 years. The natural habitat of this weed is mainly in waste places and grassland. The resistant biotype found in Israel exhibited high resistance (R/S >100) to atrazine applied pre or post emergence, but was sensitive to urea derivatives (e.g. diuron) and ALS inhibitor such as sulfometuron. Since the number of grass winter crops in the arid and semi-arid regions is restricted mostly to wheat and barley, the potential of introducing a new triazine-resistant crop such as *A. barbata* is very promising. Such a potential crop fits in both irrigated and dry land crop rotations in the region. This may be of a particular interest when this triazine-resistant crop follows maize as a preceding summer crop treated with triazine herbicides. The possibility of using this triazine-resistant biotype as a genitor in breeding programs is now in progress.

Characterization of paraquat resistance in *Commelina elegance* and *Epilobium ciliatum* (301)

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Commelina elegance and *Epilobium ciliatum* populations that exhibit resistance to paraquat (PQT) were examined. The aim of this study was to better understand and characterize the physiological and biochemical mechanism involved. Based on whole plant and leaf discs studies the resistance factor was more than 10. Uptake and translocation experiments using ^{14}C-PQT have shown that wild type (S) plants absorbed and translocated much more than resistant (R) biotypes. In addition, the relative activity the of the antioxidant enzymes: glutathion reductase (GR), ascorbate peroxidase (Apx) and superoxide dismutase (SOD) was determined. The enzyme activities in the leaves of R plant treated with PQT were higher then those of the S plants. These results may support the idea that plant resistance to PQT involves more than one mechanism.

Characterization of *Lolium multiflorum* populations selected by different herbicide doses: responses to light quality (302)

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Italian ryegrass (*Lolium multiflorum*) causes important yield losses in wheat and barley crops. Continuous use of herbicide has promoted the evolution of resistant populations. Herbicide dosage and gene flow with related resistant populations are key factors controlling the rate of herbicide resistance in ryegrass. *Festuca rubra* is resistant to diclofop-methyl. Intergeneric *Lolium-Festuca* hybrids have been reported. Phenotypic characteristics selected by herbicide application should be considered as important traits linked to herbicide resistance. Our goal was to identify phenotypic traits associated to diclofop resistance. We studied the response to light quality of *L. multiflorum* populations growing with and without red fescue (*F. rubra*), previously subjected to 4 years of herbicide control with different doses: 0x, 0.5x, 1x and 2x, being x the commercial label dose. The plants were supplemented from one side with red light and far red light for continuous 4 hours at the end of the day. A multifactorial analysis of variance with light quality, herbicide dose and presence of red fescue as principal factors was conducted. We found significant interactions between population, herbicide dose, and light quality on tiller angles ($P = 0.017$) and maximum number of tillers produced. Tiller angle of insertion of individuals growing in mixture with red fescue was modified by reduction in red:far red ratio. This response was observed in individuals selected by all herbicide doses ($P < 0.05$). However, plants growing without red fescue increased their tiller angle only if they had been

selected with dose 0x and 0.5x (P = 0.0079 and P = 0.022 respectively). Maximum tiller number decreased with reduction in red:far red ratio only in control plants (0x) growing without fescue and in plants subjected to 2x dose growing with red fescue. Increasing insertion tiller angle in far red light conditions is a plastic response to augment competitive ability for light resources. Alterations in the level of resistance by herbicide selection and gene flow with red fescue generated a complex set of phenotypic responses to changes in light quality that seems worth of further investigation.

Triazine and diflufenican resistance in wild radish (*Raphanus raphanistrum* L.) in Australia (303)

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In recent years, wild radish has become a weed of great significance in Australian agriculture because of its rapid evolution of resistance to several herbicide groups. The most recent discovery is its resistance to triazines and diflufenican. The triazine-resistant population was collected from a triazine-tolerant canola crop and the diflufenican-resistant population collected from a lupin crop. Both populations came from the northern grainbelt of Western Australia and are the first reported cases of triazine and diflufenican resistance in wild radish selected under field conditions. The diflufenican-resistant population is the first reported case of diflufenican resistance in any plant in the world. Dose-response experiments, in the glasshouse and field, confirmed the resistance status of both populations. The triazine-resistant population also showed partial resistance to diflufenican but was not resistant to a range of other wild radish herbicides, including the ALS inhibitors and phenoxys. In contrast, the diflufenican-resistant population was resistant to the ALS inhibitor herbicides but not the triazines or phenoxys. Based on this knowledge, the triazine-resistant population was successfully controlled following the application of a mixture containing ALS inhibitor herbicides and a phenoxy in a wheat crop. Effective control of the diflufenican-resistant population was also achieved following the application of atrazine in triazine-tolerant canola that was planted in rotation to last season's lupin crop. The present study shows that control of herbicide-resistant wild radish populations is still possible if there is prior knowledge of their resistance status to allow the use of alternative herbicides with a different mode of action. However, it is imperative that no single herbicide group should be relied upon. High priority should be given to the adoption of integrated weed management.

Inheritance and linkage of genes for metabolism-based herbicide cross resistance in *Lolium rigidum* Gaud. populations (304)

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Herbicide-resistant populations of the ubiquitous grass weed *Lolium rigidum* infest many thousands of farms in southern Australia. *L. rigidum* populations have resistance to a wide range of herbicides including inhibitors of ACCase, ALS, PS II, tubulin elongation, carotenoid biosynthesis, and EPSP synthase. *L. rigidum* populations have the propensity to evolve multiple resistance, which poses major management difficulties. Understanding the inheritance and linkages of genes endowing multiple resistance in *L. rigidum* is an important aid in the development of effective strategies for the management of this weed. Linkages between genes for resistance to different herbicides in multiple-resistant *L. rigidum* populations were assessed through the creation of segregating populations from crosses between resistant and susceptible populations. Two herbicide-resistant *L. rigidum* populations were used. VLR 69, which demonstrates multiple resistance to at least nine herbicide chemistries and SLR 31, which demonstrates multiple resistance to at least eight herbicide chemistries. Highly resistant individuals in a segregating F_2 population from a cross between VLR 69 and a susceptible population were selected with simazine, chlorotoluron, chlorsulfuron, or tralkoxydim. The survivors were intercrossed within treatments and the progeny assessed for resistance to each of the four herbicides. The results demonstrated strong linkage between resistance to simazine and resistance to chlorotoluron, but non-existent or weak linkages to resistance to the other herbicides. Three rates (0, 100, or 800 g a.i. ha^{-1}) of trifluralin were applied as a seed treatment to a segregating F_2 population from a cross between SLR 31 and a susceptible population. Survivors of all treatments were subsequently treated with diclofop-methyl, chlorsulfuron, or tralkoxydim. Survivors of the highest trifluralin treatment were no more likely to survive application of the other herbicides than were survivors of 0 trifluralin. This demonstrates that resistance to trifluralin in SLR 31 is not linked to resistance to herbicides from other chemistries. These studies demonstrate that multiple herbicide resistance in *L. rigidum* occurs through the accumulation of genes each endowing resistance to one or a few herbicide chemistries, rather than through a single gene endowing resistance to a large number of herbicide chemistries.

Tracing the movement of herbicide resistance in fields infested with *Setaria viridis* L. using amplified fragment length polymorphisms (305)

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Testing of seed samples collected in 1989 showed that trifluralin resistant *Setaria viridis* was endemic in numerous fields in south western Manitoba at that time. Two of these fields were systematically sampled in 1995. The seed samples collected from both fields were subjected to amplified fragment length polymorphism (AFLP) analysis. The relative genetic similarity of the samples was determined using dendrograms of genotypic clustering. Such an analysis would indicate whether the resistance gene present in the field had moved from a single point to all parts of the field or whether there were a number of different points of origin. The dendrograms of samples collected from both fields showed that there were a number of samples collected in 1995 that were genetically similar to seeds collected in 1989. This indicates that resistant genotypes present in 1989 had spread throughout the field during this time. The dendrograms also showed that a continuum of genetic similarity existed among many samples, rather than discrete groups. This was unexpected since *S. viridis* is known to be a highly selfing species (>99%) whose genetic integrity should be largely maintained from generation to generation. The absence of any large genetic groupings may be due to the extended time between the confirmation of resistance and the systematic sampling. This time would have resulted in six generations for any one identifiable genotype to change, either as a result of outcrossing or mutations. Given that trifluralin resistant green foxtail was widespread in 1989, it is possible that new introductions of seed also made the identification of the original genotypes difficult.

Relationship between breeding system and gene dispersal of sulfonylurea resistant paddy weeds (306)

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Ten species resistant to sulfonylurea herbicides are spreading and causing problems in paddy rice fields in Japan. Among them, *Lindernia micrantha* and *Monochoria korsakowii* are of the cross-pollination type, the other species being mostly of the self-pollination type. To know dispersal process of gene of herbicide resistance, the species composition and activity of pollinators, phenology and flower shapes of the weeds were studied.

Spreading of triazine-resistant biotypes of *Solanum nigrum* L.: analysis using RAPD markers (307)

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The intensive expansion of weed species constitutes a great problem in agriculture, given that the number of herbicide resistant biotypes is rising continuously. Major ecological questions associated with herbicide resistance evolution involve an intricate understanding of the interplay between gene frequency, fitness, inheritance and gene flow. RAPD (Random Amplified Polymorphic DNA) technique which allows to detect variability at the DNA level was used in this study to examine spreading of *Solanum nigrum* L. populations. RAPD analysis has some advantages over other techniques for the genetic analysis of populations, which makes this technique potentially ideal in genetic studies of this weed. Twenty five populations from Poland, France and the UK were analysed. Six populations from Poland and one from France showed target-site based triazine resistance. The affinity between individuals and factors involved in spreading of *S. nigrum* was studied using RAPD technique. Three groups of populations in which resistance has arisen independently, were distinguished. Results confirm that *S. nigrum* like other predominantly autogamous species is characterized by substantially greater genetic differences among populations and reduced genetic variability within populations. Some resistant populations from Gabin and Grojec area showed very high affinity level compared to individuals from France. The results of the present investigation suggest that migratory birds feeding on berries, such as *Turdus pilaris* and *Sturnus vulgaris*, play an important role in spreading of *S. nigrum* seeds.

Inheritance of ALS inhibitor resistance in *Euphorbia heterophylla* L. biotypes (308)

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The ALS inhibitor herbicides are the main products used for the control of *Euphorbia heterophylla* L. in soybean fields. Resistant biotypes to these herbicides have already been identified. The objective of this work was to study the inheritance, number of genes and the degree of homozygous resistant biotypes. Reciprocal crossings were carried out between susceptible and resistant parents to obtain F1 seeds. Individuals from F1, F2, RCr and RCs and parents were sprayed with imazethapyr (150 g ha^{-1}). F1 plants and the resistant and susceptible parents were sprayed with increasing rates of imazethapyr (0, 100, 200, 400, 800 and 1600 g ha^{-1}) to evaluate the degree of resistance. The F1 plants were totally resistant to the herbicide, demonstrating that the resistance is nuclear and dominant. The F2 presented high probability for 3:1 segregation, indicating that the resistance is coded by a dominant gene. The experiment with the F1 plants sprayed with increasing rates of imazethapyr, demonstrated that the dominance is complete when evaluated with up to 1600 g ha^{-1} of this herbicide.

Identification of gene sequences related to diclofop-resistant ryegrass *(Lolium multiflorum*) (309)

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The occurrence of herbicide resistance in weeds has increased in the last 20 years. An important member of the aryloxyphenoxypropionate herbicide group is diclofop-methyl, an ACCase inhibitor that provides excellent control of grass weeds in both cereal and dicot crops. Extensive worldwide use of diclofop-methyl

for grass control in wheat has resulted in ACCase inhibitor-resistant weeds. Diclofop has been used successfully to control ryegrass in wheat in the United State; however, in 1987 and 1995 diclofop-resistant biotypes of ryegrass were reported in Oregon and Arkansas, respectively. To date, no report identifies genetic mutation which affect diclofop binding and, in turn, insensitivity (resistance) in ryegrass. The mechanism of resistance to ACCase might be the presence of a mutation in the binding site of the plastidic isoform. This should be reflected in differences in the nucleotide sequences of the genes from susceptible and resistant genotypes. The objective of this work is to study the molecular aspects of ACCase-resistant ryegrass by isolating and sequencing the gene transcripts from diclofop susceptible and resistant ryegrass biotypes. cDNA fragments encoding part of the acetyl-CoA carboxylase of susceptible and resistant ryegrasses were cloned by PCR using degenerate primers based on the alignment of amino acid sequences of wheat (GenBank AF 029895) and maize (GenBank U19183). Three fragments have been sequenced so far. The partial sequence contains 453 amino acids, which corresponds to 20% of the corn and wheat ACCase. The fragments encode part of the BC, BCCP, and an intervening sequence between the BCCP and CT domain. These sequenced fragments represent highly conserved parts of the protein, based on a high level of homology between the susceptible and resistant ryegrass and also between wheat and corn ACCase.

Investigation on biodiversity of Italian *Lolium* spp. populations susceptible and resistant to herbicides (310)

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Biodiversity is one of the most relevant trait assuring the weed survival in the agroecosystem. Worldwide, one of the most relevant and serious case of herbicide-resistance is in *Lolium* spp. populations. The aim of the study was to investigate biodiversity, at both phenological and genetic level, of *Lolium* spp. Italian populations susceptible (S) and resistant (R) to diclofop-methyl and chlorsulfuron. The research was planned in order to determine: 1) morphological polymorphism; 2) electrophoretic variability of seed reserve proteins, 3) genetic polymorphism of four isozyme systems. An high variability of morphological characters between and within populations was detected. In particular, both S and R populations showed a significant proportion of off-type plants, exhibiting contrasting traits when compared with the main morphological descriptors of the three *Lolium* species (i.e. *L. rigidum*, *L. multiflorum* and *L. perenne*). Electrophoretic analysis of seed reserve proteins confirmed the high range of variation detected by morphological analysis. Electrophoretic patterns of weed populations revealed in all populations a relevant amount (30-50%) of off-types. The origin of these off-types due to hybridization among *Lolium* spp. and between *Lolium* and *Festuca* spp. was postulated. On the basis of morphological and electrophoretic survey, a unique botanical identity of these populations was not found. Both susceptible and resistant populations consists of plants belonging to different botanical species (i.e. *L. rigidum*, *L. multiflorum*, *L. perenne* and hybrids). Genotypic variation within populations explained the major proportion of total diversity at the variable detected isozymes, while the contribution of among populations diversity was negligible. The similar patterns of genetic variation observed in susceptible and resistant populations suggest that herbicide tolerance depends only partially on herbicide pressure on the weed populations, but it is mainly due to natural biodiversity and high frequency of resistance in native populations.

Biochemical and genetic characterization of weed biotypes resistant to ALS inhibitors (311)

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The weeds, *Bidens pilosa/Bidens subalternans* and *Amaranthus quitensis*, are controlled in the soybean crop by herbicides, with the acetolactate synthase (ALS) inhibitor herbicides being the most used by soybean growers. However, the intensive and repetitive use of these herbicides in Sao Gabriel do Oeste County (MS

- Brazil) and in the provinces of Cordoba and Tucuma (Argentina), selected resistant biotypes. Therefore, a research project was developed to study the genetic and biochemical characterization. To compare the acetolactate synthase (ALS) activity of resistant and susceptible biotypes of *Bidens pilosa* and *Amaranthus quitensis* to ALS inhibitor herbicides, the methodology was based on the use of ciclopronocarboxylic acid (CPCA) to inhibit the enzyme ketoacidredutoisomerase (KARI). This enzyme catalyzes the reaction immediately after acetolactate in the biosynthesis pathwayof the amino acids: valine, leucine and isoleucine. Blocking the activity of this enzyme induced the accumulation of acetolactate, which in the presence of sulfuric acid forms acetoin. The results indicated that the ALS of the resistant biotype was insensitive to ALS inhibitors. An experiment was developed with suspected resistant biotypes of *Bidens pilosa* and *Amaranthus quitensis* using this methodology after spraying the plants at two pair of leaf stage with chlorimuron-ethyl and imazethapyr. A laboratory experiment was developed in order to sequence the Domain A region that codes for the ALS of the resistant and susceptible plants of *Amaranthus quitensis*. The methodology was based on DNA extraction, followed by amplification using six different primers, electrophoresis of the PCR and cloning using pUC 18 (Sure Clone). The sequence obtained was analyzed using the program BLAST of NCBI, and compared to genebank from organisms that had been sequenced. The sequencing of the gene that codes for the ALS in resistant and susceptible of *Amaranthus quitensis*, did not show any mutation in the Domain A, suggesting that other positions of the gene could be mutated to confer insensitivity to ALS.

Stress tolerance in *Kochia scoparia* L.: phenotypic plasticity or genetic adaptation? (312)

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Phenotypic plasticity, the production of different phenotypes in different environments, is expected to play a major role in the evolution of weedy species to changing and unpredictable environmental conditions. Indeed, the vast majority of problematic weed species in modern agriculture are characterized by high levels of phenotypic plasticity. However, one of the costs of an emphasis on plastic response is a reduced range of fixed developmental adaptations. We are interested in the relative importance of these two evolutionary strategies as they affect weed responses to environmental stresses. We have identified a system of weedy biotypes in Kochia scoparia that appears well suited to investigate the trade-off between plastic and fixed development. This highly plastic species inhabits a spectrum of habitats ranging from diverse cropping systems to roadsides to saline seeps (localized areas of groundwater discharge containing high soil concentrations of salt and other toxic ions). In arable fields, extensive use of selective herbicides has given rise to populations that are resistant to several herbicide families, including acetolactate synthase inhibitors and the auxinic herbicide dicamba. Our preliminary work shows that resistance to dicamba is not due to reduced herbicide uptake or translocation, nor is it due to elevated levels of detoxification. We predict that dicamba resistance is a quantitative trait controlled by several recessive genes. To further investigate the genetic mechanisms of dicamba resistance, we have undertaken a systematic search for genes whose expression levels are differentially regulated in resistant and susceptible plants within minutes of herbicide exposure. One gene of particular interest encodes choline monooxygenase (CMO), an enzyme catalyzing the first step of glycine-betaine synthesis, a well-known osmotic adjustment agent. Significantly, northern analyses show that CMO mRNA levels are down-regulated to a greater extent and more rapidly in dicamba-resistant plants than in susceptible plants. This modulation of gene expression may be regarded as a plastic response to transient herbicide stress conditions and thus typifies the suite of physiological responses conferring phenotypic plasticity. In contrast to transient herbicide stress, saline seeps exert strong, continuous selection pressure for adaptation to high levels of salt and other toxic ions. The seeps represent the extreme of an environmental gradient which we expect to impose significant adaptive costs at a number of biochemical, ecophysiological and ecological levels. Thus, recent colonization of saline seeps by this introduced weed may have selected for fixed adaptive development, possibly at the cost of plastic response.

One well-characterized response to salt stress in K. scoparia and other members of the Chenopodiaceae is the de novo synthesis of substantial quantities of glycine-betaine as an osmotic adjustment agent. In this regard, we may expect to encounter different molecular alterations in CMO genes and promoters, as well as other physiological adaptations, in populations growing in saline seeps. We are using several techniques of molecular genetics and biochemistry to ask the following questions in adjacent herbicide-resistant and saline seep-adapted populations: Is adaptation to the strong selection pressures in saline seeps accompanied by an erosion of genetic variability? Can we identify overlapping or different molecular mechanisms that control adaptation to saline environments and resistance to dicamba herbicide?

Genetic inheritance of glyphosate resistance in an Australian population of *Lolium rigidum* (313)

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Glyphosate-resistance has recently evolved independently in several Australian populations of *Lolium rigidum*. *Lolium rigidum* (annual ryegrass) is a major weed of agricultural cropping regions worldwide, and this species has a long history of resistance to numerous herbicides. The development of resistance to glyphosate further constrains the control options for this weed. An investigation of the genetic inheritance of this trait has been conducted. A glyphosate-resistant *L. rigidum* population, demonstrated homozygous for the resistance trait, was crossed with a known glyphosate-susceptible population. The resultant F1 population showed an intermediate dose response to glyphosate treatment. There was no difference in F1 dose response regardless of the phenotype of the maternal parent. Therefore resistance is inherited as a nuclear gene with partial dominance. The F1 plants were backcrossed to the susceptible parent and the F1xS progeny assessed for resistance to glyphosate. The F1xS population exhibited phenotypic ratios consistent with those expected for a single gene trait. These results are comparable to other examples of genetic inheritance of herbicide resistance. In an overwhelming number of documented cases, a dominant or partially dominant single nuclear gene encodes herbicide resistance. This appears to be the case for glyphosate resistance in this *L. rigidum* population.

Proactive versus reactive herbicide resistance management: understanding the economic sense of herbicide conservation versus exploitation (314)

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For world grain crops, across most agroecosystems, herbicides are the preferred weed management tool. In response to persistent herbicide usage and reduced use of non-herbicide tools, herbicide resistance is now a major problem in cropping regions of Australia and North America and is an emerging problem in specific cropping ecosystems in many parts of the world. One commonality across these diverse agro-ecosystems is that the industry and growers, even when knowledgeable about resistance, have chosen to continue exploiting their herbicide resource until resistance develops. Thus, they choose exploitation over conservation and thus managing resistance retroactively not proactively. Uncertainty, economic reality, herbicide marketing strategies and many other factors combine to make exploitation of a herbicide resource an apparently logical decision for both industry and growers. Despite the risk of resistance depriving them of a valuable tool, growers apparently consider it economically rational to exploit a herbicide resource. Similarly, herbicide manufacturers faced with competition, expiring patent life, looming generic manufacturers and other factors almost universally choose to maximise short-term market share. Here, using a bio-economic model created for Australian cropping agro-ecosystems, we examine whether herbicide exploitation or conservation by growers is optimal. The results of this analysis demonstrate that while there is an economic incentive for herbicide conservation, this incentive is not great. When combined with other factors, such as uncertainty, it means that conservation is unlikely to be the preferred grower choice. Even when the grower takes a long term view, there are forces driving decision making for rapid herbicide exploitation rather than longer-term herbicide conservation. This understanding of the economic rationale for herbicide usage decision making is essential for campaigns targetted to achieve proactive herbicide usage aimed to maximise herbicide longevity.

Alternative herbicide programs for control of propanil-resistant *Echinochloa crus-galli* (L.) Beauv. in drill-seeded rice (315)

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Propanil-resistant *E. crus-galli* was first confirmed in Arkansas in 1990, and now 171 populations of propanil-resistant *E. crus-galli* have been confirmed in 20 counties across the state (nine new populations were confirmed in 1999). Quinclorac ''Facet'' was introduced commercially in rice in 1991; however, in 1998 a population of *E. crus-galli* collected from a rice field in Arkansas was confirmed to be resistant to both quinclorac and propanil. Because of the need for other control strategies, field experiments have been conducted each year at the Rice Research and Extension Center, Stuttgart, AR, to evaluate herbicide treatments for the control of propanil-resistant *E. crus-galli* in drill-seeded rice. Resistant and susceptible *E. crus-galli* were seeded across the plots in two rows perpendicular to the rice rows. In studies conducted from 1996 through 1998, clomazone at rates of 0.3 to 0.5 kg a.i. ha^{-1} preemergence proved to be an effective alternative herbicide for the control of resistant *E. crus-galli* and other seedling grasses in rice. In 1999, clomazone ''Command 3ME'' was introduced commercially in rice. Other herbicide technologies have also been found to be very effective. Anilofos, piperophos, or carbaryl, used as synergists with propanil, gave excellent control; however, there are no plans for the development of these compounds in the U.S. Fenoxaprop + safener AEF046360 ''Ricestar'' applied postemergence was found to give excellent control of propanil-resistant *E. crus-galli*, but without the potential injury to rice as experienced from fenoxaprop without the safener AEF046360. Two new graminicides, cyhalofop-butyl and clefoxydim, applied early postemergence were also promising. Bispyribac-sodium ''Regiment'' was effective on larger, 4- to 6-leaf *E. crus-galli*. New technologies involving the use of glufosinate in a glufosinate-tolerant rice cultivar, glyphosate in a glyphosate-tolerant rice cultivar, or imazethapyr in a imazethapyr-tolerant rice cultivar were also evaluated and gave excellent results. Adapted herbicide-tolerant cultivars have not yet been developed. Resistance management of *E. crus-galli* in rice appears to be predicated on the development of a variety of herbicides with different modes of action that can be rotated in the cropping system.

Diclofop-methyl sublethal doses may increase Italian ryegrass (*Lolium multiflorum*) tolerance (316)

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Herbicide resistance has evolved in *Lolium multiflorum* and *L. rigidum* populations as a consequence of the use of chemical control of weeds in winter crops. Selection pressure depends on both herbicide dose and frequency of application. Despite of the strong theoretical base on evolution, there is still argument on whether reducing herbicide dose will delay or accelerate the rate of evolution to herbicide resistance. Our goal was to evaluate the effect of diclofop sublethal doses on the evolution of resistance in Italian ryegrass. We choose 4 genets at random, from a reference population. Tillers grown in controlled environment were used to clone each genet. We applied three herbicide doses (selection doses): 0x (control), 0.0625x and 0.125x, being x the recommended label dose. After the first selection cycle, the surviving ramets from each genet were cloned again. Clones were submitted to 4 herbicide selection cycles. After the third cycle, some clones were grown in pots containing soil and the plants from all the genets were essayed for their response to 0x, 0.25x, 0.5x and 1x diclofop doses. We evaluated tiller survivorship, relative growth rate and dry weight. After the first herbicide application, tiller survivorship to the lower and the higher sublethal doses were 29% and 16% respectively and increased to 90% and 79% after the fourth selection cycle. Tiller survivorship of plants grown in pots from control clones was 30% regardless of the doses and it was 60% for 0.25x and 0.5x doses in the plants from the selected clones. The plants from clones selected with the highest sublethal dose surviving the herbicide screening, had the lowest relative growth rate (0.024 day^{-1}) and consequently lowest final biomass compared to the plants from the control clones (0.096 day^{-1}). If the increase of herbicide tolerance was the result of selection of intraclonal variation in *L. multiflorum* genotypes, intentional or unintentional exposure through herbicide drift to sublethal doses may result in enhancement of evolution of herbicide resistance in ryegrass.

Characterization of glyphosate resistant *Eleusine indica* biotypes from Malaysia (317)

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Glyphosate resistant biotypes of *Eleusine indica* (goosegrass) were collected from two locations in Malaysia. The fields from which these biotypes were collected have been treated with glyphosate for the past ten years. The glyphosate resistance observed in field trials was confirmed in pot dose experiments, in which the LD50 value for resistant (R) biotypes was approximately 2 to 4-fold greater as compared to the sensitive (S) biotype. Based on the these results, an experimental program was designed to investigate the mechanism of glyphosate resistance in *E. indica*. Parameters evaluated included uptake, translocation and metabolism of glyphosate in planta, as well as the biochemical and molecular analysis of crown tissue extracts. There was no significant difference in the uptake and translocation of ^{14}C glyphosate in the R and S biotypes. The biochemical data generated from these experiments showed a 5-fold difference in the I_{50}[glyphosate]s of the R and S 5-enolpyruvylshikimate-3-phosphate synthase (EPSPSs). The RFLP analysis of the sensitive and resistant biotype DNA identified distinct molecular markers associated with the R biotype. Further results from these experiments will be presented.

Management of herbicide resistant *Lolium rigidum* Gaud. populations in winter cereal crops in Catalonia, Spain (318)

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The presence of diclofop-methyl and chlortoluron resistant *Lolium rigidum* populations in winter cereal crops in Catalonia, Spain, triggered a search for alternative control measures. With this purpose and during the 1997/98 and 1998/99 cropping seasons, an experimental protocol has been carried out at a site (Concabella) where the effect of two different dates of crop sowing (with a delay of 2-3 weeks) on *L. rigidum* in wheat have been analysed. At the same time, during the 1998/99 cropping season, three different cropping systems

were established at two sites (Concabella and Solsona): oilseed rape and wheat under minimum tillage and wheat after ploughing. The herbicides used in Concabella were tralkoxydim and fluazifop-p-butyl in wheat and oilseed rape, respectively. The experimental design was of two randomly distributed repetitions of each treatment. The sowing delay affected the soil seed bank of *L. rigidum* (reduction up to 45%), but this control measure in the local conditions can have a variable efficacy depending on the rain recorded previously. Moreover, there can be yield losses in the crop which reached 46 kg ha^{-1} day^{-1} of delay in the present experiment. In oilseed rape, the *L. rigidum* population was reduced notably, because the seedlings showed a high sensitivity to fluazifop-p-methyl. The competitive effect of the oilseed rape affected tillering and shoot development of the surviving *L. rigidum* plants which had a very reduced biomass and fertility. Weed densities at harvest were ten times less than the ones observed in wheat under minimum tillage. Ploughing in wheat had a clear effect on the soil seed bank, setting seeds in more depth and making emergence more difficult. The *L. rigidum* soil seed bank was reduced between 40% and 86% depending on the site in comparison to the minimum tillage treatment. The use and/or combination of these different cultural methods are effective strategies to add to the traditional use of herbicides. They allow to reduce, and even prevent the appearance of herbicide resistant *L. rigidum* populations in winter cereal crops.

Herbicide control of resistant *Papaver rhoeas* L. to tribenuron and 2,4-D (319)

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During the cropping season 1998/99, four field experiments were conducted in winter cereal fields with a high infestation of resistant *Papaver rhoeas* in Catalonia (North-eastern Spain). Two fields had resistant poppies to both herbicides and two had poppies resistant to tribenuron but susceptible to 2,4-D. Seventeen combinations of pre- and early and late post-emergence herbicides were tested. The experiments were designed in three blocks containing the randomly distributed 10 m^2 pots. Application was done with an AZO sprayer. Evaluations were done counting living plants in a square meter three times in each plot every fortnight after treatment, and Abbot efficacy of each evaluation was calculated. The pre-emergence herbicides tested had high efficacy in all the tested fields where they were applied: pendimetaline (1.65 L a.i. ha^{-1}), trifluraline+linuron (0.72 L a.i. ha^{-1} + 0.36 L a.i. ha^{-1}) and trifluraline + chlortoluron (0.72 L a.i. ha^{-1} + 1.25 L a.i. ha^{-1}). No phytotoxicity on the cereals was detected in any case. In early post-emergence, the most effective group was the HBNs. The mixtures containing bromoxynil gave a high control in all fields, followed by the mixtures containing ioxinil. Diflufenican in mixture with MCPA (0.0375 + 0.375 L a.i. ha^{-1}) gave good results in three locations. Isoproturon + diflufenican (1.35 + 0.126 L a.i. ha^{-1}) controlled *P. rhoeas* at two locations only. Good control was achieved with tribenuron + metribuzine (0.015 + 0.07 g a.i. ha^{-1}) and with triclopyr + chlortoluron (0.48 + 1.25 L a.i./l) at also two locations. Terbutryn + triasulfuron (0.297 + 0.03 L a.i. ha^{-1}) had high efficacy in only one location. In late post-emergence, 2,4-D (0.6 L a.i. ha^{-1}) gave good control only at the two susceptible fields to this herbicide. The mixture 2,4-D with florasulam (0.3 + 0.00625 L a.i. ha^{-1}) was effective at the same two sites only. Dicamba at 0.192 L a.i. ha^{-1} gave high control at two locations only. A short-term control of the herbicide resistance of *P. rhoeas* to tribenuron and to 2,4-D seems possible with chemical methods, especially by using HBN's or pre-emergence herbicides.

Results of a preliminary survey to quantify the incidence of herbicide resistance in the Western Cape Province, Republic of South Africa (320)

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Herbicide resistance is a worldwide problem and, in South Africa, reports of herbicide resistance increased during the last decade, but particularly from 1997 onward. Unfortunately little data on the incidence of resistance is available. It was therefore decided to do a preliminary survey in the grain producing areas of the Western Cape Province to try to obtain more information on the incidence of resistance. Few of the reported cases were actually verified, therefore the questionnaire dealt with suspected cases of resistance. The questions were composed in such a way that individual farms could not be identified and the questionnaire was distributed to distributors and field agents of chemical companies as well as co-ops. Although more than 100 questionnaires were distributed only 13 has been returned to date. The returned papers do however cover the whole area and give an indication of trends regarding resistance in the area. It appears that before 1997, very little incidences of suspected resistance occurred. During 1997, 34 cases of suspected resistance occurred. The number of cases increased by 82% in 1998 and by another 37% from 1998 to 1999. *Lolium* spp. was involved in most cases (64%) and *Avena fatua* L. and *Raphanus raphanistrum* L. (13% each) were the second most important weeds involved in resistance incidences. A whole range of herbicides was involved, in most cases part of the aryloxyphenoxypropionates, cyclohexanediones and sulfonylureas. Although most of these cases have not been tested under laboratory conditions, field-testing indicated possible resistance. Results show that occurrence of resistance in the Western Cape Province is increasing and steps should be taken to address the problem. These steps could include more detailed surveys, a more streamlined system of laboratory testing of suspected resistance cases and an increased effort to educate farmers about the problem and the management thereof.

Characterization of imazethapyr and flumetsulam resistance and cross resistance to thifensulfuron-methyl in populations of *Amaranthus powellii* S. Wats. and *A. retroflexus* L. in Ontario (321)

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Characterization of the level of imazethapyr and flumetsulam and the pattern of cross-resistance to thifensulfron-methyl for field sampled populations of *Amaranthus retroflexus* and *Amaranthus powellii* in Ontario is critical to managing the spread of these weeds within the province. Growth room experiments were conducted from 1997 to 1999 on 37 populations of these weeds collected across southwestern Ontario. Preemergence soil applications of imazethapyr (100 g a.i. ha^{-1}) and flumetsulam (70 g a.i. ha^{-1}) showed that resistance was present in 27 out of 37 collected seed samples. Nine seed samples are resistant to solely imazethapyr, 15 resistant to both imazethapyr and flumetsulam and one resistant to flumetsulam only. Dose response experiments using foliar applied imazethapyr (0.063 to 512 g a.i. ha^{-1}) and thifensulfuron-methyl (0.031 to 256 g a.i. ha^{-1}) confirmed ALS inhibitor resistance. Resistance factors for *A. powellii* populations ranged from 1 to greater than 3300 fold the dose of imazethapyr and 0.25 to greater than 1800 fold the dose of thifensulfuron-methyl needed to decrease the dry weight of the *A. powellii* susceptible control population by 50 percent. Resistance factors for *A. retroflexus* populations ranged from 0.16 to 190 fold the dose of imazethapyr and 0.25 to greater than 1700 fold the dose of thifensulfuron-methyl needed to decrease the dry weight for *A. retroflexus* susceptible control population by 50 percent. The confirmation of resistance and the high level of cross resistance provides strong evidence for the importance of utilizing the herbicide grouping information in the management of herbicide use in Ontario.

Strategies to control canary grass (*Phalaris* spp.) resistant to herbicides aryloxyphenoxypropionates and cyclohexanediones on wheat (*Triticum vulgare* L.) as part of an IWM model (322)

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A study was carried out to confirm the occurrence of resistant *Phalaris minor* and *P. paradoxa* biotypes to the common herbicides used in the Bajio Region. This work included trials conducted under greenhouse and field conditions, where supposedly resistant biotypes had been observed. Greenhouse trials also

included susceptible *Phalaris* spp. populations. Weed control strategies were tested in several trials in fields infested with resistant biotypes (resistance confirmed in the bioessays). Mixture of herbicides, rates, application timing and wheat seed density were included. Bioessays in the greenhouse and field conditions confirmed the presence of resistance in the weed biotypes tested. The results showed a typical cross resistance and the major level was for the herbicide fenoxaprop-p-ethyl with 82% more than clodinafop and 190% more than tralkoxidim. Mixtures of clodinafop + chlortoluron + terbutryn (60 + 800 + 87.5 g a.i. ha^{-1}) sprayed postemergence showed the best chemical solution, giving up to 98% weed control and an increase in wheat yield up to 2 tons. Regarding application timing, no significant difference was found in spraying this mixture at different days before the 1st irrigation after emergence. The weed control was improved (10% average) and the yield of wheat grain was better (800 kg ha^{-1} average) when sowed a wheat seed density of 200 and 250 kg ha^{-1} in comparison to 150 kg ha^{-1}, when integrated to the use of the triple herbicide mix mentioned above.

Mixtures of fungal pathogens to control complex of weeds in rice (323)

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Most cropping systems are invaded by a complex of weeds. An often cited limitation of biological control is its high degree of specificity. A host specific-biocontrol agent will often only control a single target species allowing other weed species to flourish. Irrigated rice is commonly infested with grass, sedge and broadleaf weeds. We have demonstrated that the incorporation of several host-specific weed pathogens as fungal mixtures overcomes the limitation of narrow spectrum weed control. Experiments were conducted to determine the compatibility and virulence of applying combinations of two or three fungal pathogens to suppress growth of the target weed species in irrigated rice. *Sphenoclea zeylanica*, *Echinochloa crus-galli*, *E. glabrescens*, *E. colona*, *Fimbristylis miliacea*, *Cyperus difformis* and *C. iria* were planted in rows in a 26 x 32 x 10cm plastic tray together with the rice seedlings. The biocontrol agents were applied singly or in combination with other host-specific fungal pathogens as spore suspensions. The inoculated plants were given a 12-hr dew period and were subsequently maintained for two weeks under controlled condition in a greenhouse. Four pathogens were compared, *Sphenoclea* pathogens, *Alternaria alternata* (Aa) and S2, one *Echinochloa* pathogen, *Exserohilum monoceras* (Em), and one *Fimbristylis* pathogen (F1). There were seven fungal combinations (Aa+Em+F1; S2+Em+F1; Aa+Em; Aa+F1; S2+Em; S2+F1; Em+F1) and four single applications (Aa, Em, F1 and S2) of the pathogens targeted to control the specific weed species. *A. alternata*, whether applied singly or in combination, gave superior control compared to the other *Sphenoclea* pathogen (S2), however, disease severity of the inoculated *S. zeylanica* was not significantly different two weeks after treatment using the two pathogens. The disease level of the *E. monoceras*-treated *Echinochloa* seedlings was the same across the three *Echinochloa* species evaluated. High level of control was also provided by F1 to *Fimbristylis miliacea* and caused significant plant height reduction to *Cyperus* spp. (*C. difformis* and *C. iria*). The mixtures were compatible, virulent and synergistic with mixtures often providing superior control than when these pathogens were applied singly. Rice seedlings initially manifested susceptibility due to high disease pressure at inoculation, but the plants recovered and there was no apparent effect two weeks after inoculation

Options for the control of quinclorac resistant *Echinochloa crus-galli* L. in flooded rice (324)

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Echinochloa crus-galli (ECHCG) biotypes resistant to quinclorac were founded in four flooded rice fields in Rio Grande do Sul State South Brazil. The development of resistant biotypes in the population of ECHCG was due to the selection pressure by continuous use of quinclorac, a highly efficient herbicide on this weed, during eight consecutive seasons. The objective of this study was to evaluate the efficiency of alternative herbicides for the control of quinclorac resistant biotypes of ECHCG. Seeds were collected from rice fields with reported herbicide failure for the last two seasons. Seeds of resistant biotypes, as well as of a susceptible one were sown in pots in a greenhouse experiment. When the seedlings presented three-leaves, the herbicides were applied, except for clomazone that was used in pre-emergence. The herbicides used were bispyribac-sodium (50 g ha^{-1}), clefloxidim (170 g ha^{-1}), clomazone (400 g ha^{-1}), fenoxaprop-p-ethyl (41 g ha^{-1}), propanil (2 880 g ha^{-1}) and quinclorac (375 g ha^{-1}). Except for quinclorac, all other herbicides provided 100% control of the resistant biotypes. The susceptible biotype was controlled by all herbicides. The herbicides tested are efficient alternative products for use to control quinclorac resistant biotypes of ECHCG in flooded rice.

Chemical control of *Euphorbia heterophylla* L. biotypes resistant to acetolactate synthase (ALS/AHAS) inhibitors (325)

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The resistance of wild pointsettia (*Euphorbia heterophylla* L.) to ALS-inhibitors leads to the need to investigate the response of the resistant genotypes to herbicides with different action mechanisms. The objective of this study was to evaluate alternative herbicides for the control of *Euphorbia heterophylla* L. biotypes resistant to ALS-inhibitors. The herbicide treatments consisted of imazaquin (120 and 150g ha^{-1}), imazethapyr (7 and 100g ha^{-1}), flumetsulan (60 and 120g ha^{-1}), flumioxazin (45 and 60g ha^{-1}) and sulfentrazone (300 and 600g ha^{-1}), which were applied pre-emergence, and imazetapyr (80 and 100g ha-1), imazamox (30 and 40g ha^{-1}), imazapyr (20 and 250g ha^{-1}), lactofen (48 and 156g ha^{-1}), fomesafen (136 and 250g ha^{-1}) and glyphosate (600 and 720g ha^{-1}), applied after emergence in isolated as well as in combined form, on both an ALS- inhibitor-resistant and a susceptible biotype of *E. heterophylla*. For each biotype, there was an additional control without herbicide treatment. The ALS-inhibitor herbicides controlled the susceptible biotype efficiently, except for flumetsulan, whereas the resistant biotype could only be controlled by imazapyr at high doses. Herbicides with other action mechanisms proved to be highly efficient for the control of susceptible and resistant biotypes when applied in isolated or mixed form. Resistant *E. heterophylla* biotypes are therefore efficiently controlled by other action mechanisms than ALS-inhibitors.

Risk factors that impact resistant weed selection (326)

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Prior to 1970, weed scientists generally were not concerned with the possibility of weeds developing resistance to herbicides. Products such as atrazine and 2,4-D had been widely used for a long period of time with no large-scale failures that affected agriculture. During the 1970's, as cases of herbicide resistant weeds began to increase, growers and weed scientist began to study the phenomenon of herbicide resistant weeds and their impact on agriculture. Certain risk factors for development of herbicide resistance have been explored and described. These include the mode of action of the herbicide, persistence in the environment, effective kill rate, rotations with other herbicides, and the frequency of use. More subtle risk factors have not been as carefully studied or documented. Reacting to economic pressures, some growers may reduce herbicide rates to the point that resistant weeds may develop more quickly. This possibility is being studied with the use of glyphosate in RR crops. In the case of dicamba, the lower labeled use rate in small grains may have accelerated development of tolerant kochia biotypes relative to the higher use rates in corn. Further complicating the picture is the fact that some weeds are inherently more tolerant than others to a given herbicide. Rarely is the field use rate based on a precise analysis of the dose response of all weeds in a field to a given herbicide. Future herbicide resistance research will need to account for these additional factors if the true nature of herbicide resistant weeds is to be understood. A side benefit of herbicide resistant weeds has been the increased study of basic weed physiology and biochemistry, as well as the use of novel resistance traits in biotechnology to develop crops with new herbicide resistance traits.

Risk analysis of development of herbicide resistant weed biotypes to ACCase and ALS inhibitors in conventional and no-tillage soybean production systems in Brazil (327)

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Herbicide resistant weed biotypes have been reported in soybean fields in Brazil since 1993. Biotypes of *Bidens pilosa/Bidens subalternans* and *Euphorbia heterophylla* have developed resistance to ALS inhibitor herbicides, especially in conventional tillage areas and *Brachiaria plantaginea* to ACCase inhibitor herbicides in no tillage areas. *Bidens pilosa/Bidens subalternans* and *Euphorbia heterophylla*, under field conditions and greenhouse experiments have shown cross-resistance to sufonylureas, imidazolinones, triazolopyrimidines and pyrimidyl-oxi-benzoates. To prevent or manage resistance of these weeds, soybean growers can use herbicides, which have alternative mechanisms of action such as photosystem II and PROTOX inhibitors, sprayed in pre or post-emergence conditions. *B. plantaginea* found in soybean fields of Parana State is cross-resistant to aryloxyphenoxypropionic acids and cyclohexanediones. However, there is no other herbicide available with alternative mechanisms of action other than ACCase inhibitors. This is because the areas where *B. plantaginea* biotypes have been selected to resistance are restricted to no-tillage systems, where grasses are controlled only by ACCase inhibitor herbicides sprayed post-emergence. In Brazil, there is no survey to register the number of sites with resistant weeds, however they have increased in the last years. Integrated weed management systems should be used to reduce the risk of the increasing the number of sites with resistant weeds. Herbicides are widely used in soybean production systems in Brazil, and there is a great deal of herbicide expertise among farmers. Because of the success of chemical weed control, practitioners, farmers and several researchers have concentrated their efforts on the herbicide technology and have sometimes lost sight of the biology of the plants and integration of weed control methods.

What risks do herbicide resistant weeds present to chemical companies? (328)

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The cost of discovering, developing, and marketing a novel herbicide is approximately $100 million dollars in 2000. With such sizeable investments in new products, chemical companies hope for sizeable market share in several crops over a number of years to obtain a desirable return on investment. Short of being replaced by some other product in the market, herbicide resistant weeds can represent one of the biggest threats to return on investment for a chemical company. In several well documented examples, use of a class of chemistry by one company can create resistant weed populations which create serious problems for other companies seeking to develop herbicides with the same mode of action. Although rotation of herbicide mode-of-action is promoted as a way to reduce development of herbicide resistant weeds, the pressures of short-term profits make it difficult for companies to always actively promote such product stewardship. The reality of herbicide resistant weeds is that resistant weed populations must be viewed essentially as new weeds to be controlled with different herbicides, and that the potential of resistant weeds lurks in the background for the development of many new herbicides. From a marketing perspective, resistant weeds offer opportunity for competitors to downgrade certain herbicides, and often creates market opportunities for older herbicides which still control certain weeds. Finally, the type of resistance (single gene versus multiple gene effects) can greatly impact the development of resistant weeds for herbicides.

Echinochloa colona (L.) Link. biotypes potentially resistant to propanil in Venezuela (329)

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Echinochloa colona L. Link (barnyardgrass) resistant to propanil has been reported in Costa Rica, Colombia and USA. Recently, in Venezuela rice fields, inadequate chemical control of this weed has been observed. In order to determine possible resistance to propanil, two greenhouse experiments were established at the Facultad de Agronomia-UCV in 1997. A completely randomized design with four replications was used in both experiments. For the first trial, commercial dosage of propanil (2880 g. i.a. ha^{-1}) was sprayed on 228 populations of *E. colona* collected from the main rice growing regions of Venezuela (Guarico and Portuguesa), and over a population control (susceptible population). In the resistant test (second trial), the 49 populations that were found potentially resistant in the first trial and the check population, were treated with four increasing dosages of propanil : 1440 g a.i. ha^{-1}; 2880 g a.i. ha^{-1}; 5760 g a.i. ha^{-1}; and 11520 g a.i. ha^{-1}. First trial data were processed by multivariate analysis of tree hierarchical, while the second trial was analyzed using the non-parametric Kruskal-Wallis test. The percentage control was measured using ALAM modified visual scale (1974). Seven populations were found resistant with less than 35% of control when they were treated with propanil at 5760 g a.i. ha^{-1} . Likewise, 12 populations showed 40% control at the same rate. Results suggest the need for adequate management for these 19 populations of *E. colona* that showed resistance to propanil, in order to avoid further dissemination.

Gene flow, growth, and competitiveness of imazethapyr-resistant common sunflower (*Helianthus annuus*) (330)

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Risk of gene/trait transfer between sunflower species is a major concern in the sunflower industry. This study was conducted to ascertain movement potential of imazethapyr resistance, measure the relative growth, and competitiveness between resistant (R) and susceptible (S) biotypes of common sunflower. Susceptible biotypes of common sunflower were planted in the field in two locations in northeast Kansas at 5.5, 7.6, 15.2, and 30.4 m circles radiating out from a center of densely planted R biotypes. Pollen movement was analyzed by sampling the S progeny for the presence of imazethapyr resistance. Resistant progeny were detected at 30.4 m at both sites. Greenhouse studies were conducted to determine if there are any differences between R and S biotypes grown individually. Overall, growth analysis showed that photosynthesis, leaf area, and dry weight were not significantly different between R and S biotypes at each harvest time. A replacement series design was used to measure the competitive ability of R and S biotypes. Community analysis indicated that photosynthesis, leaf area, and dry weight were not significantly different between R and S biotypes across all proportions. As a result, R-R and S-S intra-competition equaled R-S inter-competition. In conclusion, gene flow from R to S biotypes occurs yearly with movement up to 30 m. Single plant analysis shows no differences between R and S biotypes. In addition, community results shows that biotype performance was nearly equal indicating no fitness advantage with imazethapyr resistance. Therefore, without herbicide pressure, R and S populations would tend to stabilize over time.

Resistant crops to manage resistant weeds (331)

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One of the key advantages of herbicide-resistant (HR) crops is the opportunity to use a herbicide with an alternative mode of action to control resistant weeds. In some instances this can provide flexibility for farmers who do not want to make large changes to their normal crop rotation scheme. For example, herbicide-tolerant oilseed rape can be introduced in place of conventional oilseed rape to control weeds that have developed resistance to herbicides typically used in this crop. In some locations this has been an important driving force in the adoption of HR crops. Using HR crops to manage resistant weeds raises several questions: (1) Will the new herbicide provide satisfactory control of the resistant weed? (2) Can resistance ultimately develop to the new herbicide also, if it is used inappropriately? (3) Will volunteer plants of the HR crop pose problems in subsequent years? (4) What is the likelihood that gene flow from the HR crop will lead to development of HR hybrids? And finally, (5) can these various possibilities be managed in such a way that satisfactory weed control is achieved without negative side-effects? In this workshop, Congress participants will be invited to discuss these questions. Participants with experience in addressing these topics will be identified and asked to make a brief statement of the possible scenarios. This will be followed by a general discussion in which all participants will be encouraged to share their views and experience, so that best practices to manage resistant weeds with HR crops can be identified, and potential problems avoided or minimized.

Development of a herbicide resistant crop: from chemical to seed (332)

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The development process of a herbicide resistant crop can be divided in several parts. The first two include the development of a gene or trait that confers resistance to a herbicide as well as the standard process of herbicide development for use on the resistant crop. These two parts are combined since the gene or trait must confer a minimum level of resistance to an application rate of the herbicide, which will prove efficacious in controlling weeds that normally infest the crop. Also, it is important that the gene or trait development processes coincide as different adjuvant or surfactants are tested or other herbicide combinations are considered to ensure that the resistance conferred by the gene(s) is adequate. A third part of the process is the development of inbred lines (for hybrids) or varieties relative to choosing the best genetic event that will confer the minimum level of resistance. Normally, several events are available to the plant breeder at the beginning of the process. It is important that the breeder works closely with the weed scientist to ensure that the chosen trait not only confers the adequate resistance level for efficacious weed control, but it should also be amenable for efficient breeding. Related to the rate of herbicide and breeding is the requirement of efficient screening protocols that allow the breeder to select herbicide resistant plants within segregating breeding populations. Finally, seed production and entry into the market are closely linked with technology stewardship to ensure that the combined package of seed and herbicide are available to the grower and that the development of resistant weeds is managed. The development of imidazolinone herbicide resistant crops will be used as examples to illustrate this process.

Herbicide tolerance in transgenic sugarcane, an asexually propagated crop (333)

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Sugarcane is grown in more than 80 countries throughout the tropics and subtropics. Brazil is the world’s largest sugarcane producer and crushes annually 300 million tons of sugarcane (25% of the world’s total sugarcane production) to produce both sugar and fuel ethanol on approximately 5 million hectares. Approximately 20% of this area is replanted every year during a period in which precipitation is intense and weed control is a difficult task. Present weed control management is done with pre-emergence herbicides that provide a limited spectrum of weed control. Often, several herbicide combinations are needed to achieve the desired level of weed control. Production of sugarcane varieties resistant to herbicides, using a transgenic approach, would allow herbicides to be used post-emergence to the crop and could offer less costly, more flexible weed control in this crop with less environmental impact. Among the herbicides that fit this criteria are glyphosate, glufosinate and imidazolinone. The Copersucar Technology Center has transformed several commercial and pre-commercial sugarcane cultivars with genes that confer tolerance to these herbicides and are presently being field tested. All laboratory, greenhouse and field tests are conducted within the framework of the National Biosafety Council (CTNBio), the federal agency responsible for regulatory aspects related to genetically modified organisms. Technical difficulties of developing transgenic asexually propagated crops are centered on the need to transform directly each and all desired commercial genotypes instead of a model genotype which is then used in backcross programs to incorporate the transgene in commercial cultivars, as is the strategy generally adopted in sexually propagated crops. With regard to regulatory aspects, sexually and asexually propagated GMOs have different conditions. Transgene containment is generally not as great an issue in asexually propagated crops, while costs of registration may be much greater in asexually propagated crops due to the need to approve various individual transformation events for different cultivars.

Plant transgenic overexpressing a bacterial hydroxyphenylpyruvate dioxygenase: tolerance to isoxaflutole (334)

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The enzyme, p-Hydroxyphenylpyruvate dioxygenase (hppd), catalyses the transformation of p-hydroxyphenylpyruvate into homogentisate. In photosynthetic organisms, this enzyme plays a specific and crucial role. This is because the product of the reaction, homogentisate, is the aromatic precursor of all plastoquinones and tocopherols, which are essential elements of the photosynthetic electron transfer chain, and of the antioxidative systems, respectively. It is the primary molecular target of isoxaflutole, a member of a new family of bleaching herbicides. This protein is a non-heme iron dependent enzyme, active as a homotetramer in bacteria and as a homodimer in plants. The crystal structure of *Pseudomonas fluorescens* hppd suggests that the active site of the enzyme is in the C-terminal domain; there is one non-heme iron per monomer liganded to the sidechains of His162, His 241 and Glu323. In the interest of developing tolerant plants, a bacterial hppd gene has been cloned and then introduced in tobacco. Until recently, the subcellular localisation of plant hppd was not completely established. In some reports, it was localised in the cytoplasm, and in others it was located in the chloroplast. Therfore, different constructs have been prepared and introduced in plants. Constructs were prepared either with a transit peptide for routing of the expressed protein to the chloroplast or without a transit peptide. In the field, these tobacco lines show tolerance to a high dose of formulated isoxaflutole. The tolerance of plants accumulating hppd in the chloroplasts is higher than those accumulating the protein in the cytoplasm. To improve that tolerance, directed mutagenesis of the protein was initiated, based on the knowledge of the hppd 3D-structure which allows modelling of substrate-enzyme or inhibitor-enzyme interactions

Glyphosate tolerant soybean (335)

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Field studies were initiated in 1997 designed to evaluate the biosafety of Roundup Ready Soybean in Brazil. These studies included an array of evaluations ranging from weed control efficacy to trait introgression into Brazilian soybean germplasm. These studies were designed to address potential variations to the agronomic practices in Central (Cerrados) and Southern Brazil due to the introduction of Roundup Ready soybeans. For example, probable differences in production systems include large no-till area, as well as altered weed species diversity, crop rotation and management practices. Results from these studies demonstrated that the Roundup Ready soybean weed control program was efficacious to control the predominant weed species in all soybean production areas. Furthermore, these studies showed that the RRS has a technical fit to assist in solving most of the weed management problems in Brazilian soybean production. The biosafety clearance for Roundup Ready soybean was obtain from the National Technical Biosafety Committee (CTNBio) after they reviewed the data. The technical opinion of CTNBio required that the Roundup Ready soybean fields will be monitored for five years after its commercial introduction. A comprehensive environmental monitoring plan was implemented in the 1999/2000 cropping season to address all the technical and biosafety requirements. Results from the first year of this environmental monitoring program will be presented.

Bases for resistance of rapeseed mutant lines to ALS inhibiting herbicides (336)

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Two mutant lines of *Brassica napus* (L.) resistant to chlorsulfuron were developed through seed mutagenesis and designated 19c and 30a. These lines were cross resistant to triazolopyrimidines but not to imidazolinones. Both lines showed cross resistance to the sulfonylurea herbicides tribenuron and thifensulfuron. Metsulfuron, another sulfonylurea herbicide, caused less reduction in the dry weight of 19c than 30a or the wild type. ALS enzyme extracted from 30a was more resistant to chlorsulfuron than the enzyme from 19c or the wild type. Rates of metabolism of both chlorsulfuron and metsulfuron were higher in 19c than 30a or the wild type. It is concluded that the bases of resistance are different in these mutant lines. Line 30a has gained resistance through an ALS enzyme which is less sensitive to herbicides, while line 19c has a faster rate of metabolism than the wild type.

Key learning from the development of Roundup Ready™ biotechnology in Poland (337)

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Roundup Ready sugar beet and OSR are genetically engineered to tolerate normal dose applications of glyphosate, the active ingredient in the non-selective herbicide Roundup™. Glyphosate blocks the enzyme EPSP synthase involved in the production pathway of aromatic amino acids in plants. By introducing a gene that codes for an alternative EPSP synthase, which is not inactivated by glyphosate, becomes insensitive to glyphosate. The gene coding for the alternative EPSP syntheses is derived from the soil bacterium *Agrobacterium* strain CP4. Specifically, a gene expression vector containing the modified CP4-EPSPS (enolpyruvyl-shikimate-3-phosphate synthase) and gox (glyphosate oxido-reductase) genes, respectively, was biolistically introduced into crop. The RR plant continues making the aromatic amino acids, even in the presence of glyphosate. Roundup Ready 360 SL as a product is non-selective broad-spectrum herbicides, which kill a wide variety of weeds. Roundup Ready doesn’t distinguish between weeds and crops. By making a crop tolerant to a herbicide, the selected herbicide can be used to remove the weeds without harming the crop. The advantage of that herbicide, compared to many other herbicides, is that they are less toxic and easily broken down in the environment. Both crops demonstrate capacity for quick decomposition of glyphosate. Herbicide Roundup Ready 360 Sl is exceptionally safe and has the lowest admissible toxicity (grade IV in I to IV scale). The product can be used in autumn/spring postemergence on actively growing weeds. Autumn time application in OSR goes after germination. Spring time application goes after beginning of vegetation. The best weed control effect can be achieved on actively growing weeds, when weeds are in 3-5 leaves stage, as well as twice to three application have been used. Both applications demonstrate extremely quick herbicidal effect. Recommended dose rate is 2 L ha^{-1}. Total treatment is included in the rate 4-6 L ha^{-1}. In spring time application in sugar beet goes after germination. The treatment should be carried out after the crop plant started growing, up to the phase of rows covering. The best effect can be achieved on actively growing weeds. Comparing the efficacy of different application timing the best was found to give the best efficacy enhancement at both the first and the second application timing phase. All application (three) demonstrates extremely quick herbicidal effect. Recommended dose rate is 2 L ha^{-1} per one application. Total treatment is included in the rate 4-6 L ha^{-1}. Roundup Ready OSR and Roundup Ready sugar beet were developed to facilitate agricultural practices, to improve weed control, thereby yield and to generate environmental benefits during both crop production. Roundup Ready (RR) sugar beet and OSR ideally fits to typically scenarios of fields in Poland. All field trials which had been done proved outstanding weed control and yield increase, particularly on fields strongly infested with common couch-grass. This is valuable when considered undoubtful problems farmers meet with using other products. This short characteristic clearly shows that Roundup ReadyÖ sugar beet and Roundup ReadyÖ OSR to be exceptionally profitable tool in the fight against all type of weeds.

Genetically modified *Brassica napus* L.- five different cropping systems and five years of commercial experience - what is the bottom line for farmers, oil processors, feed industry and the consumer? (338)

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Brassica napus, cultivated as winter rapeseed in Europe and China and spring rapeseed in Canada, China and Australia among many other countries, grows into having more significance in world trade in the days of genetically modified crops. Rapeseed in Europe is competing strongly with soybean according to ADM sources in Mainz, Germany. Both crops have come under pressure in the market, because of the GMO fights. Since 1995, when the first canola variety Innovator with herbicide resistance as a Novel Trait entered the food chain in Canada, a lot of experience has been gathered in the field, in the processing plants, in the supermarkets and in the feed lots of many countries. The major highlights of this periode are going to be described in the presentation and an outlook is provided from the view of the presenting author. The first part of this report has to start before recommendation from WCC/RRC committee for approval and variety registration through the Registrars Office of Canada in Ottawa in spring 1995. The new herbicides Liberty and Roundup received a positive review by Health Canada on food and occupational safety. The Novel Foods approval was given through Health Canada. The Unconfined Release and also the Novel Feeds approval went through Agriculture and Agri-Food Canada as the gateway for the approval process. It had been a challenging climb towards marketing and first sales of seed bags. It was the principle of Sustainable Equivalence of the end product which provided guidance to all stakeholders in the food production chain and regulatory approval process. After the first step in 1995, with market introduction of AgrEvo's cv Innovator, the first Limagrain variety Roundup Ready canola (tolerance to glyphosate from Monsanto) was introduced in 1996, the next LibertyLink canola variety (glufosinate tolerance, today from Aventis CropScience) followed in 1997 when also the first Plant Genetic Systems hybrids under the InVigor brand entered the market. Pursuit Smart from Pioneer HiBred has offered mutagenesis derived imidazolinone resistance (against Pursuit from American Cyanamid) to the market in the same year. In 1999, regulatory approval was given to the first varieties carrying bromoxynil tolerance, the Navigator System offered by Aventis CropScience, a result of a long collaboration between the University of Manitoba, Calgene and former Rhone-Poulenc. Yield figures will be presented as well as weed control results. For all weed control systems, comparative yield data and an evaluation of potential side effects will be presented. The development of acreages of herbicide tolerant varieties reached an estimated 60% in 1998 and estimated

70% in 1999. Some thoughts will be provided what structural changes on the seed industry will result from this market development, using Canada as the major example and a lesson to learn.

Transgenic herbicide tolerant crops: solutions, views and critical remarks (339)

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The papers in session 7 provide an overview on different research projects with herbicide tolerant (HT) crops. These papers also reflect the current global acceptance situation of this technology. The existing HT systems have proved to be successful in Argentina, Canada and the USA. There now exists a substancial research database and several years of experimental field experience for HT cropping systems. Practical examples of those applied systems are in canola, rice, cotton, soybean and corn, and will be described in this session. The use of HT crops has been demonstrated to be cost efficient, and it allows the farmer more flexibility in the timing of herbicide applications. In addition, he is able to control weeds not controlled by many conventional products. Europe and several countries in Asia and Africa are still hesitant to introduce genetically modified crops, as reflected by the ongoing discussion on questions such as outcrossing of tolerance genes, shift to new problem weeds and the dependence of the grower on certain chemicals and varieties. The application of integrated crop management (ICM) principles can prevent the above mentioned risks. The following practices are proposed in correspondence with HT varieties and will be discussed in this session: monitoring, crop rotation using sequences of tolerance systems, use of conventional crops in a succession of HT systems, and the continuous assessment of economical and ecological benefits.

A comparison of glufosinate, glyphosate, and imazethapyr for weed control in herbicide tolerant rice (340)

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Current projections are that imazethapyr and glufosinate could be available for weed control in ClearfieldÖ and Liberty LinkÖ rice, respectively, in the U. S. by 2001. The development status for glyphosate in Roundup Ready* rice appears more uncertain. If development continues, the earliest projections for this technology is 2003 or 2004. Small plot research has been conducted in Arkansas from 1996 to 1999 to develop weed management systems for Liberty Link, Clearfield and Roundup Ready rice. Trial locations have been near Stuttgart, Lodge Corner and Lonoke, Arkansas. Weed species evaluated have included red rice (*Oryza sativa* L.), *Cyperus esculentus* L. *Echinochloa crus-galli* (L.) Beauv. (propanil resistant and susceptible biotypes), *Brachiaria platyphylla*, *Sesbania exaltata* (Raf.) Rydb. ex A.W.Hill., *Aeschynomene virginica* (L.) B.S.P. and several aquatic weed species. The most consistent results with glufosinate have been with two preflood applications at 0.42 kg ha^{-1} applied to 2-3 leaf rice and repeated at the early tillering stage. Similar results have been noted with glyphosate at the rate of 0.42 to 0.84 kg ha^{-1}. Both have provided control of a broad spectrum of weed species. Sequential applications of a soil applied treatment of imazethapyr followed by a postemergence treatment, or sequential preflood, postemergence treatments at 0.07 kg ha^{-1} have provided excellent control of red rice, *Cyperus esculentus* L. and several annual grass species. While the spectrum of control with imazethapyr has been more narrow, it has excellent residual activity. The fact that Clearfield rice is not a GMO may result in faster consumer acceptance. All three technologies are very promising and all three are needed to allow rotation programs for management of outcrossing and herbicide resistance.

Control of red rice (*Oryza sativa* L.) and other difficult weeds in imidazolinone-tolerant (Clearfield™) rice (341)

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Currently there are no herbicides which control red rice (*Orzya sativa* L.) in rice. Other rice weeds are also becoming more difficult to control such as *Cyperus esculentus* L. and herbicide resistant grasses. Imidazolinone-tolerant (ClearfieldÖ) rice is currently under development as a solution to this problem. Field research was conducted in 1998-1999, at the Rice Research and Extension Center, Stuttgart, Arkansas and in a private field near Lodge Corner, Arkansas, to evaluate imazethapyr for weed control in imidazolinone-tolerant rice. Imazethapyr, alone and in combination with other herbicides, was compared to standard rice herbicide programs. A natural population of red rice plus broadcast red rice seed was incorporated into the soil with a field cultivator. The preplant incorporated treatments were then applied and incorporated. All treatments were applied with a backpack sprayer. Plot size was 2.4 m by 6.1 m with 9 drilled rows of rice in the middle of each plot. Herbicide treatments were visually evaluated for efficacy and crop injury. Yields were taken if grain shattering was not severe. Imazethapyr was shown to be very promising for red rice and *Cyperus esculentus* L. control in rice. A sequential treatment of imazethapyr at 0.07 kg a.i. ha^{-1} soil applied followed by 0.07 kg a.i. ha^{-1} postemergence as well as 0.07 kg a.i. ha^{-1} postemergence sequentials provided consistent control of several rice weed species. Red rice and other weeds were also effectively controlled with various imazethapyr programs which utilized other herbicides. Crop injury from 5 to 50 percent has been noted with postemergence imazethapyr applications. This injury prompted the initiation of experiments to evaluate crop response to postemergence applications of imazethapyr. Initial studies evaluating a higher rate of imazethapyr PPI or PRE and lower rates postemergence have been inconclusive. Injury symptoms were evident in many plots regardless of imazethapyr rates used soil applied and postemergence.

Soil conserving cropping systems with herbicide resistant cultivars (342)

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Within the next decades, we must even further increase the productivity of arable crops and at the same time decrease the degradation of soil fertility, a tremendous challenge for scientists and policy makers. Soil conserving cropping systems, ranging from mulch cover combined with minimum tillage to no-till systems can be one solution for these problems. They have become manageable with sophisticated technology but their acceptance by farmers requires that they are easy to implement. Contrary to traditional systems, soil conserving cropping systems must be adapted to regional soil and climate conditions. In a cool temperate climate, an evenly distributed high rainfall allows the implementation of diverse frost-sensitive and frost-hardy cover crops in accordance to ecological and economic needs. Maximum protection against erosion and minimum leaching of nitrate is achieved by a frost-hardy cover and fodder crop if it can be reliably controlled in a transgenic herbicide resistant maize (thr) crop after the first regrowth. In regions with less rainfall, frost-sensitive cover crops are preferable but they do not suppress weeds and volunteer crops well enough. But within a thr crop, their control can be delayed up to a defined threshold level. These (up to now theoretical) advantages regarding a more precise management of soil conserving cropping systems demands for Europe an acceptance of transgenic products but even more a diligent use of the few available broad spectrum herbicides!

Glyphosate-tolerant soybean and weed management in Argentina: present and prospects (343)

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In Argentina, the planted area with glyphosate tolerant soybean represents approximately 90% of the national soybean area. In spite of this massive adoption, information about the management of this system is scarce. The aims of this study are (i) to give an outlook of the information generated in the country dealing with weed management in glyphosate tolerant soybean, and (ii) to discuss probable weed population shifts as a consequence of the generalised adoption of this technology. Glyphosate is a non-residual herbicide, so the timing of application is crucial to maximise crop yield. Weed control should not be delayed more than three-four weeks after soybean emergence in order to avoid early competition. On the other hand, earlier applications could allow the competition of weeds emerged afterwards. The length of the critical period for weed control is variable and dependent on different genetic, agronomic and environmental factors. At times, a single glyphosate application is not enough to optimise weed control, and either more than one application or mixtures with residual herbicides are needed. No cases of weeds resistant to glyphosate have been reported in Argentina up to date. However, some weed species have shown certain degree of tolerance. In addition, herbicide selective pressure might favour those weed species with longer and later emergences. In a broad sense, the generalisation of glyphosate-tolerant soybean would tend to solve weed problems in the soybean area, characterised by both the absence of crop rotations and a heavy dependence on herbicides. More biological information is needed in order to design integrated weed management programs. This seems to be the most reliable strategy to avoid the oversimplification that the high adoption of the new technology represents.

Transgenic soybean revolutionizes perennial broadleaf weed management (344)

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Perennial broadleaf weeds are difficult to control in soybean. While these species may be suppressed in rotational crops, many perennials survive to be a management challenge in soybean, particularly in no-tillage systems because their root systems are not damaged. Glyphosate-resistant soybean offer new options to control perennial broadleaves, not only the season of application but hopefully for one or more seasons later. We have done field trials for five seasons in Wisconsin, USA to evaluate the performance of glyphosate on *Apocynum cannabinum* L. in glyphosate-resistant soybean grown in zero and reduced tillage systems. In 1995, four glyphosate rates (0.63, 0.84, 1.25 and 1.68 kg a.e. ha^{-1}) and four stages of weed development (vegetative, bud, early flower, full flower), plus several split application sequences, were tested. In 1996, a second trial on *A. cannabinum* tested the same glyphosate rates used in 1995 at two weed growth stages (vegetative and early flower). In 1997 and 1998, the four glyphosate rates and two treatment times were tested on *Cirsium arvense* (L.) Scop. and *Asclepias syriaca* L. and in 1999 we launched trials on *Mirabilis nyctaginea* (Michx.) MacM. Standard application methods, spray volumes and additives, experimental design, and data collection and analysis were employed. Visual weed ‘‘pressure’’ ratings were taken at the start of the trials, at the end of the first season, and one year after glyphosate application. All trials lead to a similar conclusion: a single application of glyphosate at 0.84 kg a.e. ha^{-1} gives excellent perennial broadleaf control the year applied and greatly reduces the weed’s density the next season. Application timing is more important than glyphosate rate: treat when the weed begins to flower and then a second application is not needed. The results can be summarized into a ‘‘three steps for success’’ program of perennial broadleaf weed management in glyphosate-resistant soybean. 1. Plant soybean in a narrow row, no-till system. This allows perennial weeds to develop rapidly and reach the flowering stage earlier than if tillage were done and does not disrupt or bury the weed’s roots. 2. Apply a reduced rate of a soil-active

preemergence herbicide before or at planting. This prevents annual weed competition with soybean while waiting for the perennial species to flower. 3. Apply glyphosate when the perennial weed begins to flower. This is usually 35 to 40 days after planting and later than when annual weeds would be treated.

Ecological cropping techniques for herbicide resistant crops (345)

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In GM-herbicide resistant crops, for the first time in history of weed control, it is possible to choose herbicides according to the environmental requirements and the efficacy for post-emergence weed control in selected crops. To prevent loss of these compounds because of new weed resistance, two main measures are advised: lower the selection pressure and alternation of herbicides. A third possibility will be presented here: change of the weed flora by green ground cover in alternative cropping techniques. Traditionally crops are seeded in an uncovered soil, enabling weeds to germinate. Then weeds are controlled as early and as totally as possible. The new technique is based on green ground cover, either permanent or at least during the establishment of the new crop. A preceding nitrate catch (cover) crop may serve as green cover. The new main crop is seeded in ploughless. The catch crop is kept green as long as possible as ’living mulch’, to prevent new weeds to germinate. Before the green mulch competes with the crop, a timely regulation is necessary. Therefore, highly selective post-emergence herbicides are needed, to control the catch crop and the weed flora efficiently. This flora inludes different species from conventional tillage. Another approach is to use naturally emerging weeds as cover plants, controlled by late post-emergence treatments. Most of the traditional post-emergence herbicides are not effective or not selective enough, but glufosinate or glyphosate in resistant crops are in accordance to this requirements. Therefore, the new herbicides should be used as tools for vegetation management in ecologically sound cropping systems. The green ground cover, in addition to positive environmental aspects, suppresses weeds, favors predators and with this, reduces pests. The technique is well developed in perennial crops, vineyards and orchards. In annual crops positive results have been achieved in maize, sugarbeet and some vegetables. The main problems to be solved are the agronomic techniques and their implementation.

Impact of herbicide-resistant maize varieties on rotational systems (346)

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Portuguese maize farmers preparing for autumn-winter crops currently use reduced tillage. Straw from the maize harvest is either left on the soil surface or it is lightly incorporated into the soil preceding autumn sowing. The introduction of herbicide resistant maize into this system is as yet unknown. A study on the possible effects of straw from four maize varieties resistant to glufosinate-ammonium (codes 98020; 98019; 96097; 96099) in the subsequent growth of wheat, chickpea, sugarbeet, alfalfa and vetch was undertaken in greenhouse conditions from May-December 1999. Control maize varieties were Anjou285, Cecilia, Prègia, and Costanza, respectively. Equal fresh weight portions of straw from each maize variety were buried in pots containing inert soil substrate. Four months later, this substrate was homogenised and separate pots were sown with: wheat (5 seeds), sugarbeet (5 seeds), chickpea (5 seeds), alfalfa (100 seeds), and vetch (5 seeds). Ten replicates were made per crop. Following a 30-day growth period, the plants were cut and weighed. There was a significant reduction in the fresh weight of all species grown in substrate containing herbicide resistant maize straws in comparison with those grown with non-resistant straws. For wheat, this reduction was between 14.8% (98019) and 40.4% (96099); for sugarbeet, between 18.7% (98020) and 32.1% (98019); for chickpea, between 4.5% (96097) and 31.1% (98019); for alfalfa, between 29.8% (96097) and 49.8% (96099); and for vetch, between 28.7% (96097) and 45.8% (98019). The growth of wheat and alfalfa was most affected by straws of the 96099 variety, whereas sugarbeet, chickpea and vetch were most sensitive to the 98019 variety. Overall, the most sensitive crop was alfalfa growing in soil containing the 96099 straw variety (49.8% reduction). Field tests are now required. Also of interest is a broadening of this research into other disciplines, namely molecular biology, allelopathy and plant nutrition.

Growing transgenic cotton under ultra narrow rows without soil-applied herbicides (347)

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Transgenic cotton is gaining popularity in the United States. Cotton cultivars engineered for resistance to glyphosate (RR), and to bromoxynil (BXN) provide an alternative tool for weed management that complements tillage and ultra narrow row (UNR) technology. RR cultivars with *Bt* gene for insect resistance (BG) could reduce pesticide inputs while maintaining productivity. Studies were conducted in 1999 at Fayetteville and Little Rock, Arkansas, USA to evaluate the performance of transgenic cotton under different cultural and weed management programs. The Fayetteville location was irrigated; Little Rock was not. Cultivars used were PM1220 BG/RR, SG125 BG/RR, DP450 BR, and BXN47. Herbicide programs included (a) preemergence (PRE) followed by postemergence (POST) and (b) postemergence herbicide application only. Preemergence herbicides used were fluometuron and metolachlor. Postemergence herbicides were either glyphosate-isopropyl amine or bromoxynil. Pyrithiobac was also applied to BXN cotton, POST, as needed to complement bromoxynil. Cotton was planted under conventional wide rows (1 m), or ultra narrow rows (0.2 m). Growth parameters, including square development and boll retention, and yield were evaluated. UNR suppressed weed growth between rows but reduced canopy width of cotton 38 to 42% compared to conventional row spacing. Intraspecific competition, shading, and limited branching of cotton in UNR reduced boll load to one to two per plant in both locations. Increased plant density in UNR did not compensate for low boll numbers per plant. This resulted in 72% higher seed cotton yield in conventional row spacing compared to UNR, averaged over cultivars and herbicide programs, in Fayetteville. There was no yield difference among glyphosate-resistant cultivars. RR cultivars yielded better than BXN47 with or without soil-applied herbicides. Omission of preemergence herbicides reduced yield in all cultivars in Little Rock where initial weed density was high. The need for preemergence herbicides was more pronounced with BXN47 because bromoxynil has limited spectrum of activity.

Bromoxynil resistant cotton in the California production system (348)

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Field studies were conducted from 1997 to 1999 to evaluate weed control efficacy and the tolerance of bromoxynil resistant cotton to bromoxynil applied at the cotyledon to 2-4 leaf cotton and post directed at layby. Bromoxynil provided 95 to 100 percent control of most annual broadleaf weeds tested including *Datura ferox, Solanum spp., Chenopodium album* and *Abutilon theophrasti*. Best control was achieved with one application of bromoxynil at 1.12 kg a.i. ha^{-1}, but most weeds were also completely controlled with the 0.56 kg a.i. ha^{-1} rate. Control of *Amaranthus spp.* was erratic and poor to moderate at all rates tested. Control ranged from 15 to 80 percent, but when bromoxynil was tank mixed with any of the selective grass herbicides (clethodim, fluazifop-p or sethoxydim) control was reduced to a completely unacceptable level of 5 percent. There was no advantage in control of the above weed species when bromoxynil was applied in a tank mix with pyrithiobac sodium or MSMA. Control of *Ipomea spp.* has been slightly more difficult. Bromoxynil applied over the top to *Ipomea spp.* provided acceptable control for 35 days when followed by a post directed treatment. Either a single over the top or single later post directed treatment provided unacceptable control. At 90 days after treatment, control was also unacceptable with an over the top followed by a post directed treatment. Best control was achieved when bromoxynil was applied to *Ipomea spp.* with 2 or fewer leaves and control was enhanced when tank mixed with MSMA.

Introgression: occurrence vs. consequence (349)

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One of the major ecological questions being raised about the introduction of herbicide-resistant crops is whether the gene will be transferred to wild relatives. Crops will hybridize with wild relatives and gene transfer between species does occur. The question should address not whether herbicide-resistance genes will be transferred to wild relatives but rather what is the consequence of that movement once it has occurred. Gene transfer from the crop to a wild relative does not translate automatically into a problem unless the herbicide-resistance gene increases the weed species' competitiveness or reproductive success. The addition of a herbicide-resistance gene may or may not provide an advantage for a weed species. In order for gene flow via hybridization to occur between cultivated crops and wild species, several criteria must be met. There must be synchronous flowering, the trait must be carried in the pollen, pollination must occur, and fertile hybrids must be produced within only one to a few generations. The gene must either incorporate into the genome of the wild relative or become a component of the genome of a new species. Backcrosses between the hybrid and either the cultivated or wild relative will play a significant role. Progeny of any of these crosses might carry the herbicide-resistant gene. Gene expression varies with genetic background so it may be difficult to predict the effect a resistance gene may have when it is incorporated into a genome. We should not make broad assumptions about the release of a herbicide-resistance gene into the environment through pollen movement. Each crop release needs to be assessed on a case-by-case basis to determine the potential for hybrid formation and the impact of the gene movement on management of the weed species. The risk of gene transfer may be higher in the center of origin of a crop or when the crop and a related weed species are grown under cropping systems which promote evolutionary selection.

Introgression from cultivated to weedy sunflower populations (350)

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Cultivated sunflower (*Helianthus annuus*) is one of the few crops in the USA that freely crosses with a widespread and economically important weed (common sunflower, also *H. annuus*). Sunflowers with transgenic resistance to insect pests, diseases, and herbicides are currently being field-tested by several biotechnology companies, and requests for deregulation of these lines are likely to be made within the next few years. The long-term goal of our collaborative research is to document the extent to which crop genes persist in wild populations and to determine whether beneficial crop genes lead to enhanced seed production in weedy relatives. Our previous studies show that crop genes move to nearby wild populations and persist for many generations. To examine this process in more detail, we established experimental field populations with known frequencies of crop genes in eastern Kansas. Plants that had been screened for unique allozyme markers were used to create F1 crop-wild hybrids (hereafter referred to as hybrids) and purely wild plants for comparison (the wild genotypes were from Kansas). In 1997, these two types of plants were used in three replicate populations with an initial composition of 50% hybrid and 50% wild (200 plants per population). Seeds were sampled in 1997 and 1998, and at least 500 seeds per population per year were scored for crop-specific allozyme markers. This experiment showed that the frequency of crop alleles dropped dramatically, from 0.25 in the parental generation, to 0.02 - 0.10 in subsequent generations. We identified several factors that were responsible for the lower transmission of crop alleles to the next generations. First, the hybrids bloomed about one month earlier than wild plants, with little overlap in flowering times, so this severely limited opportunities for backcrossing with wild plants. Second, the hybrids were smaller than wild plants, and we estimated that the average hybrid produced about 30-fold less pollen and seeds than the average wild plant. Finally, seed-eating insects and small mammals preferred hybrid seeds. Therefore, relatively few crop genes were transmitted beyond the F1 generation in this experiment. However, our other studies have shown that flowering times of hybrids and wild plants sometimes overlap much more extensively, and the numbers of seeds produced by each type of plant may be quite similar. Therefore, it seems inevitable that some crop genes will escape into wild populations, and their frequencies will vary a great deal from place to place and year to year.

Superweeds and transgenic plants: a risk balance analysis (351)

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There have many papers written about weediness. There is, derived from a plethora of attempts to define weediness, only one conclusion to be drawn: there is no definition working on a world wide basis. This is contradicted by the fact, that there are indeed weeds with a global career. These rather controversial thoughts should demonstrate that we are still far from understanding what really happens in all kinds of habitats, from pristine forests to the worst and nearly fully destroyed habitats of industrial sites. High mobility and habitat destruction can be limited, but never will we be able to controll these processes to a degree, which would allow to eliminate these major causes of plants and crops turning into weeds. Mobility, urbanisation and industrialisation are by far the most important factors triggering the biggest genetic experiment mankind has ever started with plants. This mega-experiment is still going on, accelerating in many aspects, and ecological concerns are justified. It is good to know that there are also many factors working against an uncontrollable situation: As soon as any kind of monoculture is growing, either caused by agriculture or any kind of highly successful innovation, new pests will take the challenge on, since new niches for any kind of herbivores and their predators will be offered. The above mentioned genetic experiment also has brought forward many new hybrids, a result of a breakdown of geographical barriers on all scales, new plant species have been born, which tend to occupy new ecological niches, yet another surprise. The question is therefore justified, if breeders, regulators and farmers should risk the spread of transgenes through hybridization. The few known cases of escaped transgenes do not cause (up to now!) any kind of damage, and it is highly unlikely, that this will happen on the long run with the present day transformation events. There is only a very remote possibility that escaped transgenes will cause the formation of superweeds. And if this happens, it will simply add to the list of already existing ones. In Switzerland alone, we know of a dozen of herbicide tolerant weeds through mutation. But what happens, when farmers will be named pharmers, when we will have to risk consuming mustard with transgenes producing bioplastic or hirudine? There are several possibilities to be evaluated as a remedy: 1) We will have to carefully analyse the outcrossing potential with methods meeting the needs of the precautionary approach. 2) It will be of great importance to develop strategies for a biological containment (transplastomic transformation, apomixis of all kinds). Both methods need further development and thorough testing. 3) Wherever possible, the production of environmetally potential hazardous transgene products should be done with microorganisms in physical containments, for which a safe use is established already for a long time. 4) In a limited number of cases, the production of precious and complex products by higher plants can be confined to glass houses.

Gene flow from cultivated crops to weedy relatives (352)

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Gene flow between crops and their wild relatives is an important concern to risk assessment of genetic modified organisms (GMO). Indeed, transfer of herbicide resistant genes could impair the benefits of using transgenic resistant crops and create new herbicide resistant weeds. Three different plant models, with regards to reproduction system, are studied in our laboratory in the framework of European INCO-DC and national programs. Autogamous crops are wheat and foxtail millet, predominantly self-pollinated crop is oilseed rape, and allogamous crop is sugar beet. Dalapon resistance is engineered in wheat; atrazine, trifluraline and sethoxydim resistance are conventionally breeded in millet, and engineered glyphosate and glufosinate resistance are used in oilseed rape and sugar beet. For all these species spontaneous cross-fertilisation have been proved to occur with weedy relatives. We present a review of studies concerning degree of cross-fertilisation, possibility of introgression and influence of recipient weed populations on gene flow. The more advanced study of sugar/weedy beets is used to illustrated the influence of the incompatibility and plant density of the recipient target on gene flow. It is shown that incompatibility has a low effect on gene flow and that density is the major component system to understand gene escape. Such a knowledge is necessary to design efficient agronomic management of herbicide resistance and provide farmers with guidelines to grow GMO.

Classical biocontrol - update and global issues (353)

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The classical approach of biological control of weeds involves the introduction, establishment and self-sustenance of herbivores or pathogens from the native range of the target weed into an area where the weed has naturalised and become a problem. The aim is to achieve a long-term equilibrium between the population of natural enemies and the weed, and in the process reduce the weed population below the economic or ecological threshold. Classical biological weed control does not generate commercial profit and is largely considered a public good. This paper provides an update of the current trends and challenges in the research and practice of classical biological control. International collaboration between researchers has increased considerably in recent years, with transfers of successful biological control programs from one country to another and simultaneous ecological studies on weedy species in native and exotic habitats. There is a tendency now to follow a more strategic approach in the selection of biological control agents and introduce agents that attack different parts of the weed life-cycle. A better knowledge of the genotypes of the target weeds, facilitated by the increasing availability of molecular tools, has also contributed to more effective agent selection. The integration of classical biological control with other weed management tools, such as herbicides and grazing, is considered a promising option to optimise agent impact. Risk assessment continues to be a major component of classical biological control programs. The use of molecular phylogenies has streamlined the selection of plant species for host-specificity testing of the agents. Comprehensive monitoring of the impact of agents in the field has increased significantly in recent years, although funding for such activities is still difficult to obtain. There is also increasing pressure to monitor any direct or indirect effects that some biological control agents may have on non-target organisms after release.

Problems and practice of classical weed biocontrol using pathogens (354)

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Whilst classical weed biocontrol is a tried and tested ‘‘technology’’, most of the examples have involved insect agents and the use of pathogens remains a relatively new and poorly resourced strategy, and thus can be said to be still on a learning curve. The deliberate introduction of any exotic organism into a new ecosystem involves a degree of risk and for pathogens this risk is often considered to be significantly higher compared to insects. This pathophobia, shown by both quarantine authorities and the general public alike, has been identified previously and evidence is presented to support its existence. Central to the pest risk assessment for classical biocontrol agents is a centrifugal, phylogenetic testing method, whereby plant species, selected on the basis of taxonomic relatedness, are screened against the target pathogen, typically a coevolved biotrophic or hemibiotrophic fungus, under predetermined optimum conditions for infection. In addition to a macroscopic evaluation, host-pathogen interactions are investigated at the microscopic level using a clear-staining technique. The resistance mechanisms identified so far are presented and the ambiguous results sometimes obtained are analyzed. Simulation of more natural infection conditions, by using a wind tunnel for example, may need to be employed to interpret correctly some misleading host-pathogen associations, and thus allow for a more reasoned prediction of a pathogen's behaviour once released in the field situation. The problems and practice of using pathogens, in particular rusts, smuts and powdery mildews, against invasive weeds in both the Palaeo- and Neotropics, are discussed.

Creating a framework for the successful implementation of weed biological control (355)

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During the last decade, two government initiatives have shaped the conduct of scientific research and the delivery of research results to the agricultural and environmental sectors in Australia. Firstly, to foster collaboration between researchers, the government provided funding for the creation of Cooperative Research Centres (CRCs). In the CRC process, organisations working in related areas form joint ventures to pool their diverse skills and carry out collaborative research. A successful CRC bid gains access to additional funding over seven years to fill gaps in research skills, promote synergies between the partner organisations needed to achieve the CRC objectives, and communicate research results to the end-users. At the same time, the Landcare movement, a highly successful model of community action that evolved to reverse land and water degradation and move toward more sustainable resource use, was developing rapidly amongst landholders in Australia. Landcare is very much a grass-roots process, driven by the needs of small groups sharing common problems, even though government provides support and funding for the objectives of individual groups. While these initiatives were not directed specifically at biological control, weed researchers have been quick to see their potential and capitalise on them. Weed biological control researchers have been involved in two CRCs, the Centre for Tropical Pest Management (1991-98) and the ongoing Cooperative Research Centre for Weed Management Systems (1995-2002). Moreover, many Landcare groups now form part of networks for redistributing and monitoring the impact of biological control agents. This paper describes how the two processes, one top-down and research-driven (CRC) and the other bottom-up and client-driven (Landcare), have been harnessed to create a framework for more effective biological control in Australia. Together they have greatly sped up the delivery of biological control to end-users and increased the awareness of the benefits and limitations of this management option.

Classical biological control of weeds with pathogens: a Latin American perspective (356)

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The exploitation of pathogens as classical biological control agents is a relative new, but growing approach to the control of exotic, invasive weed species. The traffic in weedy species from the New World to other regions has been substantial and natural enemies have been utilised for nearly a century, in an attempt to reduce the impact of these invasive plants. There are nine examples where pathogens from the New World have been released as classical biological control agents in other regions, and many more are currently being assessed. In Latin America, this method of weed management is much under exploited, despite the presence of a significant number of exotic weed species, invading both natural and agricultural ecosystems. For a number of these potential targets a coeveolved and damaging mycobiotia has been recorded, and seven weed examples are assessed. Despite this, Latin America does have a disproportionately low number of exotic invasive plant species when compared to other regions of the world. Possible reasons for this are discussed.

Abundance of *Araecerus fasciculatus* (Degeer) (Coleoptera: Anthribidae) on two woody weeds *Parkinsonia aculeata* L. and *Prosopis juliflora* L. in Hambantota District in Sri Lanka (357)

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Parkinsonia aculeata L. and *Prosopis juliflora* L. are recognized as widely distributed and major woody weeds of arid zones in Sri Lanka. Control of these two weeds for agriculture practices is one of the major issues in Hambantota District. The pods of *P. aculeata* and *P. juliflora* are found to be attacked by the Anthribid weevil, *Araecerus fasciculatus* (Degeer). The present study is concerned with the abundance of *A. fasciculatus* on *P. aculeata* and *P. juliflora* in different locations in Hambantota District during June 1998 to April 1999. Once a month, hundred pods of each weed host were taken from eight experimental sites and the daily emergence of *A. fasciculatus* on both weed hosts was recorded. Analysis of variance for total emergence of *A. fasciculatus* on two weeds was conducted according to a complete randomized block design. The analysis of mean abundance of *A. fasciculatus* on *P. juliflora* and *P. aculeata* was computed by using t-test. ANOVA showed that there was a significant difference between the abundance of *A. fasciculatus* on *P. aculeata*. The highest abundance of *A. fasciculatus* on *P. aculeata* and *P.juliflora* between mid-August and mid-January was coincident with low rainfall and low wind velocities. In contrast, high rainfall and low wind velocities decreased abundance of *A. fasiculatus* on *P. aculeata* and *P. juliflora*. The two distinguishable abundance of *A. fasciculatus* on both weed hosts that roughly followed two growing seasons ‘‘Yala’’ and ‘‘Maha’’ respectively. The increased infestation levels of *A. fasiculatus* on *P. juliflora* and *P. aculeata* is encouraging for further development of a weed control programme for *P. aculeata*, as reduction could be made in the use of other control measures such as herbicides and mechanical control.

Biological control of *Miconia calvescens*, the ‘‘cancer vert’’, with fungal pathogens: present and prospects (358)

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Miconia calvescens, is a small tree native of the American Tropics from Southern Mexico to Brazil. Once a botanical curiosity, Miconia is now the most devastating plant invader in Tahiti and Hawaii and is now threatening other Pacific island forest ecosystems. Introduced to Tahiti as an ornamental in 1937, *M. calvescens* spread into the Island’s native forests, to form monotypic stands of *Miconia* trees. It is estimated that more than 65% (70,000 ha) of the forested areas have been displaced by *M. calvescens*. In Tahiti, *Miconia* in now often called the ‘‘cancer vert.’’ Similarly in Hawaii where it arrived in the 1960s, miconia infests 40,000 ha on the island of Hawaii and 160 ha on the island of Maui. The search for natural enemies, initiated by entomologists (1993-1994) did not yield any potential biological control agent under Hawaiian conditions. A subsequent search for fungal pathogens began in 1995, and covered Brazil, Dominican Republic and Costa Rica. A rich pathogenic mycobiota was obtained from this plant including: *Pythium* sp.,

Ceratobasidium sp, *Corticium* sp., *Coccodiella miconiae*, *Glomerella cingulata*, *Guignardia* sp. *Phyllachora* sp., *Melanconium* sp., *Myrothecium* sp., *Pseudocercospora* sp., *Phomopsis* sp. and *Pestalotiopsis* sp. Besides fungi, a damaging species of nematode attacking miconia leaves and a severe witches broom disease, caused by a MLO, were also collected. The first pathogen to be collected and studied in detail was *G. cingulata* (antracnose). This fungus was recognized as host-specific to M. calvescens, after host-range tests were performed and introduced into Hawaii in 1997. Recently, damaging outbreaks of *Miconia* antracnose were observed, at sites unexpectedly distant from release sites. Other candidates such as *Pseudocercospora* and *C. miconiae* are also being studied and a complementary host-range testing for *G. cingulata* is being carried out in order to satisfy the requirements for its introduction in French Polynesia.

Host specificity studies of the thrips *Pseudophilothrips ichini* (Hood) (Thysanoptera: Phlaeothripidae), a potential biocontrol agent for *Schinus terebinthifolius* Raddi (Anacardiaceae), in the United States (359)

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Schinus terebinthifolius (aroeira, Brazilian peppertree) is an evergreen shrub or small tree native to Argentina, Paraguay and Brazil. Introduced into United States as a landscape ornamental in the 19th century, *S. terebinthifolius* readily invades disturbed sites as well as natural communities where it forms dense thickets of tangled woody stems that completely shade out and displace native vegetation. This invasive plant is a major problem for natural resource managers because it reduces the biodiversity of the native plant and animal communities. In addition, direct contact with a toxic resin present in the leaves, flowers, and fruits can irritate the skin and respiratory passages of sensitive humans. One of the strategies being investigated for management of *S. terebinthifolius* in Florida and Hawaii is classical biological control. *S. terebinthifolius* is considered a good candidate for biological control because large scale mechanical removal and herbicide applications are expensive and ecologically disruptive. Also, the environmental risks associated with the release of host specific natural enemies would be acceptable because no native congeners of the genus *Schinus* occur in the United States. Exploratory surveys conducted in Brazil produced several promising insect natural enemies. One of the insects identified as a potential biocontrol agent for *S. terebinthifolius* is the thrips *Pseudophilothrips* (=*Liothrips*) *ichini*. Feeding by the nymphs and adults kills the meristems and causes flower abortion. This type of feeding damage can suppress the growth rate of young plants and curtail seed production in mature trees. Host specificity studies (non-choice and multiple choice feeding and oviposition tests) were conducted with 30 plant species in 11 families. Although *S. molle* L. (aroeira salsa, California peppertree), and mango, *Mangifera indica* L. were utilized as developmental hosts in non-choice laboratory tests, field surveys in Brazil confirmed these economically important non-target plants are not attacked by *P. ichini* under natural conditions.

Fungal pathogens from Argentina as potential biological control agents for invasive *Nassella* tussock grasses in Australia (360)

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Nassella trichotoma and *N. neesiana* are native to South America and were accidentally introduced into Australia in the early 1900's. Since then, *N. trichotoma* has spread widely in New South Wales and Victoria and is now classified as a noxious weed in both states. The reduction in productivity of pastures infested with this weed has recently been estimated to cost more than AU$40 million per year. *N. neesiana* is becoming a serious environmental weed in south-eastern Australia and is also regarded as a threat to pasture productivity in that region. Both weed species have the ability to dominate large areas of highly productive pasture, displacing palatable pasture species and greatly reducing stocking rates. In the absence of effective herbicides to control the spread of these species in Australia, New Zealand or South Africa, a project to investigate the use of fungal pathogens as potential biological agents was commenced by the CRC for Weed Management Systems in Argentina in August 1999. Initial findings of field surveys and laboratory research on potential fungal biological control agents in Argentina are outlined in this poster.

***Mycovellosiella lantanae* var. *lantanae*, a potential biocontrol agent of *Lantana camara* in South Africa** (361)

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Lantana camara L. (Verbenaceae) is a poisonous, bushy shrub from South and Central America which has invaded many forest and plantation margins, savanna areas, watercourses, roadsides and degraded lands in predominantly warm moist sub-tropical and temperate areas of South Africa. Until recently plant pathogens have largely been ignored as potential biocontrol agents for *L. camara*. Samples of diseased *L. camara* leaves were collected during surveys in South and Central America from 1987 until 1997. An isolate of the fungus, *Mycovellosiella lantanae* (Chupp) Deighton var. *lantanae*, which causes symptoms ranging from small, chlorotic to large necrotic leaf spots and extensive defoliation in some areas, was collected in Florida, USA from severely diseased and defoliated plants. Inoculations onto South African biotypes of *L. camara* and a number of closely related species within the family Verbenaceae were made in quarantine, to determine its host range. Results showed that this pathogen has a very restricted host range, making it a promising control candidate which should reduce the vigour and reproductive potential of *Lantana* biotypes in South Africa. Other *M. lantanae* var. *lantanae* isolates from Florida are presently being screened to identify those more pathogenic to the South African biotypes of *L. camara*. Preliminary results show that no single isolate is pathogenic to all the South African biotypes and the use of a mixture of the most promising isolates for maximum control is being considered.

The use of fungi as biological control agents of alien invasive species in South Africa during the last decade (362)

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This past decade has seen the successful implementation of a number of biological control strategies aimed at controlling alien invasive weed species in South Africa through the use of fungal agents. Both classical and mycoherbicide approaches have been adopted. Target weeds have been *Acacia mearnsii*, *Acacia pycnantha*, *Hakea sericea*, *Acacia saligna*, *Eichhornia crassipes*, *Chromolaena odorata*, *Lantana camara*, *Myriophyllum aquaticum* and *Rubus cuneifolius*. Two mycoherbicides have been developed, namely a formulation of *Cylindrobasidium laeve* (Stumpoutâ) which kills cut stumps of *Acacia mearnsii* and *Acacia pycnantha*, and *Colletotrichum gloeosporiodes* (Hakatakâ) which kills seedlings and adult plants of *Hakea sericea*. The Australian gall-forming rust, *Uromycladium tepperianum*, released in 1988/89 is having a major impact on stands of *Acacia saligna* throughout the distribution of this weed. Studies on biological control of *Eichhornia crassipes* with South African isolates of *Acremonium zonatum*, *Alternaria eichhorniae* and *Cercosopra piaropi*, and the Brazilian rust fungus *Uredo eichhorniae* are ongoing. A South American leaf pathogen, *Mycovellosiella lantanae* var. *lantanae* has proved host specific to *Lantana camara*, and clearance for release in South Africa is pending. Current research on control of the South African form of

Chromalaena odorata, aims at finding suitably virulent isolates of the South and Central American pathogens *Pseudocercospora eupatorii-formosanii*, *Mycovellosiella perfoliata* and *Septoria ekmaniana*. Research showed that a strain of *Xanthomanas campestris* which causes a wilt on the aquatic weed *Myriophyllum aquaticum*, holds limited potential as a biological control agent because the bacterium does not penetrate into the older underwater stems, and plants recover after inoculation. The rust *Gymnoconia nitens* has been rejected as a potential agent against *Rubus cuneifolius* because of lack of host specificity.

Ecological benefits of classical biological control agents (363)

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The ecological benefits that are derived from completely successful biological control programmes are obvious and, for the most part, are the converse of the ecological damage that is caused by the invasive plant species. However, biological control alone seldom reduces the target weed species to levels where it is an insignificant component of the ecosystem. This may be because the plants are able to compensate for the damage caused by the introduced agents or because the agents have been especially selected to destroy a particular part (e.g. the seeds) rather than the whole of the plant. In cases where the target weed remains abundant in spite of biological control, substantial ecological benefits may be derived through, among others: (i) decreased dependence on alternative control methods which often cause ecological disruptions; (ii) increased water flow in riparian habitats; and (iii) restrictions on the dispersal and invasive capabilities of the problem plants. Meticulous evaluation studies are needed to determine how best to manipulate the introduced agents and thereby fully exploit their limited potential.

Negative impacts of classical agents used for weed biocontrol (364)

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Two introduced weed biocontrol agents are having potentially serious impacts on valued non-target plant populations in the USA, challenging the claim of classical biological control that it is environmentally safe. Other work suggests that these two examples may be the only cases of significant non-target impacts on native plants in the total of nearly 500 releases of insects, mites or fungi for weed biocontrol worldwide: a safety rate of 99.6%. However, many non-target impacts could be missed because of a lack of appropriate ecological studies. Another negative effect from the biocontrol of a plant can occur where the target is a weed to some people, but useful to others. This paper considers non-target impacts, and conflicts of interest, in a broader framework of all potential negative effects of classical biocontrol agents. Such a framework is provided by the new Hazardous Substances and New Organisms Act in New Zealand. The act requires the identification of risks from a new organism to a wide range of values and issues, including: the physical environment and ecosystems, economic, social and cultural well-being, native and valued introduced flora and fauna, public health, the culture and traditions of Maori, and New Zealand's international obligations. The utility of this framework is illustrated using examples from current biocontrol programmes in New Zealand and elsewhere. The most difficult and controversial negative impacts remain those concerning desirable fauna and flora. It may be useful to view classical biological control as the addition of a new plant-feeding species into an existing food web that already contains indigenous and alien components. At the very least, this approach will highlight the difficulties in identifying, measuring or predicting negative, and positive, perturbations in food webs caused by new biocontrol agents, over different spatial and temporal scales.

Economic benefits of classical biological control (365)

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Classical biological control of weeds has a good safety record, but a somewhat scanty track record of documented economic benefits. Most of the funding for biocontrol projects is utilized during the foreign exploration, host specificity testing, and introduction phases, with little appropriated for long term efficacy studies. Biocontrol projects should be evaluated in advance to estimate benefit cost ratios and internal rates of return under variable subjective scenarios and to periodically document the actual effects. Global establishment rates of biological control agents vary from 30-90% and successful biocontrol projects comprise about 25% of the attempts. Reported benefit cost ratios vary from 112/1 to 2/1. Biocontrol of *Senecio jacobaea* L. (Asteracaeae), in Oregon, yielded an 85% internal rate of return and a 15/1 benefit cost ratio. On successful long term projects, benefits can occur as steady stream returns, i.e., $5 Million US/ year for the *S. jacobaea* project in Oregon, where annual agency investment is now less than $10,000 US per year. Where it is biologically feasible, it is economically justifiable to expeditiously implement biocontrol in order to reduce annual losses in the shortest time possible. By actively redistributing *S. jacobaea* biocontrol agents, the Oregon program accomplished a successful regional project 5-10 years sooner than by the natural spread of the insects, averting $25- $50 million in losses to agriculture. A partially successful biocontrol project, i.e., one that reduces weed infestations by variable percentages over large areas, can still provide a positive benefit cost ratio, even though the degree of weed control may be less than desired. If biocontrol in Oregon reduced the top 12 weeds by 30%, annual losses could decrease by $20 million US. Where biocontrol is successful, land use must be compatible in order to prevent a ‘‘treadmill’’ of replacement weeds that could create new economic losses and need for new biocontrol projects.

Natural impact and potential for biological control of two selected antagonists of the parasitic weeds *Orobanche* spp. and *Cuscuta* spp (366)

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Parasitic weeds of the genus *Orobanche* and *Cuscuta* cause serious damage in several crops in the Mediterranean region. In Morocco, *Orobanche crenata* is the most important problem in food legumes and *Cuscuta campestris* occurs in vegetables. *Phytomyza orobanchia* (Diptera: Agromyzidae) has been identified as a herbivore of *Orobanche* spp. and *Smicronyx pauperculus* (Coleoptera: Curculionidae) of *C. campestris*, respectively. Yearly investigations on the natural impact of both herbivores have been carried out from 1994 to 1999 in the Sa’ss region in central North of Morocco. The natural infestation of seed capsules of *O. crenata* parasitising faba bean was 49, 45, 55, 51 and 44% in 1994, 1996, 1997, 1998 and 1999, respectively. The infestation of seed capsules by larvae of *P. orobanchia* causes a seed reduction between 99 and 96 %. The infestation of *C. campestris* seeds varied between 29, 4, 17 and 60 % in the years 1994, 1996, 1997 and 1998, respectively. Variations in the infestation of seed capsules under natural conditions are mainly caused by climatic factors. The use of *P. orobanchia* as a bio-control agent for *Orobanche* spp. is currently investigated showing a high probability of success in an inundative control approach. With regard to *S. pauperculus*, further research on host specificity, biology and its population dynamics is needed before this herbivore can be considered as a bio-control agent for *C. campestris*.

Impact of the introduced Mexican beetle *Zygogramma bicolorata* on the suppression of *Parthenium hysterophorus*: a case study (367)

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The Mexican beetle, *Zygogramma bicolorata* (Coleoptera: Chrysomelidae), imported in India during 1983 from Mexico was released at Vindhyanagar (District Sidhi of Madhya Pradesh, India) in 1991 for the management of *Parthenium* through biological control. A study revealed that by August 1998, the beetle had spread up to 35 km from the release point. Beetle and larval populations at Vindhyanagar were recorded throughout the year on *Parthenium* plants. Population density was recorded highest in the month of August and September and lowest in the month of December and January. The eetle was found to survive and defoliate *Parthenium* even during high temperature if microclimate of the place was suitable. The damage study showed positive correlation in decrease in defoliation intensity and beetle density corresponding to distance from the releasing point of the beetle. The beetle was found to defoliate *Parthenium* populations in patches corresponding to the build up of the population. It was observed that, at a particular site, larval and adult populations of the beetle may be very high and they are able to defoliate *Parthenium* completely but the population may remain low in adjacent sites. This defoliation pattern clearly demarcated between the complete defoliated patch and un-defoliated patch adjacent to each other. Leaf area study also revealed the damage potential of the beetle during damaged and non-damaged sampling. Data showed that up to three years, there was no significant impact of the beetle and the release of the beetle was considered a failure but, in the fourh year of its release, a significant impact in the reduction of *Parthenium* populations was found. By the end of 1998, the area up to 10 km from the released point was cleared by the beetle during rainy season except at a few places. The population buildup of the beetle was progressive in the less population buildup area. Action of this introduced beetle brought definite impact on the suppression of the *Parthenium* populations which enable local vegetation to re-establish.

Decoding resistance to biological control: *Aculus* mite and St. John's wort (368)

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Hypericum perforatum (St. John's wort) has been a perennial weed of rangelands and natural ecosystems in the southeastern states of Australia for over 100 years. The plant produces the phototoxin hypericin, resulting in stock losses and lowered production. In the past, the impact of biocontrol agents on the weed in Australia has not matched the spectacular success seen in other countries. The most recent release in 1991, of an eriophyid mite, *Aculus hyperici*, promises improved control at all sites with the exception of several in northern New South Wales, at which failure to establish is apparently due to resistance in the plant. Molecular methods were used to investigate genetic variation in the weed, to which *Aculus* susceptibility has been correlated. AFLP fingerprints resolved 18 distinct DNA profiles among 210 individuals from 40 Australian populations of St. John's wort. Bioassays have confirmed a high level of resistance in two narrow leaf genetic variants, one found at 10 sites in the vicinity of Mudgee (northern NSW) and the other from Weddin State Forest (mid NSW), and a broad leaf variant from Orange (NSW). Susceptibility was variable among individuals with the remaining 15 fingerprints. *H. perforatum* is a tetraploid pseudogamous apomict. In crosses of mite resistant and susceptible plants, the proportion of F1 seedling progeny sharing RFLP microsatellite markers (total genomic DNA restricted with Hae III and probed with M13 phage DNA) with both parents' seed was 23%, of which 60% were hexaploid, the result of fertilisation of unreduced eggsacs. Sexually produced tetraploid F1 progeny therefore accounted for only 9.2% of first generation seed. Preliminary analysis of the backcross indicates that cytoplasmic inheritance of resistance is a possibility however, further analysis of the backcross is needed in order to clarify the situation. If a genomic inheritance hypothesis is supported, a bulked segregant analysis of AFLP markers will be

performed, and markers found to associate with resistance will be screened against all other genetic variants.

Exploration in South America for potential biological control agents of *Heliotropium amplexicaule* Vahl, an invasive weed in eastern Australia (369)

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Blue heliotrope, *Heliotropium amplexicaule* Vahl, is a perennial, spreading broad-leaf weed of temperate South American origin. It was introduced into Australia in the late 19th century as a garden ornamental and now occurs in four states. In northern New South Wales and southern Queensland it has undergone rapid recent spread, in both cultivated pastures and areas of native vegetation. It is considered a serious weed in these areas because it competes with desirable summer pasture species and is toxic to stock. Conventional methods, including herbicide use have had limited success in reducing its impact and have not stopped its spread. In late 1998, a project was initiated in Argentina to survey for potential biological control agents in the native range of the *H. amplexicaule*, and evaluate their potential to control the weed. This poster outlines the results of field surveys and laboratory research on four candidate agents, including a preliminary open-field experiment to determine their host-range. As a result of the studies, two insects, the defoliating chrysomelid beetle, *Deuterocampta quadrijuga*, and the root-feeding flea-beetle, *Longitarsus* sp., have been selected for further study in quarantine in Australia.

Update of developments in bioherbicide research (370)

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An overview of developments in bioherbicides will be presented. Much recent research has focussed on formulation for production, shelf-life and application. Although invert emulsion formulations have shown promise for application, by overcoming dew requirements, they have not been widely adopted for a number of reasons. Several dry formulations such as granules and powder have been used successfully for production and storage of inoculum. However if used as the application formulation, these must await dew, rain or irrigation to begin to act on the target weed. The use of natural and artificial polymers has been the subject of recent investigations. These include gums, polyacrylimides including various combinations and chemical modifications. The interaction between water content and water activity in these systems may be crucial in ensuring their efficacy.

Striga biocontrol - obstacles overcome (371)

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Fusarium oxysporum isolate M12-4A is currently being evaluated for the biological control of *Striga hermonthica*. In field trials, chlamydospore powder harvested from small-scale fermentors reduced *S.*

hermonthica emergence by 92%. Complete inhibition of *S. hermonthica* emergence occurred when the chlamydospore powder was added to the soil at sowing and when sorghum seeds coated with chlamydospores were sown. Effective biological control of *S. hermonthica* was achieved using a simple fermentation system with sorghum straw as the inoculum growth substrate. For inoculum delivery to the farmers' fields, sorghum seeds were coated with the inoculum using arabic gum as the adhesive. This simple delivery system permits a uniform inoculation of the field as well as the proper positioning of the inoculum in the immediate environment of sorghum roots, where *S. hermonthica* attaches to its host. To facilitate a broad usage of *F. oxysporum* M12-4A for the biocontrol of *S. hermonthica*, we are promoting an inoculum production strategy based on a cottage industry model that utilizes a liquid fermentation process and inexpensive locally available substrates including sorghum straw and arabic gum. To assure quality control, primary inoculum is produced centrally and encapsulated in small gelatin capsules as starter cultures. Each capsule contains 0.001 g of inoculum and a 1 kg box of capsules is sufficient to produce Fusarium inoculum for treating up to 8,000 hectares of land infested with *Striga*. In the villages traditional cooking pots filled with water and a small amount of ground sorghum straw are sterilized over a fire, allowed to cool, and the starter culture added. The mixture will ferment for 10 to 14 days, the product is then air-dried and ground, and can be stored for several months. When planting season arrives, the farmers cereal seeds are coated with a thin film of arabic gum solution and the dry powered Fusarium inoculum sprinkled onto the seed surface. The biocontrol becomes a ''seed technology''. The farmer plants his seeds and at the same time protects his crop from the ravages of *Striga*. The application rate of Fusarium is equivalent to approximately 80 grams per hectare. The village-level manufacture of Fusarium will give women in rural communities more economic and social power. The preparation of the dried inoculum both fits into women's traditional sphere of work and provides a new source of income. This year, field testing of the *Fusarium-Striga* biocontrol process is occurring in six Malian villages. We plan to phase this technology in gradually, from village to village and then from country to country, to include all regions afflicted with *Striga*.

Phytotoxins of weed pathogens: good tools for improving biocontrol (372)

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Many plant pathogens are able to produce phytotoxins, bioactive metabolites having different chemical structure, mechanism of action, specificity with respect to the plants, biological activity, environmental impact, and stability. Most of the known and studied phytotoxins are produced by plant pathogens due to the interest in understanding of plant disease caused by agriculturally important toxigenic fungi. In the last decades, thanks to the increased interest in weed biocontrol using pathogens, many weed pathogenic microrganisms have been discovered and studied, and many of them belong to important toxigenic genera. So, the perspective of finding new phytotoxic metabolites of weed pathogens has been strongly enhanced. Depending on their biological and chemical characteristics, these bioactive metabolites could be of great help in biological weed control, and different approaches are in progress or seem to be predictable: 1) study of the role of toxins in plant-pathogen relationship: the knowledge of meaning of phytotoxins in plant disease, mechanism of action and biosynthetic pathway could be of great help in drawing weed bio- and integrated control strategies; 2) direct application with weed pathogens: phytotoxins have different spectra of action with respect to the producer pathogens; their modulated use with pathogens could increase herbicidal efficacy of the fungus, in terms of pathogenicity, virulence, speed of action or selectivity; 3) discovery of new classes of natural herbicides: many phytotoxins have toxicological properties that render them good frames to create new classes of natural and safe herbicides, or that could be synthetized, or modified in their functional groups changing their biological activity; 4) use as biomarkers: to correlate toxin production with other physiological or biotechnological pathogen characters could permit an easier *in vitro* selection of the most useful strains, i.e.: more virulent isolates, faster growers, higher conidia producers.

Influence of spore concentration, adjuvant concentration, and bioherbicide application rate on the field efficacy of *Bipolaris sacchari* (E. J. Butler) Shoemaker as a biocontrol agent for *Imperata cylindrica* (L.) Beauv (373)

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Field experiments were conducted in the summer and fall of 1999 to determine the influence of spore concentration, adjuvant concentration, and application rate on the efficacy of *Bipolaris sacchari*, a potential biological control agent for *Imperata cylindrica*. Two similar trials were conducted in Gainesville, Florida on 0.25 m^2 plots using a completely randomized design with four replications per treatment. The treatments included: three levels of spore concentration (0, 5.0 x 10^5, and 1.0 x 10^6 spores/ml [trial 1], and 0, 5.0 x 10^5, and 1.5 x 10^6 spores/ml [trial 2]); three levels of adjuvant concentration (0, 18%, and 26% [oil to water proportion]); and three rates of application (0,100, and 200 ml per 0.25 m^2). The adjuvant used was composed of Sunspray 6E horticultural oil, Fisher light mineral oil, and sterile distilled water. Disease severity and phytotoxic damage were visually estimated as a percentage of blighted biomass per plot. Plots were evaluated weekly, from the second to the sixth week after inoculation. Results indicated that field efficacy of *B. sacchari* is influenced mainly by the interaction of spore concentration and application rate. At any given week, plots that were sprayed at the rate of 200 ml/0.25 m^2 with 10^5 or 10^6spores/ml formulated with 18% or 26% adjuvant had significantly higher disease and damage severity (94% average DS for the two trials) ($P=0.05$) than the other treatments. The adjuvant alone (18% or 26%) without spores, applied at 100 or 200 ml/0.25 m^2, was not sufficiently phytotoxic to significantly damage *I. cylindrica*.

Field survey and preliminary evaluation of biological control of *Matricaria perforata* using funfal pathogens in Saskatchewan, Canada (374)

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Matricaria perforata has been spreading rapidly in the Canadian Prairie provinces, and Saskatchewan has reported severe infestations in 7 major cropping areas covering different soil types and climate. Management of this weed has been difficult primarily due to the ineffectiveness of commonly used herbicides at crop-tolerant rates. Field surveys have been conducted across major infestation areas in the province since 1994 to identify and evaluate plant pathogens for biological control of this weed. Various crop fields, roadsides, slough edges were inspected for the presence of the weed and signs of disease on the foliage, stem, or root. Diseased plants were examined further in the lab and causal agents were isolated and tentatively identified. A series of bioassays were developed to evaluate the pathogenicity of the isolates and their efficacy in suppressing the weed. In the field survey, diseases were not commonly observed on *M. perforata* during growing seasons, especially on flowering or matured plants. Several leaf-spot diseases caused by *Colletotrichum* sp., *Alternaria* sp. and unidentified fungi were found repeatedly in different areas of the province, although severity was relatively low. Preliminary bioassay has confirmed high pathogenicity with 12 of the screened isolates on seedlings of the weed. Further studies are being conducted to evaluate the feasibility of these pathogens as potential biocontrol agents by examining the impact of growth stage of the weed and environmental factors on infection and disease development.

Isolation and pathogenicity of the strain QZ-97a as a biocontrol agent for ***Veronica persica*** (375)

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A strain QZ-97a of *Colletotrichum* spp. was isolated from diseased plants of *Veronica persica*. According to the characteristics of pathogenicity and culture, it was identified as *Colletotrichum gloeosporioides*. Pathogenicity test showed that this fungus had obvious virulence to *Veronica persica* in both laboratory and greenhouse, while safety test showed it was safe to most of the main crops infested by *Veronica persica*. So, this strain QZ-97a of *Colletotrichum gloeosporioides* could potentially be developed as a mycoherbicide for *Veronica Persica*.

Exploitation of microbes for biocontrol of ***Trianthema portulacastrum*** L (376)

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Trianthema portulacastrum L. commonly known as horse purslane, black pigweed, carpet weed, gudbur, hogweed, itcit and santha belongs to the family Aizoaceae. This weed is indigenous to South Africa and presently occurs in tropical and subtropical areas throughout the world. This weed is an aggressive coloniser and competes strongly with crops and vegetables such as potato, pigeon pea, soybean, maize and mustard. It has become a noxious weed and attained a status of number one troublesome weed of agricultural and vegetable fields because of the frequent occurrence and reported losses in yields due to competition for nutrition. Recently, there has been a large upsurge in the interest on biological weed control, reflecting increasing environmental concern over pesticide use. Presently there are over ten mycoherbicides which are commercially being used around the world. No significant work has been done on the biocontrol of horse purslane. A total of three leaf spot diseases caused by deuteromyceteous fungi e.g. *Cercospora trianthemae*, *Drechslera indica* and *Gibbago trianthemae*, and a mosaic virus have been recorded on this weed. *G. trianthemae* Simmons was first of all isolated on this weed in 1986 from Cuba, USA (Texas) and Venezuela. In 1990, a leaf spot disease due to this fungus, causing epiphytotics was observed for the first time at Kurukshetra (India). This isolate differs in certain characteristics from that recorded on this weed in the USA. Of the three fungal pathogens recorded on this weed, only *G. trianthemae* has been evaluated for its biocontrol potential. The result of the study conducted at Kurukshetra University are presented and the possibility of the development of a mycoherbicide is discussed.

Effect of storage temperature, granule size, and inoculum type on the viability of ***Fusarium oxysporum***, a pathogen of ***Striga hermonthica***, encapsulated in wheat-kaolin ("Pesta") granules (377)

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An adequate shelf-life of formulated mycoherbicides is considered an essential requirement for their commercial production and acceptance. The objective of this study was to investigate the effect of the storage temperature, the granule size, and the type of incorporated inoculum on the viability of *Fusarium oxysporum*, a pathogen of *Striga hermonthica*, in wheat-flour kaolin (Pesta) granules. Different propagules

(microconidia, chlamydospore-rich biomass and a mixture of microconidia and mycelial fragments) were encapsulated into two sizes of granules (0.5 mm to 2 mm and 0.25 to 0.5 mm) and each preparation was stored in the refrigerator as well as under room temperature for 3 and 6 months, respectively. Regardless of the type of formulated propagules and the granule size, all samples stored in the refrigerator maintained a higher number of CFUs (Colony Forming Units) compared to those kept under room temperature. Under both temperature regimes, the material with the larger particle size maintained more viable propagules than the smaller one in case of conidial and mycelial formulations, and vice versa in formulations containing chlamydospore-rich biomass. All in all, preparations with chlamydospore inoculum showed a longer shelf-life than granules containing mycelial fragments and/or microconidia. In the chlamydospore-containing formulations kept in the refrigerator, 100% of the initial CFU were found after six months of storage. Therefore, chlamydospore-rich biomass of *F. oxysporum* seems to be the most suitable inoculum for long-term storable formulations.

Enhancing the efficacy and safety of bioherbicides (378)

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Numerous plant pathogenic fungi have been isolated from noxious weeds and evaluated as potential mycoherbicides. Few of these pathogens have shown adequate control of their target weed in field situations and, as a result, few have emerged as commercially viable products. We have developed strategies to enhance the virulence and field efficacy of mycoherbicides, therefore increasing their commercialization. The dispersal of a mycoherbicide may be limited by the movement of the fungal propagules throughout the soil profile. In a live-seed delivery system, a fungal pathogen is coated onto a non-host seed and broadcast over a weed-infested area. The pathogen is distributed throughout the soil profile as the carrier root system develops and the concentration of the pathogen increases within the rhizosphere of the carrier plant. In addition, the infested area is re-seeded with the carrier plant facilitating reclamation and exclusion of other noxious weeds. Fungal plant pathogens with enhanced virulence have been selected by exposing the pathogen to toxic analogs and screening for overproduction of certain metabolic end products that regulate biosynthetic enzymes via feedback inhibition. Both increased mortality and an accelerated kill rate are observed in plants treated with these variants. Additional strategies for improvement and commercialization of mycoherbicides will be presented.

Novel formulations of mycelia from liquid fermentation (379)

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The production of large amounts of fungal spores for preservation and formulation is considered a major constraint to their effective use as mycoherbicides. Conversely, it is easy to produce large amounts of mycelia in liquid culture. Additionally, there are many advantages to using asporogenic mutants of biocontrol agents for biosafety, and because of the rapid hydration, outgrowth and infection by mycelia. Few successful attempts have been made to store fungal mycelia alone. Late log-phase liquid fermenter cultured mycelia of two *Fusarium* spp. specific to the parasitic broomrapes (*Orobanche* spp.) were isolated and formulated in alginate beads or in ‘‘Stabileze’’ (starch, sucrose, corn oil, and silica), and air-dried. æStabileze’ formulations exhibited less than 30% loss of mycelial viability for over 9 months and retained pathogenicity to the weed for over a year, while mycelia harvested earlier, and conidia from liquid culture exhibited more than 40% loss of viability. Mycelia from liquid culture yielded nearly 20 times more colony

forming units (cfu) of *F. arthrosporioides* (FARTH) and 4 times more cfu of *F. oxysporum* (FOXY) than spores at late log phase, when the hyphae were chopped to 170 micrometer pieces. Potential soilborne mycoherbicides must compete in the soil biota, and spread through and remain in the crop root zone throughout the growing season. We transformed FOXY and FARTH with a selectable hygromycin resistance (hmr) marker gene and visual marker b-D-glucuronidase (gus), and/or green fluorescent protein (gfp) visual marker genes. These markers allowed monitoring the growth of both FOXY and FARTH from these formulations on crop roots when they are mixed into soil. Indeed, they were found throughout the profile and rhizosphere throughout the growing season in large pail experiments.

Wide host-range pathogens as potential bioherbicides: risk analysis (380)

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Host-specificity is a prerequisite for exotic pathogens intended as classical or inoculative biological weed control agents to avoid unintentional effects in non-target species. By contrast, we propose that host specialisation is an unnecessary constraint for pathogens intended as bioherbicides when these pathogens are indigenous or endemic to the region in which their use is proposed. Locally increased inoculum density is a characteristic of the bioherbicide approach to weed control and may result in an additional risk of disease in non-target plants growing beyond the biocontrol site, or in crops planted at the site at some later time. The appropriate measure of this ‘‘relative’’ risk is the ratio of the density of inoculum added due to the deployment of the bioherbicide, to that naturally occurring in the ecosystem of interest. An acceptable value for this ratio must be set that reflects the risk averseness of the decision-makers in government departments, growers and the public at large. Spatial and temporal variation in this ratio for a particular bioherbicide programme may be quantified using models for the escape and dispersal of inoculum created at biocontrol sites in conjunction with estimates of the density of naturally occurring inoculum of the pathogen. Using such models, risk analyses have been conducted for the plurivorous plant pathogenic fungus *Chondrostereum purpureum* (Pers.: Fr.) in The Netherlands and in Canada. These models (along with molecular marker studies in Canada) have enabled the regulatory authorities to sanction and define the conditions for the safe use of *C. purpureum* as a mycoherbicide for the control of *Prunus serotina* Ehrh, *Alnus* sp., *Acer* sp., *Populus* sp. and *Salix* sp. in forestry. Similarly, in New Zealand models have been applied to estimate minimum isolation distances and withholding periods for *Sclerotinia sclerotiorum* (Lib.) de Bary used as a mycoherbicide to control *Cirsium arvense* (L.) Scop. in pastures.

Development of the bacterium, *Ralstonia solanacearum* [Smith] Yabuuchi et al. as a biocontrol agent for *Solanum viarum* Dunal (381)

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Certain strains of *Ralstonia solanacearum* (E. F. Smith) Yabuuchi et al. (=*Pseudomonas solanacearum* E.F. Smith) (RS) are highly pathogenic to *Solanum viarum* (SV), a pasture weed in the southeastern United States. Initial greenhouse trials on containerized plants proved that SV can be killed by injecting a cell suspension of RS into the main stem or by swabbing the cells on the cut surface of the stem clipped at the soil line. Since mowing is commonly used for SV control, a post-mowing application or a simultaneous application during mowing of RS are considered to be rational methods for field-testing. Trials were established in Sumter (S), and Levy (L) counties in Florida. The S site was in a pasture under full sunlight and the L site was under partial shade in an oak hammock. After 4 weeks, treatments and percent healthy plants for the S test were: RS injected 69% vs injected control 100% ($Pr >$ Chi Square = 0.0014), RS cut-swab 21% vs cut-swab control 100% ($Pr >$ Chi Square = 0.0001). After 3 weeks, the L test results were: RS injected 10% vs injected control 40% ($Pr >$ Chi Square = 0.0004), RS cut-swab 10% vs cut-swab control 70% ($Pr >$ Chi Square = 0.0001). Thus, RS treatments significantly reduced the percentage of healthy plants at each site. A third field study was established in Hendry county, Florida to test the effectiveness of the Burch Wet Blade™ (BWB) as a system to deliver RS to SV. Treatments included a BWB-applied control (medium extract), RS applied at 23 L ha^{-1} with the BWB, and RS applied at 23.4 L ha^{-1} with the BWB plus sprayed at 560 L ha^{-1}. Both RS treatments significantly reduced the regrowth of SV ($P = 0.0003$). RS applied as a post-cut treatment or applied simultaneously during mowing are effective methods of controlling SV under field conditions. This is the first demonstration of the effectiveness of the BWB as an application device for the delivery of a biological agent to control a weed.

An integrated approach to control *Chenopodium album* by using a fungus, its phytotoxins and reduced doses of herbicides (382)

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Ascochyta caulina (P. Karst.) v.d. Aa and v. Kest. is a fungus studied for the biological control of *Chenopodium album* L., a noxious and widely distributed weed. Spray application of conidial suspension to *C. album* plants causes plant death or retarded growth due to induced large necrosis on stems and leaves. From the liquid cultures of the fungus, two main phytotoxic metabolites, a new unusual *bis*-aminoacid *N*-glucoside (named ascaulitoxin), and *trans*-4-aminoproline have been purified and characterized both chemically and biologically, showing promising herbicidal properties. A chemical procedure based on ion-exchange chromatography column has been set up, permitting to easily release a fraction containing large amounts of those toxins together with other active metabolites whose identification is in progress. In order to investigate on the possible implementation of fat-hen biocontrol, many greenhouse experiments on fat-hen plants grown in pots have been drawn, spraying suspensions containing different combinations of: *A. caulina* spores, the mixture of fungal metabolites at different concentrations, and one or two post-emergence herbicides (metribuzin and/or rimsulfuron) at reduced rates. In a semi-field experiment, fat-hen plants in transplanting trays were first grown in a nursery and then transferred in the field at the four-leaf-stage have been used. Combined treatments of fungal spores, mixture of toxins (600 g ha^{-1}), metribuzin at r.d. (30 g ha^{-1}) and a promising deleterious rizobacteria having herbicidal properties were sprayed. The experiments have shown that in several cases, the efficacy of a single control agent is strongly enhanced when it is used in combination with the others, suggesting additives or synergistic effects. In particular, greenhouse and field experiments have proved that mixture of toxins as well as herbicide are of great help for fungal efficacy, even when used at very low doses. These results confirm the perspectives of integration of chemical and biological weed control methods.

Multiple-pathogen strategy: a novel approach for bioherbicidal control of several weeds (383)

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A ''multiple-pathogen strategy'', in which three or more host-specific fungal plant pathogens are combined and applied inundatively for the control of several weeds was evaluated. In a model system, the following

weed species were tested: *Amaranthus hybridus* L. (PW), *Senna obtusifolia* (L.) Irwin & Barneby (SP), and *Crotalaria spectabilis* Roth (SC). The pathogens tested were *Phomopsis amaranthicola* Rosskopf et al. (PW pathogen), *Alternaria cassiae* Jurair & Khan (major host, SP; alternative host, SC), *Colletotrichum dematium* (Penz.ex Fr.) Grove f.sp. *crotalariae*, and *Fusarium udum* (Butler) f.sp. *crotalariae* (Kulkarni) Subramanian (SC pathogens). Spore suspensions of each pathogen (10^6 spores per ml) and a mixture of the four pathogens (1:1:1:1 v/v; total 10^6 spores per ml) were tested on the weed seedlings grown together in pots. The pathogens completely killed their respective weed hosts, when used alone or in a mixture. The pathogens did not lose their efficacy and host-specificity when used in a mixture, and therefore, the pathogen mixture could be used for simultaneous control of several weeds. Similarly, the bioherbicidal control of several weedy grasses with a pathogen mixture was evaluated using three fungi indigenous to Florida: *Drechslera gigantea* (Heald & Wolf) Ito, *Exserohilum longirostratum* (Subram.) Sivan., and *E. rostratum* (Drechsler) Leonard & Suggs. isolated from *Digitaria sanguinalis* (L.) Scop., *Dactyloctenium aegyptium* (L.) Willd., and *Sorghum halepense* (L.) Pers., respectively. In trials conducted in a greenhouse, each pathogen ($2x10^5$ spores/ml) as well as a mixture of the pathogens (1:1:1 v/v; total $2x10^5$ spores/ml) caused 82.5-100 percent disease severity on *D. sanguinalis*, *D. aegyptium*, *Sorghum halepense*, *Cenchrus echinatus* L., *Panicum maximum* Jacq., *P. texanum* L., and *Setaria glauca* (L.) Beauv. In a host-range trial, crop plants tested were either immune or resistant to each pathogen and the pathogen mixture. In separate field trials conducted in Florida, an emulsion-based inoculum of *D. gigantea*, *E. longirostratum*, and *E. rostratum* ($5x10^5$ spores/ml) and a mixture of these pathogens (1:1:1 v/v; total $5x10^5$ spores/ml) almost completely killed the seven weedy grasses mentioned above, and a natural population of *Panicum maximum*, a major weed in citrus in Florida. The weed control lasted for more than 10 weeks. Thus, *D. gigantea*, *E. longirostratum*, and *E. rostratum* have potential to be developed as bioherbicides for the management of weedy grasses. The multiple-pathogen strategy is a novel and effective means of weed control.

Development of rhizobacteria for biological control of grass weeds (384)

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Two of the most abundant annual grass weeds in the Canadian Prairies are wild oat (*Avena fatua*) and green foxtail (*Setaria viridis*). Prolific seed production and the development of herbicide-resistance make these weeds economically important to farmers. Utilization of naturally-occurring rhizobacteria with weed-suppressive properties can be developed as biological weed control agents. Three bacterial strains applied as pre-emergent bioherbicides in a variety of granular formulations using different rates of application were evaluated to determine their efficacy in the field. Field results indicated that aboveground biomass and weed emergence of wild oat are reduced by as much as 57% and 64%, respectively with one bacterial strain. Two bacterial strains applied within furrow with a granular formulation reduced aboveground biomass and weed emergence of green foxtail by more than 50%. However, not all granular formulations were found to be compatible with the bacterial strains. Field application of these bacteria is feasible, but additional research on the development of suitable granular formulations for application is required. The results further indicate that detailed evaluation of various formulations and their individual ingredients must be carefully scrutinized and evaluated for their compatibility with respect to bacterial survival and efficacy in the field.

Effect of bacteria on broomrape seed germination (385)

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The germination of *Orobanche* seeds in nature occurs when the broomrape seeds are within close proximity to host roots. Controlling the parasitic weed, broomrape, using this approach is potentially plausible as we

learn how to induce broomrape seed germination in the absence of host plant. In our laboratory, the growth regulator, GR24, was able to induce seeds to germinate (up to 25% of more than 250 seeds) when applied at 1-2 ppm. Accordingly, we have conducted experiments testing the effect of bacterial isolates on seed germination in presence of GR24 (2 ppm). Our preliminary results suggest that bacteria may enhance the effect of GR24 by more than 100% relative to GR24 induced germination i.e. control value. (7% of 250 seeds). Although, these experiments are in their early stages and many experiments must be conducted to confirm this result, the hypothesis that some bacteria may stimulate the germination of broomrape seeds in the absence of other factors such as host plant or GR24 is a testable hypothesis. Currently, we are conducting experiments testing our hypothesis. We thank Deutsche Forschungsgemeinschaft (DFG) for funding this work. Grant No. SA739/3-1.

Cirsium arvense **(L.) Scop. population regulation in pastures using *Sclerotinia sclerotiorum* as a mycoherbicide** (386)

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Cirsium arvense, is an economically serious weed of New Zealand pastures. It is inadequately controlled by conventional methods and a classical biological control programme has to date been unsuccessful. Furthermore, the phenoxy herbicides commonly used can be damaging to pasture legumes. The plant pathogenic fungus, *Sclerotinia sclerotiorum* occurs sporadically on *C. arvense* throughout New Zealand, reducing the productivity of the weed's shoot and creeping root system. Disease is not caused in either *Lolium perenne* or *Trifolium repens*, the dominant species in New Zealand pastures. Our objective was to develop this pathogen as a mycoherbicide for *C. arvense* in pasture. *S. sclerotiorum* was formulated as either a dry granule or a water-miscible powder incorporating a food source and additives to produce products capable of several months storage. In field experiments the former was applied with a modified fertiliser spreader and the latter with a modified hydraulic sprayer. Over several growing seasons, in contrasting climatic regions, applications of the granule formulation of *S. sclerotiorum* to vegetative *C. arvense* shoots in the spring months of October, November and December reduced the ground cover of *C. arvense* on 67%, 67% and 33% of occasions respectively. On the occasions when the fungus was effective the ground cover was reduced on average to between 74% and 38% of that in untreated populations. Applications made later in the growing season were generally not effective. Early spring applications also tended to result in lower shoot population densities in the next spring. Correlations of ground cover of *C. arvense* with climate parameters suggested that efficacy increased with frequency of leaf wetness, but declined with excessive rainfall due to the formulation being washed off the *C. arvense* foliage. Comparison of the dry granule and water-miscible formulations revealed that the latter was less dependent upon leaf moisture.

Impact of *Glomus* spp. on the competition between wild oat and wheat (387)

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Weed incompetitive spring wheat (*Triticum aestivum* L. cv. Oslo) and wild oat (*Avena fatua* L.) were grown alone and in combination with or without arbuscular mycorrhizal fungi (AMF)(*Glomus clarum, G. etunicatum, G. intraradices, G. mosseae* , or a composite mixture of the four AMF species) for up to 55 days in soil. Preliminary results indicate that when grown alone, Oslo benefitted most from *G. etunicatum* compared to the other AMF species. In addition, *G. etunicatum* significantly ($p<0.05$) reduced the shoot fresh and dry weight of wild oat when grown alone or in combination with Oslo. Neither wild oat nor Oslo benefitted from inoculation with *G. mosseae*. The least beneficial AMF species for Oslo when grown with wild oat was *G. clarum*, which significantly ($p<0.05$) reduced shoot fresh and dry weights of Oslo.

Inoculation of Oslo and wild oat with the composite AMF mixture resulted in reduced growth. Results suggest that the weed incompetitiveness of Oslo was eliminated following inoculation with AMF. However, this response was restricted to some AMF species, indicating that crop/weed competition mediated by AMF species is specific. This not only suggests that the mycorrhizal dependency of wild and cultivated plants varies, but there are also specific interactions between AMF and plant species which can be used in the biocontrol of weeds.

The importance of the integration of biological control into management systems (388)

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Biological control is one of several tools that can be combined or integrated in space and time to effect successful management of weeds in rangelands, natural parks, aquatic sites, agronomic crops, annual horticultural crops, and perennial horticultural crops such as vineyards and orchards. Economics may dictate a need to integrate biological control with other tools, and political or social concerns may be important, especially in non-cropland areas. In all cases, for successful integration to occur, reliable data must be available on life histories of the protected vegetation, the target weeds, and the natural enemies employed so management can decide how and when to use biological control. This workshop will provide only a glance at a few aspects of this very complex area. Dr. C. Doug Boyette will focus on endemic weed pathogens inundatively employed as microbial herbicides. His work includes several examples of synergizing fungi that attack annual weeds. Systems that synergize biological control agents are of special interest if they can reduce the cost per increment of control. Dr. Heinz Muller-Scharer has done extensive research on enhancing the spread and impact of a naturalized obligate fungus attacking a native weed, *Senecio vulgaris*, in arable crops; this is termed the augmentative or system management approach. Dr. Gerald Anderson will report on a perennial exotic rangeland weed, *Euphorbia esula-virgata* and The Ecological Areawide Management (TEAM) approach that employs the classical approach using insects combined with extant soil-borne pathogens and mixed sheep and cattle concomitantly. (Sheep eat spurge; cattle do not.) Transferring the technology must account for ancient antagonisms between cattlemen and sheepmen. These brief accounts will lead to in-depth discussions on promising areas of research for more enlightened and profitable use of biological control agents.

Synergizing fungal pathogens to enhance host range and efficacy (389)

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Many constraints that limit the practicality of bioherbicides can be overcome with innovative formulation and application approaches. For example, aqueous suspensions of *Colletotrichum truncatum* (Schw.) Andrus & Moore require 6-to-8 h of dew for optimum control of hemp sesbania [*Sesbania exaltata* (Raf.) Rydb. ex A.W. Hill]. However, when spores are formulated either in invert or crop oil emulsions, dew requirements are reduced to less than 1 h, and weeds controlled 90-to-95% in the field. The host ranges of *C. truncatum* and *C. gloeosporioides* (Penz.) Sacc. f. sp. *aeschynomene* (CGA) are altered by these formulations. Northern jointvetch [*Aeschynomene virginica* (L.) B.S.P.] is made susceptible to *C. truncatum* while hemp sesbania becomes susceptible to CGA. In other studies, the host range of *Alternaria crassa* (Sacc.) Rands from jimsonweed (*Datura stramonium* L.), can be expanded to include several unrelated weeds such as hemp sesbania, when spores are amended either with dilute fruit pectin or plant filtrates. An isolate of *C. gloeosporioides* from coffee senna (*Senna occidentalis* L.) is weakly virulent on sicklepod (*Cassia obtusifolia* L.), a problem weed in the southern U.S. When conidia are formulated with unrefined corn oil and the surfactant Silwet L-77, over 90% control of sicklepod is achieved in soybean plots. These studies show that bioherbicide aggressiveness can be increased and host resistance decreased using formulation additives. This should result in more efficacious, predictable, and economically practical bioherbicides.

An integrated, biologically based, approach to control leafy spurge (*Euphorbia esula* L.) (390)

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The Ecological Area-wide Management (TEAM) - Leafy spurge project is a USDA-Agricultural Research Service program focused on the Little Missouri River drainage in the states of the Dakotas, Montana, and Wyoming. Its primary goal is demonstrating ecologically based Integrated Pest Management (IPM) strategies that can be used to achieve effective, affordable leafy spurge control. IPM offers the flexibility needed by landowners and land managers by allowing different management strategies for varying situations. Major components of TEAM Leafy Spurge include: 1) Operations - supervises the acquisition and distribution of biological control agents; 2) Assessment - quantifies and monitors the extent, distribution and change of leafy spurge infested ecosystems, as-well-as socio-economic factors related to leafy spurge infestation and management; 3) Supporting research - focuses on the continued improvement of proven management strategies and the development and transfer on new integrated management strategies; and 4) Technology transfer - is responsible for increasing public awareness of the economic and environmental problems caused by leafy spurge and other invasive weed pests, for stimulating widespread interest in aggressive management programs by private, local, state and federal land managers, and for creating and distributing informational and educational materials that can be used to implement effective, affordable and ecologically sustainable leafy spurge control management practices. TEAM Leafy Spurge stresses teamwork and has assembled an experienced group of researchers and land managers into a focused, goal-oriented team. The program's collaborative effort enables participants to share resources and expertise to provide ecologically based IPM strategies that can be used to achieve effective, affordable and sustainable leafy spurge control in North America. To date, *Aphthona* spp. flea beetles are clearly providing the most affordable and sustainable mechanism for controlling leafy spurge, and as such, are proving an excellent foundation for the TEAM Leafy Spurge program.

The importance of integration into management systems (391)

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A native of Eurasia, leafy spurge was first reported in the state of Massachusetts in 1827. Leafy spurge now occurs abundantly on the northern Great Plains of the United States and the Prairie provinces of Canada, where it often forms stands dense enough to displace native plants and restrict cattle grazing. Biological control of leafy spurge in the United States began in the 1960s with the introduction of *Hyles euphorbia*. Fifteen nonindigenous insect species have been approved for release in the United States for the control of leafy spurge. Primary methods of attack include consumption of above-ground plant material, consumption of root material, and blocking seed production. *Aphthona sp.* flea beetles have produced the greatest impact on leafy spurge. The *Aphthona sp.* larvae feed on leafy spurge roots, increasing plant morbidity, reducing plant health and creating pathways for the introduction of plant pathogens. Data collection indicates that flea beetles can reduce leafy spurge stem densities by as much as 80%-90% over large areas. While leafy spurge continues to increase in the United States, techniques for control - while still evolving - continue to improve. Measuring the success of biological control has traditionally been approached from the perspective of agent/host interactions. Too often our perception of success or failure is predetermined by how we choose to view the problem. Multiple dimensions of success exist when one views the issue from a broader perspective. We must evaluate the success of weed control in terms of biological, ecological, scientific, social, economic, political and legal success. Evaluation of leafy spurge control in each of these thrust areas indicates that the program has been successful, at least in part. Successful leafy spurge control is on the horizon. How long it will take to be realized depends on our commitment to solving the problem and our willingness to work as a cohesive team in each of the major thrust areas.

Improved weed management for resource poor farmers: constraints and opportunities (392)

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Resource-poor smallholder farmers in much of the tropics and sub-tropics continue to have little or no access to chemical weed control technologies. As the rapid transition has taken place in these regions from slash and burn bush rotations to systems of continuous cultivation, due to increasing population pressure, farmers have continued to rely on manual labour, hand tools or draught animal powered (DAP) implements. Weeding recommendations, based on critical periods of competition, fail to take into account the constraints farmers face in trying to achieve the timely establishment and maintenance of a weed free crop. Arable production is but one aspect of the household livelihood strategy so a constraints analysis must take account of the competing demands for household resources. Likewise the design and evaluation of possible improvements must be based upon farmers own criteria for technology selection and adoption. Studies in Africa, including cocoa in Ghana and cereal-based systems in southern Africa, demonstrate how farmers have a deep understanding of the issues which need to be integrated to achieve timely weed control. Developing a clear understanding of indigenous farmer knowledge and their resources provides the starting point for developing and targeting appropriate recommendations. Recent work has concentrated on the role of tillage, including land preparation where perennial species such as *Cynodon dactylon* for example, are a problem, optimising the use of DAP weeders, integrating herbicide use with tillage, weed suppressive covers and crop cultivars, and integrated management of parasitic weeds through fertility enhancement, inter-cropping and deployment of resistant cultivars. If weed management research is to make a sustained impact for resource poor farmers the key problems in the system must be identified, for example an affordable supply of implements and spare parts, maintenance, and extension support for knowledge based technologies. To make informed decisions on the adoption of practices for management of the parasitic weed *Striga*, use of cover crops and inter-cropping for weed suppression or use of a herbicide, farmers need to be provided with a basic understanding of the biological processes involved.

Socio-economics and risk influence the adoption of integrated weed management (393)

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Farmers throughout the world vary considerably in their socio-economic circumstances and access to weed control technology. For integrated weed management practices to be adopted, factors other than biological and technical feasibility must also be considered. Profitability at the farm level is an important determinant of the selection and use of farm inputs globally. Farmers are reluctant to adopt long-term approaches to controlling weeds unless the new practices provide returns on the investment in the first season. New integrated approaches that include the use of herbicide resistant crops can be more profitable than traditional

weed management practices. They can increase flexibility in herbicide application timing and allow farmers to target especially difficult weeds. For these reasons, weed control systems that include a herbicide resistant crop may be adopted rapidly, where bio-safety guidelines and intellectual property rights are conducive to their use. The development of integrated weed management (IWM) practices that require labor must take into account the overall availability of field workers and competing demands for labor. Risk also affects significantly the speed and extent of adoption of new practices. Small-scale subsistence farmers are averse to trying new approaches, as they can ill afford to lose any production of the crop they use for subsistence. Some consumers avoid products made with transgenic crops because of a perceived health risk. Tradition and education are factors that can influence the adoption of IWM practices, particularly in developing countries. Compatibility with farmers' socio-economic circumstances, coupled with effective education and extension programs, is essential for widespread adoption of effective IWM practices

The role of competitive plant types in weed management (394)

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Ensuring a crop's ability to compete with weeds is an established agronomic objective and is usually a key aspect of integrated weed management practice. Increased attention has recently been focussed on differences between crop cultivars in their ability to compete with weeds. In part, this has been due to the recognition that modern, input responsive and high yielding cultivars may be less competitive with weeds than traditional plant types and therefore often not suited to the low input farming systems commonly found in the tropics. In these systems, farmers commonly rely on hand labour as the main intervention against weeds and as labour is commonly a scarce resource, and crop losses due to weeds can be serious. Elsewhere, in agricultural systems which have in the past focussed on high input use, concerns about the environment have encouraged interest the development of weed competitive crop plant as one means to reduce the level of herbicide use. Studies in tropical and temperate regions have identified considerable differences in competitive ability among cultivars of rice, wheat and barley as well as a number of other field crops. In cereals, crop canopy development, light interception, plant height and root growth have been positively correlated with competitive ability, but the relative importance of these as well as trade-offs are poorly understood. In addition to the morphological differences, allelopathic ability has been identified in some cultivars. The development of input responsive competitive cultivars well adapted to specific environments requires an improved understanding of the mechanisms involved in competitiveness, new screening methodologies and advanced breeding tools, such as marker aided selection. Such developments are likely to ensure that competitive cultivars become increasingly important components of integrated weed management practices in many production systems.

***Striga*: a joint challenge to science, extension and farmers** (395)

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Infestation by parasitic weeds of the genus *Striga* (Scrophulariceae) is considered to be one of the major biological constraints in cereal production in Africa. Even with regular surveying, spot spraying with herbicides, and ethylene injection, as practised in North Carolina (USA), it took several decades and millions of dollars to reduce the infestation of *Striga asiatica*. In Africa, *Striga* mainly affects crops of small-scale, subsistence-oriented farmers, who in general do not have any financial means for external inputs. Control methods which require no financial means such as hand-pulling, crop rotation with trap and catch crops, or the use of organic manure are most attractive to farmers. However, cultural methods do not prevent losses in the present crop and farmers must be aware to apply a long-term control approach, preventing a further reproduction and distribution of seeds and depleting the *Striga* seed bank. Visual extension material can help to create awareness, to explain the biology of *Striga*, and to introduce control methods to farmers. A group extension programme supported by visual aids, as developed for northern Ghana, meets these requirements. Science is challenged to develop low cost integrated *Striga* control methodologies for the African farmer which have an immediate effect on the initial stages of the *Striga* life cycle in order to improve yields already in the year of application. At present, this effect may be expected mainly from resistant varieties, from fungi specific to *Striga* spp. applied as bio-herbicides, as well as from herbicide treatments at a low dose to herbicide resistant crops. For a future acceptance of new technologies, an active involvement of farmers and extension workers as co-researchers in the process of innovation development is of foremost importance.

Weed management in barley and wheat in small farming systems in semi-arid regions (396)

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The average yield reductions due to weeds in barley and wheat were estimated as 15%-20% and 25%, respectively, in Jordan. Under low input agriculture, the potential yield increase is limited due to lack of enough rainfall, low soil fertility, as well as to the social and economic aspects of the farmer. The choice of the weed control practice should be based on its cost effectiveness, in order to be adopted by farmers, especially in subsistent small farming communities. The application of 2,4-D was not cost effective in many cases, when other tolerant weeds such as grasses were present and when annual precipitation fell below 400 mm. Three-year field trials were conducted with the aim of formulating a weed management strategy, utilizing all possible small farmer inputs to reduce weed impact on crop yield. Date of planting, fertilizer rates, spacing and chemical weed control were the main factors tested. Closer spacing, early planting and increasing the fertilizer rates did increase crop yields. Cost effectiveness were better than chemical applications, especially if two herbicides were to be used for the control of both broadleaf and grass weeds.

Study on the utilization of arable weeds in the Solu Khumbu district in Nepal (397)

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Weeds are considered to cause harm if not controlled in crops fields. However, they are used traditionally as feed in some developing countries. The nutritional value of weeds confirm that fodder weeds may be an important feed for livestock production. The utilization of arable weeds as a supplemental feeds for cattle during winter was studied the actual use and nutritional value to find possibility as fodder weeds in Junbesi valley with an altitudes of 2 300 m to 3 000 m in Solu Kumbu region in Nepal in 1996 and 1997. The weeds were grown in the crop fields after the harvests of pure wheat and mixed corn and potatoes. According to the differences of management practices, the weed species were different. *Digitaria sanguinalis* was the dominant species in wheat fields, and *Galinsoga parviflora* and *Drymaria cordata* were the dominant species in mixed-crop fields. Weeds were harvested, dried and stored until October for winter feed. The dry matter production of weed was 448 g m^{-1} in wheat fields of Phaphul (2 300 m). *Digitaria sanguinalis* had 2 190 stems m^{-2} in wheat fields and D. cordata and G. parviflora had 1 470 stems m^{-2} and 491 stems m^{-2}, respectively. In the mixed-crop fields, the high stem density of the three species supported high weed production. *Digitaria sanguinalis* in the wheat fields and *D. cordata* in the mixed-crop fields

produced 187 000 seeds m^{-2} and 16700 seeds m^{-2} , respectively. *Galinsoga parviflora* produced about 40 000 seeds m^{-2} in the wheat and mixed-crop fields. This suggests that high seed productions annually form rich seed bank, resulting in establishment of weed population in each field. Weeds had high content of crude protein and crude ash in dry matter, compared with other feeds. The utilization of weeds with high adaptation to various environments may be the advanced method for animal production in development countries.

Weed management practices in the maize cropping systems of the Central Highlands of Kenya (398)

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Maize and beans are the major food crops for the people in the Central Highlands of Kenya. Maize takes a leading role and is therefore, the staple food supplying energy and beans take a second position supplying nearly all the body protein requirement. The two crops are normally grown together and rarely does one see sole crops of maize or beans. When grown together more labor per unit area is required in weeding than in the sole crops The reasons advanced by farmers for inter-cropping are many such as sharing of resources for the two crops etc. Given the disadvantages and the advantages, it is important to note that it is a system that has evolved over time and that it is part and parcel of a farming system that has been found to be sustainable under current socio-economic circumstances. Mechanized production methods have limited use because the land has been subdivided into small parcels and therefore, it may not be economic to own expensive equipment. Sometimes, the land terrain may not favor mechanization since the slopes are steep and dissected by rivers and springs. The rough terrain make the highlands fairly cumbersome to mechanize. However, there are cases of mechanized or semi-mechanized production. These include oxen plowing/ weeding. Herbicide use in maize production systems in the Central highlands is a feasible solution but inter-cropping has been a drawback. Experimental work carried out in the Highlands has proven that chemicals can be used to manage weeds. The major drawbacks hindering the uptake of herbicide technologies include ignorance of the farmers on the use of herbicides, unavailability of the chemicals at the local markets and expensive herbicides. Sometimes the herbicide may be available but it is packaged in inappropriate containers that are aimed for large-scale farmers. This paper explores the various methods farmers in the Central Highlands practice in maize based cropping systems to cope with weed management and compares the chemical management with physical management.

Changes in weeding practices in the cotton growing zone of northern Cameroon (399)

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During the rainy season, farmers in the West African cotton belt concentrate their physical and financial efforts on attempting to control weeds. Their priorities at the start of the season are sowing and weeding food crops; the plots intended for cotton are then cleared, generally using animal-drawn ploughs, which often results in only superficial, irregular tilling. The weed clearance provided by tilling is particularly short-lived if the weeds are only partially dug in, and weed problems increase the later the crops are sown. Farmer practices in northern Cameroon for land preparation and weed control have changed substantially as a result of R&D programmes. In 1976, Cameroon was the first French-speaking African country to introduce pre-emergence herbicides on cotton and maize crops, under an intensification drive including tilling and harrowing with light machinery. Paraquat, which was introduced in 1987 and initially only used in mixtures with pre-emergence herbicides, is now very widely used, and has contributed to the success of direct seeding on a weed mulch. Glyphosate has been used since 1996, following the introduction of diuron and atrazine in 1992, which replaced the binary products distributed previously, hence cutting costs and significantly increasing the areas of cotton and maize treated. These four generic herbicides are now a driving force in changing cropping systems. Within cotton-maize rotations, chemical weeding facilitates integrated control type approaches. However, herbicides can increase weed invasion problems when used as part of an extensification strategy. The organizational conditions that enabled the impressive development of chemical weeding in northern Cameroon included the integration into the cotton commodity channel of training, monitoring, logistics and credit operations.

Response of *Imperata cylindrica* (L.) Raeuschel to glyphosate, handweeding, and cover crops in maize and cassava (400)

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Imperata cylindrica is one of the most difficult weeds to control in slash and burn agriculture in West Africa. Manual weeding, the most popular intervention used by small-scale farmers, is ineffective in areas where fallow periods are less than five years after each cropping phase. Field studies were conducted at Avrankou in Benin, Ogoja and Ezillo in Nigeria from 1997 to 1999 to evaluate *I. cylindrica* control, crop yield, and net returns from the use of cover crops, glyphosate and handweeding in maize and cassava. The experiment was arranged as a split plot design. Main treatments were glyphosate (1.8 kg a.i. ha^{-1}) and two levels of handweeding (five or two times). Subplot treatments were cover crops [*Mucuna cochinchinensis* (Lour.) A. Chev, *Pueraria phaseoloides* (Roxb.) Benth, *M. cochinchinensis* + *P. phaseoloides*] and plots without cover crops. Glyphosate plots yielded 33 and 59% more maize than weeding five or two times, respectively. Weeding five times yielded 20% more maize than weeding two times. All plots with *M. cochinchinensis* sole or intercropped with *P. phaseoloides*, yielded lower maize than plots without cover crops and plots with *P. phaseoloides*. Glyphosate and weeding five times had the highest cassava yields, 19.2 and 16.9 t ha^{-1}, respectively. Weeding two times yielded 41% and 24% less tubers than glyphosate and weeding five times, respectively. Cassava yields were not affected by cover crops. The dry matter of *I. cylindrica* was lower in glyphosate plots than in all weeded plots at all locations. *M. cochinchinensis*, sole or in mixture, reduced the dry matter of *I. cylindrica* most at Avrankou, irrespective of the main treatment. In maize, the net benefit was highest in glyphosate plots without any cover crop. Handweeding integrated with *M. cochinchinensis* + *P. phaseoloides* had the lowest revenue because they had the highest cost of production.

Using weed growth stage to reduce herbicide rates (401)

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Concern for the environmental impact of herbicides and the desire to reduce production costs have stimulated research in decreasing application rates. Post-emergence herbicide use may be reduced by adjusting rates to suit specific weed growth stages. Greenhouse and field experiments were conducted to investigate the dose-response relationships of bentazon (0.14 û 2.24 kg a.i. ha^{-1}), fomesafen (0.045 û 0.720 kg a.i. ha^{-1}), and imazethapyr (0.0045 û 0.0720 kg a.i. ha^{-1}) for use in dry and edible pod beans in New York State. Dose-response curves were generated for four weed species: *Abutilon theophrasti* Medicus, *Ambrosia artemisiifolia* L., *Solanum ptycanthum* Dun., and *Solanum sarrachoides* Sendtner. Herbicides were

applied at cotyledon to two, two to four, and four to six true leaf stages, both with and without a crop oil concentrate (bentazon, imazethapyr) or a non-ionic surfactant (fomesafen). Field studies were conducted for all weed species except *S. ptycanthum*, for which no adequate field populations were found. Field studies confirmed greenhouse results indicating that rates of bentazon and fomesafen could be reduced 50 to 75% when applications were made to *Abutilon theophrasti* and *A. artemisiifolia* at the earliest growth stage. Fomesafen did not control *Solanum* spp. beyond the four leaf stage. Fomesafen rate reductions were only possible with *S. ptycanthum*. Bentazon controlled *S. sarrachoides* at all growth stages with reduced rates but did not control *S. ptycanthum* at any growth stage. Imazethapyr failed to control any of the weed species, regardless of rate or weed growth stage. With bentazon, surfactant increased control slightly, but did not overcome the inherent tolerance of *A. artemisiifolia* and *S. ptycanthum*. Surfactant marginally increased control with fomesafen when applied at the lowest rates and latest growth stages. Difficulty in making timely applications and the risk of herbicide resistance development necessitate a conservative approach in recommending reduced herbicide rates.

Minimum Lethal Herbicide Dose (MLHD) for weed control (402)

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The efficacy of a herbicide treatment is determined by many factors related to the herbicide product, the application technique, the weed spectrum and the environmental conditions. For environmental, economic and social reasons, herbicide use in agriculture should be minimized. Worldwide, several decision support systems have been developed to take into account herbicide efficacy determining factors to support minimization of herbicide use. When minimizing or rationalizing herbicide use, it is important to know shortly after spraying whether an applied dose (e.g. a lower than the label dose) will be sufficient to control the weeds. This appeals to the farmer's risk perception of possible insufficient weed control. The Minimum Lethal Herbicide Dose (MLHD) method contains an approach that allows the farmer to reduce this risk. In the method, the efficacy of a herbicide treatment is measured shortly after the application of the herbicide by using a portable chlorofyll fluorescence (cf) measurement technique. On the basis of cf readings of treated weeds, it is concluded whether the recommended MLHD is indeed sufficient to control the weeds, or whether an additional treatment is needed. Farmers in the Netherlands responded positively to the MLHD method. In farmers participative projects, the MLHD method was tested for photosystem II inhibiting herbicides on more than 30 farms for two years. In comparison with common practice, the MLHD method resulted in 1998 in a reduction of herbicide use of circa 50%, a comparable level of weed control, and a significant increase of crop (maize, sugar beet and potato) yields. The results of 1999 show similar trends. It is concluded that the MLHD method is an important tool in reducing risks of insufficient weed control when minimizing or rationalizing herbicide use. The method will be extended to herbicides other than photosystem II inhbitors in the near future.

Weed management on Vertisols for small-scale farmers in Ghana (403)

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Vertisols and vertic clays represent a vast crop production resource (300 million hectares worldwide) that is underutilised, mainly because of problems with weeds and excess water. These montmorillonitic clays are generally more fertile and have higher water holding capacities than many tropical soils, but they are difficult to manage as they are very sticky when wet and hard and cloddy when dry. Research in Ghana has shown that it is technically possible to increase crop yields by 90% in normal wet seasons by using raised

(camber) beds to control water, but further increases in yield potential are prevented by high populations of *Cyperus rotundus* L. and *Imperata cylindrica* (L.) Raeuschel. These challenges have been addressed by on-station and on-farm research to determine the effectiveness of glyphosate and camber beds for weed management and crop production in maize-based farming systems. Field trials have shown that tuber populations of *C. rotundus* could be reduced by 95% after glyphosate at 1.8 kg. a.e. ha^{-1} was applied at the beginning of four cropping seasons during 1997 and 1998. The combination of glyphosate for weed control and camber beds (5 m and 10 m wide) to shed excess water has produced maize grain yields of 2.7 t ha^{-1} - a significant increase over the typical yields of about 1.0 t ha^{-1} with traditional methods of hoe weeding on flat land. Economic evaluations have shown that that the returns to small-scale farmers (at US$40 ha^{-1}) could be increased tenfold by the combined use of herbicide for weed control and reduced tillage systems.

Effect of different methods of weed control on growth response, yield and nutrition value of broccoli (404)

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Studies were conducted in 1998-1999 to evaluate the influence of weed infestation and weed control methods used after herbicide treatment on some morphological features (leaf weight, heads size, weight of whole plants), yield and nutrition value (contents of dry matter, ascorbic acid, and nitrates) of broccoli. The experiments were carried out on pseudopodsolic soil (1.5 % O.M.). Broccoli was transplanted in July for autumn harvest. Herbicides: trifluralin (0.96 kg ha^{-1}) and oxyfluorfen (0.36 kg ha^{-1}) were used before planting and propachlor (5.28 kg ha^{-1}) 7-8 days after planting. Trifluralin was incorporated with the soil. After herbicide application, the plots were systematically hand weeded and results were compared to those not weeded. The efficacy of herbicides and phytotoxicity to broccoli were evaluated 22-25 days after planting. The content of chlorophyll was estimated after 29-34 days, as a difference between quantity of light emited and absorbed by chlorophyll, expressed as a SPAD values. LAI was determined with a Sun Data logger before first harvest. The heads of broccoli harvested after 71-82 days were analyzed. Dry matter was determined by gravimetric method, ascorbic acid by Tillman’s method and nitrates by potentiometric method. Oxyfluorfen and propachlor gave very good weed control. All herbicides applied were selective to broccoli. There were no differences between the yield obtained from the plots treated with herbicides and systematically weeded after the treatment whereas the yield from not weeded was significantly lower. The results of experiments revealed that content of chlorophyll in the leaves and dry matter, ascorbic acid and nitrates in the heads did not change under herbicide treatment and different manner of weed removal after their application. Results suggest that effective weed control in broccoli can be obtained with the herbicides: trifluralin, oxyfluorfen and propachlor, followed by supplementary hand weeding.

Implications of universal adoption of reduced herbicide inputs (405)

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This workshop discussion session will examine the ways that herbicides can be used more selectively and in reduced quantities, by both targeted approaches and by integration with other means of control. This may allow exclusion of their use within certain ICM systems, which links with the techniques utilised for weed control in organic systems. We will have with us Dr Per Kudsk, who is one of the World’s leading exponents of selective and targeted dose use of herbicides. The development of precision in decision making, even with simplest herbicides, will save money, reduce environmental costs and produce better results. With ad hoc invitees and participation from the floor we will look at IWM, examining the

approaches that will allow reduced herbicide inputs, and how they differ for different farming systems and farming scales Although our research programmes appear to give us some of the answers to reducing reliance on herbicides, as well as using those we use more precisely, how successful are we in achieving a good adoption rate on the farm or smallholding. What kinds of holding can cope with which innovations? How can we improve the adoption of technologies that may be more complex to manage than the simple use of herbicides at or near the manufacturers' recommendations? The consequences for weed management and crop production of the near-universal adoption of technologies which reduce herbicide use will be considered, as well as the social impact of reduced herbicide use, and if the discussion leads that way, the social and commercial impact of the increasing demand for organic produce.

Modern immunochemical methods for pesticide detection (406)

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Registration of pesticides is not primarily determined by efficacy but by human/animal toxicological concerns, environmental fate and impact on water, crops, foodstuffs, and avoidance of pest resistance. Furthermore, to register new, low use-rate pesticides (e.g. sulfonylureas, imidazolinones), applied at doses 100-fold lower than older chemistries, innovative, sensitive chromatographic, immunoassay, and bioassay methods are required. Immunochemical detection has numerous advantages over bioassay and conventional detection/quantification systems, including lower costs, higher sensitivity and specificity, and ease and speed of analysis. Immunoassays can be used as stand-alone quantification assays and/or as a tier 1 screen to quickly and efficiently eliminate samples containing no contaminants (negatives) prior to analysis of positive samples by more costly and complicated GC and/or HPLC methods, thereby saving money and time. Currently, polyclonal antisera-, monoclonal antibody (mAb)-, and recombinant antibody (rAb)-based immunoassays are available for quantification of herbicides at ppb levels, or lower, in water, foodstuffs, etc. Polyclonal antisera are simple and inexpensive to produce but often have lower specificity and limited supply as reagents. mAb and rAb have the advantages of high specificity and a constant source of uniform, high quality antibodies for large-scale production. rAb technology refers to cloning of antigen-binding regions of an antibody molecule, and its subsequent expression in bacterial systems. This technology offers a powerful alternative to hybridoma technology. In addition, phage-display technology can be used to create cDNA libraries encoding antibody fragments. Fusion of the antibody fragments with the coat protein of a bacteriophage allows rapid screening to identify antibodies with high specificity/affinity. Furthermore, cDNA fragments encoding antibodies with desired specificity can be isolated from selected phage and cloned into plant-expression systems for large-scale production of antibodies. Expression of herbicide-specific antibodies in plants may be an effective strategy to induce resistance to herbicides. Plants expressing antibodies may also be cultivated as rotation crops to remove residual pesticides from soil (bioremediation). Not only can antibodies be used for herbicide detection/quantification, phytoremediation, generation of herbicide resistant crops, but they can also be used in high throughput screens to identify novel lead chemistry.

Biochemical and physiological tools in herbicide action research (407)

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Discovering how herbicides function requires the application of an extensive array of new and classical tools in an experimental concept designed to yield the maximum amount of information on a broad front. Today, the route to the herbicidal target spans the complete spectrum of research techniques, from whole plant physiology to biochemical and molecular approaches. Thus, a partnership of different disciplines is essential. Our strategy will be illustrated by recent mode of action research into auxinic herbicides, which had resisted all efforts to elucidate their mode of action since their initial discovery, over 50 years ago. We focused physiological and biochemical methodology on the question of quinolinecarboxylic acids (quinclorac, quinmerac) in susceptible dicots. Physiological observation in whole plants and in selected bioassays and their biokinetic fate, characterised by radiotracer techniques, indicated a hormone-like response pattern typical of auxins. This placed the compounds in a new category of auxinic herbicides. Phytohormonal profiling using immunological and physico-chemical methods combined with assays of enzymatic activities in the putative target pathway suggested that the induction of 1-aminocyclopropane-1-carboxylic acid (ACC) synthase in ethylene biosynthesis is a primary effect. This was found to correlate closely with massive accumulations of abscissic acid (ABA), leading to reductions in stomatal aperture and CO_2 assimilation, thus inhibiting plant growth. Similar observations have been made with other auxinic herbicides and natural auxin at high concentration in a variety of dicot species. Causality was established by molecular dissection of the target pathways using inhibitors and mutant and transgenic plants defective in hormone synthesis or signaling. Thus, a multidisciplinary approach has revealed that the primary event is a herbicide-induced increase in ethylene biosynthesis which stimulates the formation of xanthoxal by increasing xanthophyll cleavage, leading to the accumulation of ABA. This accumulation is the final agent responsible for the observed physiological effects.

Light scattering spectroscopy for determining mode of action (408)

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Light scattering or diffraction methods have been used in the study of biologically active molecules for the last few decades. The development of faster light detectors, more powerful light sources as well as fast analog data acquisition cards that interface with personal computers has resulted in novel analytical techniques (e.g. flow cytometry) based on light scattering methods that have contributed significantly to the study of cells. Other applications of light scattering include quality control in polymer manufacturing as well as medical diagnosis (e.g. scanning ophthalmoscope to study retinal damage). All light scattering techniques are based on the principle that living cells scatter light differently owing to their internal structure. When a cell suspension is placed in an optical cuvette, a portion of the transmitted light is scattered at various angles the extent of which is determined by the internal structure of the cell. At a given angle, scattering intensity will change over time in relationship to concomitant physiological changes within the cell. This information is valuable as it can be used to understand various aspects of cell physiology. We have pioneered the use of light scattering spectroscopy to study physiological aspects of intact plant protoplasts. The non-invasiveness of this technique coupled with the ability to obtain data in real-time has provided mechanistic information of auxinic herbicide action in wild mustard. We compared the light scattering properties of protoplasts from an auxinic herbicide-resistant (R) biotype of wild mustard, isolated in the mid-1980's from a field in Western Canada that had been treated annually with a herbicide mixture of mecoprop, dicamba and 2,4-D for over 10 years, with its wild-type susceptible (S) counterpart. The Mg-ATP-dependent light scattering signals obtained from R protoplasts were unaffected by up to 50 μM picloram, whereas the signal amplitude from the S protoplasts decreased 40% and abolished by 20 and 50 μM picloram, respectively. Signal amplitude from the R protoplasts could be decreased by simultaneous incubation with 50 μM of both picloram and verapamil, a calcium channel blocker. Conversely, incubation of S protoplasts with the calcium ionophore A23187 in the presence of 0.5 mM calcium reduced the inhibitory effect of picloram. These observations indicate that calcium ion dynamics modulate auxinic herbicide resistance. Our presentation will show how light scattering signals are interpreted to elucidate mechanism of action.

Adaptation of a quick-test to detect resistance in *Lolium rigidum* Gaud. to tralkoxidim in Petri dishes (409)

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During the cropping seasons 1996/97, 97/98 and 98/99 160 seed samples of *Lolium rigidum* Gaud. were collected in winter cereal fields of Catalunya (North-eastern Spain). Some of the samples were taken randomly without knowing the spraying history, but the majority of the selected fields had had low herbicide efficacies in controlling *L. rigidum* being suspicious to be resistant to herbicides. In order to characterise the susceptibility of these populations, pot experiments in tunnel were conducted. These trials needed at least three months to give results without including the waiting period to break the primary dormancy of the seeds. Due to these inconveniences of the greenhouse tests the quick-test in Petri dishes described by Moss (1999) was adapted to the collected seed characteristics. The aim was to try to get the results soon enough to recommend a possible control strategy in the fields. This abstract describes the adaptation of the methodology for the active ingredient tralkoxydim. Previous germination tests with standard local susceptible and resistant populations showed that temperature and periods of illumination had little effect on the germination rates but that the continuous moisture in the Petri dishes was important. Before the screening was made, some tests with the standard populations resulted that 0.3 ppm active ingredient of tralkoxydim showed best the differences between susceptible and resistant populations. After choosing this herbicide dose and the optimum germination conditions, the different populations were tested. Seven ml of a 0.3 ppm herbicide solution were poured into each Petri dish. Filter paper was added and the *L. rigidum* seeds placed on it. The dishes were piled up and placed in a closed plastic bag in order to avoid evaporation. After 15 days, the percentage of germinated seeds with shoots longer than 1 cm was recorded. Finally, the resistant populations found were sown again in eight doses of tralkoxydim and a log-logistic curve was adjusted for each case. In this way, the resistance degree could be compared between the standard populations.

Novel tools in weed management for the field: an overview (410)

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Weed management has been one of the key issues in most agricultural production systems, especially before herbicides became available. With the end of the 1940s, chemical weed control more and more replaced hand weeding, mechanical and rotational weed management. The application of herbicides was one of the main factors enabling intensification of agriculture in developed countries in the past decades. The crop losses due to weeds, if not controlled, are usually significantly higher than those caused by diseases and animal pests. Even with the control methods presently used, crop losses inflicted by weeds are still rather high, and of the same magnitude as those for diseases and animal pests. This indicates that there is still room for optimization in weed management, which in turn asks for new tools and/or novel approaches. Without any doubt, also in the future, weed management will be dominated by the use of herbicides. Precision application will be key to their continued use, either as patch treatment or online by sensor driven systems, including new nozzle types. Diagnostic techniques for real time weed identification and herbicide dose optimization for effective weed control as well as to minimize their environmental impact will lead to a more rational weed control avoiding blanket applications. Direct injection of selective herbicides using novel sprayer technology will also aid in more targeted applications. Approaches for a more rational chemical weed control and ecological considerations as well as the introduction of alternative control methods, however, may be counteracted by the introduction of herbicide tolerant crops. This technology

provides additional tools for cost-effective, flexible, broad spectrum post-emergence weed control. Therefore, non-chemical alternative control measures also need to be analyzed with regard to their costs, efficacy and environmental impact in order to better integrate these tools into weed management programmes. For biological control the challenges are the effective application and stimulation of epidemics in the crop. Genetically optimized organisms may also be critical in this context. In physical control many new tools are being developed. Guided hoes and fingerweeders make it possible to control weeds very close to the crop. Here also, sensors may allow for further optimization. Combinations with critical period approaches need to be reemphasized with all of the above control measures.

The use of diagnostics based on chlorophyll fluorescence in chemical weed control: research developments and farmer experience (411)

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Technological developments have resulted into diagnostic techniques that allow the farmer to rationalise herbicide doses depending on the weed spectrum and weed size in the field. An example is the Minimum Lethal Herbicide Dose (MLHD)-method. This method aims to minimize herbicide use without increased risk of residual weeds. Based on information of weed species and weed size, the lowest dose rate that results in full control by a photosystem II inhibiting herbicide is calculated. One or two days after treatment the herbicide efficacy is assessed by using a portable chlorophyll fluorescence (cf) meter. Based on the cf readings, the farmer can decide whether a retreatment is required to guarantee full control and calculate its dose. Based on tests at experimental farms, it was hypothesized that this method allows farmers to reach a marked reduction in herbicide use, while in less than 10% of the treatments a retreatment is necessary. The MLHD-method was tested on farm in a two year period with 30 farmers. In this farmer participative project, the perspectives and restrictions of using this type of diagnostics in weed management were assessed. In general, the farmers considered the method as very useful, giving it an average score of 8 on a scale of 1 (not useful) to 10 (very useful). As a main advantage they mentioned that the crops were less hindered in growth from the MLHD-doses than from the label or common practice doses. The farmers could easily measure the chlorophyll fluorescence and interpret the readings. However, about half of the farmers indicated that the dose calculation routine should become less complicated. With diagnostic tools like the MLHD-method, farmers can demonstrate that they use no more herbicide than is strictly necessary. The method could be included in a system defining Good Agricultural Practices and could become an item to be taken into consideration in a system of farm certification.

Tools of molecular biology for the field (412)

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Molecular biology offers the ability to detect genetic differences, independent of environmental factors. Tools can then be developed that allow detection to be fast and reliable. Until recently there has been little information on many aspects of the biology of weed species, including the structures and sizes of populations and the molecular bases of important traits. By generating new information on these aspects, the tools of molecular biology open a window for a new scientific direction in weed science and subsequently offer new facilities for the field. Molecular biology tools for the field can be classified into those requiring determination of DNA sequence (allele specific-PCR, microsatellite-PCR) and those that can be used to generate genetic fingerprints (i.e. patterns specific to each individual or population). These tools include randomly amplified polymorphic DNA (RAPD)-PCR, amplified fragment length polymorphisms

(AFLP) and inter-simple sequence repeat (SSR)-PCR. Allele specific-PCR has been used for the detection of herbicide resistance in weeds, and cross-pollination from transgenic oilseeds. The detection and sequencing of genes offers the chance to detect sequences which can be useful for crop improvement by interspecific hybridisation and transformation. The use of genetic fingerprints to analyse biodiversity has lead to new insights into population structure and the strategies by which weeds invade new habitats. In the future, these studies should help predict weeds' ability to evolve in response to changes imposed by management practice, agrochemicals, biotech innovations and global change in climate or socio-economic factors. Advances in molecular medicine and plant breeding have provided techniques such as PCR amplification of specific alleles (PASA), single strand conformation polymorphism (SSCP)-PCR and DNA-chip technology that can be extended to weed science applications including the molecular basis of important traits. In addition, weed genetics will not be confined to single gene-based traits and is already addressing polygenic traits such as dormancy, competitiveness and enhanced metabolism-based herbicide resistance. Greater understanding of these traits will enable the farmer to predict the short and long-term consequences of interventions. Manipulation of these traits can be incorporated into biotech products such as ''smart crops'' and ''introgression mitigators''. In the long-term, the detection of genetic differences may become an important part of precision agriculture.

Herbicide bioassays for rapid and effective decision-making (413)

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Bioassays are standardised test procedures that use a biological organism to determine the toxicity of a test chemical. These tests may be used for the preliminary assessment of new chemicals or the study of the activity, persistence and movement of a chemical or mixture of chemicals through the environment. In order for a bioassay to be effective, it must be rapid (i.e., with a minimal number of steps), reproducible, sensitive, small-scale and inexpensive. Often a correlation between the laboratory results and the environmental effects is desirable. The test species should be easily obtained, produce a consistent response, be economically or ecologically important and be readily cultured or maintained in the laboratory. Bioassays might take longer than chemical detection methods but the results are more biologically relevant. Several bioassays using terrestrial plants, and emergent and submersed aquatic macrophytes have been published as guides by the American Society for Testing and Materials (ASTM). These bioassays are reliable indicators of the toxicity of some sulfonylurea (SU), imidazolinone (IMI) and triazolopyrimidine (TZP) herbicides, which are difficult to detect chemically using standard analytical techniques. Laboratory testing with chlorimuron (SU), flumetsulam (TZP) and imazethapyr (IMI) on the submersed macrophyte, *Myriophyllum sibiricum*, indicated that *M. sibiricum* is sensitive to toxic effects caused by these herbicides. The IC_{50} values for root length were below the expected environmental concentrations, based on the agricultural maximum label rates for Ontario. For example, the IC_{50} for root length was 0.4, 2.5 and 4.2 mg a.i. L^{-1} for chlorimuron, flumetsulam and imazethapyr, respectively. Biological test methods for terrestrial plants are being developed by Environment Canada. As part of this initiative, a research program has been undertaken to select a battery of appropriate test species and identify performance criteria. The test methods have been evaluated in the laboratory using organic and inorganic contaminants and different soil types. Procedural modifications were required to address problems inherent with use of different contaminants and soil types. An overview of the laboratory test methods using diuron and copper sulphate in different soil types with method modifications will be presented. These new laboratory bioassays can be used as reliable tools for assessing herbicide toxicity to plants in water and soil.

Evaluation, calibration and a new option for setting up logarithmic sprayers (414)

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In two laboratory experiments the solutions of the tracers (NaCl, blue dye and fluorescein) were diluted, or concentrated, injecting in the mixture tank, solutions with higher or lower concentrations, respectively. The injection was performed in steps of 10 ml, using a hand operated dispenser. In the field trial, $CuSO_4$, $ZnSO_4$, and $MnSO_4$ were used as tracers. The concentration of MnSO4 was uniform in all solutions and enabled the estimation of the application volume in each target (glass plates of 7.6 x 2.6 cm). The plates were washed in 30 ml of distilled water and the solutions were analyzed to assess the concentration and the total amounts of the three salts. The application volume and the concentrations of CuSO4 (increasing with time) and $ZnSO_4$ (decreasing with time) were estimated using these data. Regression analyses were performed using logarithmic (log Y = 2-cX) and Gompertz (Y = e [a - e (- b - c x)]) models. The concentrations of the tracers and the percent of liquid in the mixture tank that was replaced were expressed as functions of the spraying time, distance from the start point of the plot or total volume of liquid sprayed or pumped. The best fitness was provided by the Gompertz model, using the total volume of liquid sprayed or pumped as independent variable (R ranged from 0.99214 to 0.99738). The results in laboratory and field studies were similar. Setting up the logarithmic sprayer aiming the continuous increase in the rates improved the fitness of both models, and enlarged the range of rates that could be assayed. For the small targets used in the field experiment, the high variability in the concentration of the tracers in different nozzles of the boom and the great variance of the spray deposits are important limitations to the use of logarithmic sprayers.

Placement of fertilizer increases the competitive ability of spring barley (*Hordeum vulgare* L.) on sandy soil (415)

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By placing the fertilizer in the soil close to the crop seeds, the crop might be favoured in respect to uptake of nutrition and thereby achieve better competitive ability over the weed. This was investigated in two field experiments where spring barley was sown at two different depths (4 and 6 cm) and fertilizer was placed at four different depths between every other row (0, 6, 9, and 12 cm). The experiment was conducted on a sandy soil and a clay soil. The experiments showed that the sowing depth did not have any significant effect on the weed biomass on clay soil, but there was a weak indication that crop yield was larger when the crop was sown at a depth of 4 cm. Fertilizer placed at a depth of 9 and 12 cm resulted in a higher crop biomass in the beginning of the growing season, and thereby increased the competitiveness of the crop, but it did not affect the crop yield at harvest time. On the sandy soil, the sowing of the crop at a depth of 4 cm resulted in significantly more crop biomass and less weed biomass than sowing at 6 cm. When fertilizer was placed at depths of 6, 9 and 12 cm, crop biomass production was significantly larger than if the fertilizer was placed on the soil surface, and there was significantly more weed biomass, when the fertilizer was placed on the soil surface than if it was placed at depths of either 6, 9, or 16 cm. The experiments showed that placement of fertilizer has a significantly greater effect on the sandy soil than on the clay soil.

Cost-benefit analysis of crop protection (416)

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The topic of the paper is on crop protection or precisely, on chemical crop protection and its alternatives. Pesticide use in agriculture is a highly controversial issue because of polarized viewpoints. The debate on the risks, the general necessity and the economically optimal levels of pesticide use has not come to an end. Proponents of pesticides see them as an indispensible input factor in modern agriculture and in meeting the challenge to feed the worlds growing population, while critics point to the potential and actual risks to humans and the environment and would like to see a ‘‘pesticide-free world’’ with organic agriculture as the dominant strategy in food production. Unfortunately the public discussion very often lacks of going more into detail of the problem. Hence, in public and politics, there is an increasing belief that agriculture can be environmentally acceptable only if the use of modern chemical input factors is reduced substantially across-the board or is completely banned. This one-sided and certainly oversimplified view is unsatisfactory and neglects alternative strategies coping with the potential risks of chemical input use and prevents policy measures of being differentiated enough and more efficiently. The aim of the paper is to get a more objective assessment of costs and benefits of different strategies of crop protection and to cover the economic as well as the non-economic effects. It is an integral part of a study at Giessen University analysing the positive and negative market-driven and external effects of crop protection using a Computable General Equilibrium model for Germany and the GTAP-Framework in a world wide context. Numerous studies have considered this aspect, but doubts remain whether all important cost components were included and whether they get the appropriate monetary equivalents. The paper gives first results on how to derive these equivalents and their quantitative levels.

Economic effects of a ban on pesticides in Danish agriculture. A CGE model analysis (417)

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In Denmark, the debate about the desirability of using pesticides and the possible adverse implication for ground water, human health, fauna and flora was recently intensified with the set up of the governmental Pesticide Committee. The Committee was given the task of analysing agronomic, economic, environmental and legal implications of reducing the use of pesticides in Danish agriculture. The economic analyses clearly illustrate that pesticides are a crucial input factor in the crop sectors, and a complete ban on the use pesticides would probably imply drastic changes in agricultural production. At the same time, such significant effects in the agricultural sector could lead to notable effects in the other parts of the Danish economy thereby reducing significantly long term consumption possibilities. The analysis is based on sound agronomic and farm account data and a specifically tailored computable general equilibrium (CGE) model for the Danish economy. One of the strengths of the analysis is the special efforts that was devoted to ‘‘getting the data right’’ and the consistency of results with the microeconomic and agronomic analysis undertaken by experts in these fields. A complete ban on the use of pesticides will reduce the Danish production of cereals by 70 per cent explained by significantly lower yields and profitability. A similar pattern is found for rape, potato and sugar, and the production of these commodities fall by 97, 69 and 63 per cent, respectively. The decline in production (and exports, employment and gross factor income) in the crop sectors results in a significant lower national income. If the derived effects in the rest of the Danish economy are included, then a complete elimination of the use of pesticides in agriculture leads to a 0.8 per cent decline in real national income. Long term private consumption possibilities decline by 1.7 per cent. The agricultural and macroeconomic effects are naturally somewhat smaller in less drastic scenarios as compared with the case of a complete ban on pesticides.

Pricing the attributes of plant protection products: applying the Choice-Based-Conjoint-Analysis (418)

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There has been a lot of progress and innovation in the crop protection sector within the last years. The plant protection products get more and more specialized and are tailored to the needs of different people. At the same time farmers reduce the use of plant protection products to minimize their costs, and the plant protection issue have become part of the public interest. With respect to consumers‘ preferences, food shall include as few as possible residues, have a high quality and look healthy at the same time. Last but not least, food industry and traders have certain expectations about the raw material treated with plant protection products. These requests are a special challenge for the crop protection industry providing farmers and other agents in the food chain with the desired characteristics or attributes. A survey will be conducted to find out which requests are made to plant protection and the processed products. The survey will take place in Germany. The survey with the farmers distinguishes between the use of herbicides, fungicides and insecticides and also the different commodities (cereals, maize, sugar beets, and rape) to find out the different requests for attributes of plant protection products and commodities in the food chain. The attributes chosen for the survey are the following: degree of environmental stress, effectiveness of the products, use options and price. The use of price as an attribute is the special feature of Choice-Based-Conjoint Analysis (CBC-Analysis) software, a special form of the Conjoint Analysis which is used for the survey. Because price is one of the attributes in the concept, it is possible to derive the implicit prices for all other attributes. The CBC-Analysis enables the non-option as one of the choices as well, thereby the decision process is very realisticly simulated. The results can be used to develop new and innovative plant protection products and to commercialize them with respects to the needs of society.

Site-specific weed management: scales in a spatial spiral (419)

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Agricultural production systems vary in many ways, including scale of operation, commodities produced and philosophical approaches to management. Crop production systems can be viewed on several spatial scales. These scales exist as a continuum ranging from individual plants in a field to plant populations, fields, farmsteads and regions. ‘‘Precision agriculture’’ is often equated with sub-whole field management of agricultural practices, therefore ‘‘precision weed management’’ is primarily thought of as sub-whole field weed management or patch spraying. Site specific management, a more appropriate term, transcends spatial scales and implies that spatial scale be defined by the management question being asked. We argue that increased information across a range of spatial scales can be used to enhance the management of weeds in agroecosystems. A building body of experimental evidence suggests sub-whole field weed management could be improved if additional information on soil, physiographic, and weed variation are used to shape the decision process. For example, crop injury can be minimized and efficacy enhanced by characterizing soil variability in terms of herbicide bioavailability, then using that characterization to guide preemergence herbicide applications. At the farmstead scale, growers and researchers are working through a facilitation process to derive locally adapted recommendations for cropping practices that include integrated weed management. Here, fields in a local growing area are grouped by their similarity and are used as replicates of a similar field site condition under a common climate and management regime. The potential to enhance the quality of data from such on-farm trials through landscape analysis holds considerable promise for the future. Finally, at the scale of a watershed or agroecoregion, the performance of specific practices like herbicide type and rate, or crop rotation sequences, could be assessed under broad physiographic, soil and

climate regimes. Conceptually, it would be possible to identify characteristics of cropping systems that make them vulnerable to species persistence, weed invasion or reductions in groundwater quality.

Importance of sampling resolution for site-specific weed management (420)

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The within field spatial variability of weeds, soils, nutrients and consequently crop yield has been demonstrated by many site-specific projects. Little consistency in the spatial pattern or, correlation between variables has been observed between field sites. Weed sampling methodologies can be divided into two types, discrete and continuous. Discrete sampling, in the form of rectangular grids, has been the most widely used technique, with many different grid resolutions being used. The choice of grid resolution should be based primarily on detailed ecological and population knowledge of the target species, although the dispersive impact of the management practices, and the resolution and specifications of the control equipment should also be considered. Unfortunately, insufficient quantities of such detailed ecological data have been collected to allow for such structured decision making. In reality, the choice of grid resolution is often based on the size of the area to be sampled and the availability of labour and funding, and these restrictions are unlikely to change. The choice of sampling resolution, the position of samples for discrete sampling and the spatial analysis technique or model can greatly affect the accuracy of the resultant weed map. If too coarse a resolution, or an inappropriate spatial model is used, information will be lost and populations inadequately represented. This obviously has important implications for the success of subsequent weed control measures and the long-term success of site-specific weed management. To demonstrate these issues the spatial distribution of Avena spp. was assessed using discrete and continuous sampling techniques at different resolutions and the data analysed using different spatial models and parameters.

Creating reliable and accurate weed treatment maps (421)

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There are several systems available that are capable of spatially varying herbicide application, ranging from on/off systems to complex injection metering equipment, with simultaneous application of two or more different herbicides. These systems can use two basic techniques: changes to the chemical concentration of the spray solution or, alteration of the total spray volume. Developing treatment maps for these spray systems means that the relationships between spatial variability of weeds, soils and the technical specifications of the variable dose rate machinery all need to be considered. This means that weed or soil mapping resolution should be linked in some way to the characteristics of the spray equipment. However, choosing an appropriate resolution to adequately represent the weed and soil parameters while maintaining economic and technical viability is difficult. The ability to be able to vary dose rate and chemicals means that the mapping system should also consider different species and variations in weed density, as well as the variability of texture, pH and soil organic matter. Converting the weed and soil maps into treatment maps must allow for the sprayer’s time response, forward speed of the spray equipment, positioning uncertainty, mapping accuracy and movement of weed seeds. For the success of variable rate equipment, it is necessary to have a quick time response between rate changes. There are experimental devices capable of changing dose rates in less than one second, while some commercially available systems do not offer such a quick response. The success of spatially variable herbicide application depends upon continuous planning, adequate and accurate mapping methodologies, understanding of weed and soil spatial variability and interactions and spray equipment technology.

Why are weeds in patches? (422)

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Two hypotheses can be used to explain the spatial heterogeneity of arable weeds. The edaphic factor hypothesis holds that weed patchiness is due to spatial heterogeneity in edaphic resources and environmental conditions. The dispersal and fate hypothesis holds that weed patchiness is controlled by chance dispersal of a seed to a given location. The purpose of this paper is to discuss the dispersal and fate hypothesis of spatial heterogeneity of weeds. This paper will attempt to address the paradoxical association between long distance weed seed dispersal and patchy spatial pattern. If seeds are dispersed a sufficient distance, it would seem obvious that the species should eventually spread and completely cover a suitable area. However, observed weed populations display highly aggregated spatial patterns that seem to have a degree of spatial stability in time. One explanation for this aggregation is that very few weeds seeds are dispersed long distances. Although combines can disperse wild oat seeds up to 150 m, interpretation of this result using simulation modelling reveals that only a very small proportion of seeds are dispersed this far. Factors contributing to the low proportion of seeds which are dispersed long distances by combine harvesters include herbicide mortality of weeds, pre-harvest seed dispersal and export of weed seeds with harvested grain. Because of the low proportion of weed seeds that are dispersed a long distance, the weed seeds can be confined to well developed patched. Simple probability dictates that most of these sites will occur within established weed patches where there is a high density of weed seeds in the seed bank. Characteristics of the seed dispersal curve may also lead to a patchy weed spatial pattern. Theoretical models of seed dispersal and the resulting spatial pattern suggest that if the tail of the seed dispersal curve declines at less then an exponential rate, the species expands by establishing new colonies establishing beyond the original patch, rather than as advancing front. Weeds may exhibit a patchy spatial pattern because of dispersal and fate even in the absence of edaphic and environmental heterogeneity.

Herbicide application on railways (423)

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Weeds are a major problem on railways in Brazil and are frequently controlled with herbicides. As for any other chemical application, environmental agencies are concerned about soil and water contamination so studies are being carried out to evaluate these application systems. Railway spraying differs from crop spraying because of the spray boom design and operational conditions; only a few hectares of surface area on a railway can be many kilometers long so high levels of spatial variability of soils and weeds are expected. Since railway sprayers use similar technology to crop sprayers, it is possible to adopt concepts from Precision Agriculture for weed control. The objectives of this study were to evaluate spray distribution and losses of railway sprayers used in Brazil and to assess spatial variability of soils and weeds on railways. This work is part of a research project aiming at the development of a system for spatially variable herbicide application on railways. The sprayers were tested in field conditions and the track was divided in three parts for the spatial variability analysis: a central and two lateral swaths. Soil samples were collected for pH, texture and soil organic matter analysis and weeds were surveyed at 4 different places for soil coverage and species assessment. The results for total losses showed relationship with environmental conditions; further work must assess airborne drift to evaluate the risk of contamination on nearby areas. It was concluded that the sprayers should be re-engineered for better spray deposit uniformity since it will be a key feature for the adoption of spatially variable herbicide application. Soil and weed survey gave important information for defining weed control strategies and sprayer development. For spatially variable application, it was found that a general time response must be within 2 seconds, considering spray application at 20 km/h. It is also clear that at least two herbicides must be available at the same time, so injection metering should be used.

Mapping site-specific weed management (424)

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Site-specific weed management is varying weed management within a field in response to the varying composition of the weed population. In many fields, this strategy may reduce the risks of herbicide use and enhance weed management without reducing crop yield since herbicide use may be limited to where control is economically justified and in other areas, management may be more closely matched to the weed population. A timely, cost-effective and realistic map of the weed population is needed to prescribe site-specific weed management for a field. Maps for spatially variable fertilizer application have been made by interpolating sample data, but sampling weed populations is costly. In studies in corn fields, the average cost of identifying and counting weeds was $.08 for seedlings (.3 m^2 quadrat) and $3.04 for seeds in a soil core (5 cm diameter; 10 cm deep). Further, it may be necessary to observe many sample units in a field since the range of spatial dependence of a weed or seed bank population may be short (< 60 m). Making a weed map may be practical if limited sample data is combined with other more convenient or less expensive sources of information about the spatial variability of the weed population. Possible sources include aerial photographs, sample data from previous years, knowledge of spatially variable management activities, and maps of field characteristics that may be correlated with weed populations. The most valuable source may be a grower's or consultant's knowledge of the weed population. In the U.S., some growers and consultants are already mapping the weed populations. Others don't create maps, but base management decisions on their knowledge of the spatial variability. Innovative techniques will be needed to combine information from different sources since some information may be qualitative and sources may represent different measures of the weed population. While an aerial photograph may represent weed biomass, a grower's map of weed pressure may describe variation in biomass plus an assessment of other factors that influence the competitiveness of weeds. Fortunately, weed maps to prescribe site-specific weed management only have to be accurate enough for making good management decisions. Not all errors in describing spatially variable weed density or pressure will lead to mistakes in selecting management. Methods of making weed maps should be evaluated by both the accuracy in describing the composition of the weed population and the resulting management decisions.

How can farmers use precision agriculture technology to make better decisions in the field? (425)

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The management of weeds and other limitations in the field should, in theory, be greatly improved by the provision of yield maps, spectral imagery and other information from precision agriculture. After all, the quality of field management decisions is constrained largely by uncertainty, which is caused by a lack of accurate information about site- and time-specific behaviour. In practice, however, additional information may be irrelevant if it focuses on accuracy without considering how it will be used. It may be unhelpful, for example, to focus solely on the effects of crop nutrition if the crop is also influenced strongly by weeds and disease. In fact, from the range of methods *currently available* to support complex site-specific decisions, few seem appropriate for practical use. Better methods are emerging, but in the meantime we have opted for an empirical approach of on-farm experimentation. For the growing number of farmers with yield mapping capability, this is easily achievable. Experiments can be installed over entire fields, and provide valuable insight into the site-specific behaviour of crops. The results can persuade the farmer to change application rates, modify cultivation practice or retire land from cultivation. Our experience is that this approach is acceptable to farmers because it uses the analysis of yield maps to support, rather than replace, the strongly intuitive basis of most farmer's decisions. Using examples from Western Australia, this paper will illustrate the concepts and practice of empirical experimentation over whole fields. It will also demonstrate from the results why, in this context, more deterministic approaches remain difficult to apply.

Predicting weeds in time and space from seedbank, seedling, or mature weeds (426)

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Weed distribution is highly variable within most agricultural fields. Knowing the location of weeds would allow precision application of herbicides to control these weeds. Seedbank, seedling, and mature weeds at harvest were measured in order to predict weed distribution in succeeding crops. Measurements were made on a 50 m by 45 m grid in a 40 ha field. Soil cores (10 cm wide by 10 cm depth) were sampled, seeds separted by elutriation and counted. Seedlings were counted (25 cm by 25 cm quadrat) and removed before each field operation. Mature plants with seeds were counted (5 m by 5 m quadrat) at harvest. Black nightshade seedbank, seedling, and mature plant data were spatially structured, with the distance between samples explaining more than 50% of the variation in dissimilarity between samples. The direction between pairs of samples also was a source of variation between samples as indicated by directional semivariograms. Indicator semivariograms and kriged maps were constructed and used to predict weed frequency distribution at different locations within a field. Maps created in this manner accurately predicted weed seedlings between 30 and 75% of the time, depending on crop and data set used to construct the map. Maps created from seedling data provided better predictions of weed distribution than did seedbank data.

Soil heterogeneity affects the emergence dynamics of *Helianthus annuus* (427)

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Soil characteristics such as soil organic carbon (SOC) content are correlated to the presence of *Helianthus annuus* L., and other species. Field and greenhouse studies were conducted to determine if microsite or within-field variation in SOC influence *Helianthus* seedling emergence and survival. Plot locations were selected on the basis of soil color and landscape position. *Helianthus* seeds were treated to break dormancy and planted to the crop row (ridge) or to the between-row space (furrow). Ridges were treated with one-half of farmer applied rates of herbicide (acetachlor + atrazine) or remained untreated. Furrows were not treated with herbicide. Seedlings observed six weeks after planting were considered survivors of herbicide management. In field experiments, furrow microsites in high SOC locations (no herbicide) had greater seedling survival compared to low SOC locations in both years (significant at $P=0.05$ in 1999). Ridge microsites generally had higher seedling survival when compared to furrow microsites (significant at $P=0.001$ in 1999). In herbicide treated ridges, more seedlings survived in high SOC locations than in low SOC locations. A greenhouse study was conducted on soil collected from the same field site to further explore the effects of SOC. Herbicide treatments included: control, one-eighth, one-quarter, and one-half the field recommended rate. Greenhouse experiment results confirm a differential seedling response to within-field variation in SOC. *Helianthus* above-ground freshweight, expressed as a fraction of control treatment freshweight, was significantly correlated ($P<0.05$ and $r>0.57$) to % SOC for each herbicide rate. Each regression line indicated a 27% increase in relative freshweight per % SOC increase. Within-field SOC and microsite differences are important among characteristics that determine niche suitability for *Helianthus*. Related studies have been conducted to determine the effect of location on other *Helianthus* growth stages.

Modes of movement of invasive plants (428)

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Several general modes of immigration via water, wind, animals and gravity have evolved among vascular plants: the specific modes across all species represent an enormous array of dispersal agents and circumstances. However, even in total, these modes are dwarfed by the role played by humans as plant dispersers in the last 500 years. Human involvement in moving plants across the globe and into new, often widely separated ranges, results both from accidental and deliberate introductions. Accidental introductions have long attracted biologists: introductions via wool waste, solid ballast and as seed contaminants amongst the seeds of crops are all represented by classic examples. However few naturalizations, i.e., permanent establishment of immigrant species in new ranges, have apparently resulted from such accidental introductions. Physical and biotic barriers to persistence, both acute and stochastic, cause wholesale extinction among these usually small, quite vulnerable populations. By contrast, deliberate introductions of plants for food, forage, and ornamentation and as sources of fiber and medicine form the major modes of immigration that result in plant naturalizations. In a growing list of national and regional floras, over half of all naturalizations can be traced to a historic, deliberate introductions. In the United States, this list of deliberate introductions include some of the most damaging weeds in U.S. agriculture: *Aegilops cylindrica*, *Cynoglossum officinale*, *Eleusine indica*. Often the species has long been abandoned as a crop, such as the source of a putative medicinal agent (e.g. *Cuscuta epithynum*, *Hypericum perforatum*). Such species are however powerful reminders that humans will continue to introduce species deliberately into new, vulnerable ranges that they would not otherwise reach. The consequences, both positive and negative, of such introductions need to be evaluated carefully before deliberate entry. Whatever the evaluation, deliberate movement will accelerate as international commerce expands

The postal system as a vector for invasive species (429)

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The internet has joined mail order catalogues as a major source of seeds, bulbs and plants. Internet sites have been set up by long established companies keeping up with modern technology, specialist societies, and new businesses based solely around a webpage. There are also online ‘‘billboards’’ where participants can trade material. With the popularity of e-commerce, it is now easier than ever to obtain plant material from anywhere in the world with purchases usually being shipped by mail. During the period from August 1998 to June 1999, quarantine officers at the Perth mail exchange scanned 31,743 parcels, and found Quarantine Risk Material including plants, cuttings and soil in 2,664 of the parcels. Australia has several documented cases of nurseries supplying serious weed species such as *Hieracium aurantiacum*, *Onopordum nervosum* and *Stipa tenuissima* (syn. *Nassella tenuissima*) whose seeds were obtained by mail. An alarmingly high number of other species that are well documented as weeds are available from internet suppliers. These include: *Acacia karroo, Eichhornia crassipes, Hieracium aurantiacum, Hypericum androsaemum, Nassella trichotoma, Salvinia molesta*, and *Zantedeschia aethiopica*. In addition to the weed problem, plant material and soil can harbour pathogens and pests. This is a difficult issue with many contributing factors. Gardeners and horticulturists are often unaware of quarantine requirements, suppliers deal with different regulations for each country, some collectors will go to any lengths to obtain particular plants, and what may be perfectly acceptable as a garden plant in one country may well be a noxious weed in another. Unfortunately it is difficult to regulate items coming through the mail, and even harder to prosecute offenders. The internet is beyond the control of any one agency or country - what can be done to stem the tide of internet-sourced invaders?

Study of red rice distribution (*Oryza. sativa* var. *sylvatica*) in Italian rice fields (430)

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Lately, the spread of red rice in the European rice-fields has been very high. The common monoculture technique and the use of contaminated seed, albeit certified, are the most likely causes of the red rice diffusion. Italian seed trade norms allows the presence of a maximum of 5 red grains per 0.5 kg in the certified seed of the second generation. Red rice shows many features of aggressivity which favour it in the competition with cultivated rice and make it a real weed. Red rice features are variable. The most frequent color of the pericarp is red, but there are also white, brown and purple types, and this feature shows high correlation with shattering. Seeds often show dormancy so that they can be quiescent for several years. Hulls and husks are pubescent and the awn is almost always present either on the panicle or on a part of it only. The awn length of the spikelets of the same panicle can either be the same or differ. In order to improve weed control, we studied the variability of the morphophysiologic features of the plant and of the panicle in red rice and its phenotipic distribution in Italy. Five sites were randomly chosen in each area with the same soil and climatic features and with the same cultivation system. At each site, a rice field was chosen to sample 5 red rice panicles of the main culm. As in 1995, sampling at the end of September, a variability has been noted for the ripening time, in 1996 the panicles were sampled both at the beginning and at the end of September. For each plant the following features where considered according to the IPGRP-IRRI Rice Advisory Committee, (1980) (lightly modified): culm length, ligule form, knot color, panicle type, panicle awning, awn length, awn color, rachis length of the sampled panicle, grain color. The data showed significant differences for specific characteristics taken into consideration. Through cluster statistic analysis we tried individualize the various types of red rice in Italian rice fields; of these we were able to recognize around 16.

Distribution and importance of *Rottboellia cochinchinensis* (Lour.) W. Clayton in maize production in Mexico (431)

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Rottboellia cochinchinensis (itchgrass) is an annual grass of Asian origin that has invaded a diversity of cropping systems in Latin America. Surveys were conducted in maize growing areas in the states of Campeche, Veracruz and Oaxaca in Mexico to determine the distribution and importance of this weed. *R. cochinchinensis* was observed infesting maize fields at three locations in Campeche (Felipe Carrillo Puerto, Salinas de Gortari and near Edzna). About 80% of the growers interviewed in the Felipe Carrillo Puerto area south of Champoton recognised *R. cochinchinensis* as a troublesome weed and most of them (63%) indicated having had the weed in their fields for 5-10 years. Two thirds use herbicides to control *R. cochinchinensis* either alone (54%) or in combination with manual control (slashing) (21%); the remaining 25% rely exclusively on manual slashing. The most commonly used herbicides are nicosulfuron, paraquat and glyphosate. Where *R. cochinchinensis* is a problem, rice was planted in the past and the weed appears to have been spread as a contaminant of rice seed. Serious widespread infestation of maize, rice and sugar cane crops was also found in the Tres Valles and Tierra Blanca area (state of Veracruz) and around Tuxtepec, Jalapa de Diaz and Nopaltepec (state of Oaxaca). *R. cochinchinensis* is conspicuous on road

verges throughout this area and farmers claim it is now found wherever rice has been planted, having been first seen in the late 1960s. The majority of maize growers interviewed in Oaxaca consider *R. cochinchinensis* a competitive weed and control it with herbicides, primarily paraquat, and by slashing. Prior to the introduction of *R. cochinchinensis* only hand weeding was used in the area. Moving north, *R. cochinchinensis* has already reached areas around Martinez de la Torre where it has become a troublesome weed in citrus production.

Pine invasion and control in an Argentinian grassland nature reserve (432)

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The Ernesto Tornquist nature reserve is one of the last relicts of native Pampas vegetation in Argentina. Alien trees have been introduced in the area, mainly to ‘‘improve’’ the natural landscape. Before this introduction, the area was almost deprived of native trees, with the exception of some scattered individuals restricted to riparian habitats and other areas specially protected from natural fires, so alien tree naturalisation implies the introduction of a totally new life form. In 1998 we began a mechanical control plan for a stand of *Pinus halepensis* Mill. that showed a 20-fold increase in its occupancy area since 1967, and grows in a sector of conservation priority. The population consists basically of young individuals shorter than 4 m. Despite this, individuals are producing seeds and the population seems to be self-sustaining. The trunks were cut at 40 cm from the soil in 10 m diameter circles placed systematically inside the stand. Since the start of the program we saw no re-sprouting, so mechanical removal seems to be a good alternative for the control of this species. We studied the age structure of the population trying to find any association between recruitment and environment events in order to improve the management of the invasion and to prevent a further spread of the species. We counted cut trunks rings and found that the age structure of the population has a mean peak represented by the 5-9 year-old cohorts. This unusual recruitment can be associated to a natural fire. Wildfires that have been the reason for the absence of trees in the Pampas are now a significant factor for pine expansion. However, if conveniently managed, fire could be the clue for alien tree control, basically if its frequency is greater than the time elapsed between pine recruitment and maturation.

Survey and analysis of exotic weeds in China (433)

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A total of 108 species of exotic weeds belonging to 23 families were identified and recorded in China through investigation and referring to the related literatures. Among the exotic weeds originating from various regions in the world, those originated from America accounted for 60%. Concerning the introduction sources, 58% of the exotic weeds were introduced as useful plants, while the others were introduced accidentally with transportation, imports of agricultural products, etc. The analysis of introduction time indicated that the exotic weeds had been introduced since ancient times, and introductions increased as international exchanges grew. The distribution of the exotic weeds in China was governed by the integration of the inherent ecological adaptability of the weeds, their spread capability and human activities.

Invasion and impacts of New World stipoid grasses in Australia (434)

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A recent survey of herbaria identified eleven New World stipoid grass species naturalised in Australia. A number of these are causing massive impacts to Australian agriculture and the environment. *Nassella trichotoma* and *N. neesiana* were recently recognized as Weeds of National Significance by Australia's National Weeds Strategy. *N. trichotoma* is costing Australia more than $50 million a year while *N. neesiana* is regarded as one of the worst environmental weeds of native grasslands in south eastern Australia. Ornamental grasses have recently become very popular and the global availability, sale and promotion of exotic plants via the Internet, e-mail, popular gardening books and magazines has led to an increased rate of exotic grass introductions into Australia. One of these grasses, *Nassella tenuissima* was legally brought into Australia during the late 1990's-2000 from wholesalers in Great Britain and Germany under its synonym *Stipa tenuissima*. It is very closely related to *N. trichotoma* and would be expected to have similar impacts. Climate matching has shown that *N. tenuissima* could invade almost six times the area occupied by *N. trichotoma* in Australia. A ''weed alert'' was posted for this species on a weed email discussion group (''Enviroweeds'' - CRC for Weed Management Systems) that has resulted in plants being removed from 15 plant nurseries and initiation of a publicity/product recall campaign aimed at recovering 23 plants sold to the public. The Australian Quarantine and Inspection Service (AQIS) has a weed risk assessment system for screening new plant introductions which is possibly the best process of its type in the world. However, the system is founded on a dynamic list of permitted taxa that includes many ''permitted genera'' such as *Stipa* spp. which has enabled the introduction of *N. tenuissima*. For greater confidence that potential new weeds will be excluded from Australia, genera on the permitted list should be immediately replaced with appropriate species.

A methodology to assess invasiveness and impacts of weeds in south eastern Australia (435)

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Resource conditions can be assessed using a combination of scientific data and expert knowledge. The problem is how to integrate human judgements with quantitative assessment techniques. The Analytical Hierarchy Process is a Multiple Criteria Analysis technique which addresses this problem. Complex issues can be broken down into a set of related criteria, a method that is used across many problem domains. By mapping out issues as a set of nested criteria, a decision hierarchy can be developed. The process also allows for relative importance or weight applied to each criteria and group. This multi-layered system rests on database and GIS layers which contain spatial and tabular data from the department's corporate database. Victoria's Pest Plant Assessment project has established a procedure to assess and prioritise any plant on its intrinsic abilities to invade suitable Australian ecosystems and its present and potential impacts on social, environmental or agriculture land uses. The assessment procedure is split into three main parts. A scoring system which analyses a plant's intrinsic invasiveness characteristics, the present distribution and potential distribution (utilising climate modelling programs) which is linked to GIS databases enabling present and potential impacts to be estimated on social, environmental and agricultural values.

Australia's national and state weed laws and regulations: a new approach (436)

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Legislation and planning in Australia for managing weeds became more focused with the launch of the National Weed Strategy (NWS) in 1997. This strategy aims to ensure that plant quarantine and

phytosanitation are key actions in weed management through activities at national, state and local levels to prevent the introduction and spread of invasive plants and to ensure their control where already present. The strategy goes beyond general phytosanitary principles by considering invasive plants of agriculture, forestry and environment, equally. At a national level changes have included the reinforcement of the Australian Quarantine and Inspection Service's role in regulating plant imports with the adoption of a new weed risk assessment system to assess all new plants entering the country and an increase in surveillance of potential sources of weed importation. New quarantine and environmental legislation have increased the ability of the federal government to make regulations for the control of non-native species. Action on invasive plants already in Australia is a role for state and territory governments. The NWS recognised that weeds do not stop at fence lines or borders and it aims to foster and improve cooperation within and between states and territories in Australia. Programs developed at state levels have included: state weed strategies, determination of the twenty weeds of national significance, contingency planning for new weeds and coordination of public awareness including a national Weedbuster Week. This paper uses Queensland as a case study of how States have increased phytosanitary actions to target weeds. Activities include: a strategic weed eradication and education program to target quarantine pests, the introduction of new legislation to prevent the sale of environmental weeds and the development of local government pest management plans dealing with weeds.

A plant quarantine system for the Galapagos Islands (437)

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The breakdown of the natural isolation of Galapagos, resulting in the introduction of alien species, is the greatest threat to the native biodiversity of the archipelago. Tackling this problem requires a two-pronged approach: reduction of the rate of arrival of new organisms and control or eradication of species that have already been introduced. An initial design for an international-standard quarantine system for the islands was developed in the early 1990s. Implementation of this system raised several problems, including lack of finance and legal framework, and difficulties inherent in establishing controls that are normally regarded as international, within a country. The Special Law for Galapagos, passed in 1998, sets out requirements for the regulation of human activities and provides the legal backing for quarantine control. The quarantine system addresses introduction of alien plants to the archipelago as well as transport of both introduced and native plants between islands. Problems to be tackled include deliberate introduction of useful plants, deliberate introduction of plant products for consumption, which could become accidentally established (e.g. viable spice seeds), and accidental introduction of propagules of non-useful plants. Small-scale funding permitted the implementation of a pilot project in 1999. Inspection and control points were set up at land and sea ports in Galapagos, for control of both incoming and inter-island traffic, and guidelines produced for movement to and between islands (especially to uninhabited islands). Development of the system uses a participatory approach, involving many institutions and interest groups. The system is based on permitted lists, with products classed as permitted, restricted or prohibited, and any product not appearing on the lists being prohibited pending specific approval. Products are added to permitted lists following a risk assessment procedure. Establishment of the full system, including control at departure points in mainland Ecuador, awaits larger funding.

Managing weeds in New Zealand's protected areas: the policy and the practice (438)

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The New Zealand Department of Conservation (DOC) manages 30% of New Zealand's land area. DOC recognises over 240 naturalised plant species as invasive. Left unchecked, weeds could degrade at least

575,000 hectares of conservation land within 10-15 years and cause the local or national extinction of native communities or species at over 150 sites. DOC takes a strategic approach to managing weeds. It aims to protect important places (site-led control) and reduce future risks from weeds at a regional or national scale (weed-led control). Several support tools have been developed: a strategic plan, surveillance plan, electronic database, weed manual, and standard procedures for planning, prioritising and monitoring operations. A weed risk analysis model, originally developed for border control, may further refine the system for prioritising weed-led programmes. Four years after implementation, there is still a gap between policy and practice. There are few weed-led programmes despite their high priority in DOC's strategic weed plan. Managers often perceive weed control as less valuable than other conservation work. This may change with the development of a novel system to compare diverse conservation outcomes. The system allows managers to identify the mix of management activities that will achieve the greatest conservation value for a given budget. The system uses quantified estimates of site value with and without management, urgency, feasibility, cost-effectiveness, and complementarity and worth of the new capability. A recent trial of the system with a diverse suite of projects showed control of *Pinus* spp. and *Lupinus arboreus* to be far more cost-effective conservation projects than those that have traditionally received funding. This system may help close the policy/practice gap.

USDA APHIS noxious weed regulatory programs and the safeguarding review (439)

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USDA APHIS is the agency responsible for regulation of Federal Noxious Weeds in the United States. This is currently done through an official Federal Noxious Weeds list, established by regulation. Candidate weeds for addition to the list are evaluated through a risk assessment process. APHIS duties include border and internal U.S. interdiction programs for Federally regulated invasive weeds, as well as development or oversight of official eradication or management programs for regulated weeds already present in the U.S. These programs may be done by APHIS or, more commonly, in cooperation with State or Federal cooperators. Recently APHIS has begun implementation of a Safeguarding Review, managed by the U.S. National Plant Board and involving surveys of various APHIS cooperators. This process was designed to identify areas of concern within APHIS organizational and program structures, and to strengthen our program for protecting agriculture and the environment.

Mexican quarantine system for weeds (440)

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Free trade increases opportunities to spread weeds among countries. In order to avoid introduction of foreign weeds, Mexico developed a system based on: a) a list of forbidden weeds, b) inspection of shipments, c) identification of weed seeds, d) release or refusal of shipments. As a result, 26 species belonging to 13 families have been intercepted over a 6-year period.

Establishment of interagency partnerships for addressing new invasive species: local to global (441)

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Currently, a national effort has begun in the United States to foster the establishment of new partnerships at the local, state, regional, national, and international levels to provide a coordinated framework for

interagency cooperation in addressing all types of invasive species. On a local level, Weed Management Areas are being established to promote interagency collaboration in on-the-ground management of invasive plants. On a state, regional, and national level, Interagency Invasive Species Councils are being established to foster better communication between all agencies and groups that are responsible for invasive species prevention and/or control. Currently, State Invasive Species Councils are being established in all interested states to coordinate interagency activities in addressing invasive plants, insects and diseases, aquatic nuisance species, and injurious wildlife. Each council is usually composed of 30 or more federal, state and local agencies, academic institutions, environmental and conservation groups, and industries that are involved with invasive species. Primary goals of the State Councils are to: develop a State Executive Order on Invasive Species; develop a State Invasive Species Management Plan; develop a State Invasive Species Early Detection Network. At the national level, a National Invasive Species Council has been established under Presidential Executive Order #11312, that was signed by President Clinton on February 3, 1999. Other goals under the Order include development of a National Invasive Species Management Plan by August, 2000; increased interagency coordination and cooperation; improved federal legislation and regulations to address invasive species; and an internet based Invasive Species Information Management System. At the international level, the Invasive Species Specialist Group of the World Conservation Union is working to create an internet based Global Early Warning System for Invasive Species. The ultimate goal of this effort is to link all invasive species information management systems around the world through the internet to promote information sharing and early alerts on new invasive species.

Eradication of *Striga asiatica* from the United States (442)

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The parasitic weed *Striga asiatica*, commonly called ‘‘witchweed was detected established in the USA in 1956. This alien and invasive species that was known to be a serious problem to crops in Africa, was deemed to be a threat, with catastrophic consequences, to USA agriculture. The presentation chronicles the events of the decision making processes related to this pest and the actions that were taken to eradicate this weed from the USA. These events include: detection, identification, assessment, decision on action needed, commitment to action action program organizational infrastructure, basic and applied research, development of eradication methodologies and the implementation of the eradication program. The decision making process, the actions taken, the procedures followed and the mistakes made in the USA *Striga* program may be used as a point of reference for governments to use in dealing with other taxa of introduced pest plants that become established in and pose a threat to a countries crop productivity and its ecosystems. Recognizing and effectively dealing with an invasive, alien species is a major challenge to a country. But if preventing the entry and establishment of a pest taxa fails, the failure to protect that country through effective mitigation could result in a biological disaster

Industry’s role in approaching invasive plant management (443)

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Industry has been involved with invasive plant management as a matter of altruistic as well as commercial interest. Industry manufactures weed management materials that are used for control of unwanted plants. It is clearly in our interest to have our products used properly, according to label instructions. We do the field research to determine what rates of herbicides, including proprietary and off-patent ones, give the best efficacy at optimum cost. Tank mixes of different herbicides are also tested. In order to make good label recommendations, the optimum growing conditions for application of herbicides are determined. Industry has a responsibility to ensure that its products are used properly for the benefit of the environment. Industry has brought a unique perspective to invasive plant management because of our realization that no single method of weed control is optimum for all conditions and ecosystems. Therefore we have embraced a position that all methods of weed management - mechanical, chemical and biological - should be a part of any project's strategy. Ultimately, some type of habitat restoration may be necessary also, since the best weed control is healthy growth of native or other desirable vegetation in a given ecosystem. Monsanto company in particular has been invited by many organizations and governmental agencies worldwide to assist them in their invasive plant management programs in situations varying from tropical rainforests to deserts, from restoration of antiquities to coastlines, from riparian areas to temperate forests.

The United States Executive Order on Invasive Species (444)

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On February 3, 1999, President Clinton signed the Executive Order on Invasive Species (#11312). Under the new order, federal agencies are directed to prevent introduction, detect and respond to new infestations, monitor populations, restore native habitats that have been invaded, conduct research to enhance prevention and control of invasive species. Also, the new order established a National Invasive Species Council to: oversee the implementation of the order, encourage planning and action at local, state, and regional levels; provide guidance to federal agencies on prevention and control of invasive species; foster development of a coordinated network to document and evaluate impacts of invasive species, as well as a coordinated information management system; and to develop a national Invasive Species Management Plan by August, 2000. A non-governmental advisory committee will also be established to assist the National Council in its deliberations. The implementation of the Executive Order, and the development of the National Management Plan will be discussed.

The ecology of invasive alien plants: mechanisms of invasiveness of the exotic weed, Scotch broom (*Cytisus scoparius* L-Link), in Bristish Columbia, Canada (445)

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Scotch broom (*Cytisus scoparius* L-Link) and gorse (*Ulex europeaus* L.) are exotic weeds which pose a serious threat to forested and other landscapes in southwestern British Columbia. These exotic weeds have several characteristics which promote their invasiveness and displacement of native plant species, e.g. reduced leaves, active stem photosynthesis, nitrogen fixation, profuse seed production, longevity of seed banks, rapid vertical growth, adaptability to various ecological niches, and lack of natural enemies. There is little data on the impact of Scotch broom and gorse on conifers in Bristish Columbia. Therefore, two experimental sites were established on southern Vancouver Island to determine the nature and extent of invasiveness of Scotch broom in forested areas, and its impact on conifer crop trees and other plant communities. Accordingly, field experiments were carried out to measure light infiltration (PAR, photosynthetically active radiation) and effects of competition of Scotch broom on Douglas-fir (*Pseudotsuga menziesii* Mirb.) seedling growth. Results demontrated that Scotch broom not only reduces the input of PAR but also retards the height-volume growth of conifer seedling. Details and future prospects for control will be discussed.

Impact and management of selected alien and invasive weeds in Malaysia with some action plans instituted for biological diversity (446)

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Management and control methods have been devised and implemented for several invasive species in Malaysia, namely for *Chromolaena odorata*, *Cordia curassavica*, *Mikania micrantha*, *Mimosa pigra*, *Asystasia intrusa*, *Eichhornia crassipes* and *Salvinia molesta*. Management strategies are being identified for other alien plants such as *Pennisetum polystachion*, *Rottboellia cochinchinensis*, *Passiflora foetida* and *Pistia stratiotes* that are potential threats to the environment and agro-ecosystems. The most noxious weeds in Malaysia have been accidentally introduced and the methods used to address the problems of invasive species (also for fauna) include preventing entry as a priority measure through detection and strict quarantine regulations; minimizing unintentional and unauthorized introductions; ensuring that intentional introductions are adequately evaluated through post-quarantine procedures; encouraging development and implementation of eradication and control campaigns, including biological control and providing a framework for legislation and international cooperation.

Global policy changes needed to stop biological invasions caused by international trade (447)

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International trade has become the primary driver of one of the most dangerous and least visible forms of environmental decline: introductions of harmful invasive species. The trade liberalization agreements of the early 1990s, have, as intended, stimulated much greater volume. World imports and exports overall bounded up 50% between 1990 and 1997. Human population growth, faster travel, deeper penetration and exploitation of formerly remote areas, climate change, and other global socioeconomic trends in addition to the trade increase are threatening more invasions worldwide. The United Nations Environment Program's report on major global trends, GEO-2000, states the problem thus: ''The economic and ecological importance of species invasions, an inevitable result of increasing globalization, also appears to have become more significant''. Legal, institutional, policy, scientific, and technological improvements are not keeping pace with the increased risks. With economic globalization, the invasives-driven facets of Earth's ecological decline will undoubtedly worsen unless there are sweeping and powerful policy improvements to match the global scale of the threats. Solutions? To slow the rush of global biological homogenization, policy makers must: 1) create a less fragmented institutional response; 2) move to a regulatory approach that allows no new non-native species to be imported unless they have been carefully assessed and shown to be safe; and 3) commit much greater funding to meet the multitude of demands in preventing accidental introductions and controlling existing infestations. This paper addresses global policy and institutional changes to achieve those solutions, with an emphasis on needed actions by the Word Trade Organization and the parties and Secretariat to the Convention on Biological Diversity and the International Plant Protection Convention.

The precautionary approach and phytosanitary measures (448)

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Among the international instruments most relevant to regulation of the transboundry movement of plants is the International Plant Protection Convention (IPPC) and the Agreement on the Application of Sanitary and

Phytosanitary Measures (the SPS Agreement) of the World Trade Organization (WTO). These two agreements are distinct instruments with different objectives, but they are complementary where they overlap in their provision for the application of phytosanitary measures. Phytosanitary measures are regulatory actions taken to prohibit or restrict the movement of people or articles in international commerce for the protection of plant health, including natural flora, from pests of plants and plant products, including weeds. A fundamental tenet of both the IPPC and the SPS Agreement is that the application of phytosanitary measures is technically justified based on scientific principles and evidence. Risk analysis is identified as the means to systematically collect and evaluate scientific information for this purpose. Where international standards set by the IPPC are in place, governments may adopt the standards as the basis for their phytosanitary measures without a risk analysis. In the absence of sufficient information for the formulation of international standards or where decision makers are uncomfortable with the level of uncertainty associated with risk analysis as the basis for phytosanitary measures, both the SPS Agreement and IPPC allow for provisional measures to be taken for precautionary purposes. The application of provisional measures establishes an obligation for the government imposing the measures to actively pursue the information needed to fully review the measure for appropriateness through risk analysis. Key elements of risk analysis include: (1) the probability of an adverse event; (2) the magnitude of the consequences of the adverse event: and, (3) the uncertainty associated with the information used for assessment. The importance of uncertainty in risk analysis and the degree to which a decision regarding acceptable risk accounts for uncertainty are not well understood by many governments and the criteria used by governments for this purpose are not yet internationally harmonized. Significant opportunity currently exists to articulate the role and importance of uncertainty in risk analysis as the basis for phytosanitary measures and thereby clarify the application of a precautionary approach within the context of the rules-based global trading system.

Water hyacinth: a global menace (449)

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Water hyacinth, *Eichhornia crassipes* (Mart.) Solms-Laub., continues to be a global menace, affecting aquatic biodiversity, hindering the use of water resources, tourism, recreation, economies, and trade, and endangering human and environmental health. The problems caused by this invasive Neotropical weed are most severe in countries of Africa, Asia, and Americas. Among the possible control options, chemical herbicides, physical methods such as manual and mechanical removal, and biological control are effective under different situations. These methods have merits as well as limitations in terms of their cost and feasibility, undesirable side-effects, and the ability to meet the control objectives. An integrated approach to the management of water hyacinth, using all applicable control methods, with biological control serving as the foundation, is the best strategy to attain a sustainable solution to this weed problem. Published literature and anecdotal and empirical evidence lead us to the conclusion that biological control has been a key to the overall success of water hyacinth management programs in several parts of the world. However, in some tropical countries, the weed grows at rates that far outstrip the ability of existing biological agents to control this plant. Further improvements in biological control are therefore needed, and recent efforts to research and utilize additional agents are promising. Coordination of control efforts, regional cooperation among countries affected by this weed, choice of suitable control methods for integration, and a sustained commitment to a control strategy are essential for long-term success in the management of this global menace.

Aquatic weeds problems in hydropower systems (450)

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Aquatic weeds, especially macrophytes, are serious problems in hydropower systems, affecting the multiple utilization of the water body, including fish production and fishing activities, transportation, aquatic sports, boating, irrigation, and hydroelectric production. There are also serious problems with insect-borne human diseases and poisonous animals in cities located near these reservoirs. The macrophyte community varies with the reservoir age, sediment composition, bottom topography, water transparency, and nutrient concentrations of the water body. In recently dammed reservoirs, the water nutrient concentration is low and the transparency reduces quickly due decomposition of plant and animal residues. The macrophyte colonization is small in these reservoirs. The marginal aquatic weeds are the first colonizers, followed by macrophytes, beginning with some mosses, ruderal grasses, and sedges. With time, the nutrient concentration increases and some submerged macrophytes, such as *Egeria densa*, *Egeria najas*, *Ceratophyllum demersum*, and *Hydrilla verticillata*, find suitable conditions to grow in relatively shallow waters (six to eight meters maximum). Simultaneously, the marginal diversity is increased by *Polygonum* spp., *Ludwigia* spp., *Pontederia* spp., *Eichhornia azurea*, and others. When the nutrient concentration reaches eutrophic levels, there is profuse growth of floating macrophytes, such as *Eichhornia crassipes*, *Pistia stratiotes*, and *Salvinia* spp. In very shallow reservoirs, this process is quick, especially if the sediment is rich in nutrients, and in reservoirs that have any source of eutrophication. Worldwide, there are reservoirs of all evolutionary stages, depth, eutrophication levels, and water turbidity. So, the problems with macrophytes are diverse mainly because the kind of responsibility of the hydropower companies with regard to social and environmental issues vary depending on the country. The more accountable problems are those that involve lost revenues due to reduced energy production, damage to turbines and protection screens, and weed-control costs. In some countries, the hydropower companies incur costs of environmental and social problems caused by the reservoir. In these situations, protection of the icthyofauna, insect control, and maintenance of the quality of water used for consumption and irrigation systems are other accountable charges.

Weed species, station design and operational features contributing to management problems in New Zealand hydroelectric lakes (451)

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Submerged plants present the most serious weed problems in New Zealand hydro-lake operations, since cool temperate climates and lake size provide unfavourable conditions for floating and marginal plants. Steep shoreline gradients reduce available habitat for weed colonisation, despite the presence of potentially problematic species. High turbidity can prevent submerged plant growth, while moderate turbidity can reduce weed problems, although this can be partially mitigated by weed species tolerant to low light conditions (e.g., *Egeria* and *Ceratophyllum*). Hydro lakes with fluctuating water levels τ5 m have minimal littoral weed growth and routine fluctuations have been used to avert nuisance growth of weeds. The extent of problematic weed growth tends to be in direct proportion to water clarity, stability of lake levels, extent of gentle shelving littoral margins and stability of sediments, while the nuisance value of submerged weed species in hydro-lakes depends upon their biomass, proximity to surface waters and susceptibility to uprooting. A hydro-lake in a flooded channelised valley will often have its long axis in line with the siting of the power station. In such cases, wind and water movement will often synchronise to channel both water and dislodged weed directly towards station intakes. In such cases, shoreline stranding may be minimal, so that weed growth may still present a management problem even if the area of growth is small relative to open water. The following factors were used to compile a measure of relative potential weed impact: ratio of available weed habitat to open water; shape and morphometry of shoreline; littoral gradients and substrates; water clarity/turbidity; and water level fluctuation. Any hydro-lake scoring above 12 could be expected to present some inconvenience to power generation, given the presence of suitable submerged weed species. Scores for New Zealand hydro-lakes are discussed along with detail on submerged weed problems. *Elodea canadensis* and *Ranunculus trichophyllus* are widespread throughout New Zealand, have reached their full potential impact and present minimal concern to managers of hydro-lakes. *Lagarosiphon major* presents a risk for various South Island hydro-lakes. The two submerged weed species that pose the greatest risk to hydro-lakes in New Zealand are *Ceratophyllum demersum* and *Egeria densa*. Both are common throughout the North Island and dominate in Waikato hydro-lakes. Eventually both species will become widespread throughout South Island waterbodies. These species have a marked seasonal turnover of biomass, with efflux and accumulation on hydro-lake station intakes during autumn.

Aquatic macrophytes in Brazilian reservoirs: an ecological perspective (452)

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A large number of reservoirs have been constructed in the last 30 years in Brazil, primarily for hydroelectric power generation. The formation of a new lentic system commonly creates a favourable environment for aquatic plant growth. Population explosions of free-floating species may be observed immediately after reservoir construction as a result of the first pulses of nutrients from inundated land and vegetation, as observed in Tucurui Reservoir (State of Para) where massive stands of *Salvinia auriculata* developed. After stabilisation, the succession of aquatic plant communities depends mainly on the water quality and morphometric features of the reservoir. Free-floating species are usually found in more eutrophic waters, while submerged species grow in less turbid oligotrophic sites. Among the free-floating plants, native species such as *Eichhornia crassipes*, *Pistia stratiotes* and *Salvinia auriculata* are troublesome in several Brazilian reservoirs. In more oligotrophic, clearer waters, Egeria najas and E. densa, both submerged natives, may be more problematic. They are especially found in reservoirs at the end of cascades of reservoirs, where high water transparency due to the trapping of suspended solids and phosphorus is common. Nevertheless, some large, deep reservoirs with well developed fetches or poor water light penetration, like Itaipu (Brasil-Paraguay), have been facing localised problems with free-floating or submerged plants. Unlike the situation in many other countries, the aquatic weed species in Brazilian reservoirs are mainly native. The large area of the reservoirs is a major problem in their effective management. Approaches which have a long-term impact on all aquatic plant species present (e.g. water level manipulation; watershed management to reduce nutrient inputs) may be the best approach if the aim of cost-effective long-term management is to be met, but such approaches require inter-agency cooperation and often entail substantial costs.

Evaluation of a combination of two pathogens as a potential bioherbicide for *Eichhornia crassipes* [Mart.] Solms-Laub. under field conditions (453)

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Previous attempts to develop a bioherbicide for *E. crassipes* failed due to the inability of bioherbicide products to provide practical, acceptable levels of weed control under field conditions. We hypothesized that acceptable levels of control of this weed could be achieved by combining two fungal pathogens and applying them in suitable formulations. To test this, we evaluated two pathogens, *Cercospora rodmanii* Conway and *Myrothecium roridum* Tode ex Fr., in small-scale field trials. Sixty PVC frames, each 2.3 m^2, were constructed and strung lengthwise at 0.3 m intervals in a small pond and arranged in three rows, (20 frames each). Six kg of *E. crassipes* plants from a natural, uniform population were placed in each plot. Mycelial fragments (*C. rodmanii*; 0.08g/ml) or spores (*M. roridum*; 10^6-10^8/ml) were used as inoculum that

was sprayed onto the plants at the rate of 250 ml per plot. For inoculum production, the fungi were grown on potato dextrose broth with 5% yeast extract in Roux bottles (*C. rodmanii*) or on *Lolium multiflorum* (Lam.) seeds in glass bottles (*M. roridum*). The inoculum was prepared in either of the following carriers: 0.5% Silwet L-77 or a 50% oil emulsion (5 ml Sunspray 6E, 45 ml Fisher light mineral oil, and 50 ml water). The fungi were tested singly and in combination. The treatments were applied with hand-pumped, 6-liter tank sprayers. Appropriate controls were maintained. Benomyl [(50% a.i. concentrate) 0.016 kg a.i./ 7 ha] and carbaryl [(50% a.i. concentrate) 0.007 kg a.i./ 1.4 ha] were applied to some plots to create disease-free and insect-free treatments. The experiment had a split-plot design with three replicates. The treatments were applied four times at 4-week intervals. Disease severity or phytotoxic damage severity (DS) was assessed 3 days after inoculation and thereafter 3 times per week for a total of 21 weeks, using a pictorial key for foliar necrosis. Highest DS over time was achieved with *C. rodmanii* + Silwet (2.97), *M. roridum* + Silwet (2.95), and both fungi + Silwet (3.0) [$P<.0001$; LSD of slopes]. Unsprayed control plots and those treated with oil emulsion only were the least effective treatments. At harvest (week 21), *C. rodmanii* + Silwet (30.83 kg) and *C. rodmanii + M. roridum* + Silwet (36.47 kg) were the most effective treatments with a 68% and 62% reduction in biomass, respectively, compared with the least effective treatment, oil emulsion control (95.0 kg) [$P<.0001$; LSD of means].

The problem of water hyacinth in Mali: present status on distribution, biology and control (454)

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The origin of the proliferation of water hyacinth (*Eichhornia crassipes*) in still water in Mali is due to the severe socio-economic problems. Surveys showed that water hyacinth is mainly located in the Niger River and recently in the Bani River. The infestation begins upstream from Bamako to beyond Macina. The most important cases of infestation are found around the city of Bamako, the COMATEX (Compagnie Malienne de Textile) at Sègou, the dam of Markala and the irrigation canals of Office du Niger. Studies showed that the areas of waste water rejection to the river around Bamako are the areas of wide proliferation of water hyacinth. This waste water was classified according to its source and its means of dispatching to the river. Chemical analyses of water samples taken from exude points revealed concentrations of ammonium nitrogen, nitrites, nitrates, phosphates and salts. The levels of these elements are often higher than the standards for drinking water approved by WHO (World Health Organisation). The vegetative propagation of water hyacinth in these waters indicated that a single plant of water hyacinth can generate another plant in 4 days. The control of water hyacinth is at its beginnings. Up to now, there is a remarkable lack of synergy between the different institutions involved in dealing with the water hyacinth problem. Presently, there are two ways to control water hyacinth: manual removal which is the most used and recently biological control. Biological control has been initiated by the introduction of insects *Neochetina eichhorniae* et *N.* bruchi of Ghana and Zimbabwe. Thousand of insects released are developing in situ. With regard to water hyacinth control, a strategy and framework have been elaborated involving an integrated pest management based on biological control.

Introduction and establishment of *Neochetina bruchi* (Coleoptera curculionidae) for the biological control of waterhyacinth in Mexico (455)

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Waterhyacinth is the most prevalent aquatic weed in Mexico. As part of an integral control program, insects were used for biocontrol. Some 1 200 *Neochetina bruchi* adults were imported from the USA. Before their release, three generations were checked for pathogens and reproductive health. No pathogens were found. For mass production, one pair of adults per plant was inoculated on all of the plants in each of 20 ponds. Five days later, the adults were removed. After 64-75 days, the next generation adults were harvested twice a week. This system allowed for the production of 4 000 healthy and reproductive colonies of Neochetina each month. Between 1994 and 1998, 84 911 *Neochetina* spp were released at 7 sites in Mexico. Regular monitoring revealed feeding scars by adults on leaves and tunnelling by larvae in the petioles, demonstrating that *Neochetina* are now established. However, four years after the first lots were released, no substantial change in the plant cover has been observed.

Mechanical removal of aquatic weeds: operational and economic analysis (456)

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Mechanical removal of aquatic weeds has been used as an option to biological and chemical control strategies because of environmental restrictions in some places in Brazil. The aim of this study was to develop a model to calculate costs and to perform sensitivity analysis in order to evaluate the influence of some economic and operational factors on the cost of the process. The operation was studied in a reservoir linked to a pumping plant. It consists of some cranes floating on rafts that are used to cut weeds and throw them into the water flow to the pumping system. Before the suction intake there is a floating barrier to trap the weeds, which are removed from the reservoir by another crane, fixed on the embankment. The weeds are stored for some time and then transported to a disposal place. In addition, there is a fence to protect the suction intake from weeds that passed through the barrier and a mechanical system to clean up the fence. Data related to the total volume of weeds transported to the disposal place were collected along 14 months, as well as the volume produced per square meter of infestation for the major weeds was assessed. The company that runs the system provided costs and other parameters. A model based on operational and cost parameters was developed to calculate the total cost per hectare of weeds removed by the system. The results showed an average monthly cost of US$ 17 780 per hectare of weeds removed. Despite the high costs, the system was able to control only 4% of the infested area on the reservoir by the time of the data collection. Using simulated data for glyphosate application, chemical control would cost only 0.2% of the mechanical removal cost. The sensitivity analysis showed that the compaction of the weeds for transportation, the volume of weeds produced per square meter of infestation removed and the cost of transportation are major parameters for the optimization of the system.

Growth of *Potamogeton pectinatus* L. in the irrigation system of the Rio Colorado, Argentina (457)

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The most important water management problem in the lower valley of the Rio Colorado (62 37' W, 39 23'S) is flow reduction in water channels caused by infestations of *Potamogeton pectinatus*. The aim of this study was to analyze the annual growth cycle of this submerged species in order to improve its management. Monthly plant samples were taken during the growing seasons (Oct-Mar) of 1995-1996 (1SE) and 1997/ 98 (2SE) in an irrigation channel. During these seasons, water temperature varied from 12 to 25°C, and means of conductivity, turbidity, pH and water depth were 1.1 mS cm^{-1}, 27 NTU, 7.9 and 1.20 m, respectively. Maximum plant length and maximum stem elongation rate were 150 cm and 2.1 cm day^{-1} during 1SE, and 267 cm and 3 cm day^{-1} in 2SE respectively. Regression analysis showed the same exponential growth rate of stems between October and February in both seasons, represented by the function: length = 34.1 $e^{0.01x}$ (x = days of growth). The average above ground plant growth rate was 9.9 mg DW day^{-1} for both seasons. There was a continuous increase of plant biomass with a peak in February

of 802 g DW m^{-2} in 1SE and 1656 g DW m^{-2} in 2SE, with an average weight gain of 6.56 g DW day^{-1} . The DW leaves/ DW stems ratio decreased from 7.2 in October to 1.0 in January. Maximum chlorophyll content, measured only in 2SE, had a peak of 4.1 mg g DW^{-1}. Despite the growth differences found between both seasons, this study found that plant growth was most rapid early in each season (Oct-Dec), and the available habitat in the water channels was occupied by *P. pectinatus* by December.

Recent advances in biology and control of submersed aquatic weeds in Brazil (458)

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In Brazil, submersed aquatic weeds have created great problems for water utilization. Large amounts of this type of vegetation can clog intake screens and turbines used in hydroelectric power plants and hinder navigation in shipping lanes, restrict recreational activities, cause property values to drop and restrict water availability for irrigation. The major submersed species are *Egeria densa*, *Egeria najas* and *Ceratophyllum demersum*. With the objective of developing integrated weed management programs, mechanical, biological and chemical control have been studied emphasizing efficacy, economical and environmental evaluations. Besides chemical control, the following activities were carried out: periodical surveys of the weed infestation in major reservoirs of Sao Paulo State; evaluation of the genetic variability of the populations using DNA and isozymes eletrophoresis; collection and multiplication of natural enemies to be used in biological control programs; preliminary studies on mechanical control using harvesters. Regarding chemical control, several advances were reached: development of experimental procedures for laboratory and field experiments; studies on the degradation and safety of herbicides; development and evaluation of application equipment; development of procedures to be used in flow studies using food dyes available in Brazil; development of procedures to be used in the evaluation of potential environmental hazards. In experiments in laboratory, water containers and ponds, fluridone showed high environmental safety and efficacy in the control of *E. densa* and *E. najas* and was the first herbicide authorized to be used in large scale experiments. Three areas of 20.8, 27.15 and 17.64 ha, in the margins of the Tiete river, have been treated periodically with the herbicide. Up to now, high control levels were achieved for *E. densa* and *E. najas* without negative effects to water quality, non target species and wildlife.

Break-Thru™ S321: a new tankmix adjuvant for aquatic herbicides (459)

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A new organomodified silicone surfactant, Break-Thru S321 (Goldschmidt) was evaluated in tankmix with isopropyl amine salt of glyphosate for the control of both floating and submerged aquatic weeds. Glyphosate is an excellent herbicide. However, the most common formulations are not used on aquatic weeds because of their toxicity to fish and aquatic organisms. The toxicity is due to the surfactants in the formulations, rather than the active ingredient, glyphosate. A special formulation of glyphosate, which does not contain any surfactants, is labelled for aquatic use. It requires the addition of a tank mix surfactant. Aquatic weeds common to the southeast United States and Brazil were used. They were collected from the wild and planted in large plastic tanks of water at Campinas, Brazil. Only one weed species was planted in each tank. Herbicide applications were made with a CO_2 powered backpack sprayer. Break-Thru S321 was evaluated at 0.025, 0.05, 0.1 and 0.2% v/v in the tankmix with glyphosate at 1680 g a.e. ha^{-1} and 2400 g ha^{-1}. The nonionic surfactant Aterbane was included as a commercial standard. Break-Thru S321 at 0.025% v/v in the tank mix with glyphosate at 1680 g ha^{-1} gave excellent weed control. It was better than the nonionic surfactant at 0.5% on the floating leaf weeds water lettuce *Pistia stratiotes* and *Echinornia crassipes*. Similarly Break-Thru S321 was very effective in improving the control of the submerged weeds *Sagittaria*, *Heteranthera*, and *Polygonum*.

Keeping restored irrigation drains free from cattail (*Typha subulata*) sprouting with imazapyr (460)

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Cattail is a perennial species able to live in shallow water, causing obstruction of water flux in irrigation drains. Because of its fast sprouting from rhizomes, irrigation drains are mechanically restored every year at a very high cost. The purpose of this research was to find the rate and the number of annual applications of imazapyr, a compound able to be absorbed into cattail young plants and translocate through phloem to the rhizomes, in order to keep a previously restored irrigation drain free from being populated again by cattail. Imazapyr was applied on 06/23/98 over cattail plants sprouted from rhizomes in an irrigation drain restored mechanically 60 days before, at the rates of 0 (check), 500, 1000, 1500, 500 +/ 500, 1000 +/ 500, 500 +/ 1000, 750 +/ 750, 1000 +/ 1000, and 1500 +/ 500 g ha^{-1} of a.i., respectively in one or two applications spaced over four months. Evaluations of cattail control were made by counting of sprouts on 08/23/98 and 12/22/98, 60 days after imazapyr applications. Besides cattail, other plants were recorded living in the drain or on its margins: *Brachiaria mutica*, *Cyperus* spp., *Calotropis procera*, *Polygonum hydropiperoides*, and others. No significant differences were observed among imazapyr rates at the first evaluation. However, the second evaluation, 180 days after the first application of imazapyr, showed that 500 g ha^{-1} was not enough to keep the drain free from cattail sprouting for such long period. Application of 1000 g ha^{-1} of imazapyr or a higher rate is suggested for a good cattail control and maintenance of the drain. No side effects were observed on non-target species.

Imazapyr application timing for cattail (*Typha subulata*) control in irrigation drains (461)

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Cattail (*Typha subulata*) is a perennial species able to live in shallow waters, causing obstruction of water flux in irrigation drains. Because of its capability of sprouting from rhizomes, mechanical removal from the drain is not feasible. A few months later the drain is infested again by the weed. Chemical control, on the other hand, has shown to be efficient but herbicide absorption and translocation may be influenced by relative air humidity and air temperature at application time. This field trial was carried out to study the best daily application timing of imazapyr, a compound able to be absorbed into cattail leaves and tanslocate through phloem to the rhizomes. Imazapyr was applied on 04/14-15/98 over cattail plants at the rates of 0 (check), 1000, and 2000 g ha^{-1} of a.i., at 8:00, 10:00, 12:00, 14:00, 16:00, and 18:00 hours with a lateral boom sprayer equipped with two 0C20 nozzles. Two months after imazapyr application cattail plants were burned and cut close to the drain surface to allow rhizome sprouting. Evaluation of cattail sprouting was made by counting on 09/17/98. Besides cattail, other plants were recorded living in the drain or on its margins: *Brachiaria mutica*, *Cyperus* sp., and *Ludwigia suffruticosa*. No significant differences were observed between the two imazapyr rates nor among application timings. Four months after application, imazapyr showed its capability of being absorbed by cattail leaves and translocated to the rhizomes. Over 92% of the cattail stumps showed signs of senescence without sprouting. No side effects were observed on non-target species.

An ecosystem-based regional approach for aquatic weed control (462)

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Several examples related to the presence aquatic weeds are discussed for different parts of the world, to show that ecological and environmental issues should be a primary concern in the management of aquatic vegetation. This discussion considers an ecological-based approach in dealing with the problems associated with aquatic vegetation. Such an approach is strictly necessary due to the importance that water has for domestic human consumption, energy and food production and in some cases for other commercial and industrial developments. The presence of aquatic weeds is associated in most cases with human activities, such as the creation of large water reservoirs, or irrigation areas. Such areas provide suitable environments for aquatic plant growth. Frequently, agricultural land-use within a given catchment area feeds water rich in sediments and agrochemicals into waterways, making nutrients available for rapid plant growth. The physical chemical characteristics of the water will be dependent on the surrounding environment, and in time the dominant type of aquatic vegetation will be a response to the interaction of several key factors controlling the aquatic system. Measures are necessary to ensure that aquatic plant problems do not reduce the productivity of water systems for human use; however, in many cases they can have side effects which contribute to the deterioration of the ecology and integrity of the aquatic ecosystem, affecting water quality and biota diversity. In this context the issue of aquatic weed management cannot be separated from the complex interactions with the natural and human-modified environments of a given region, nor from the quality of the water required for human use. The basis for managing aquatic weeds and preserving the sustainability of aquatic ecosystems, should be focussed regionally on understanding the functioning of a particular water environment, and on the knowledge of the biology and ecology of aquatic plants.

Why isn't alien ecological impact extrapolated geographically? (463)

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New findings of our worst non-native, invasive aquatic plant species add locations to the distribution map, and add a new group of stakeholders (citizens, scientists, politicians, commercial interests, environmental groups, etc.) to the fray. Questions that have been asked many times before are asked again, including questions about ecological impact of alien plants. To determine if research conducted before must be repeated in each new location, stakeholders must decide if ecological impacts are adequately documented in other parts of the world, and whether that information is applicable to their lakes, rivers, impoundments, and channels. The published studies include a variety of invasive species, and a variety of impact areas. Negative effects of water hyacinth (*Eichhornia crassipes*) on native algae populations have been documented, for instance, but little has been published on such seemingly obvious impacts such as reduction of native macrophyte coverage and diversity. Impacts to native plant communities have been well studied for Eurasian watermilfoil (*Myriophyllum spicatum*), but this species has not created the level of international problem typical of several other invasive aquatic plants. The question of applicability is harder to address: categories of impact such as loss of native plant coverage and diversity should be more universally applicable than, for instance, impact on a particular component of a lake's fishery. Providing a thorough assessment of what has been learned in other lands (and lakes) and a reasoned estimation of its applicability to new locations may help distinguish the science from the politics as the stakeholder conversation continues.

Potential control of *Hydrilla verticillata* by use of a classical biocontrol agent in combination with a competitive native species (464)

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The possibility of controlling *Hydrilla verticillata* (hydrilla) with the combination of a classic biocontrol agent (*Hydrellia pakistanae*) with a new plant competition technique was investigated in this two-year tank study. Hydrilla is an aggressive aquatic weed native to Asia which is currently causing enormous management and ecological problems in North America. For this experiment, Hydrilla was planted in sixteen 14,000 liter tanks either alone or in the presence of *Vallisneria americana*, a competitive, non-nuisance aquatic plant native to North America. Half of these tanks were then inoculated with Hydrellia larvae. Hydrellia populations were monitored and amended as needed to maintain a viable biocontrol population within these tanks. After two growing seasons, the tanks were harvested for plant biomass. In the absence of Hydrellia (the biocontrol agent) or Vallisneria (the competing plant species) Hydrilla grew luxuriantly and quickly expanded into neighboring, unplanted pots within the tanks. In the presence of Vallisneria, hydrilla mass was reduced and the expansion of the original plants into neighboring pots was minimal. In the presence Hydrellia, the hydrilla plants were noticeably damaged and total biomass in the tanks was reduced, although expansion into neighboring pots was not slowed In addition, the Hydrellia damage was shown to decrease the photosynthetic potential of affected Hydrilla stems by approximately 50%. The combination of both the biocontrol agent and the presence of a competing plant species resulted in lower mass and slower expansion of the original Hydrilla plants.

Large scale cattail (*Typha subulata*) control with imazapyr in restored irrigation drains of Janauba, MG, Brazil (465)

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Gorutuba, an irrigation project established by the Brazilian government (CODEVASF) to develop the Janauba region, has a large extension of drains built to remove water excess from irrigated areas. Cattail (*Typha subulata*), a perennial species able to live in shallow waters, is a major concern in the project area, causing obstruction of water flux in irrigation drains. Because of its fast sprouting from rhizomes, irrigation drains have been mechanically restored every year, at a very high cost. This research had the objective of verifying agronomic and environmental effects of a large scale application of imazapyr on cattail control in a wide drain restored mechanically 60 days before. Imazapyr was applied on 06/23/98 over cattail plants at the rate of 1000 g a.i. ha^{-1} with a lateral boom sprayer equipped with two OC20 nozzles. Water samples for determining residues of imazapyr in laboratory were taken 60, 120, 180, and 240 m from the initial point of herbicide application, immediately after, 30min., and 1, 2,4, 8, 24 and 48 hours after spraying. Evaluations of cattail control were made by counting of sprouts on 08/23/98, 60 days after imazapyr application. Besides cattail, other plants were recorded living in the drain or on its margins: *Brachiaria mutica*, *Cyperus* sp., *Calotropis procera*, *Polygonum hydropiperoides*, *Sorghum arundinaceum*, and *Nymphaea ampla*. Imazapyr at the rate of 1000 g a.i. ha^{-1} showed a good performance over cattail plants with 100% control 60 days after application. Lab results showed that imazapyr residues were 0.360 ppm

immediately after application and decreased to 0.024 ppm 48 hours later. No side effects were observed on non-target species.

Relative tolerance of mat-forming algae to copper and its implications (466)

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The major method used for algae control in the U.S. is the application of copper, either as copper sulfate or copper chelates. Certain groups of phytoplanktonic algae, such as the green algae, are known to be more tolerant to copper than groups such as the cyanobacteria. Through experience, commercial applicators suggest that mat-forming algae also differ in their susceptibility to copper, but to this point, data to support these observations have not been available. Laboratory studies in which unialgal cultures of selected mat-forming algae were exposed to a range of copper concentrations show a clear progression in copper tolerance. The EC_{50} values (concentration of copper in mg Cu/L that results in 50% reduction of biomass) were grouped as follows: less than 0.003 (*Spirogyra* Link, *Oedogonium* Link), approximately 0.050 (*Hydrodictyon* Roth, *Pithophora* Wittrock, *Rhizoclonium* Kª), and greater than 0.200 (*Oscillatoria* Vaucher ex Gomont). (Note: these concentrations are lower than EC_{50} concentrations expected in the field because they were determined in culture medium with very small amounts of algae, conditions quite different than in most field situations). These data are important to us in the midwestern part of the U.S. because *Oscillatoria* is becoming a more frequent component of mat-forming algae infestations. The *Oscillatoria* infestations are caused by at least five different species, each of which is very tolerant to copper. Circumstantial evidence suggests that the increasing frequency of this mat-forming cyanobacterium is due to elimination of more sensitive genera (such as *Spirogyra* or *Rhizoclonium*) with heavy copper dosing. In addition to concerns often expressed about copper use, such as buildup in the sediments, toxicity to invertebrates, and possible (although not well verified) resistance of phytoplanktonic cyanobacteria, another compelling reason to seek alternative approaches to copper is the buildup of copper-tolerant mat-forming algae.

The spread of *Myriophyllum elatinoides* Gaudich. and *M. aquaticum* (Vell.) Verdc. from stem fragments (467)

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Myriophyllum elatinoides and *M. aquaticum* (Haloragaceae) are two submersed plant species, whose luxurious growth causes problems in irrigation systems, lakes and ponds. Mechanical clearance (cutting, dredging) is the most widely practiced method used for their control, but this technique encourages vegetative reproduction through plant fragmentation. Since the mechanical procedures cause the burying of plant fragments in the sediment, the aim of this work was to study the potential of fragments of both species to sprout from various soil depths in the same growing season. The study was conducted in a greenhouse, using 12 tanks (150 L) interconnected by a water circulation system. Stem sections of adult plants of both species, two- or five-node-length (2n and 5n, respectively), were planted in 800 cc pots, then submerged in the tanks. Planting depths were: surface (S), subsurface (SS), 1.5 cm (D1), 2.5 cm (D2), 5 cm (D3) and 10 cm (D4), resulting in the following treatments: 2nS; 2nSS; 2nD1; 2nD2; 2nD3; 2nD4; 5nD2; 5nD3; 5nD4. A complete randomised design with four replicates was used. A sprouting of 100% was observed for both species in the 2nS treatments, with an emergence time of 6.25 1.25 days for *M. elatinoides* and 5 0.81 days for *M. aquaticum*. In the 2nSS treatments, a 50% sprouting was observed only for *M. elatinoides*, with an emergence time of 4 0 days. No sprouting was found for D1 or deeper treatments 20 days after planting. The growth rate of emerged plants was higher in *M. aquaticum* than in

M. elatinoides. Results showed that sprouting was successful only when nodes were not completely buried, suggesting that light is probably a limiting factor in the establishment of vegetative propagules of both species.

Effects of twenty-four herbicides on the growth of green algae *Chlorella pyrenoidosa* (468)

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The effects of 24 herbicides which have 15 different chemical structures and 9 different classes to the green algae (*Chlorella pyrenoidosa*) were studied through 96 h acute toxicity tests in this paper. Experimental results indicated that the acute toxicities of the selected herbicides were all high. Compared with the others, the acute toxicity of hormone-type herbicides was considered as the lowest and that of photosynthesis-inhibiting herbicides, the highest

A comparison of control techniques for *Spartina anglica* in a South-East Australian estuary (469)

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Physical and herbicide treatments of an estuary infestation (Tasmania, South East Australia) of *Spartina anglica* were compared to determine an optimum treatment for medium to long term control of this estuarine weed. Treatment plots (slash/smother, slash, slash/glyphosate/smother, and glyphosate) were compared with a nil treatment in a randomised complete block design with four replicates. Slashing consisted of cutting the grass to ground level; smothering consisted of covering the grass with a black polyethylene cover; glyphosate treatments consisted of applications of 24g a.i. L^{-1} to the plants. After twelve months, *S. anglica* was harvested from treated plots. Samples were oven dried at 70°C for 48 hours and then weighed. Data was subject to an analysis of variance using MINITAB software. The Fischer's protected Least Significant Difference was calculated at a level of significance of $P = .05$. Analysis of results indicated the most effective treatments were slash/smother and slash/glyphosate/smother; these treatments resulted in 97% less biomass than in the nil treatment. As there was no significant difference between these two treatments, it was concluded that the slash/smother treatment was suitable for medium to long term control of rice grass. In practice, this treatment could be combined with follow up smothering and hand removal and would be ideally suited to smaller satellite infestations of *S. anglica*.

Teaching effective weed management skills to agricultural producers and other land managers (470)

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Weed recognition and effective use of integrated tools and strategies are skills that must be acquired by farmers and other land managers to successfully control weeds. These skills can be taught using a wide variety of methods, ranging from personal one-on-one contacts, to large group instruction, to mass media delivery. Some of the most common weed management training opportunities for farmers in the United States are workshops and seminars offered frequently by university and/or industry specialists. In some instances this training is also provided via satellite or other two-way electronic communication systems to reach remote audiences. Many State Departments of Agriculture now encourage farmers and other licensed

herbicide applicators to attend weed training sessions by offering recertification credit incentives. Individual and group tours of replicated weed control demonstrations established by weed management professionals on farmers' fields can provide highly credible instruction on the safe and effective use of herbicides or other control methods. Extension weed specialists and agricultural industry representatives produce a wide range of brochures, bulletins, books, videos, and slide sets containing current information on weed identification and control. County Extension agents, agricultural product representatives, and private agricultural consultants provide farmers with personalized decision-making information. The internet has become an increasingly valuable training tool and source of specific weed management information. There farmers can quickly access information that will help them identify unknown weeds and select appropriate control options for their circumstances.

Weed control advising in an European Mediterranean region (471)

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Among the Mediterranean countries, Spain could be an example of a medium developed agriculture. During the past twenty years agricultural labor has been reduced by half, being nowadays 8% of total labour as average, but there are some regions where it is higher than 20%. Most young people have disappeared from farming and we have an average of nine farmers, generally older than fifty, for each 100 ha. During 1999 a survey was carried out in Aragon, which is representative of Spain's agricultural developed regions, to investigate aspects of weed management extension. The results were compared with a similar survey made in 1981. The survey was made through an official plant protection bulletin, that is freely distributed by farmers or managers. Over 265 usable responses were received. In the region surveyed, farmers grow fruit trees (peach, pear), wheat, alfalfa, maize, rice and horticultural crops under irrigation and winter cereals, olive, almonds and vineyards in dryland. *Cynodon dactylon*, *Avena* spp., *Amaranthus* spp., *Lolium rigidum*, *Salsola kali*, *Sorgum halepense*, *Cyperus rotundus*, *Echinochloa* spp. and *Setaria* spp. were considered to be the most important weeds. Weed control information is delivered to farmers through the herbicide dealers, administration services and the farmers association/cooperative technicians. The price (indicated by 49% of the respondents), lack of effectiveness (48%), fear of crop damage (42%) and observed phytotoxicity are the main problems with herbicides as ranked by farmers. Environmental damage and herbicide resistant weeds worried 16% and 5% of farmers respectively. Only 3% do not use herbicides. Official instructions (mailed in the bulletin) were understood by 77% (1999) and 95% (1981) of farmers; 88% (95% in 1981) considered that they were useful, while only 58% (64% in 1981) believed that they were sufficient. These figures show the higher complexity of the weed management recommendations given nowadays, due to more stringent pesticide regulations. Moreover, 66% of farmers consider that pesticides are not correctly applied. The new requirement that an official sprayer license be obtained after a specific training course could improve this aspect. The more frequent suggestions to improve the official information received about herbicides were: selection of the best products among those labelled (56%), more information (47%) including herbicides prices and treatment costs (55%) and results from the official trials (46%). The Cooperative technicians, the plant protection R+D official centres, the University, the Spanish Weed Science Society (founded in 1989), the Herbicide Resistance Committee and the Working Group of the Plant Protection Services have significantly contributed to the extension and transference of the R&D results in weed science, but there is still a long way to go.

Educating weed management professionals as solution providers in tropical agribusiness (472)

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The development of competitive systems for weed management depends on the availability of well trained and educated professionals who should be familiar with the complexity of the agribusiness. Weed Science is a complex discipline without a well defined core curriculum while educating people in most college and universities. Nevertheless, we must continue to examine critically how to prepare personnel for careers in weed science. The first consideration in training weed management professionals is to recognize the responsibilities of individuals and organizations involved in conducting weed science programs. The major objective of educating professionals for being solution providers whether in research, teaching or extension is to impart information and curiosity and critical thinking into these people minds. Weed science is most effective when viewed as a component of the entire production system. These approaches and experiences are not usually met yet at many universities. However, research and transfer technology networks should improve the dissemination of knowledge and help demanders to outline and express interactively their problems. The communication capabilities of the Internet have already demonstrated viability and value to enhance the organization of scientific work. The strengthening and modernization of EMBRAPAs technology transfer processes aim to develop mechanisms to increase the amount of people who will benefit from the communication and agribusiness events in Brazil. Computer systems, satellites, TV networks, online education (distance instruction), CD-ROM and videotapes are the most recently applied information and communication technologies in addition to an increased use of the traditional communication events and products such as technical publications. Among new possibilities, a technological information network would provide technical assistance personnel, online access to databases with solutions to the operational problems of agribusiness.

Sharing information with no-till farmers (473)

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There is a no-tillage cropping revolution happening world-wide. Both Paraguay and Western Australia have very high farmer adoption rates (60%). This revolution is largely attributable to herbicide technology and the safe transfer of systems knowledge to and among farmers. Under the general topic of ‘‘Novel-Tools’’ for spreading weed science information, I will share some of the techniques that WANTFA uses. Where do new ideas come from? Agricultural scientists often take the credit for farmer ideas. Publishing papers on these ideas gives credit to the scientist, and not the farmer. Papers help scientific career paths, and such rigour enables polished talks. However, the important issue is - how to help the farmer who has already solved that problem and now has a more pressing one? Leading edge farmers are often frustrated by this scientific validation period. Because for many scientists - this is their life. Not all agricultural scientists have the farmers interests at heart. Grass roots systems success! For example - farmers have been observing weed benefits from no-tillage for nearly a decade. Yet local data is only now emerging to verify this. This is not necessarily a criticism of individual scientists. However, there is farmer frustration when research contradicts farmer experience, and what do you do then? If there is a conflict, then the farmer must be right, even if he loses the argument, for it is the farmer that makes the living from the farm - or is the scientist living on the system? If scientists want to be useful then they must take the time to understand the system. What novel tools? Listening, collating, disseminating, promoting discussion and providing a forum may not be new tools. But the way we use these tools has been the key to their success for us. The specific mediums we use are: a newsletter, conferences, field days, scientific input and a recent web page (wantfa.com.au). The full talk provides more on the method, or more accurately, the spirit of communication, which is not to, but with, the farmers - the team approach!

Didactic strategy for technology transfer on weed control, management and eradication (474)

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The wrong application of measures for terrestrial and aquatic weed control increases the investment costs and also causes several adverse effects such as dissemination and selection of species resistance against herbicides, as well as environmental and soil contamination. The communication deficiency and training of users, as well as the inadequate formation of the trainers which are in charge of the technology transfer which was developed or adapted for weeds control, management or eradication, are part of this problem. In Mexico, an integrated strategy is applied in order to prepare trainers in irrigation, focus on a better use of the water in the field field, through a 40 hour course which considers technical and didactic aspects, as well as in-field demonstrations. The performance of the trainers, which were evaluated through direct observation and interviews was significant, since a more adequate instructional, technical and group planning management was identified. The above didactic strategy is considered to be feasible to be applied in weed fields, adapting didactically themes such as planning and design of didactic materials and instructional behaviour; on the technical aspects, themes such as biology, ecology, and control, management and eradication from an integrated point of view are need to be adapted. In order to implement the aspects which were seen in the classroom, the in-field part is carried out in field plots, canal or demonstrative meadow, according to the weed which is locally important. These trainers become sensitive to their duty and mission for the technology transfer to the final users. The several problems caused by weeds demand global strategies, where not only human, technical and institutional, but also in a short term, international efforts are required.

Growth boxes and permanent displays to show creeping perennial roots (475)

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Large growth boxes and permanently mounted portable displays of plants grown in them have proven very effective for demonstrating the extent of underground development of *Cirsium arvense* (L.) Scop. and other creeping perennial weeds. A 30 cm segment of root is planted in an aboveground box filled with loam topsoil in the spring. After a full growing season, the underground system is exposed by washing (hopefully with minimal damage). The growth box is placed at a field day site so that it can be opened and used as a demonstration. Freshly opened boxes contain plants with underground systems exposed, intact, and alive. The relatively large amount of growth coupled with the development of buds and emergence of shoots graphically illustrate the survival and reproductive capabilities of creeping roots. The growth box has one layer of 2 cm exterior grade plywood on the sides and ends, with a double-layered bottom. The box is reinforced with strips of 5 X 10 cm lumber in each inside corner and three more parallel to the ground on the outside of the sides and the ends. Threaded rods (0.8 cm dia) are run through the reinforcing strips on the sides to keep the sides from spreading and give the box strength. Lag screws are used to hold the boxes together. After the field day is over, the plants are dried down with the roots intact. The roots are mounted in a display box that can be exhibited. The dried root exhibit is mobile, relatively permanent, and graphic. Our permanent portable trifold display measures 60 X 90 X 12.5 cm when folded and 180 X 90 X 12.5 cm when open. At least a week of effort scattered over six to 12 months is required to complete and mount a display. We believe the benefits are worth the effort.

Safety conditions for glyphosate applicators in *Eucalyptus* forests using knapsack sprayers and spray lances attached to tractor powered sprayers (476)

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Safety conditions of operators applying glyphosate in *Eucalyptus* forests from Aracruz Celulose S.A. using lever operated knapsack sprayers and compression sprayers, and hand lances attached to tractor powered sprayers were evaluated and the efficiency of protective clothing was estimated. Potential dermal exposures

(PDE) of the operators were assessed with the knapsack sprayers, applying 300 L ha^{-1} of spray solution containing 1% of Roundup (480 g of glyphosate/L) on stumps. Evaluations were conducted also on the loaders of compression sprayer. Regarding tractor powered sprayers, one type of spray equipment consisted of tractor trailed sprayer fitted with a 9 m boom positioned 2.3 m high, to which were attached 6 hoses, each measuring 5 m long and connected to a spray lance which was handled by one operator. The PDE of the tractor driver and of 6 operators of hand lances, applying 120 L ha^{-1} of spray solution containing 3.34% of Roundup (480 g of glyphosate/L) on stumps, were evaluated. Another sprayer used was a tractor sprayer with single 70 m long hose ending in a hand lance. The lance was handled by one operator who had a helper to pull the hose, applying 600 L ha^{-1} of 1% Roundup. Evaluations were conducted for the operator and the helper. The PDE were estimated in 22 body parts in 10 replications Efficiencies of protective clothing were estimated considering 80% control of PDE by overall with hood, 99% by gloves, 95% by boots and 90% by mask. Safety of operators was evaluated using the margin of safety formula [MOS = NOEL/ (Absorbable Amount of the Exposure X 10)] being safe if MOS $>$ 1 and unsafe if MOS $<$ 1. Working conditions for all these operators were safe (3.7 $<$ MOS $<$ 44.5) with or without using protective clothing, except for six operators handling lances without protective clothing (MOS = 0.8).

Farming system implications of herbicide resistant *Lolium rigidum* (annual ryegrass): how RIM (a bio-economic simulation model) can help us understand them (477)

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The presence of herbicide resistance on farms represents a management challenge for farmers. Integrated weed management systems (IWM) are promoted as a means of managing herbicide resistant weeds and/or delaying resistance development. Yet many of the control options considered within the framework of IWM are either new to existing cropping systems, require significant capital outlay or are perceived to present threats to other components of the cropping system. Workshops for farmers have been developed using the Ryegrass Integrated Management model (RIM) to highlight the value of using IWM to manage annual ryegrass. RIM is a bio-economic simulation model. The model enables users to investigate the impact of different biological, cultural, mechanical and chemical weed management options. This is achieved through nomination of an enterprise sequence (rotation) over a 10-year period and selection of individual control treatments in each year. There are 35 treatment options that the user can select from and design into an IWM system. A key benefit of the model is that the tasks the user has to perform are very simple (the selection of rotation and control options) yet the results presented capture many complex biological interactions. The farmer workshops have increased understanding of IWM and the impact of herbicide resistance on the farming system. This has been achieved through group discussion of key model output, such as ryegrass numbers and economic costs and returns, and through the process of designing control strategies. The large degree of flexibility built into the model enables farmers to personalise scenarios. The model is a means of assessing the value of control treatments with little personal risk to the grower. Sensitivity analysis can be used to assess the potential impact of individual control treatments in a range of situations. This makes RIM a very valuable decision support tool.

A web site to supplement an introductory weed science course (478)

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Undergraduate courses in weed science typically include lectures, laboratories, and supplemental information such as manuals, slide sets, and handouts. Through use of the internet, this supplemental information can be provided in a systematic manner easily accessible to all students on and off campus. A web site was designed and constructed to assist in teaching an introductory course in weed science. The site contains course information such as the syllabus, requirements and descriptions of a weed collection, photos and descriptions of weed species students are required to identify, and information on herbicide families, chemistry, and mode of action. The site was first used in 1998 with improvements made in 1999. The site was monitored for use and a survey of the students was conducted to assess the value of the site.

Educating politicians and decision makers about weeds and weed science (479)

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Many in the scientific community question the value of trying to educate politicians and other decision makers about issues relative to their disciplines. Many consider that their science speaks for itself and that it is poor use of their limited time to attempt to educate these groups about the issues related to their science. However, nothing could be farther from the truth! Politicians in particular greatly influence monies allocated for research by weed scientists and weed management by governmental agencies. In turn, decision makers in governmental agencies ultimately determine how monies allocated by politicians for research or weed management are used by their agencies. There are key elements that should be used when educating politicians and decision makers. The issue must be driven by private enterprise or it must affect private enterprise and the basic economic system of a particular country. There must be a strong relationship between the issue and the people; i.e. the issue must have public support. It is essential to have data to support the position that one develops. These data should be generated through sound research and must address economic, agricultural, and environmental perspectives. It is important to point out problems, and it is essential to offer solutions. Political support at the local level is of prime importance because local politicians can help to persuade higher level politicians. A group seeking to educate politicians and decision makers about weed science or other scientific issues should be drawn from as diverse a stakeholder group as possible and they should seek the support of their scientific societies. Develop position papers that take a stance, but be willing to negotiate an acceptable compromise. Most importantly, be consistent and persistent.

Risks, science and politics of GM crop plants (480)

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The development and commercialisation of genetically modified organisms (GMOs) has generated an unprecedented amount of controversy compared to past technological innovations. At the international level, public and government attention has focused on the movement of GMOs across national boundaries and the ensuing potential risks to the agricultural environment and biodiversity. The attitude of politicians around the world varies significantly with respect to such risks. Those who see as their first priority the support of knowledge-based industry which makes a strategic contribution to the competitiveness of national economy tend to dismiss such risks as unwarranted by ‘‘sound science’’. It is also generally accepted that, on occasions, regulatory decisions regarding GMOs are taken under the strong pressure of commercial and trade expediencies. This pressure makes it difficult to justify a case-by-case precautionary approach and thus ‘‘absence of evidence’’ of environmental risks is frequently equated with ‘‘evidence of absence’’. The burden of proof is thus transferred to those who advocate such risk(s). However, more often than not, many of the issues related to the use and commercialisation of GMOs have little to do with ‘‘sound science’’ and are mainly of a socio-economic nature. Although science plays a pivotal role in identifying and solving environmental problems, it is not in itself a sufficient basis for political decision making. The paper attempts to identify some of the main issues involved in regulation of GMOs, the role of scientific advice

and public perception in shaping policies and mechanisms that may enhance public confidence in political decision making.

Legislating for sustainable weed management in Tasmania, Australia (481)

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In order to ensure the benefits of weed science are realised through the application of on-ground weed management activities, it is important that there is political, public, and legal support for these management activities. As part of an overall strategic approach to weed management in Tasmania, weed scientists extended their role to developing a scientifically sound weed management law to ensure there were legal requirements for integrated and sustainable weed management operations. The Weed Management Act 1999 places a statutory requirement for assessing the weed risk of plants if they are to be declared weeds under the Act. In addition simply declaring a species as a weed under law is recognised as being insufficient to ensure action against that weed. Once a plant species is declared a weed, there is a statutory requirement to develop a scientifically sound weed management plan for that species which not only contains details as to exact actions needed against the weed and legal requirements to undertake those actions, it also details responsibilities for undertaking those actions. Further the laws require regular review of these plans to ensure they are being implemented appropriately. Finally, both declaration and weed management plan preparation processes are subject to extensive consultation with the general public and provides anyone interested with opportunity to participate in the process. Such laws, as part of a government/community joint strategic approach to weed management, not only lead to a ‘‘weeds-aware’’ society, they provide an atmosphere in which advances in weed science and improved weed management capabilities can be fully realised.

Awareness of invasive weeds by governments (482)

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The Weed Science Society of America and its regional affiliates (Northeastern Weed Science Society, Southern Weed Science Society, North Central Weed Science Society and Aquatic Plant Management Society) collectively fund a full time representative to work with the national legislature and government agencies. A primary role of this liaison has been to improve awareness of the problems caused by weeds and the existence of a scientific discipline dedicated to mitigating these problems. Fortunately, invasive species has become an issue of national concern that has provided weed scientists an opportunity to increase awareness of invasive plants. During the past year Weed Science Society of America members have been invited to testify at hearings in both chambers of the legislature. Another member was invited to join a panel of distinguished scientists that addressed a group of state governors who gathered to discuss invasive species problems. These small accomplishments are significant milestones in a long term effort to create a national resolve to address the problem of invasive plants. In addition significant efforts have been made to reach people throughout the government because the resolve to address weed problems must be expressed at all levels. A single person in the right position who is unaware or unconvinced of the problem can curtail funding and progress in entire agencies. To create this general awareness, the Weed Science Society of America joined a consortium of concerned individuals and groups both inside and outside the government to organize the National Invasive Weed Awareness Week in February 2000. Weed scientists and weed management practitioners from throughout the country came to Washington, DC to participate. The week featured seminars for congressional staff and for the general public, interagency meetings of the federal agencies with land management responsibilities, exhibits in a public area at the capitol, legislative training sessions for visiting scientists and numerous direct consultations with congressional and administration staff. In addition to raising awareness it is important to apply the expertise which exists within the scientific societies. In many of the land management agencies that are responsible for weed management on extensive acreage there are either too few or no professional weed scientists employed. As a result the full range of methods and experience available to solve problems is often not realized or utilized. In response WSSA and its affiliates sought to have members included on a prestigious Invasive Species Advisory Council that was created by a an Executive Order of the President. The three candidates nominated by WSSA to represent different geographical regions and technical expertise were all appointed to the council. The public interest in the entire invasive species issue has presented weed scientists an opportunity to perform a public service which will be widely appreciated. It has provided an opportunity to demonstrate the value of an often overlooked discipline. There is an opportunity to extend the good will that has been created into better public appreciation of the science as it is applied in agronomic, recreational, industrial, aquatic and landscape environments. The evolution of this good will is dependent on the willingness of scientists to participate in public outreach activities.

National Weedbuster Week: linking weed communication and action across Australia (483)

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National Weedbuster Week (NWW) is part of an Australian weed awareness program and has been running nationally for three years in October with increasing momentum. NWW evolved from a Queensland project and has expanded with support from all levels of Government, Natural Heritage Trust, National Weeds Strategy Executive Committee, Council of Australian Weed Science Societies, the Cooperative Research Centre for Weed Management Systems (CRC), the community and industry. NWW aims to increase the awareness of weeds within Australians, and improve links between Australian community groups, Government, and industry that are involved in weed management to increase coordinated on-ground weed management action. The overall program treats weed awareness as a Social Product. The weed awareness Social Product is divided into the three components; idea, practice and tangible objects. These components are marketed to the target audience and/or adopted by them. The idea component utilises an extensive media campaign and focuses on audience beliefs, attitudes and values. The behaviour component focuses on participation at one of the many NWW activities across Australia in addition to promoting the good behaviours needed for weed management. The tangible product component combines the development of NWW promotional materials in addition to weed awareness information material that is linked to the yearly themes. A character known as Woody Weed has been developed to assist the promotion of NWW and overall weed awareness. The 1999 NWW program was successful in attracting thousands of Australians too greater than 600 events that ranged from weed removal and regeneration to displays, seminars and field days. Over 400 different groups from agencies such as Government, Landcare, Coastcare, Bushcare, Greencorp, schools and private enterprise conducted the events. Many of these groups are now joining together to share resources to gain mutual benefits as part of NWW. The success of NWW relies heavily on acceptance and action from groups and agencies. In 1998 over 350 weed related media hits were recorded nationally during NWW which equated to over $370 000 media publicity. In 1999 in excess of 550 different weed related media hits were recorded during NWW. Future proposals include the strengthening of networks with other countries and organisations to develop an International Weedbuster Week.

Weed control technology transfer systems in Nigeria and the United States of America (484)

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Weed control remains a major limiting factor to efficient crop production in the developing countries but not in the developed countries. This paper analyzed the support systems for weed control technology (WCT) transfer in the United States of America (a developed country) and Nigeria (a developing country). The objectives were to describe the current status of WCT transfer in both countries, identify factors that account for the adoption of modern weed control practices, and discuss future challenges. The United States has a dynamic WCT transfer system driven by demand for science-based information. It is sustained by the combination of a responsive and proactive agricultural research and extension based in Land Grant (state funded) universities, a strong public and private sector support for research into innovative weed control technologies, and a highly competitive economy. In Nigeria, WCT transfer is slow and incapapble of responding to the needs of a competitive economy. Government is the main engine that drives WCT transfer. Support for research or participation in technology transfer by the private sector is insignificant. In the United States, the level of clientele awareness and adoption of current weed control recommendations measure the success of cooperative extension in WCT transfer. Accountability is also entrenched in research grant agreements to ensure that grant beneficiaries focus on WCT objectives. Profit-oriented organizations involved in WCT generation and marketing, compete vigorously to retain or win customers. In Nigeria, government determines how WCT is transferred. Crop production remains unprofitable and lacks motivation for private sector investment in research to support WCT transfer. In the 21st century, biotechnology will have great impact on weed control practices. The dynamic research and extension system in the United States will, as always, respond to the challenges of the new dispensation. However, Nigeria needs active participation of the private and public sectors in an agricultural policy that integrates a WCT transfer system that is responsive to the realities of the 21st century.

Balancing initial vs residual activity of soil-applied herbicides (485)

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Reducing herbicide use while maintaining adequate weed control is the main goal of precision or site-specific weed management. Because of the high weed density and diversity of our arable fields, and more importantly the different nature of New Zealand soils, the herbicide recommendations developed in other countries are often not suitable for New Zealand agriculture. Most of our soils are acidic (pH 5.5-6.5) and contain high organic matter levels (5-15%). Many soils contain a high proportion of allophane clays derived from volcanic materials. Our results from a large number of greenhouse and field studies have confirmed the significant negative relationship between herbicide phytotoxicity and soil organic matter and clay content. However, the effect of increasing organic matter levels diminishes at the higher end of the range, which contrasts with many theoretical studies and with results of experiments using soils fortified with charcoal. Our research on herbicide-nutrient interactions determined that normal and moderate rates of phosphate fertiliser application had no marked effect on phytotoxicity of soil-applied herbicides. Field studies have also proven that both the initial and residual activities of some herbicides were significantly increased by heavy soil compaction. Adequate soil moisture at time of application was found necessary for optimal efficacy, and temperature had a strong influence on degradation rates of the herbicides studied. Using bioassay methods we have shown that although the residual activity of a herbicide from a given concentration varies greatly between soils, it is fairly similar if the initial concentration is adjusted to the GR_{50} value of these soils. Research efforts should therefore be directed at accurately defining the initial application rates of herbicides for different soils. Adjusting herbicide rates to suit soil characteristics will

minimise residue carryover and environmental contamination problems in addition to providing the desired weed control while avoiding crop injury.

Soil desorption of herbicides and environmental impact (486)

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This paper demonstrates how herbicide soil desorption could affect environmental safety. Soil-bound paraquat was almost not desorbed and environmentally safe, whilst soil-adsorbed quinclorac was desorbed proportionally to the residual concentration, the time-period and the amount of soil water flow, causing problems in agriculture. After 26 years of continuous paraquat use, soil residues in 120 Korean orchards, mostly kaolinite soil, were ca. 7.54 ppm in 1996 and 1997 surveys. Except for an extreme of 35.02 ppm, two thirds of the soils contained bound-paraquat less than 15 ppm. Paraquat binds very strongly to soil, but strong binding capacity and binding-tightness differ according to the type of clay mineral; kaolinite is the lowest. The strong adsorption capacity (SAC-WB) of Korean orchard soil was ca. 253.5 ppm in the surveys. Bound paraquat below SAC-WB value was almost not desorbed; in a typical kaolinite ploughed soil, only 3.53 10^{-4} and 0.07% of the bound paraquat were desorbed from the soil containing 255 and 364 ppm of bound paraquat, respectively. Though quinclorac has been known to be slightly adsorbed by soil, we found that quinclorac was easily and much adsorbed to silty clay loam of kaolinite (Kf = 12.48 on Freundlich isotherm). The soil-adsorbed quinclorac by 20 DAT accounted for more than 99.4% of the total amount of quinclorac applied. Quinclorac desorption continued until the residue disappeared from the soil. Desorption was much slower than adsorption. Our study also showed that tomato, the most sensitive crop to quinclorac, did not grow normally even with the irrigation water containing 10 ppb quinclorac, and in the soil containing 0.1 ppb. This easy-desorbing characteristic could cause phytotoxicity to following crops (e.g. Solanacea crops), and to crops irrigated with quinclorac-contaminated water, although quinclorac has been known to be quite safe to wildlife. The differences in desorption thus resulted in contrasting fate of these herbicides; the use of quinclorac is now banned in Korea and Japan. At present, data on adsorption are fairly available but desorption data are not. Further study on herbicide desorption in relation to environmental safety would reduce the environmental impact of herbicides.

Sulfonylurea persistence in various climates of Australia (487)

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Sulfonylureas are used extensively in the wheat regions of Australia, which consist of varied climatic zones with large differences in patterns and amounts of rainfall and temperatures. Persistence and movement of chlorsulfuron were measured at sites with similar soils across the south-east (SE) and north-east (NE) wheat regions. Soils were alkaline (pH 7.0-9.0) vertosols (clay 45-70%). The NE region has a sub-tropical climate with summer dominant rainfall and warm temperatures, whereas SE experiences Mediterranean climate with winter dominant rainfall and cool temperatures. Persistence of residues at all sites and movement at SE were determined by bioassay based on inhibition of root length of maize, lentil and pea seedlings. Movement of residues at NE was determined by enzyme linked immunosorbent assay. The NE sites were sown with sorghum and sunflower, whereas SE sites were sown with canola, lentil and medic. Persistence increased at sites in north to south direction, which was associated with decreasing winter temperatures from an average of 23 C (most northern) to 10 C (most southern). Chlorsulfuron residues in 0-10 cm at 5-6 months after early winter applications ranged from not detectable in most northern site to 2 ppb in southern sites. At 5-6 months, no residues were detected below 0-10 cm in NE sites, but substantial residues were

detected to 40 cm in SE for up to 2 years. These differences in leaching are likely due to differences in degradation rates and in-crop rainfall. The differences in persistence and leaching between sub-tropics and Mediterranean sites had a large impact on re-cropping. Response of sorghum and sunflower in NE was strongly related with thermal time ($R^2 = 0.72$-0.78), more so than plant-back, and was unaffected by rainfall τ300 mm. However, a minimum plant-back of 2 years was needed for sensitive crops in SE due to long persistence of residues in the very alkaline soil profile.

Soil persistence of herbicides and replacement crops. What to learn from 20 years of field experiments? (488)

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At the University Experimental Farm, the question ‘‘Which replacement crop(s) can be planted safely in case of crop failure?’’ is being addressed since 1978 by carrying out ‘‘field persistence experiments’’ using a simple setup: herbicide application on 3 m wide strips on a bare sandy loam soil in the fall and/or in spring followed at about 20 and 5 WAT respectively by seeding, across treated and untreated strips, 21 test crops into a seedbed prepared by shallow, non-inversion tillage operations; reseeding at about 30 and 15 WAT of 4 test crops on early harvested strips. Today, with some 250 ‘‘herbicide - dose - time of application’’ combinations evaluated, in a number of experimental years ranging from 1 to up to 11, it is clear that invaluable information can be derived from the experiments and used advantageously not only for primarily technical purposes but also for education and training: (1) Visualization of herbicide action (activity, selectivity, mode of action, symptomology) through the soil, for a wide range of compounds to a wide range of test crops, representing 21 plant species and 8 families; (2) Selection of suitable bioassay test plants for monitoring soil degradation of herbicides; (3) Assessment of eventual risk for carry-over injury to rotational crops by the late test crop reseeding. Results from further separate experiments with a similar setup illustrate the significant effects (1) of type of soil tillage (inversion versus non-inversion), used for seedbed preparation prior to installing the replacement crops, and of degree of herbicide mobility on replacement crop response; (2) of soil pH on test crop injury by cereal and maize sulfonylureas. Finally, to facilitate extension, a vast amount of experimental results has been included into the RECROP database with electronic and printed versions.

Phytotoxic persistence of chlorimuron and metsulfuron in soils of the Pampean region of Argentina (489)

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Chlorimuron and metsulfuron are sulfonylurea herbicides widely applied in the humid Pampean region of Argentina for soybean and wheat crops respectively. Persistence of these herbicides in soil can affect subsequent crops as sunflower. Soil and herbicide characteristics along with rate of use strongly influence persistence of these herbicides. Information regarding chlorimuron and metsulfuron persistence in Argentina is limited. The objective of this work was to determine persistence of chlorimuron and metsulfuron in two soils of Buenos Aires province of Argentina. Sunflower (*Helianthus annuus* L.) plants were grown in pots under glasshouse conditions at different times after herbicide application in order to detect the presence of herbicides in soil. Rates of 0x, 0.5x, 1x, 2x and 3x were applied to soil for both herbicides. Recommended rates (1x) for chlorimuron and metsulfuron were 12.5 g a.i. ha^{-1} and 4.02 g a.i. ha^{-1} respectively. Balcarce (7.5% OM and 5.9 pH) and San Cayetano (4.0% OM and 6.8 pH) soils were used. Phytotoxicity of

herbicides was measured in terms of plant height reduction (PHR) relative to check (0x). The limit of persistence of herbicides was considered when a 10% of PHR was achieved. Phytotoxicity of both herbicides increased at higher rates. Besides, PHR was higher in San Cayetano than in Balcarce soil. Persistence at recommended rate was 70 and 170 days after application (DAA) for chlorimuron and metsulfuron respectively in San Cayetano while, for Balcarce persistence was 21 and 71 DAA respectively. Application over the recommended rates greatly increased the persistence of chlorimuron in both soils whereas metsulfuron had little response. Differences between soil and herbicide characteristics explained persistence of chemicals while influence of initial rate was mainly restricted to chlorimuron.

Residual activity of fourteen soil applied herbicides determined by bioassay tests (490)

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In a Mediterranean-type climate such as that of Cyprus, it is possible to raise several crops within the same year. Control of weeds with herbicides may cause problems to follow-up crops if residues persist long enough to affect sensitive crops. A grower needs to know what can be safely sown after a treated crop is harvested or fails, and a new one is to be sown. The purpose of the present study was to determine for commonly grown crops the safe sowing period after the application of herbicides in three different seasons. Fourteen herbicides were studied, namely aclonifen, alachlor, chlorthal-dimethyl, diphenamid, flurochloridone, linuron, metribuzin, napropamide, oxadiazon, pendimethalin, prometryn, propachlor, propyzamide, and terbutryn. Test herbicides were applied on two soil types, a clay-loam and a heavy clay, in autumn, winter and spring. All plots were sprinkler - irrigated before and after application. Beginning two weeks after application and at three weeks intervals thereafter, test crops were sown in all treated as well as in untreated plots, which were irrigated as required for the duration of the trials. Fast-growing crops were allowed to grow for three weeks and slow-growing ones for four weeks before the activity of herbicides as growth reduction was visually assessed. When such reduction fell to 10% or less it was considered that the crop concerned could be safely sown in treated soil. Persistence, measured as biological activity, was shortest for propachlor, being just two weeks for most crops, and longest for flurochloridone. The phytotoxicity of flurochloridone persisted for more than 32 weeks on the most sensitive crops. For all other herbicides persistence was intermediate. Degradation was most rapid following spring application; it was slower following autumn or winter application. Persistence was longer in clay-loam than in heavy clay. Data, therefore, are presented only for the former soil type.

Persistence of fomesafen and imazamox soil-applied to bean crops under three water levels (491)

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The study of the factors that determine the persistence of herbicides in soil is important when working in irrigated systems, where it is necessary to use the same area for more than three crops per year. The objective of the assay was to evaluate the persistence of the herbicides fomesafen and imazamox under three different water levels applied on beans plants. The assay was conducted at Embrapa Arroz e Feijao, in Santo Antonio de Goias, GO, Brazil, dark-red latosol, in 1998. The experimental design was a randomized block with four replicates. The treatments consisted of applications of fomesafen (250 and 500 g a.i. ha^{-1}), imazamox (40 and 80 g a.i. ha^{-1}) on beans and a control, under water levels (average during the cycle), 2, 4 and 6 mm day^{-1}. The concentrations of the products as a function of days were evaluated by means of biological assays using sorghum as the test plant. The half-life (DT_{50}) of the products, the concentration of the products in soil so as not to result in any phytotoxicity effects on subsequent corn and sorghum crops

and the days needed to plant the subsequent crops were evaluated for each treatment. On average, the herbicide fomesafen presented a higher DT_{50} (higher persistence) than the herbicide imazamox. The highest degradation index of the herbicides in soil (fomesafen and imazamox) is obtained with levels of 6 mm day^{-1}, and so, the greater the water level is, the smaller the number of days needed to plant subsequent crops. Subsequent crops respond differently to herbicides on soil. Sorghum was the most sensitive to herbicide residues. If we consider the irrigated system and that the planting of the crops subsequent to winter beans is done from 75 days after the herbicide application, we would have serious restrictions for planting sorghum subsequent to beans when the herbicides fomesafen (250 g a.i. ha^{-1}) and imazamox (40 g a.i. ha^{-1}) were applied on the latter. In the case of corn, we would have restriction for planting if the water levels applied on beans were lower than 6 mm day^{-1} for the herbicide fomesafen (250 g a.i. ha^{-1}) and 4 mm day^{-1} for the herbicide imazamox (40 g a.i. ha^{-1}).

Sulfonylurea effects on following crops under semi-arid conditions in western Canada (492)

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The effect of residues from sulfonylurea herbicides on following crops has been a concern for several years in western Canada. There are other herbicides that persist just as long but residues from some of the sulfonylurea herbicides can injure the most susceptible crops at concentrations of < 1.0 çg/g soil. Therefore, with some sulfonylurea crop combinations > 90% of the applied herbicide must dissipate before the susceptible crop can be grown without injury. In addition, the cool semiûarid climate and pH > 7.5 in some soils tend to cause long−term persistence of sulfonylurea herbicides in western Canada. Field and laboratory experiments have been conducted to determine the effect of these herbicides on following crops. Of the crops grown in western Canada sugar beet and legumes such as alfalfa and lentils were the most susceptible to injury from sulfonylurea herbicides. Safe planting times after herbicide use for most susceptible crops on soils with pH > 7.5 and organic matter < 4% were > 6 years for chlorsulfuron, > 3 years for metsulfuron and triasulfuron and < 12 months for tribenuron. The phytotoxicity of sulfonylurea herbicide residues was highly correlated with soil organic matter. Clay content and soil pH did not have a significant effect on the phytotoxicity of sulfonyurea residues; however, dissipation may be slower in high pH soils. In the field, sulfosulfuron injured susceptible crops such as barley and canola for at least one year after application in soils with < 4.0% organic matter but did not cause injury, one year after application, in soils with > 4.0% organic matter. Field results with some sulfonylurea herbicides indicate phytotoxic levels may remain longer under drought conditions. The field testing of crop tolerance to sulfonylurea residues has in most instances provided sufficient information that producers can grow following crops without herbicide injury.

Persistence of low rates of metsulfuron-methyl in soil under permanent pasture (493)

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Metsulfuron-methyl is widely used around the world for controlling weeds in both cropping and non-cropping environments. It is known to have long persistence in basic soils but considerably shorter persistence in most acidic soils and in tropical climates. In New Zealand, this herbicide has been evaluated at low application rates (3-12 g a.i. ha^{-1}) for control of several weeds in permanent pastures. A series of trials carried out in spring and in autumn at four diverse locations throughout New Zealand evaluated the field persistence of metsulfuron-methyl residues using bioassay methods. Soil samples were taken to 5 cm depth at regular intervals and immediately frozen prior to bioassay in the greenhouse. Separate freshly collected soil from each site was used for the concurrently run calibration curves. Of the three test species used, *Lolium multiflorum* (L.) was least influenced by soil type and season with detection limits of 2-5 μg kg^{-1} soil, while the limits for *Trifolium subterraneum* (L.) and *Sinapis alba* (L.) ranged from 1-15 μg kg^{-1} soil. The persistence of metsulfuron was dependent on application rate and was influenced by the amount of rainfall in the first week after application. Other climatic factors, location, and soil properties had less influence on the length of persistence. In the trials that received more than 20 mm of rain in the first 7 days, phytotoxic residues from 3 g a.i. ha^{-1} metsulfuron-methyl dissipated within 28 days and from 12 g a.i. ha^{-1} within 42 days. In the trials that received less than 7 mm of rain in the first 7 days, phytotoxic residues from all rates required at least 63 days to disappear. The variations in persistence due to rainfall could create problems for farmers using the herbicide prior to pasture renovation or for the subsequent sensitive crops.

Effects of low rates of halosulfuron on carrot, celery, and onion (494)

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Halosulfuron is registered for postemergence weed control in corn. It is very effective on yellow nutsedge. As a sulfonylurea herbicide, it may persist in the soil for a long period of time. The current replant interval for vegetables ranges from 8 to 36 months. The objective of this research was to determine the potential carryover injury to carrot, celery, and onion in organic soils. Experiments were conducted in the greenhouse and field. In an experiment at MSU Muck Research Station, halosulfuron was applied to the soil at 0.036, 0.071, 0.140, and 0.28 kg a.i. ha^{-1} in September 1998. Carrot, celery, and onion were planted in the spring of 1999. Nutsedge suppression and crop injury were evaluated during the 1999 growing season and the crops were harvested at maturity. In the greenhouse, two experiments were conducted. In the first experiment, halosulfuron was applied preemergence at rates similar to those used in the field. In the second experiment, muck soil was applied with halosulfuron at 0.004, 0.009, 0.018, and 0.036 kg ha^{-1} to simulate residual halosulfuron concentrations in the field. Field application of halosulfuron 0.140 and 0.28 kg ha^{-1} gave good yellow nutsedge suppression on July 12, 1999. Lower rates were less effective in suppressing nutsedge. Carrot, celery, and onion treated with halosulfuron 0.28 kg had visual injury in midseason. Carrot and celery had yield reduction at that rate. There was no reduction in onion yield at any halosulfuron rate. None of the other herbicide treatments caused yield reduction. When similar rates of halosulfuron (0.036 - 0.28 kg ha^{-1}) were applied to soil preemergence in the greenhouse, weeds and crops were killed at all rates. In the second experiment with reduced rates, halosulfuron 0.009, 0.018, and 0.036 kg significantly reduced fresh weight of broadleaf weeds only. Fresh weight of carrot and grasses was significantly higher than the control with halosulfuron 0.036 kg ha^{-1}, probably as a result of better weed control. No treatment differences were observed in celery or onion. It appears that labeled rates of halosulfuron (0.036-0.071 kg ha^{-1}) will not cause serious carryover injury on carrot, celery, and onion planted on organic soil.

Clopyralid dissipation in plants and soil (495)

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Clopyralid is a broad-spectrum herbicide for difficult weed control in vegetable crops, sugar beets, rape and cereals. It is widely used in combination with other herbicides at application rates to 0.2 kg a.i. ha^{-1}. Field experiments were conducted to get more information on its dissipation in plants and soil under actual field conditions. Plant and soil (from 0-5; 5-10; 10-20 cm layers) samples were taken at regular intervals. Analytical methods included extraction under alkaline conditions, derivatisation using ethanol and conc.

H_2SO_4 and analysed by GC. Residue analyses in soil (pHKCl 6.0-6.3, humus 1.83-2.0) showed a fast disappearance of clopyralid. In the arable layer, the herbicide was detectable 14 days with the highest concentration in 0-5 cm layer. Its persistencein plants lasted more longer. Applied in different crops, clopyralid was detectable for about 56 days and the amount of residues depended on doses. There was no significant differences on its dissipation process when the herbicide was used in mixture with mecoprop and desmedipham.

Environmental behavior of herbicides in irrigated rice in the ''low lands'' agroecosystem (496)

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The irrigated rice culture occupies more than 900 thousand cultivated hectares in the states of Rio Grande do Sul (RS) and Santa Catarina (SC). Herbicides contribute for the maintenance of the good productivity of the ''orizicolas'' crops, guaranteeing what is expected from a cropland with environmental savings. The water flow in the irrigated rice crops contributes to the removal of herbicides from the treated area, reducing its biological efficiency and risking to pollute superficial and subterranean ''mananciais hidricos''. Thus, concomitant studies must take place to evaluate the fate of the herbicides in the environment. In this context, a study of the environmental behavior of glyfosate, quinclorac, clomazone, atrazine and imazaquin herbicides is being developed, focusing microbiological and chemical degradation, absorption on soil colloids, aerial deposition, distribution and movement of herbicides in soil and water. These, in RS, consist in herbicides widely used in the conventional and direct plantation of irrigated rice in rotation with corn/ soybean systems. In the pre-germinated system, in Santa Catarina and RS, pirazosulfuron-ethyl is being evaluated. Since 1999, irrigated rice production systems are being monitored in the surroundings of Laguna Mirim and Laguna Patos, with collection of water samples from drainage and rivulet networks, soil and sediments in the cropland. Results of the chromatographic analysis will be presented. Investigations about the degradation of the clomazone by isolated bacteria from irrigated rice soils in RS, in the period of 1992-1996, have indicated that *Pseudomonas* sp. cepa CLGZ1 is capable of degrading this herbicide. In this study we observed different groups of bacteria capable of degrading glyfosate, quinclorac and clomazone in irrigated rice production system using these herbicides repeatedly. The fungi *Mucor* sp., *Helminthosporium* sp., and two species of *Fusarium*, respectively, present different sensibilities to the glyfosate herbicide.

Assesment of clomazone bioavailability in strains of *Beijerinckia* isolated from the soil in Rio Grande Do Sul, Brazil (497)

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Currently one of the most important challenges in soil science is the development of soil quality criteria to be used in environmental hazard assessment. The enzymatic capacity from the microbiological community to catalyze pollution transformations is extensive and very diverse. The soil zone near the plant root, named rhizosphere, is generally rich in sugars, aminoacids and microorganisms. The biodegradation rates in the rhizosphere are greater than in non-rhizospheric soils. Bacterium of the genus *Beijerinckia* have been studied in the degradation of aromatic compounds such as: biphenyl, naphthalene, phenanthrene and anthracene and also as biological indicators for heavy metal toxicity in soils. The objective of this work was to assess the behaviour of bacterium identified as *Beijerinckia* species, isolated from the Rio Grande do Sul soils, and to compare with concentrations of its active ingredient and its commercial formulation. A strain of *Pseudomonas* sp. (CLZG1) and three strains of *Beijerinckia* sp. were used. These strains were inoculated in a plate with mineral salts (MS) agar and in shake-flask cultures with MS broth, both supplemented with variable concentrations of clomazone and commercial preparation of clomazone: from 0 ppm to 1000 ppm. The inoculated plate and flasks, were incubated at 28 C and its growth observed for 96 hours. All strains grew and therefore they are bond to success in the degradation study of clomazone.

Herbicide use and world food production: risks and benefits (498)

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For most of the next century, we will need to produce enough food for nine billion people instead of the six billion we are trying to feed today. If we try to improve the average diet as well, we may need to double annual world food production for most years of the next century. There is not much more land that can be devoted to agriculture without having an enormous environmental impact on forested or wilderness areas. Furthermore, a higher proportion of agricultural land may be used, industrially, to produce fuel or fibre instead of food. Thus, we may need to grow twice as much food on even less land than we are using today. We are currently using using three million tons of herbicides each year in agriculture, worldwide. What will the benefits and risks be if this level of herbicide use is continued or increased? What will they be is herbicide use is discontinued? Several years ago, farmers in highly developed, industrialized countries could expect a three or four fold return on money spent on herbicides. Is this still true? Can we meet world food demands if producers stop using herbicides because of reduced economic benefits? Can better use of IWM preserve the economic benefits of herbicide use? Although crop losses are currently greatest in less industrialized countries, can we meet the educational and training requirements to safely increase herbicide use in these areas? These are just some of the questions facing weed scientists as agriculture faces its greatest challenge in history between now and the year 2100.

The impact of gene technology on weed management systems (499)

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Transgenic crops and pastures have the potential to radically change agronomic practice producing higher yields of agricultural commodities with greater nutritive value on less land devoted to production. These changes to agricultural systems may have significant implications for weed management strategies. The first wave of transgenic crops in world agriculture has been dominated by two introduced traits, insect tolerance and herbicide resistance. Although herbicide resistant crops allow greater flexibility in weed management, generally resulting in lower production costs there has been considerable focus on the environmental risks involved. The possible risks have been well documented and include the possibility of the herbicide-resistant biotype itself becoming a weed, the chance of gene transfer between the herbicide-resistant crop and weedy relatives and the potential to exacerbate current herbicide resistance problems. None of these potential risks are likely to be of equal significance in all cases so it is necessary to examine each situation on a case by case basis to determine whether the possible environmental problems are acceptable and manageable. Moreover, ecological risk assessment is characterised by a multiplicity of techniques and methods, partly because of the relative immaturity of the science and partly due to the complexity of ecological management issues. More sophisticated risk analysis of the introduction of genetically modified crops to particular agricultural systems may be necessary to adequately assess the long-term ecological impact of such changes to agronomic practice. Apart from herbicide resistance crops, other applications of gene technology to crop and pasture plants are likely to have significant impact on weed control strategies.

The possibility of genetic modification allowing plants to thrive in normally hostile environments, e.g. conditions of drought or cold stress, saline soils or nutrient-deficient environments, could significantly alter weed control problems and require the adoption of different control methods. Gene technology may also be used to develop other weed control strategies based on, for example, early seedling vigour, changed plant architecture or enhanced allelochemical production. Again, the impact of the introduction of such genetically-modified crops will need to be carefully assessed and monitored.

Herbicide tolerant crops: managing risks of weed resistance (500)

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Potential problems with herbicide tolerant crops include that they could reduce options for control of crop volunteers, changed herbicide use practices could lead to increased resistance in weeds to key herbicides, and hybridisation between crops and weeds could transfer herbicide resistance genes to weeds. Current Australian regulatory and research approaches to these concerns will be outlined, with particular reference to canola and cotton. These may provide ideas for the management of the risks of herbicide tolerant crops in other countries. Herbicide resistant crop volunteers can at present be controlled by alternative herbicides, but perhaps not if several different herbicide resistances are introduced into neighboring crops and hybridisation occurs between them. Further, one way to avoid excessive dependence on any given herbicide would be to use the deployment of herbicide resistance genes to encourage herbicide rotation. The following recommendations have been adopted by two Australian government committees at the suggestion of our CRC: ''(1) If the herbicide to which resistance has been introduced is currently used to control volunteers of the crop, or other weedy outbreaks of the crop, management plans will be required for control of these weeds by other means; (2) Pyramiding of genes for resistance to more than one herbicide in a given cultivar should be avoided, unless experimentally demonstrated to be useful and effective in a particular farming system; and (3) The same herbicide resistance trait should not be introduced into different crops used in a rotational system in a given region. However, if this does occur, management plans should be devised to limit the use of the same herbicides on the same paddocks in the successive years, to avoid the development of herbicide-resistant weeds.'' The potential for hybridisation between crops and weeds has been quantified for canola in realistic field experiments using herbicide resistance as a marker. The low frequency of outcrossing observed with wild radish (*Raphanus raphanistrum*) compared to the estimated current frequencies of resistance in annual ryegrass (*Lolium rigidum*) implies that outcrossing is less likely than direct selection to cause problems with resistance in the Australian context.

Risk and benefits of herbicides: a global perspective (501)

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Contrary to what scientists and extension agencies had previously thought, a critical evaluation of risks and benefits of herbicide use must be done before developing an integrated weed management strategy. Due to medium and long term demand for crop productivity gains and the supply of agricultural labour, increased demand of herbicides can not be overlooked. In developed countries, stringent regulations, mandatory reduction in herbicide use, basic research on side effects of herbicides, herbicide resistance prediction models and innovative research in developing eco-friendly herbicides have altered the way herbicides are used. On the contrary, poor farmers in developing countries have limited choice of herbicides and use same herbicide repeatedly over the years and may face the problem of herbicide resistance. The cost and benefits of herbicides are unevenly distributed in different cropping systems. Many times, typical economic objectives to maintain net income and ensure survival of peasantry are not seen with limited availability of herbicides at unaffordable cost. Unlike the use of hoes, herbicide use require skills and careless herbicide application due to ignorance results in inadequate weed control, damage to the crop and may adversely affect the environment. Improper application of herbicide sometimes create health hazards to human and animals. Poor handling, application, storage procedures and environmental safety are not considered important. So solve such problems, the research and extension interface in farmers participatory approach should be increased. The enlightenment of small and big farmers will be translated into high quality safety standards and more effective policy making. In developing countries, it is much more necessary to formulate and implement integrated weed management strategy for protecting the environment and natural resources with an adequate food supply for rapidly increasing population. Weed scientists in these countries need to make more allowances for making necessary corrections based on the experience of developed countries. Although herbicides will not lose their privileged position, ecological information need to be made as one of the many means in reducing the load of herbicides both in developed and developing countries.

Consequences of clomazone drift on production characteristics of Hamlin orange (502)

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The experiments aimed to evaluate the effects of clomazone (alone or in mixture with atrazine) drift off on quantitative and qualitative aspects of orange production. Increasing doses of clomazone, in two formulations, and ametryne were tested, with drift evaluated at three stages: at flowering, on fruit up to 2 cm of diameter, and on fruit with 2-4 cm. The experimental design was a completely randomized blocks, with 15 treatments and three replications. The experimental unit was 10 orange fruits. We evaluated: fruit morphological feature, fruit color, flower and fruits abortion and leaf chlorophyll content. Drift comparable to the recommend dose promoted abortion of fruits up to 2-cm diameter. Lower doses did not affect fruit abortion. Fruit diameter was reduced with drift above 25% of clomazone alone at the recommended dose and 50% when in mixture with ametryne or in the microcapsule formulation. Clomazone at 50% (alone or in mixture with ametryne) promoted clorotic and necrotic spots in the fruit skin and promoted the death of new sproutings stems. There were no qualitative effects on the juice.

Drift effects of 2,4-D on cotton (503)

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Corn sown areas have been expanding for two decades in the Cukurova Region of Turkey. In this region, cotton has been one of the most important crops. The increase in corn areas, especially as a second crop, has caused herbicide drift problems in cotton fields because corn and cotton fields often are located next to each other. 2,4-D is recommended in corn fields to control broadleaf weeds and has been widely used because of its reasonable cost. Drift effects of 2,4-D on cotton have been known for years. However, there has been a need for quantitation of these effects in order to resolve quarrels between farmers. A field experiment was conducted in 1999. Herbicide rates from half to 1/64 of the recommended field dose of 2,4-D were sprayed on cotton at two different growth stages, the square stage of cotton and the beginning of blooming, to simulate application times of 2,4-D in corn. In addition, 1/128 and 1/256 rates were added to the later application time, at the beginning of blooming. The effect of herbicide rates on cotton height varied with application time. Average plant height decreased in response to increasing herbicide rate, except for the 1/64 rate at the earlier application time, at the square stage. At the later application time, cotton height increased at the lower application rates (1/256 through 1/16), but decreased at higher rates. Yield reduction paralleled increasing application rates at both application times. Even at the 1/256 application rate, yield was 3 times lower than the untreated check. Late application caused an apparent delay in maturing; in addition, increasing callus growth on roots and stem was observed, especially at higher rates

for later application. Branches generally elongated more than the main stem for earlier applications of 2,4-D. Some quality comparisons were made. Ginning percentage was significantly different, but it is difficult to provide a meaningful explanation. 2,4-D application did not change fiber length and strength, but fiber thinness decreased at increasing application rates.

Influence of long-term application of triazine herbicides on ecosystem (504)

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The negative effects of triazine use in different crops have been observed in many European countries. Influence of long-term application of triazine herbicides on behaviour, succession of segetal and ruderal plants, the level, movement of herbicidal residues and enzymatic activity of soil were investigated. The investigation has been conducted on a site where every year, for 36 years, increased doses of herbicides were applied to each experimental field. Triazine herbicides were applied in doses: 5 and 10 kg a.i. ha^{-1}. During the first 5-10 years, herbicides controlled all weed species occurring in this trial, then the weeds appeared again and for 36 years application of triazine herbicide, from 27 weed species: 12 species became resistant and 11 species were eliminated. The residues of the active ingredient were determined in 20-cm layers up to the depth of 1 m. Additionally, horizontal movement of active ingredient of residues in the soil profile was investigated. The residues were located mainly up to the depth of 40 cm. In the layer between 60 to 100 cm, the amount of residues did not exceed 10^{-3} mg kg^{-1}. High dose of triazine herbicides applied annually caused major changes in the enzymatic activity of the soil microorganisms. The biological mineralization of P-organic components was significantly depressed by the herbicides. Study of protein degradation showed that the activity of the alkaline proteolitic complex was very low and significantly suppressed by triazines. In the case of the acid proteolitic complex, the effect was not so strong. Herbicides significantly influenced this activity. Transformation of polysacharides of plant origin expressed by xlanase activity was affected by herbicides, similarly to acid proteases. These data suggest a significant shift in the microflora community taking part in mineralization of plant residues. Such changes could affect the quality and quantity of humic matter in soil.

Moral certainty in agriculture (505)

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Those engaged in agriculture possess a definite but unexamined moral certainty about the correctness of what they do. The paper examines the origins of that certainty and questions its continued validity. The paper argues that those engaged in agriculture are morally certain about the rightness of their activity. The basis of that moral certainty is not obvious to those who have it or to the public. In fact the moral certainty that pervades agricultural practice is potentially harmful because it is unexamined. Suggestions for re-moralizing agriculture are made to approach the question of where moral values originate, and what are or ought to be the moral standards for agriculture in our post-industrial, information age society. Part of re-moralizing agriculture will be giving up some of our hubris about the goodness of our culture and its agriculture. The paper advocates analysis of what it is about our agriculture and our society that thwarts or limits our aspirations for agriculture and needs modification. We must strive to nourish and strengthen those features of our agriculture that are beneficial and change those that are not. To fit ourselves to this task, we must be sufficiently serious to study ourselves and our institutions and dedicated to the task of modifying both.

Ethical concepts underlying weed management practices in organic farming in Europe and traditional agriculture in Bolivia (506)

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The consideration of ethical concerns in weed management raises the question whether there exists a common epistemological ground for dealing with them, or whether ethical issues underlying weed management practices are related to different world views and should therefore be seen in a constructivist perspective. To answer these questions, a systematisation and analysis of main weed management practices of ‘‘modern’’, organic, biodynamic and traditional Andean agriculture were carried out. Results showed that each of the above systems of weed management practices is closely related to the underlying central ethical imperatives claimed by the different agriculture systems. Further, it could be demonstrated, that management practices and the underlying ethical principles of the four agriculture systems have a philosophical foundation defined by a science based materialism, ‘‘ecologism’’, anthroposophy or Andean cosmovision respectively. Differences in the world views are clearly reflected in the specific concepts of plant species in general and ‘‘weed’’ in particular. These concepts shape the specific set of ethical values guiding present weed management. Weed management practices of the investigated agricultural systems thus reflect different ethical codes. This ethical diversity embraces individualistic-utilitarian, (economic damage threshold of ‘‘modern’’ agriculture), socio-terrestrial (organic agriculture), cognitive-cosmic (biodynamic agriculture) and cosmic-spiritual (traditional Andean agriculture) positions. Weed management practices of the organic, biodynamic and traditional Andean agriculture show epistemological discrepancies with ‘‘modern’’ weed management practices. The main discrepancy is related to their basic assumption on the degree of objectivity of a spiritual dimension on reality. To overcome a purely materialistic world view is an important element in the search for alternative, less harmful weed management practices. Therefore, far-reaching changes of the ‘‘modern weed’’ management practices cannot be achieved by reducing analysis to a set of technological, economic or ethical issues with a supposed universal validity. Consequently, involved social actors should internalise a world view that provides the foundation for ethical values that are going beyond egoistic or utilitarian ethical codes. Further development of weed management practices will therefore have social and pedagogic implications.

Opportunities for enhancing rice competitiveness (507)

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Weeds are a major constraint for rice production worldwide, and their control relies heavily on herbicides and/or hand weeding. Limited labor and herbicide availability in certain areas, as well as herbicide resistance, and environmental and health concerns in high input systems demand new avenues for weed control in rice. Enhancing rice competitiveness against weeds might improve weed control, providing a low-cost and safe tool for IWM. Research has shown considerable variability in competitiveness among irrigated and rainfed rice germplasm. Leaf area index (LAI), tiller number, canopy light interception, and total biomass recorded not much before 40 days after emergence, correlated positively with irrigated rice competitiveness against *Echinochloa colona* in Latin America. Similarly, work with rainfed rice at the West Africa Rice Development Association (WARDA) in the Ivory Coast indicated that LAI, specific leaf area (SLA), tiller number, PAR extinction coefficient, leaf angle, and dry matter partitioning to leaves can predict rice competitiveness. A fivefold difference was found among California cultivars in their ability to suppress *Echinochloa phyllopogon* seed production, and a threefold difference in tolerating competition by this weed; competitiveness was correlated with early rice height and SLA development. However, a perceived tradeoff between yield potential and competitive ability has limited research despite evidences that competitiveness and high yields are compatible goals. Species specificity may be an issue, and traits for belowground interference should also be addressed. Research at IRRI and in Arkansas suggests significant rice allelopathy against certain weeds. A lack of correlation between rice traits measured in monoculture

and under competition has often been observed, suggesting that plasticity could require breeders to conduct selection under competition. Breeding for competitiveness is thus a valid breeding objective that would be greatly facilitated if the opportunities for using advanced molecular techniques were further explored.

Weed management implications and trends of direct seeding in Asia (508)

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This paper briefly reviews the pattern of changes in rice establishment methods that have been taken place in Asia and their implications for weed management practices. Total direct-seeded rice in Asia occupies about 21% of the total rice area (132.8 M ha), but about 11% if only rainfed lowland and irrigated rice ecosystems are considered. There is a great potential for a shift to direct seeding, but it will be limited to Southeast Asian countries where population densities are low and labor cost is escalating. In both East Asia and South Asia, adoption of direct seeding is rather slow and a major shift to direct seeding is unlikely to occur. Transplanting, either mechanized or by hand, will continue to be the major planting method in Asia in spite of the increasing trend towards direct seeding. Weed infestations in direct-seeded rice are 2 to 3 times higher than in transplanted rice, and the dominant species have shifted to grass weeds and weedy rice. The high costs of weed control might be a major constraint to the widespread adoption of direct seeding methods, particularly dry seeding. The key to the success of direct-seeded rice is the availability of efficient weed control methods. Herbicides have been the most common weed control tool in direct-seeded rice. Thus, a presently available IWM package (effective herbicides properly combined with other management technologies), based on rice ecosystems and economic conditions, can satisfactory control the dominant weeds including grass weeds. Difficulties in controlling weedy rice may be minimized by the introduction of herbicide resistant rice which still needs further testing for possible risks.

Weed management: direct-seeded rice in the USA (509)

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Weeds are the most important pest constraint in USA rice production. This is largely because rice is direct-seeded on 100% of the 1.1 million ha, allowing weeds to compete from the beginning of crop establishment. The crop is sown primarily by dry seeding in the Mississippi delta, water seeding in California, and a combination of both along the Gulf Coast. Laser-guided land formation, precision water management, crop rotation, tillage and certified seed are among the cultural practices used to suppress weeds. Herbicides are necessary to achieve levels of weed control sufficient to maintain economic viability, primarily because relatively small numbers of the most competitive weed species such as *Echinochloa*, can reduce rice yields 10-20 %. The introduction of semi-dwarf cultivars concomitant with high fertility and low water management have exacerbated weed problems in the past two decades. Generally, more than two herbicide treatments per hectare are used to control weeds. Increased applications, particularly of the same herbicide, have led to widespread weed resistance as well as to external concerns such as drift damage to sensitive crops and the deterioration of downstream water quality. Although cultural practices and herbicides have significantly improved weed control over the past fifty years, rice weed management in the USA is barely maintaining the status quo, if not moving backwards. Innovative new technologies including ecologically-based management practices, competitive cultivars, transgenic rice engineered for herbicide resistance and improved application methods must be combined with highly knowledge-intensive management skills to maintain and improve rice weed control.

Weedy rices (510)

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Weed infestation is considered one of the most limiting factors for paddy rice yield. Weed populations are increasing mainly due to intensive cropping. Although the weedy rices are less disseminated in rice fields than *Echinochloa*, they are not easily controlled. The term weedy rice usually refers to annual *Oryza* species populations, including all different forms of red rice and wild rices. Weed rice is highly undesirable for both rice farmers and to rice industry. Weed rice reduces farmers production both quantitative and qualitatively. It is considered a serious rice problem in over 50 countries of Asia, Latin America and Africa. In Latin America, the weed rice is a much older problem than in Asia, where weeds are controlled mainly by transplanting rice, water management and hand weeding. Farmers in many Asian countries, however are changing from transplanting to direct seeding, therefore weed rice is becoming a major problem. Besides competitiveness and grain color, other traits like easy and early shattering and dormancy also induce weed rice seeds to persist in the soil for several years. Phenological and morphological similarities between the major weed rices and cultivated rice challenge weed rice control in rice fields. Weedy rice populations occurring in many rice fields vary as for seed dormancy, seed longevity in the soil, and herbicide sensitivity. Weedy rice seed dispersal occurs mainly through contaminated rice seeds. Weedy rice control requires a program approach that includes several management practices: a combination of preventive, cultural and chemical control. The most important measure to prevent weed rice is the use of high quality rice seed free of weed rice. Cultural practices include the use of stale seedbed technique, water-seeded rice, rice transplanting, crop rotation, and management practices to reduce weed rice seed bank. In the future, herbicide resistant rice cultivars may become another useful tool for weedy rices management in irrigated rice.

Herbicide resistance in weeds and rice cultivars (511)

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Worldwide nineteen weed species associated with rice have evolved resistance to herbicides, including the most widely used compounds such as propanil and some of the most recently introduced chemical groups such as the sulfonylureas. Resistance to herbicides in rice weeds is increasing and will probably become more important as production method, especially in Asia, is changed from transplanted to direct seeded rice. Direct seeded rice is more dependent on herbicides and increased selection pressure undoubtedly will make resistance more common. Propanil resistance is widespread in *Echinochloa colona* (L.) Link in Central America and Colombia, and increasing in importance in Mexico and probably in other areas of Latin America where it has not been formally reported. The congeneric *E. crus-galli* (L.) Beauv. resistant to propanil is also an important weed in USA, Greece, Sri Lanka and Thailand. Species of *Echinochloa* have also evolved resistance to butachlor, molinate, thiobencarb, quinclorac, bispyribac and fenoxaprop. Important cases are those of *E. crus-galli* resistant to butachlor and thiobencarb in China and *E. phyllopogon* (Stapf.) Koss with multiple herbicide resistance in California. Twelve species, most of them aquatics, are resistant to sulfonylurea herbicides in four continents and *Fimbristylis miliacea* (L.) Vahl, *Limnocharis flava* (L.) Buchenau and *Sphenoclea zeylandica* Gaertn. are known to be resistant to 2,4-D in Asia. Rice varieties resistant to imidazolinones, glufosinate or glyphosate are being tested under field conditions and will be commercially introduced soon, especially aiming to control weedy *Oryza* species and herbicide-resistant weeds. Dependency on these herbicides is likely to select herbicide resistant populations and there is ample concern about gene flow to weedy *Oryza* species, especially to red rice (*Oryza sativa* L.). Integrated weed management and rational herbicide use in rice is imperative to contain resistant populations and to prevent new cases of herbicide resistance.

Suppression of seed viability of red rice (*Oryza sativa* L.) using maleic hydrazide and glyphosate (512)

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A field study was conducted in 1998 to evaluate maleic hydrazide and glyphosate applied in rice, as inhibitors of seed viability (SV) of strawhull and blackhull types of red rice (*Oryza sativa*). INIA Tacuari, a short season-variety, was drilled into a seedbed with seeds of both types of red rice. Maleic hydrazide at 1.44, 1.8 and 2.16, and glyphosate at 0.36, 1.08 and 1.8 kg a.e. ha^{-1} were studied. Each combination of products and rates was evaluated at three times of application (TA). When rice reached 38, 23, and 9% of green grains (weight basis), determined the first (FTA), second (STA) and third time of application (TTA), respectively. At FTA, panicles of red rice (*O. sativa*) had basal spikelets just flowering; at STA, panicles were from milky to soft dough stage; and at TTA, panicles were at the hard dough stage. For strawhull type, maleic hydrazide at FTA lowered SV by 31% (over check) at 2.16 kg ha^{-1}; however, at STA and at TTA there was no reduction. The number of filled and empty seeds, based on 1000-seed samples, was not affected and neither was the number of viable filled seeds. Glyphosate reduced SV by 51% (average over rates) and 40% at FTA and at STA, respectively; however, in the TTA, there was no effect. Glyphosate rates of 1.08 and 1.8 kg ha^{-1} lowered significantly SV by 36% (averaged over TA) and 45%, respectively. For the number of viable filled seeds, glyphosate rates of 1.08 and 1.8 kg ha^{-1} reduced by 74% and 71% at FTA, and by 59% and 56% at STA, respectively; however, there was no effect at TTA. For blackhull type, the reduction on SV was 15% (averaged over rates) for maleic hydrazide and 42% for glyphosate at FTA.

Bioefficacy of herbicides to combat the weed menace in transplanted rice (513)

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Weeds are considered to be one of the major bottlenecks in realizing the potential yields of rice in almost all parts of the world. This is mainly due to the environment in which rice is cultivated. The use of herbicides is becoming a widely followed agronomic practice to combat weed menace among rice growers in India. Several products are on the market with varying degree of efficacy to combat weed problems. Two new low voluminous herbicides (MON-12037 and MON-8435; Monsanto, Mumbai, India) are evaluated for their bioefficacy to control weeds in transplanted rice. The experiments were carried out at the Agricultural Research Station, Siruguppa during 1999 and laid out in RCBD having 15 treatments each. The experiment on MON-12037 consisted of three levels at 8,12,16 g a.i. ha^{-1} applied alone or in combination with two levels of machete at 0.75, 1.00 kg a.i. ha^{-1}. While in experiment on MON-8435, five levels at 75, 100, 125, 150, 300 g a.i. ha^{-1} applied at 0-3 and 6-8 days after transplanting (DAT). Butachlor, topstar-80 and pretilachlor at1.25, 0.07 and 0.625 kg a.i. ha^{-1}, respectively were also included. In both trials, untreated control and hand weeding were included for comparison. The results indicated significantly lower rice yields in unweeded check in both the trials. Application of MON-12037 irrespective of the levels either alone or in combination with machete recorded similar yields. However, the highest rice yield was obtained when MON-12037 at 16 g a.i. ha^{-1} was applied in combination with machete at 1 kg a.i. ha^{-1}. Similarly, increase in the level of herbicide MON-8435 from 75 to 300 g a.i. ha^{-1} did not have effect on rice yields. Time of application did not affect the yields thus suggesting that any time between 0-8 DAT is optimum for application. The other three herbicides included in the trial recorded comparable yields with MON-8435. Hand weeding in both experiments recorded similar yields with the best performing herbicide treatments. The higher rice yields in herbicide applied treatments could be attributed to lower number of weeds which reduced competition with rice to harness the resources efficiently.

Differential response of U.S. *Oryza sativa* (red rice) accessions to environment, herbicides, and disease (514)

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Red rice (*Oryza sativa* L.) is an economically important weed in much of the dry-seeded rice produced in the southern United States, and increasingly, throughout the world. It is an especially troublesome weed because it and commercial rice are the same species and can interbreed at low rates. Red rice accessions were collected from Arkansas and other southern rice producing states. The phenotypic diversity of their responses to environment, herbicides, and diseases have been evaluated systematically in greenhouse, field, and laboratory experiments at Stuttgart, Arkansas from 1995 through 1999. Of the approximately 160 entries presently in the red rice collection, about two thirds are strawhull, awnless types and ten are crosses with rice. Red rice plant heights range from as little as those of tall commercial rice cultivars to more than 1.5 m; heading dates range from about one week earlier to several weeks later than typical commercial cultivars; and biomass and tiller production are more than double those of commercial cultivars. While most of the red rice accessions are medium-grain types, some of the crosses are long-grain types, suggesting a long-grain rice parent. The red rice accessions differ moderately in tolerance to standard rates of several herbicides, including post-emergence glufosinate and imazethapyr, and pre-plant incorporated molinate, and to cold temperatures. Red rice accessions differ substantially in their resistance to five races of rice blast (*Pyricularia grisea*), including IC-17 and IB-49, the most prevalent races in Arkansas rice fields. More than 85% of accessions were highly resistant to IC-17, whereas less than 10% of accessions were highly resistant to IB-49. Collectively, this information can be useful in developing control strategies for red rice and in the eventual identification and transfer of desirable genes from red rice into rice.

Red rice-rice competition in flooded conditions (515)

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Red rice (*Oryza sativa* L. var. *sylvatica*) is an annual weed which has been reported to cause severe infestations throughout Europe. The objective of this study, carried out in the 1997-1998 period was to determine the competitive relationship between 4 red rice densities and 2 long-cycle rice varieties, continuously grown in flooded conditions. The red rice densities were 0, 10, 20 and 40 plants m^{-2}. The cultivated varieties were Thaibonnet, which is characterised by a short height and long grain and Arborio, which is instead characterised by a tall height and medium grain. Both crop varieties were broadcast planted in a flooded field at 600 seeds m^{-2}. The experimental design was a randomized block, with 50 m^2 plots and 4 replications. No significant differences occurred over the years for all the parameters considered to evaluate the weed crop interactions. The red rice densities of 10, 20 and 40 plants m^{-2} reduced the rough grain yield of commercial rice in Thaibonnet and Arborio by 26.5, 32.8, 52.0% and 29.7, 41.3, 60.5%, respectively. The leaf area of red rice was 2.5 and 3.2% higher than in Thaibonnet and Arborio, respectively and was not influenced by weed density. The red rice density did not remarkably affect the crop height either. In all the competitive conditions, the red rice was 36% taller than Thaibonnet and as tall as Arborio, since the beginning of the stem elongation. Red rice at 10, 20 and 40 plants m^{-2} reduced straw dry weight of cultivated rice 24.5, 35.5 and 42.2% in Arborio and 72.3, 83.4, and 87.1% in Thaibonnet, respectively. The red rice grains m^{-2} counted on the soil surface immediately after crop harvesting were 2056, 4833, and 7081 in Thaibonnet and 2743, 4325, and 9618 in Arborio at 10, 20, and 40 red rice plants m^{-2}, respectively. The results of this research pointed out that red rice infestations, already from the density of 10 plants m^{-2} resulted in a severe yield reduction of both rice varieties and in a great risk of weed seed dissemination.

Effect of tillage practices and pre-emergence herbicides in rice (516)

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Rice is the most important food cereal, which can grow under direct seeding and transplanting methods. Among this, direct seeding is less costly than transplanting due to lower requirement of labour and water. In view of this, direct seeding is gaining popularity in much rice growing countries and also in India. The main disadvantage of direct seeding rice is high weed infestation. Effective and timely weed control is necessary in direct seeded rice. Nowadays, labour for hand weeding is becoming too expensive. It is therefore of the greatest interest and necessity to develop new integrated strategies for weed management in direct seeded rice to ensure the sustainable rice production to meet the requirements of growing population. Investigations were carried out for two seasons (July 1998 - November 1998 and June 1999 - October 1999) at FIPPAT farm, Padappai, to observe the efficiency of three pre-emergence herbicides, applied under three different tillage systems viz., conventional tillage, conservation tillage and no tillage, for controlling the mixed population of weeds in wet-seeded rice. The herbicide treatments included were (i) pretilachlor 50 EC at 750 g a.i ha^{-1} (ii) butachlor 50 EC at 1250 g a.i ha^{-1} (iii) oxadiargyl 80 WP at 100 g a.i ha^{-1} (iv) hand weeding (2 times) and (v) no weeding (control). Oxadiargyl and pretilachlor applications controlled weeds effectively in both the seasons. These herbicide resulted in grain yields comparable to hand weeding and also incurred lower costs. So, oxadiargyl at 100 g a.i ha^{-1} and pretilachlor at 750 g a.i ha^{-1} applied under conservation tillage system may therefore be recommended for effective and economical weed control under wet-seeded rice.

Efficacy of novel rice herbicides on weeds (517)

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Field experiments were conducted to evaluate six novel herbicides for their weed controlling ability at six locations representing different agro-ecological zones in Sri Lanka. The herbicides, fentrazamide + propanil (FeP), anilofos + ethoxysulfuron (AnE), oxydiagryl + propanil (OxP), anilofos + bensulfuron methyl (AnB), cyhalafopbutyl (Cy) and clomazone (Cl) were tested against the standard recommendations propanil (Pr) and hand weeding. The treatments were arranged in randomized complete block design with four replicates with a no-weeding treatment as a control. Of the tested herbicides, OxP showed slight phytotoxicity to the rice crop which recovered a few days after application. All treatments significantly decreased grass weed biomass at six weeks after seeding. In all locations, FeP showed the highest efficacy in controlling grass weeds followed by Cl, AnB, AnE, Cy, Pr and OxP respectively. The highest yield was recorded from FeP treatment followed by hand weeding , AnE, AnB, OxP respectively. Although Cy and Cl were effective in controlling grasses, their efficacy controlling sedges and broadleaf weeds were low, thus the grain yield in plots treated with these herbicides were lower.

Past and current challenges of soybean weed management (518)

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The leading soybean world producers are the USA (50%), Brazil (20%), and Argentina (12%). Soybean production has reached 160 million metric tons, and has increased about 30 million metric tons per decade, since the 70's. These increase in production occurred due to an expansion of cropped area and an increase on crop productivity. In both scenarios, weed management played a crucial role on the positive output. Soybean weed management has changed considerably during these past four decades. During the 70's, weed control depended mainly on mechanical methods, both prior and after soybean emergence, whereas chemical methods occupied partial importance. The increase in farm size and the need to reduce labor and time of farm operations prompted an increase in no-tillage systems. With the shift from conventional to no-tillage, mainly during late 80's and the 90's, chemical weed control has become the predominant method of weed management. Several ecological and management differences between conventional and no-tillage systems are the basis for the change occurred on weed demographics. Compared to conventional, no-tillage systems tend to have higher grass weed infestation, higher weed diversity, longer period of weed germination and consequent higher diversity in weed size for post-emergence applications. Independent of tillage systems, during the 90's, weed resistance began to gain importance on soybean areas across Brazil. Decreased grain prices are driving the need to reduce costs. Potential strategies to reduce weed management costs include: vigorous cover crop, reduction of herbicide rate associated to sequential herbicide application, herbicide resistant crops, custom application, herbicide purchase through Internet, and precision ag weed management. In the next millennia, environmental and consumer concerns will affect farm operations and, certainly, will bring new challenges to soybean weed management.

Soybean production in the eastern cornbelt (519)

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The United States produced 74 M mt of soybean in 1998 on 28 M ha. Over 60% of this production was in 10 midwestern states. Increasing use of conservation tillage, particularly no-till, constitutes a major shift in soybean management practices. Between 55 and 60% of the soybean in Indiana and Ohio on the eastern side of the cornbelt was no-till in 1999 while no-till soybean production in Nebraska on the western side of the cornbelt was close to the national average of 32%. The goal set by government agencies is to have 60% of the total U.S. soybean production in no-till by 2002. In the midwest, soybean are grown in wide rows (76 cm) or in narrow rows (30 cm or less). Most of the no-till production is in narrow rows. The average row spacing in Indiana in 1998 was 33 cm. The major changes in weed control practices are the decreased use of tillage and the introduction of herbicide-resistant crops, particularly glyphosate-resistant varieties. Over 50% of the U.S. soybean production was in glyphosate-resistant soybean varieties in 1999 with another 15% increase expected for 2000. Glyphosate is now the most used herbicide in soybean in the U.S. Substantial reduction has occurred in the use of chloroacetamides, imidazolinones, dinitoanilines, and bentazon. The broad spectrum of species controlled, the relatively flexible application window, freedom from soil residues, reasonable cost, and reduced number of chemicals in inventory make glyphosate and glyphosate-resistant soybean attractive to chemical dealers and farmers. Some or our research has shown two applications of glyphosate provides adequate control of problem weeds such as *Sorghum halepense* (L.) Pers. and *Cirsium arvense* (L.) Scop. in no-till soybean.

Soybean weed management in Argentina (520)

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The two major changes in soybean production in Argentina in recent years were: 1) increase in no-till soybean area, and 2) the introduction of glyphosate tolerant (GT) soybean varieties to the market. The rapid spread and increase of these new technologies included important changes in weed control methods. A weed population and management survey submitted to 140 consultants of 9 regions in the Argentinian soybean belt was conducted in 1999 to determine: 1) the most common weeds in soybean, 2) the most troublesome weeds in regular and GT soybean, 3) percent of the area in regular and GT soybean, 4) percent of the area in no-till and conventional tillage, 5) percent of preemergence herbicide used in regular and GT soybean, and 6) weed management methods in GT soybean referred to amount of applications during the growing season, rates, and mixtures with other herbicides. The most common weeds are different for each region. The 5 most troublesome weeds, average of the 9 regions, in regular soybean are: *Chenopodium album*, *Cyperus rotundus*, *Amaranthus hybridus*, *Cynodon dactylon*, and *Digitaria sanguinalis*, and in GT soybean are: *Cyperus rotundus*, *Cynodon dactylon*, *Conmelina diffusa*, *Chenopodium album*, and *Solanum sisymbriifolium*. In 1998, 65% of the soybean area was planted using GT soybean varieties with an expected area of 83% for the next season. In addition, no-till soybean composed 52% of the total area in 1998 with an estimation of 61% for 1999. In regular soybean, 55% of the area was treated with preemergence herbicides in 1998 with no change expected for the next season. By contrast, in GT soybean varieties only 9% of the total area was treated with preemergnce herbicides in 1998 with an expected area of 12% for 1999. Weed control in GT soybean varieties was based on glyphosate applied postemergence at the following rates and timings: 37% of the area was treated once, 52% received two applications, and 10% three applicactions at 1.25, 1.06 and 0.62 kg a.i. ha^{-1}, respectively. In conclusion, there is a trend to increase both the area in no-till and the use of GT soybean varieties. Glyphosate is the predominat herbicide used in GT soybean varieties with a very low percent use of preemergence herbicide or mixtures with other postemergence herbicides. The most common weeds are different in each region, however, three out of five most troublesome weeds are similar, average of the 9 regions, in regular and GT varieties. Some concerns arise from the result of this survey: 1) potential development of glyphosate weed resistance, 2) changes in weed population through weeds that are not easily controlled by glyphosate or herbicides available in the market, and 3) a question: are the farmers loosing soybean yield due to early weed competition because of the trend to make the first glyphosate application late in the season in order to avoid a second applicaction?

Soybean weed management in the Cerrados (Brazilian Savannas) (521)

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The Brazilian ecosystem Cerrados covers an area of about 200 million hectares, with only 5 percent of this area cultivated with annual crops, of which 6.5 million with soybean. Cerrados resembles the African Savannas except for differences in soil, which are acid, with low fertility, high available aluminum and low moisture holding capacity. It is characterized by a tropical climate, with a dry and a rainy season, with 80 percent of the total rainfall concentrated between October and April. Yearly rainfall ranges from 1200 to 1800 mm. Soybean was firstly introduced in Cerrados by the end of 1970 and today it is responsible for more than 50 percent of Brazil's total soybean production, with yields of 2671 kg ha^{-1} average, which is higher than in the traditional areas of the south. When soybean is cultivated in new Cerrado areas, were the natural vegetation is composed primarily of small trees, shrubs and native grasses, there is little problem on weed control during the first two or three years. In these areas the first weeds are *Sida rhombifolia*, *Acanthospermum australe* and some regrowth of shrubs and perennial weeds. After two years of cultivation, however, other weeds appear in the field: *Commelina benghalensis*, *Bidens pilosa*, *Hyptis suaveolens*, *H. lophanta*, and many others. In recent years, new species have been introduced in the area or moved within Cerrados, and became very troublesome, such as: *Tridax procumbens*, *Senna obtusifolia*, *Desmodium purpureum*, *Melampodium divaricatum*, *Chenopodium album*, *Pennisetum setosum*, *Nicandra physaloides* and *Sorghum halepense*. Nowadays about 50 percent of the soybean in the Cerrados region is cultivated under no-tillage system, which increased considerably the use of desiccants. Some weeds tolerant to the desiccation herbicides, such as *C. benghalensis* and *Synedrellopsis grisebachii* are becoming predominant in extensive areas under no tillage. The use of post emergence herbicides has also increased in the recent years due to no-tillage practices. Herbicides are used on more than 80 percent of the Cerrados soybean acreage. A recommendation table, specific for weed control in Cerrados, is published annually, with data originated from research results of the government and private institutions working in the region.

Reduction of weed infestation in no-tillage systems with sequential application of herbicides (522)

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The shift from conventional to no-till planting systems reduced the opportunities to control weeds before crop planting. Two experiments were conducted in southern Brazil with the objective to evaluate weed control with sequential application of burndown herbicides and to compare it to only one burndown application in the no-till system. Treatments tested consisted of: sulfosate (396 g ha^{-1}), sprayed 20 days before planting (DBP), complemented with paraquat (200 g ha^{-1}) at soybean planting time, and sulfosate (495), applied seven to ten DBP. An untreated control was added to the experiment. Sequential application of herbicides controlled new weed emergence flushes and, 30 days after planting (DAP), reduced weed biomass by 40-50% compared to only one application of herbicides. Plant biomass of *Brachiaria plantaginea*, *Bidens* sp, *Digitaria horizontalis*, *Euphorbia heterophylla*, *Richardia brasiliensis* and *Sida rhombifolia* was reduced by 50 to 90% with sequential application versus only one application. The weeds emerged before soybean with one application, whereas the soybean emerged before the weeds with sequential application. As a consequence, 30 DAP soybean biomass was 40% higher in the treatment with sequential application of herbicides than with only one burndown application. We concluded the sequential application of burndown herbicides increased the opportunities to control weeds before soybean emergence in no-tillage system, increasing crop competitivity at early growth stages.

Studies on the bio-efficacy and phytotoxicity of quizalofop-ethyl applied at different concentrations to control weeds in soybean (*Glycine max* L.) (523)

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Weed management in soybean had really been a challenging factor due to the unpredictability of rains and unavailability of timely labour. Soybean, being a rainy season crop, is infested mostly by grass weeds. A field experiment was conducted to study the bio-efficacy and phytoxicity of quizalofop-ethyl (Targa Super 5EC) at the concentrations of 25, 37.5, 50, 75 and 100 g a.i. ha^{-1} to control weeds in soybean. Application of quizalofop-ethyl at 50 g ha^{-1} was found most effective and was at par with 37.5 g ha^{-1}. The herbicide controls grass weeds, particularly *Echinochloa crus-galli* and *E. colona* very effectively and efficiently without any phytotoxic effect on soybean at all doses. It did not control *Cyperus rotundus* but suppressed growth and dry matter production whereas it was ineffective in controlling broadleaf weeds. Highest yield of 1613 kg ha^{-1} was recorded under the concentration of 50 g ha^{-1} by giving 16.20% higher yield to that of alachlor at 2.0 kg ha^{-1} and 63.0 and 39.0% over weed check and farmers practice respectively. The phytotoxic effects (necrosis, vein clearing, wilting, epinasty and hyponasty) were not observed under any concentration. Thus, it is highly selective and safe to the soybean crop.

Effect of herbicides on nodulation, shoot biomass and seed yield of rainfed soybean grown on vertisols (524)

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Field experiments were conducted over two years (1996 & 1997) to evaluate the effect of herbicides on symbiotic traits, shoot biomass and seed yield of soybean grown on vertisols under rainfed conditions. Eight herbicides viz., pre-plant (trifluralin), pre-emergence (alachlor, pendamethlin), post-emergence

(fenoxaprop, propaquizafop, imazethapyr, lactofen, anilophos), two hand weeding (30-45 DAS) and control (weedy check) were included in the study. Nodulation and shoot biomass was recorded at 50% flowering stage and yield at harvest. The study revealed that herbicidal treatments inhibited the nodules/plant at the rate of 4.9-14.8% as then the hand weeding, except the alachlor, pendamethlin, fenaxyprop and imazethapyr which were identical to hand weeding. In contrast, nodules / plant showed superiority by 0-31.9 % when compared with the control (weedy check). The nodule dry weight/plant enhanced by 3.1 - 36.3 % and 2.0-15.8 % as compared to weedy check (control) and hand weeding, respectively. The application of trifluralin, propaquizafop and anilophos marginally reduced the nodules - dry weight as than the hand weeding. Similarly, shoot dry biomass enhanced with the herbicides application over the control (weedy check) and the increase was 1.4-41.4 % but when compared with hand weeding, shoot dry biomass was reduced (3.3-20.2 %). A significant improvement in the seed yield by 11-45.3 % was noticed over the weedy check but, when compared with hand weeding (30- 45 DAS), seed yield was found less at rates of 3.5-23.5 % which showed the superiority of hand weeding. The study revealed that the application of herbicides had a stimulatory, inhibitory or no-significance on nodulation, shoot biomass and seed yield. In general propaquizafop, trifluralin had little effect, while anilophos had maximum inhibitory effect on nodulation and shoot biomass.

Determination of timing of weed control to produce seed from Roundup Ready soybean (525)

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The information on timing of glyphosate application on seed yield and quality in Roundup Ready soybean is not available, therefore, this research was initiated. In a two-year research (1997 & 1998), the effect of glyphosate application timings on three maturity group (MG IV, cu H4994; MG V, cu H5164; and MG VI, cv H6686) Roundup Ready soybean were conducted in a split-plot design. In 1997, MG IV with application of glyphosate at 5 weeks after emergence (WAE) produced 3126 kg ha^{-1} seed which was significantly higher than other application timings except multiple application (MA). MG V produced the highest seed yield (3270 kg ha^{-1}) when weeds were contolled by applying glyphosate through MA and was not significantly different from 2 WAE (3122 kg ha^{-1}), 4 WAE (3110 kg ha^{-1}) and 5 WAE (3116 kg ha^{-1}). In 1998, MG IV with application of glyphosate at 3 and 4 WAE produced seed yields of 3324 and 3530 kg ha^{-1}, respectively, which was significantly lower than MA (3920 kg ha^{-1}). MG V produced significantgly higher yields when weeds were controlled at 2, 3, and 4 WAE in comparison to other timings, but were similar to MA. During both years, MG VI produced the highest yield when weeds were controlled through MA and at 2 WAE. In terms of seed quality, seed produced in 1997 from MG IV and V when weeds were controlled at 7 WAE showed significantly highest germination (82 and 92%), germination index (10.7 and 13.4), and cold test emergence (43 and 82%), respectively. Whereas in 1998, standard germination (71.8 and 79.8%), germination index (9.1 and 10.0), and cold test emergence (18 and 45%) for MG IV and V, respectively were significantly higher when weeds were contolled at 6 or 7 WAE than with other weed control timings. Seeds produced from MG VI showed significantly higher germination (85.5%), germination index (11.1), and cold test emergence (77.5%) when weeds were controlled at 2 or 4 WAE, or through MA than other weed control timings.

Effectiveness of postemergence herbicides following early preplant applications of sulfosate in no-tillage soybean (526)

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The increased weed density and the extended period of time over which emergence occurs in a given growing season in no-tillage must be accounted for weed management systems to be effective. A field

experiment was conducted during the 1998/99 season at the research farm of the Universidade Estadual de Ponta Grossa, PR, in soil with 12 years under continuous no-tillage system. The objective was to investigate the effects of sulfosate applications prior to soybean planting on the density and timing of weed emergence, and their impacts on the effectiveness of postemergence herbicides. At soybean planting time, grass weed densities consisting of *Brachiaria plantaginea* (Link) Hitch. and *Digitaria ciliaris* (Retz) Koel. in plots treated with sulfosate and sulfosate + 2,4-D applied 26 days before planting (DBP) followed respectively by paraquat + diuron and paraquat applied just before soybean planting (early preplant application, EPP), were significantly lower than in plots treated with sulfosate and sulfosate + 2,4-D applied 12 DBP (traditional preplant application, TPP). The same trend was observed at the time of the postemergence herbicide applications, with the EPP plots presenting 690 plants m^{-2} compared to 1086 plants m^{-2} in the TPP plots, indicating competitive advantage of the EPP applications. However, when such weed infestation was allowed to compete with the soybean, significant yield reduction occurred compared with the postemergence applied plots. At harvest, although weed control obtained with the early postemergence application of the mix fomesafen + fluazifop-P-butyl (100 + 100 g a.i. L^{-1}) was effective, it resulted in significant soybean yield reduction in the TPP plots, compared to the EPP applied plots. This may be explained by the lower density and favorable stage of development of the grass weeds in the EPP plots. The sequential application of the mix fomesafen + fluazifop-P-butyl (200 + 200 g a.i. L^{-1}) showed no significant differences in both EPP and TPP treatments. Results indicate that the effectiveness of postemergence herbicides in no-tillage soybean is influenced not only by the preplant treatment but also the weed density and timing of application.

Weeds in agroforestry systems: a critical review (527)

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Agroforestry is a land use system with deliberate presence of trees or other woody perennials in crop or livestock fields with beneficial interactions. It has been mistakenly assumed that any presence of trees in agroecosystems are favorable. Many advantages or disadvantages of agroforestry systems (AFS) remain untested, in comparison to other land use systems or their monocultures. Reduced weeding requirements due to the presence of trees on the one hand, and increased competition by trees with the annual crops growing underneath, on the other hand, are both mentioned in the literature. If allelopathic effect of one component of the SAF may be beneficial by suppressing weeds, the potential for allelopathy between tree crops and annual crops is high in AFS since we know very little about the interactions between species and there are many possible combinations in these systems. The resource sharing has competitive, differential and complementary aspects. Competition is displayed by a crop having a preferential access to a resource, differentiation occurs when the access to resource pools is partitioned in space or time and complementarity occurs when a combination of species capture a greater fraction or have a more effective utilization of the available resource than when the same species are grown as sole crops. The objective of plant management in AFS is to combine crops in a way to maximize resource complementarity. Taking that in account, less resources will be available for weeds. If this goal is achieved, one can expect less weed competition in AFS. This is particularly common in young perennial plantations with underutilization of land in its initial growth stages. However, when weed infestation occurs in AFS their control may be more difficult than in the monoculture of their components because of a possible different selectivity of each crop in the AFS to herbicides and a greater difficulty of machinery use. Consequently, the interactions between crops in AFS need to be studied in much more detail, in respect to resource sharing and allelophatic effects. Furthermore, weed control processes need to be adapted to couple with particularities of AFS.

Selectivity of glyphosate, oxyfluorfen, simazine and thiazopyr on carob tree (*Ceratonia siliqua* L.) (528)

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The application of herbicides for the control of the competition with other species has been little used in the replanting of forests. This situation has been due to the lack of studies on the effects of these chemical products on the reafforesting species. With present trend in the protection of soils from erosion and in the minimization of the environmental impact on reafforesting, the use of herbicides could be increased. Reafforestation in land previously used for agriculture is a new sphere in which weed control is vital since competition is much fiercer and causes a high rate of tree loss. This study aimed to assess the effect of herbicide application on a species such as the carob tree (*Ceratonia siliqua* L.), for which an assay was conducted under controlled conditions where four herbicides (glyphosate, oxyfluorfen, simazine and thiazopyr) where applied, each one at a field dose and at a double dose. To evaluate the effects, different mophological (height, diameter and foliar area) and physiological parameters (chlorophyll content and photosynthesis level) were measured. The results indicate that simazine and thiazopyr did not have any noticeable effect. The treatments carried out with oxyfluorfen had a slight effect, whilst the glyphosate applicationshad a negative effect on all the parameters.

The sedges: are they still the world's worst weeds? (529)

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The authors of ''The World's Worst Weeds'' (LeRoy Holm et al., 1977) classified *Cyperus rotundus* L. and *C. esculentus* L. as our most important and difficult to manage weeds. It appears that this is still the case. A search of titles in the CAB Abstracts from 1975 to 1999 found 545 papers on these sedges. More than 60% were on *C. rotundus* and 29% appeared in the 1975-79 period. The number of papers decreased for the next 15 years (an average of 16% for each 5-year period) but increased to 22% of the total for 1995-99. What has this research revealed? Have more effective control measures reduced their seriousness? Have we learned more about their biology and ecology that has improved our means of combating or coexisting with them? Have integrated management programs reduced their seriousness? Do we have a better understanding of crop interference and threshold information regarding the sedges that has improved growers' understanding of the interactions of these weeds with their crops? These are some of the questions we hope this session of the Congress addresses. My research on *C. esculentus* in the early 1980s found that two to three seasons of effective suppression with either preplant incorporated thiocarbamates or acetanalides or postemergence bentazon plus cultivation approached eradication of this sedge. Research in the 1990s found similar results with repeated or alternate year applications of halosulfuron on *C. esculentus*. However, the use of glyphosate in glyphosate-resistant maize failed to give adequate suppression and thus repeated use of glyphosate alone in a maize-soybean rotation would quickly lead to an increase of *C. esculentus*. In contrast, *C. rotundus* is quite susceptible to glyphosate and building transgenic maize and soybean into cropping systems where this species is serious may both minimize its interference the season glyphosate is applied and reduce the infestation the next season.

Cyperus rotundus L.: current and needed research on its biology (530)

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Cyperus rotundus biotypes, dormancy and sprouting regulation, and tuber survival are important aspects of its biology that will be reviewed. Genetic variation was shown for *C. rotundus* biotypes by random

amplified polymorphic DNA (RAPD) analysis. There is generally more variation from geographically diverse populations than from clones collected from a smaller geographical base. However, genetic variation was found for upland and lowland biotypes collected from the same village. In addition to RAPD analysis, sesquiterpene composition of essential oils have been used to characterize *C. rotundus* biotypes. Four distinct chemotypes were shown for *C. rotundus* collected from diverse geographical areas, with varying allelopathic capacity. Many morphological characteristics of *C. rotundus* showed significant variation among clones from locations around the world and also lowland and upland biotypes from the same region. It is clear that many *C. rotundus* biotypes exist. These may have different competitive and allelopathic characteristics, dormancy and sprouting requirements, and respond differently to control strategies. While apical dominance has a major role in tuber dormancy, soil moisture, light, oxygen content and temperature influenced the sprouting process. Diurnally fluctuating temperature strongly regulated the sprouting process. The sprouting process can be characterized in two steps: budbreak and shoot elongation. Budbreak occurred readily once individual tubers were exposed to sufficient moisture, but few buds elongated at constant temperature. The buds elongated readily when exposed to fluctuating temperature. When tubers were present on chains, most tubers produced budbreak, but only one or two shoots elongated in response to fluctuating temperatures. Diurnally fluctuating temperature strongly stimulated shoot elongation, and may be a key factor in regulating emergence of *C. rotundus* shoots. *C. rotundus* tuber half-life was determined to be 16 months and the 99% mortality period was 42 months in Costa Rica. It is likely that variation among environments and biotypes will occur.

***Cyperus rotundus*: Current and needed research on purple nutsedge management** (531)

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Purple nutsedge (*Cyperus rotundus*) is still an important weed infesting different crops in tropical and subtropical conditions. The interference that this weed causes to annual, perennial and vegetable crops by competition for water, light and nutrients and allelopathy is very high. It is very likely that integrated management programs including prevention, cultural, physical, biological and chemical methods have reduced its seriousness in several countries. Recently new chemicals have been developed that present good results of purple nutsedge control, such as imazapyr, imazapic, sulfentrazone, halosulfuron, flazasulfuron, ethoxysulfuron, pirazosulfuron-ethyl. Several glyphosate rates and application timings were compared with conventional control programs in glyphosate-resistant crops. The use of glyphosate in transgenic soybean has permitted high control level of this weed. Mixture of glyphosate + 2,4-D has presented good translocation and effective control of this weed. Knowing the best conditions of herbicide application is very important because its application during the dry season does not reduce purple nutsedge population effectively. The translocation to underground parts of purple nutsedge is high at high relative humidity and low plant water stress. In sugar cane producing areas of Brazil, good results are being obtained with mechanical control in the dry season and application of glyphosate during the rainy season. Today the mechanical harvest in sugar cane has influenced the weed population. Purple nutsedge is not well controlled by sugar cane crop residue over the soil, but the interference is reduced, and the control can be excellent by using several herbicides. Some interesting results are being obtained by biological control of purple nutsedge. A fungal pathogen *Dactylaria higginsii* is being tested as a potential bioherbicide for purple nutsedge control, but it is important to distinguish the biotypes of purple nutsedge to develop strategies for a successful biological control. The use of electricity to control weeds has been tested in Brazil, and purple nutsedge was more tolerant than other weeds.

Interference and management of *Cyperus* in vegetable crops (532)

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Cyperus rotundus and *C. esculentus* are difficult-to-control weeds commonly found in vegetable fields. Interference by Cyperus spp has reduced the yield of tomato, pepper, eggplant, watermelon, asparagus, carrot, and beet, among others, by as much as 90%. The critical period of interference of *Cyperus* spp. with vegetables is usually long: 2 to 10 weeks after transplanting for *Cyperus esculentus* in tomato, and the complete season for *Cyperus rotundus* in onion and radish. Management of *Cyperus* spp. in vegetables includes physical, chemical and/or cultural practices such as promotion of pre-plant sprouting of *Cyperus* followed by chemical and/or mechanical suppression; thick plastic mulch; solarization; soil fumigation; manipulating crop density and fertilization; selective chemical herbicides and hoeing. Methyl bromide, an effective suppressor of *Cyperus* spp. in vegetable crops, will not be available for agricultural use in the near future, due to its ecological impact. In some cases, alternative *Cyperus* management systems are based on one or a few selective herbices. In most cases, physical and chemical *Cyperus* management alternatives available to growers are not practical, economical and/or sufficiently effective when individually implemented. Densities of 25 *Cyperus rotundus* or *Cyperus esculentus* plants m^{-2} have reduced the yield of tomato and other vegetables by more than 10%. Since initial *Cyperus* densities can be higher than 100 plants m^{-2}, economically important *Cyperus* densities are likely to occur, even achieving 80% suppression when individual means of control are implemented. Due to incresing environmental concerns regarding the reliance of agriculture on chemicals, a more integrated approach for the management of *Cyperus* spp in vegetables is required.

***Amaranthus*: importance as a weed, taxonomy, life cycle and global distribution** (533)

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In *Amaranthus* genera more than ten species are recognized as weeds competing with numerous arable crops. *Amaranthus* weedy species are annual and, in the temperate zone, they usually have one generation. These weeds as C4 plants with high net photosynthesis, low both CO_2 compensation point and water use efficiency are very strong competitors especially at higher temperature. *Amaranthus* weeds as tolerating drought and wide range of pH, if grown on rather rich soil, are capable for intensive reproduction. With indeterminate growth habit, they may easily produce up to 100 000 seeds per plant what together with seed vitality up to 30 years play significant role in seed bank. Seeds of amaranth are easy dispersed by animals after ingestion (seeds are of very high nutritional value), by wind and as contaminants of crop seeds and of farm machinery. Germination of amaranth seeds is triggered by light and stimulated by nitrogen and higher temperature with the optimum between 30 and 40^{o}C. An easiness of hybridization in *Amaranthus* genera, including cultivated species, together with large intraspecies differentiation of some morphological parameters makes the taxonomical identification quite difficult. All amaranth weedy species are of New World origin and spread to new territories by man. Two species, *A. retroflexus* and *A. viridis*, are important, widespread weeds in arable land of all continents. Control of weedy species of amaranth, taxonomically close related to cultivated species is challenging, especially that it is reputed that wild species are progenitor of cultivated ones what makes possible to transfer some characters from crops to the weeds.

The story of the incomparable weed: herbicide resistance in *Amaranthus*, distribution and mechanisms (534)

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Amaranthus is a genus of tropical origin that is currently widely distributed all over the world, with more than 60 weed and crop species in America, Asia, Europe and Australia. As pioneer annual weeds that produce many seeds, they infest agronomic, horticultural and ornamental crops as well as roadsides and neglected areas. Being efficient C-4 plants, they are highly competitive and vigorously thrive in sunny and warm habitats. Resistance to almost all herbicide groups was detected in many species of this genus with some species such as *A. blitoides* conferring multiple resistance. Triazine resistance was detected in at least seven *Amaranthus* species in Europe, Asia and America. The altered target site and maternally inherited triazine resistance has evolved mostly in maize, sorghum and orchards where atrazine and simazine are applied repeatedly. Cross-resistance to several urea derivatives and uracils as well as negative cross-resistance to swep, pyridate, benatzon, DNOC and ioxynil were also reported. Paraquat resistance was reported in *A. lividus* from South East Asia following repeated use of the herbicide for more than 20 years. A trifluralin-resistant *A. palmeri* was found in cotton monoculture in the US. These resistant biotypes exhibited varying levels of cross resistance to other dinitroaniline herbicides, but no differences were detected in their response to herbicides from other groups. Resistance to ALS (or AHAS) inhibitors has evolved rapidly in *A. retroflexus, A. blitoides, A. palmeri, A. rudi* and *A. powellii* indicating the high initial frequency of resistant plants in the population. In most cases the resistance is based mostly on an altered target site (ALS). Different mutations in the ALS lead to erratic levels of cross resistance, making the response of the whole plant unpredictable. This phenomenon combined with the multiple resistance to other herbicide groups hamper any attempt to develop rational and practical weed control management.

Sorghum halepense (L.) Pers. population dynamics in the agroecosystems of south of Santa Fe province, Argentina (535)

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Panicle production with highly dormant and viable seeds (ca. 85%) exhibits a bimodal pattern extended from February to April. A panicle may bear ca. 250 seeds. Seeds laid in the soil exhibit a rhythmical induced dormancy, whereas those being laid in deeper layers would exhibit an imposed dormancy. Afterripening broadens the range of favorable soil humidity for germination to proceed. This species requires alternate temperature for germination and different covers produce differents seedling recruitments. During summer crop cycle, ca. 53% or total seeds are predated. Under no cultivation soils, seed survival is about 7 years, but under cultivated ones, viability loss is very high. Asexual propagules include rhizomes and crown. The crown has extremely short internodes, delayed ontogenic development and silica deposits. Rhizome biomass shows an annual cyclic pattern with maximum values early in the autumn and minimum values early in the spring. This general pattern slides backward or forward according to the type and time of cultivation & associated crops. Rhizome generation maps have been obtained for the weed under soybean and corn crops. A thermal model available has been validated: under a soybean crop, minimum rhizome biomass is achieved with 200 Accumulated Thermal Units (ATU), whatever the initial density may be. By this moment, tillering does not account for more than 20% of total and Aerial/Subterranean Biomass ratio is 0.8. Herbicide spraying in this period allows to optimize control and it is compatible with maximum crop yields. However tiller height (influenced by original rhizome length) may interfere with proper

spraying in some circumstances. Early glyphosate spraying (180 ATU) achieves higher control than late spraying (250 ATU) but the contrary is true for haloxyfop-methyl. Rhizome produced by seed plants is only relevant when initial rhizome population is very low (complementary strategies). Weed competition on soybean and corn yield has been studied using tiller density as independent variable and linear models was fitted in first instances. Further research demonstrated that weed relative cover estimates properly crop yield loss.

History and future importance of *Sorghum halepense* (L.) Pers. in the U.S.A (536)

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Sorghum halepense is an aggressive, rhizomatous perennial that is one of the world's worst weeds and one of the most troublesome weeds ever introduced into the U.S.A. Following its introduction into the U.S.A., *S. halepense* was well established as a pernicious weed of agricultural and non-agricultural areas by the mid 1800s. Despite the use of multiple tillage operations and cultural and chemical control practices during the past century, *S. halepense* persists as a formidable foe for crop production in the tropical, subtropical, and temperate climates of the U.S.A. Early control methods were restricted to plowing and hand hoeing. Numerous herbicides and herbicide application technologies were developed for the control of *S. halepense* during the last 50 years, such as preplant incorporation of dinitroanaline herbicides, spot spraying, recirculating sprayers, and rope wick applicators. The advent of postemergence grass herbicides were effective in reducing *S. halepense* population levels in cotton and soybean until herbicide-resistant *S. halepense* evolved. Recently, the use of glyphosate in glyphosate-resistant crops has been effective in controlling early season *S. halepense* populations. Additional historical information on the biology, ecology, and control of *S. halepense* and its future importance and research needs will be discussed.

Sorghum halepense in European crops (537)

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In Europe, every year, 10 to 30 different weed species may infest each crop and, if not controlled, cause economic losses by reducing yields. The most common and destructive weeds in Europe, especially in the Mediterranean countries, are:of the broaleaf species, *Amaranthus* spp., *Chenopodium album*, *Solanum nigrum*, *Convolvulus arvensis*, *Cyperus* spp. and of the grasses, *Digitaria sanguinalis*, *Echinochloa crus-galli*, *Setari*a spp., and *Sorghum halepense*. More specifically, *Sorghum halepense* (L) Pers. infests cropland in more than 10 countries in Europe (Spain, France, England, Italy, Greece, Hungary, Romania, Russia, Bulgaria, Albania, Turkey, Yugoslavia) and in more than 58 countries all over the world. In Europe, *S. halepense* is reported as an economically significant weed and among the 10 most troublesome weeds in major agronomic crops like maize (in Greece, Italy, Spain, Hungary, Romania, Poland, Yugoslavia), Cotton(in Russia, Greece, Turkey, Italy, Spain), sugar beets (in Greece, Italy), and tobacco (in Spain, France, Greece, Bulgaria, Poland, Turkey, Albania, Yugoslavia), in fruit orchards (in Greece, Italy, Spain), in vineyards (in Spain, Greece, Yugoslavia), in olive groves and in vegetables. In Greece, yield losses in maize, due to *S. halepense* coming from seed and rhizomes, were 60 and 80%, respectively. Control of *S. halepense* is possible today in many crops with preemergent herbicides (for *S. halepense* coming from seed) and almost in all crops with postemergent herbicides in the chemical families of aryloxyphenoxypropionates, or cyclohexanidiones, or sulfonylureas. Only the species *S. halepense* has been found in Europe. Herbicide resistance of *S. halepense* has not been reported yet in Europe. However, in Greece, studies in vivo with 70 ecotypes and in vitro with 4, revealed differences in glyphosate tolerance.

S. halepense is a very competitive and destructive weed but today it is not considered as a serious weed as in the past since certain herbicides can control it in most crops.

An overview of parasitic weed control (538)

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Striga and *Orobanche* parasitic weeds constitute one of the most important biotic constraints to the production of food crops in Africa and the Middle East. *Striga* parasitic weeds may cause yield losses of up to 80% in the staple food and industrial crops of the region, including cereals, such as sorghum, pearl millet, finger millet, maize, rice, wheat, and sugar cane, and some broadleaf crops, such as cowpeas, sunflower, soybean, groundnut, tobacco, and various cultivars of beans. The subsistent resource-poor farmers in the marginal areas of rainfall and poor soil productivity are the most affected by *Striga* weeds. Serious losses of vegetables, legumes, sunflower and tobacco production are caused by *Orobanche* spp., which mainly occur in North Africa, the Near East and in a few Latin American countries. Permanent mono-cropping and lack of suitable crop rotation, impoverished soils and reduced rainfall, incorrect cultural practices (including the use of crop seeds infested by parasitic weed seeds) and the lack of other preventative measures are the major factors favouring continuous interference of parasitic weeds with several crops. There is no single effective method for the control of parasitic weeds. The most effective approach is the integration of different environmentally friendly control measures that are economically feasible to smallholders. *Striga* spp are best controlled by preventing their reproduction and build up of the seed bank in soil through the use of clean crop seeds, hand-weeding, direct application of 2,4-D in cereal crops for preventing seed-setting, rotation of affected crops with effective trap crops to induce suicidal *Striga* seed germination and increasing fertility of the soil through the use of organic manure and N-fertilisers. Some tolerant cultivars are available, but the attachment of haustoria to host crops can also be delayed using imazapyr for crop seed-dressing. Research has also been carried out for possible application of *Fusarium* pathogens for *Striga* control. For *Orobanche* spp the approach should be similar to the above with regards to improvement of soil fertility, but N-fertilisers are not always compatible in some affected crops. The use of tolerant cultivars is another option. Application of post-emergence glyphosate at reduced rates (0.02-0.04 kg a.i. ha^{-1}) have been successfully used in some crops, such as faba beans and sunflower. Increased extension work is still required with farmers for them to adopt the available methods for the control of parasitic weeds.

Striga control by restoring soil fertility (539)

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Parasitic *Striga* species (Family Scrophulariaceae) thrive on degraded soils, the majority of soils in tropical Africa. They occur worldwide, in Africa (native continent of the genus), Asia, America and Australia. Literature review indicates *S. asiatica* (L.) Kuntze, *S. gesnerioides* (Willd.) Vatke and *S. hermonthica* (Del.) Benth. as the species currently causing agricultural problems. *S. asiatica* and *S. hermonthica* parasitize cereal crops in contrast with *S. gesnerioides* which parasitizes leguminous plants like cowpea (*Vigna unguiculata* (L.) Walp. and also plants of the families Agavaceae, Convolvulaceae and Euphorbiaceae. Parasitism by *Striga* may inflict up to 100% yield loss. Ammonium nitrogen impairs germination and attachment of *S. hermonthica* seedlings to roots of the host plant. It also reduces production of germination stimulant by the host. A more remarkable effect on *Striga* is expected from organic matter as compared to mineral fertilizers. In situ production of organic matter by growing a short fallow cover crop which improves soil fertility has been studied. Velvet bean (*Mucuna utilis* (L.) DC is adopted by farmers as cover crop in Bènin. Leguminous trap crops like cowpea (*Vigna unguiculata*), soybean (*Glycine max* (L.) Merrill, groundnut (*Arachis hypogaea* L.), etc. are also available which induce suicidal germination of *S. hermonthica* seeds and may also contribute soil nitrogen. In contrast to mucuna they produce marketable seeds. Choice of a trap crop should be based on its specific and general effectiveness indices. Early sowing of a trap crop may be more effective for *Striga* control than late sowing. Establishment of a cover crop or a trap crop may require application of a limited amount of a mineral fertilizer.

Progress on *Striga hermonthica* control in East Africa (540)

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Striga is a parasitic weed which affect cereal productivity in East Africa with losses of between 30-90% very common. Major progress in the *Striga* witchweed control has been in the identification of resistance in major cereal crops especially maize. *Striga* resistance genes have been identified in *Zea diploperenis*, a wild relative of maize which is being incorporated into the adapted local maize genotypes through backcrossing. The genes would then be mapped through marker assisted selection. Parallel to this effort, a large collection of transposon-induced mutations in the genome of maize adapted to African conditions are being constructed using the mutator type transposable elements. After the resistance is confirmed, genes for resistance will be tagged then isolated for clonning. Seed dressing acetolactase (ALS) target-site resistance maize mutants (PH 3245-IR) seed with Mg-imazapyr or pyrithiobac-Na at 30 g a.i ha^{-1} has been observed to provide up to 12 weeks of *Striga* control at minimal cost. In addition to the use of these new genetic tools to identify resistance, cereal germplasm with wider genetic variability continue to be evaluated for durable resistance to *Striga*. As part of the integrated control strategy, new cultural practices or old ones are being refined to manage the weed. Improved short term land fallows for 6 months using either of *Crotolaria*, *Sesbania*, *Tephrosia* and *Acacia* species among others cause suicidal germination of *Striga*, and thus help reduce the seed bank. Catch cropping with susceptible hosts (Sudan grass or sorghum), transplanting maize or sorghum to escape the most vulnurable stage of *Striga* attack; inter-cropping susceptible host with *Desmodium*, a fodder legume, to suppress *Striga* growth while at the same time repelling stem borers from attacking the cereal can each or all be integrated with resistant genotypes to help reduce the harmfull effect of the weed.

Prospects for *Orobanche* control in the 21st Century (541)

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Parasitic weeds of the genus *Orobanche* (broomrapes) are vicious pests of many agricultural crops. They have a tremendous impact on world agriculture. Unlike other weeds they are devoid of leaves and are totally dependent on a host plant for nourishment. In the 20th Century the means for *Orobanche* control included sanitation, weeding, soil fumigation and solarization, selection and breeding of resistant crops, trap and catch crops and biological agents. By the end of the century some herbicides proved relatively effective in certain crops. In addition, some new approaches developed only recently, like the use of herbicide resistant crops, and crop seed treatments. However, no method is thus far practical and economic in the majority of crops. *Orobanche* research in the last twenty years contributed to our understanding of some crucial steps in the development of the parasite and in host/parasite relations. Research has 1. Described seed metabolism during preconditioning and germination, and identified germination stimulants. 2. Discovered enzymatic processes during haustorium invasion. 3. Established host responses to *Orobanche*, resistance mechanisms, and host genes that are induced during penetration. 4. Revealed demographic data of the parasite and developed molecular markers for important species. These research achievements should be exploited for the development of novel control methods. Three new strategies for *Orobanche* control can be envisaged: A. Manipulation of known metabolic pathways, by developing specific herbicides that will only affect the parasite. B. Development of artificial resistances by genetic engineering, based on knowledge of crucial steps of infection and on the availability of suitable promoters. C. Maintaining an equilibrium between the parasite population and its hosts by constant supply of a biocontrol agent that will keep *Orobanche* seed production to a minimum. An integrated approach combining various control methods will allow a long-term solution of the *Orobanche* problem.

Rimsulfuron: a new tool for *Orobanche ramosa* control in potato (542)

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Field studies were conducted to evaluate the efficacy of rimsulfuron for *Orobanche ramosa* control in potato. Rimsulfuron was applied POST at 10, 20, 30, 40 and 50 g a.i. ha^{-1}. Each rate was tested for single and sequential (twice or three times) application at 20, 40 and 60 days after potato emergence (DAPE). Results indicated that rimsulfuron at all tested rates significantly reduced *Orobanche* shoot number and dry weight compared to the control. Rimsulfuron at 10 g a.i. ha^{-1} reduced *Orobanche* infestation by 58% when applied once (20 DAPE) and 88% to 100 % when applied two (20 & 40 DAPE) or three times (20, 40 & 60 DAPE). Sequential application of 20-50 g a.i. ha^{-1} reduced *Orobanche* infestation and shoot dry weight by 100%. All tested rates except for the single application of rimsulfuron at 10 g a.i. ha^{-1} produced compact potato plants with small leaves. Phytotoxicity was mostly reflected in the tuber quality with a high incidence of malformed and small tubers.

Interaction of Plant Growth Promoting Rhizobacteria (PGPR) with maize and *Striga hermonthica* (Del) Benth. seeds (543)

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The onset of *Striga* parasitism on maize depends on the germination of parasite seeds being stimulated by host root exudates. PGPR, which enhance root growth in maize, might be involved in the interaction host plant-parasite. In laboratory experiments PGPR isolated and collected from maize rhizosphere in *Striga* infested fields were studied to define their role during *Striga* germination and attachment. Seedlings of ‘‘Pioneer 3152’’ (commercial hybrid) and ‘‘Local White’’(Kenyan land race) maize varieties were inoculated with 8 PGPR isolates. A new method with Petri-dishes divided in chambers was designed to study their effect on *Striga* seeds. Results showed that *Striga* seeds swelled up considerably, but did not germinate. Seeds eventually died due to softening and disintegration of seed coat and embryo tissues. Local White seedlings inoculated with AZT-S, PSD-W, AZT-Q and AZP-F1 produced exudates that significantly increased the percentage of dead seeds. These observations are linked with a significant decrease in percentages of swollen seeds. PGPR had no effect on *Striga* seeds in treatments with Pioneer maize. This suggests specificity of Kenyan PGPR-isolates to the local maize variety. Their association may benefit the host plant not only by promoting growth but also providing protection against *Striga*. Further experiments with other 24 PGPR isolates are presently being conducted, using the same technique. Simultaneously, a new method for observing *Striga* developmental stages was designed. It consists in growing maize seedlings in plastic bags containing Fahreus Agar, inoculating them with PGPR and applying *Striga* seeds to their root system. It was observed that germination took place even 5 cm apart from maize roots, probably due to diffusion of exudates and bacterial products through the agar. After 10 days most of the germinated *Striga* seeds had died off without developing haustoria. This suggests that PGPR could also inhibit development of *Striga* after germination has been triggered.

Linking research, extension and farmers: *Striga* control strategies for western Kenya (544)

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Striga hermonthica (Del) Benth., a parasitic weed that infests maize and other cereals, is a major constraint to food production in many sub-Saharan countries. However, small-scale farmers rarely adopt *Striga* control technologies. A project implemented in western Kenya in 1995 developed and tested agronomic methods for controlling *Striga*. In 1998, the project began to develop strategies and training materials to disseminate these technologies because surveys of farmers and extension agents showed that knowledge about *Striga* biology and control was very limited. Two organizations, the National Extension Service (NES) and a NGO (CARE-Kenya), each using different approaches to farmers' training and adaptive research, were identified as collaborators. The NGO uses a strictly participatory approach in which adaptive research farmers (ARFs) conduct on-farm trials while group resource persons train their farmers groups on new technologies. The major problems of this approach are sustaining farmer-managed-research in time and verifying whether farmer-to-farmer training has been successful. In contrast, the NES selects farmers to set-up on-farm trials and conducts training sessions and field days open to all farmers. Their major problem is the continuity of training since extension agents often lack incentives and the means to conduct their work. Extension agents of both organizations were trained on *Striga* biology and control. Manuals and picture-series on these topics were provided and scientific backup and assistance given for training sessions. During the first 9 months, the NES trained more than 2000 farmers and implemented 8 on-farm demonstrations. The NGO selected 64 ARFs and approximately 200 farmers' groups, implemented 16 on-farm trials and initiated the training of farmers. The NES will be encouraged to follow up farmers who participated in training sessions and assess the impact of these sessions on adoption. In 2001, a survey will be conducted to assess the impact of both approaches on knowledge dissemination and adoption of *Striga* control methods.

New possibilities for *Cuscuta* management in some vegetable crops (545)

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Cuscuta is a parasitic flowering plant which twines its tendrils on the foliage of several vegetable crops. It causes serious losses on chard, mallow, mint, onions, radish, red beet, tomato, turnip and other vegetables grown in the Middle East. Several control measures have been used to alleviate crop losses. These include prevention methods such as planting of uncontaminated crop seeds, crop rotation, various cultural practices, biological and chemical control methods. Soil-applied, contact and post attachment application of herbicides are used with varying degrees of success. Pot experiments were conducted to study the efficacy of glyphosate and glufosinate ammonium for the control of *Cuscuta campestris* L. on some vegetable crops. It was found that post-attachment application of glufosinate at 25 ppm (a.i.), sprayed on mint at a volume of 100 cc m^{-2}, gave good selective control of *Cuscuta*. In the same trial, glufosinate at 50 ppm and above was toxic to mint as was glyphosate at 100 ppm and above. Chard, red beet and radish were tolerant to 25-50 ppm glufosinate, and to 75-100 ppm glyphosate. In the case of tomato, glyphosate at 25-75 ppm controlled *Cuscuta*, but caused some phytotoxicity to the crop. The application of glyphosate at 25 ppm controlled the parasite without apparent phytotoxicity to mallow. It is recommended that lower concentrations of the herbicides tested as well as others such as chlorsulfuron and imidazolinones be evaluated in the future for selective control of *Cuscuta* in vegetable crops. With the release of genetically modified cultivars of herbicide resistant crops, post-attachment application of herbicides becomes more feasible.

Conditioning, CO_2 and GR24 influence ethylene biosynthesis and germination of *Striga hermonthica* (546)

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Germination of witchweed (*Striga hermonthica* [Del.] Benth), a parasitic weed on poaceous crops, requires conditioning in a warm moist environment and a subsequent exposure to a stimulant. The roles of conditioning period, CO_2 and a strigol analogue (GR24) in ethylene biosynthesis and germination of the parasite were investigated. Conditioning and exogenous CO_2 increased the seed's capacity to oxidize 1-aminocyclopropane-1-carboxylic acid (ACC). A combination of GR24 and ACC increased ethylene production by more than 3-fold in comparison to the rates obtained using these compounds separately. Aminoethoxyvinylglycine (AVG) completely inhibited ethylene induction by GR24, but not by ACC. A GR24 treatment made subsequent to conditioning in GR24 did not induce ethylene. ACC oxidase activity in crude seed extracts was increased by conditioning and CO2. The enzyme displayed an absolute requirement for ascorbate. Absence of exogenous Fe2+ reduced enzyme activity by 14%. GR24 applied during conditioning reduced germination. ACC was, invariably, less effective in inducing *S. hermonthica* germination than GR24 even at concentrations which induce more ethylene than concurrent GR24 treatments. It is concluded that conditioning removes a restriction on the ethylene biosynthetic pathway in *S. hermonthica* seeds, GR24 modulates the key enzymes in ethylene biosynthesis and germination of the parasite results from the joint action of GR24 and the ethylene it induces.

Effect of fodder legumes on stimulation, attachment and emergence of *Striga hermonthica* on maize (547)

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A method to control *Striga* infestation is the use of trap-crops either in sole stands to decrease the *Striga* seed bank in the soil or as intercrops in maize to reduce *Striga* attachment to the host and suppress emerged *Striga* plants. Three pasture legumes, *Mucuna gigantica*, *Stylosanthes guyanensis* and *Desmodium sp*. were investigated for their ability to induce germination of conditioned *Striga hermonthica* seed, for their effect on *Striga* attachment and on *Striga* shoot emergence. Laboratory experiments showed that the root exudates of the legumes stimulated up to 70% more *Striga* seeds to germinate than exudates of maize. Legumes and maize were also grown in pots to observe *Striga* attachments 90 days after planting. The maize-*Mucuna* combination had the highest number of attachments while all other combinations and maize planted in pure stand had lower numbers of attached *Striga*. The experiment showed also that *Striga* attached in considerable numbers to *Mucuna* roots but seedlings did not develop further. The other legumes had none or only very few *Striga* seedlings attached to their roots. In a field trial the number of emerged *Striga* shoots 12 weeks after planting were counted. Maize intercropped with legumes had a clearly lower *Striga* infestation than maize in pure stand. Grain yields of maize were highest in the maize-*Mucuna* combination followed by maize-*Stylosanthes*, maize in pure stand and maize-*Desmodium* respectively. These experiments show that the legumes tested are better stimulant producers than maize and therefore have a potential as *Striga* trap crops. However, they do not prevent or reduce attachment of *Striga* to the maize roots if planted as intercrops. The lower number of emerged *Striga* shoots in maize intercropped with legumes can be attributed to the shading effect of the legumes or a change in humidity and temperature conditions due to their dense canopy. Fodder legumes can reduce *Striga* infestation as trap crops or due to suppression of emerged *Striga*. They can form a valuable part of an integrated *Striga* control strategy for western Kenya.

Cynodon dactylon (L.) Pers.: a noxious global weed or a useful plant? (548)

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Cynodon dactylon (common bermudagrass) is a perennial weed reproducing by seeds, rootstocks, and stolons. It is a very serious weed when established, normally found in open places, pastures, and in most cropped areas, both in irrigated or dry land. However, improved cultivars of bermudagrass are useful forage species in some areas of the world. A mixture of warm (*Cynodon dactylon*) and cool season turfgrasses (perennial ryegrass) must be managed to maintain high quality golf greens. The plant is well adapted to a wide range of soils. It grows better where mean daily temperatures are above 24 C. Freezing point of Cynodon is -2 or -3 C. The temperature that start growing is 8°C. Nevertheless growth rate above vs below ground are not sychronous. After 7 days of desiccation no growth was reported, the humidity critical point being around 15%. The paper shows a survey on the subject of more than 30 weed scientist of different climatic and crop areas of Spain. Also the importance of this plant in others nations of the word. It seems that the non selective herbicides glyphosate and sulfosate have change the importance of this weed. Nevertheless, in certain vegetable crops like onions or tomatoes, direct seeding is handicapped by this still very aggressive weed. In tree crops, kiwis and vineyards, it is still a very difficult weed to control.

Status of *Cynodon dactylon* as a weed in cuban agriculture (549)

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Hierba fina, Bermuda grass, couch grass, grama seda, devil's grass zacate Bermuda, grama Espa±a and chiendent, are just some of the several names given to *Cynodon dactylon* (L.) Pers. in more than 80 countries where its presence has been reported as one of the worst weed with a worldwide distribution. *C. dactylon* was introduced in Cuba as a forage plant and was reported by Sauvalle in 1873. In 1933, Roig already referred to the damages caused by this species in economic crops. Since then and for many years, *C. dactylon* was a problematic weed in citrus as well as in banana, pineapple, sugar cane and in a lesser degree, in vegetables and tobacco. Studies made by Casamayor and Garcia in 1977, showed, among other things, the existence in Cuba of at least 19 cytotypes and ecospecies with different chromosome numbers, with morphological differences and with different biochemical responses and living habits. All these forms of the weed were satisfactorily controlled only by the herbicide bromacil, used in citrus and pineapple. Pèrez and Labrada, on the other hand, studied and defined in 1985, its germination, its agamic reproduction, its phenological stages and productivity under the Cuban conditions. The Registration of predominant weeds made in recent years in Cuban citrus orchards show values for *Cynodon dactylon* of 5%, 4, 3.5 and 0% from 1995 to 1999, respectively. This reduction in the presence of the weed is mainly attributed to the systematic and efficient use of glyphosate which in turn, has altered the natural composition of weed associations in the sense of dicot predominance with a ratio of dicot/poacea of 7.52.

Management of *Cynodon dactylon* in Israeli agriculture (550)

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Cynodon dactylon was described as ‘‘widespread and problematic weed’’ of Syria, Palestine and Sinai, more than a hundred years ago (Post, 1896). The botanist Eig (1929) defined it as ‘‘the most vicious weed of Palestine’’. The development of intensive and irrigated agriculture in the twentieth century was associated with developing methods for *Cynodon* control (Horowitz, 1996). Mechanical control using hand digging for removing the rhizomes in the early decades of this century was replaced by deep moldboard plowing in the clay-loam soils or frequent shallow cultivations in the loess and sandy soils. The use of herbicides has entirely replaced the mechanical methods of *Cynodon* control. Glyphosate is generally used on stubble and in directed application in plantations. The recently developed herbicides inhibiting acetyl-CoA carboxylase selectively control grasses including *Cynodon* in post-emergence application in most broadleaf crops. Herbicide application suppressed *Cynodon* and removed the weed from most of the traditionally infested regions. We did not yet identified evolved resistance of *Cynodon* to acetyl-CoA carboxylase inhibitors or other herbicides, as has already happened with some annual grasses, since the weed in our region is rarely propagated by seeds. There are yet no reports of evolved herbicide resistance of *Cynodon* to any herbicide in the world. Integrated control methods may keep the weed suppressed, although changing to minimum tillage has been increasing field infestation with perennials, including *Cynodon*.

Ecotypic differentiation among clones of *Cynodon dactylon* (L.) Pers. from grasslands and croplands of the pampas region (551)

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Most of the comparative studies about clonal growth were performed on taxa from different genera and with species which propagate by rhizomes or stolons. Cynodon dactylon possesses both types of propagating structures in proportions and characteristics very variable among clones. The objectives of this work were to compare vegetative traits of four clones invading natural grasslands and four from annual crop farms located 100 to 700 km appart in that region. According to the main factors in controlling growth and survival in each of those environments, we hypothesized that attributes related to stress tolerance and consolidation of the captured space prevail in grassland clones and that attributes related to a guerrilla foraging pattern for a fast exploitation of high resources patches prevail in cropland clones. After seven vegetative generations under uniform glasshouse conditions, clones were planted in a field experiment where the growth of 6 plants of each clone was followed during three months. According to a completely random design, the clones were compared in attributes relative to the plant level and of rhizome and stolon phytomers. Cropland clones almost doubled total biomass and the canopy height and had higher proportion of aerial biomass and soil cover than grassland clones. Their stolon and rhizome internodes were slender and longer than in the latter. Leaf size was very variable within each group of clones but the arrangement of leaves on the aerial shoots was more compact in the grassland clones. Distribution of the plant biomass density along the distance to the origin of each clone described two contrasting pattern of space occupation with adaptive significance. The grassland clones had a concentrated pattern of biomass distribution and an amoeba-like contour while the cropland clones were more extended with a tentacle-like contour.

Vertical tillage and dispersion of vegetative structures of *Cynodon dactylon* (L.) Pers. (552)

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Cynodon dactylon invades almost 22 millions hectares in the most productive areas of Argentina. Spatial growth of the weed is mainly through vegetative structures (stolons and rhizomes) that spread in the field forming patches. In cultivated systems, vertical tillage seriously disturbs the biomass and spatial structure of *Cynodon dactylon* patches affecting the population dynamics of the weed. The objectives of this study were: (i) to quantify effects of tillage implements on dispersion of vegetative structures of *Cynodon dactylon* and (ii) to analyze the establishment ability of dispersed units and their spatial growth and biomass. Two experiments were carried out under field conditions in the Pampas, before soybean sowing

(Experiment 1) and after sunflower harvesting (Experiment 2). Weed patches were identified and painted in the field. Weed biomass in each patch was determined and, afterwards, they were chiseled and a disc plus spike harrow in tandem was passed twice. Weed vegetative fragments were surveyed along 100 m long transects using a grid procedure. Fifty fragments were randomly marked to determine establishment and growth of *Cynodon dactylon* vegetative structures after dispersion. The implement sequence dragged and moved vegetative structures out from their original patches in both experiments. In Experiment 1 structures from dense (550 g m^{-2}) and thin (167 g m^{-2}) patches were dispersed 32 m and 4.5 m, respectively. In Experiment 2 the structures were dispersed up to 62 m. A negative exponential function fit the spatial distribution of the dispersed vegetative units in the field. Tillage dispersed 13% of the original patch biomass. However, only 5% of the dispersed units established new patches of colonization. Despite a high dispersion cost, weed spatial growth was increased by tillage when the area occupied by dispersed units was considered in Experiment 1.

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