European Weed Research Society

3rd Workshop of the EWRS Working Group:

WEEDS AND BIODIVERSITY

Lleida (Spain)

12 – 13 March 2009

3rd Workshop of EWRS Weeds and Biodiversity
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Proceedings of the Workshop
Edited by Universitat de Lleida
D.L. xxxxx 2009

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Arable biodiversity: evolving challenges

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Consideration of diversity in arable systems can on the one hand be looked at as the driver of crop protection interests, but on the other hand, the driver for sustainability. The agrochemical era of agriculture had as its goal the achievement of monoculture cropping. In high value vegetable production, this is still very much the aim, where even minor contamination can cause expensive halts to processing. However, beginning as far back as the 1960s and Rachel Carson's "Silent Spring" (1962), there have been increasing concerns about pesticides, many of which are used in agriculture. Whilst Silent Spring was particularly aimed at the organochlorine DDT, the resulting interest in environmental affairs has over time resulted in more critical examination of production systems. Changes in flora and fauna associated with arable land across Europe often reflect changes to more efficient, more intensive management. Thus there are conflicting pressures on biodiversity and recent research has mirrored the concerns of change and production needs. The challenge for future research is to recognise the drivers and the causes and provide the understanding and tools to balance needs and outcomes under changing circumstances. More than this, it is the role of research to inform policy by looking ahead and asking the "what if?" questions.

Currently, we need to understand pressures from the agricultural perspective, such as food security, biofuel production, climate change and global agricultural markets, and from environmental perspectives, such as species loss, eutrophication, water usage, sustainability and landscape change. Intricately connected to both are the sociological interactions of human perception and rural development. There are a series of key questions that research can inform, at different spatial and temporal scales. Can we farm without diversity? If not, and history has some lessons for us, what level of diversity is needed and where? Can we understand the role of diversity? If so, can it be exploited for land use objectives? Current and future research should address these topics. I will speculate on some of the questions and give my thoughts on where future arable biodiversity work should go, covering landscape ecology, food webs, species redundancy, ecosystem function, integrated production and selection pressures.

Biodiversity and the management of weeds and other non-crop vegetation in arable farming systems

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It has become increasingly apparent over the past decade that the success of future agricultural systems will no longer be determined using the single criterion of high yield. Instead, multiple performance criteria are likely to be used. In addition to increasing demands for food that is abundant, affordable, and safe, society is likely to ask the agricultural sector for a clean environment; soil, water, and wildlife conservation; biofuels with favourable greenhouse gas emissions characteristics; and recreational opportunities. These increasing demands are likely to occur in a world of markedly higher petrochemical energy prices, and more variable and more severe weather.

Three elements of this picture of the future are especially relevant to managers of weeds and other non-crop vegetation in arable farming systems.

First, diversified cropping systems that include perennial forage crops in sequence with annual cereal, pulse, and oilseed crops can be used to manage many weed species effectively while strongly reducing requirements for herbicides. Such systems can also reduce soil erosion, fertilizer and fossil fuel use, agrichemical emissions to air and water, and production costs, while sequestering carbon in the soil and maintaining yields at high levels. Results from a 9-ha cropping systems experiment near Boone, Iowa, USA, will be used to illustrate these types of outcomes.

Second, non-crop vegetation within and around crop fields can provide a wide range of ecosystem services, including conservation of soil and water resources, and provision of habitat for pollinators, natural enemies of crop pests, and native plants and animals. Manipulating the species composition of non-crop vegetation in desirable directions is a continuing challenge. Nonetheless, strategic placement of non-crop vegetation at key landscape positions ("targeting") can result in environmental benefits that are disproportionately greater than the fraction of the landscape that is diverted from crop production. Results from an experimental watershed study conducted near Prairie City, Iowa, USA, will be used to demonstrate the environmental impacts of integrating strips of native prairie species into maize and soybean fields.

Finally, growing interest in the use of lignocellulosic feedstocks for producing liquid fuels and other industrial chemicals may create opportunities for new crops that are potentially profitable and effective for water quality protection, but which are also potentially invasive and weedy in the landscapes in which they would be introduced. Native herbaceous and woody species grown on marginal land may provide a less productive, but safer set of alternatives. Recent developments in the American Midwest will be discussed to illustrate the types of biofuel options currently being evaluated.

Session 1:

Various Biodiversity Services

Rewarding farmers for delivering arable plant diversity – a case-study approach

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Within a case study, a regionally-scaled market-based payment scheme for arable weed diversity has been implemented in the administrative district of Northeim, Germany. In this scheme, farmers are rewarded for the provision of weed diversity (also referred to as ecological goods) on their fields. In contrast to current action-orientated agri-environmental schemes in which farmers receive compensation payments for adopting certain management measures, the proposed payment scheme is based on a payment by results approach in which farmers are rewarded for the weed diversity actually present on their fields. Instead of applying fixed-priced payments, the payment scheme includes an auction mechanism to purchase the ecological goods from farmers. Within the case study, separate ecological goods for organic and conventional farmers based on a predefined number of weed species were designed. During the auctioning procedure, every farmer in the region was permitted to place a bid containing the ecological good on his farm land and a self-calculated price for the respective production. Price discrimination is than used to choose between those bids with the highest economic efficiency.

A first auction for ecological goods in arable land was conducted in 2007/08. 18 farmers submitted a total of 65 bids for an area of 105 ha. Due to budget constraints, only 62 bids with a total area of 102 ha were accepted for the production of ecological goods. Interviews and surveys on reference fields revealed that participating farmers adopted their management to the production of weed diversity by reducing herbicide rates, only controlling grass weeds or by completely omitting herbicide application. However, on-the spot-controls in June/July 2008 showed that 30 % of the fields did not comply with the required weed species number and therefore received no payment.

A second auction is currently conducted in 2008/09. 17 farmers submitted 104 bids with a total area of 266 ha of arable land. Due to a limited budget, only 62 bids with an area of 142 ha could be accepted and will be monitored for compliance in 2009. The increased number of bids indicates that the implemented scheme gained acceptance among farmers and can be utilised as a successful tool for the conservation of weed species diversity.

Control of the toxic grassland weed *Colchicum autumnale* within a nature conservation project

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Recently, the toxic grassland weed *Colchicum autumnale* has increased in extensively managed grasslands in parts of Austria. As the toxic components persist in hay and silage, the fodder can hardly be used anymore. However, low-productivity grasslands are very valuable from a nature conservation point of view. The objectives of the interdisciplinary project are to find out i) why *Colchicum autumnale* has been increasing and ii) how to reduce it without deteriorating the present nature conservation status of the grasslands.

From 2006-2008 we established 8 research plots. Within each plot 4 different treatments were applied and within each treatment 5 permanent subplots (1 m^2) were established. In these subplots each individual of *Colchicum autumnale* was recorded and revisited several times a year. To analyse the data via a matrix population model, the plants were categorized into 5 different life stages: seedling, small vegetative (one leaf), medium vegetative (two leaves), large vegetative (three or more leaves) and generative plant.

The first results show that the absolute number and proportion of large vegetative and generative plants was declining at the plots that were cut in the middle of May. Already in the second year of the study only a negligible amount of plants of the early-cut-treatment was able to flower (12 plants compared to 553 plants of the control treatment). The population growth rate λ was less than 1 at the early-cut-treatments (0.91 and 0.94), whereas λ of the control and the flower-removal-treatment showed values of 1.21 and 1.40, respectively. These preliminary results imply that a high abundance of *Colchicum autumnale* can be reduced by early cutting in May. However, further investigations are required to study the soil seed bank, the germination requirements and the vegetative reproduction of *Colchicum autumnale*, as well as the influence of early cutting on species richness.

Isolation and pollination of wild plants in arable fields

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Research has demonstrated the importance of wild plants in cropped areas for providing seeds and other resources for higher taxa. Diversity and abundance of arable plants decreases with increasing distance from the field margin. This distribution has been ascribed to changes in management from the edge to the middle of arable fields and restricted dispersal by field margin plants. One repercussion of this distribution is that individuals and small aggregations of wild plants become isolated from field margins and other semi-natural sources of pollen and pollinators. This project investigates how isolation within crop-fields affects the pollination and reproduction of wild arable plants.

Field experiments using four wild plant species, with contrasting traits, were carried out to measure pollinator activity and fruit and seed production of isolated plants in fields with different crop types.

(1) The self-incompatible open-flowered annual, *Raphanus raphanistrum* showed a significant reduction in fruit set when in wheat fields and isolated from the field margin at a distance of 70 metres. Later experiments revealed that fruit set is also reduced when isolated in oilseed rape fields, but the effect was less pronounced. This suggests that a flowering crop such as rape may facilitate the pollination of wild plants more than a non-flowering crop such as wheat. Indeed, numbers of bees visiting *R. raphanistrum* in the oilseed rape fields were higher than those in adjacent wheat fields.

(2) A reduced fruit set was also found in isolated experimental patches of the annual *Papaver rhoeas,* but not in the perennial *Primula veris.* This is likely to reflect contrasting breeding strategies and will be a significant when the results are used to make predictions about long term effects of pollination disruptions in different functional groups of arable plants.

(3) *Glechoma hederacea* will be used in 2009 experiments to investigate how apparency of in-field wild plants, in relation to a standing arable crop, affects their pollination and reproduction. Experimental plants will be raised up above the height of the cereal crop to compare their pollination and reproduction levels with plants left at ground level.

The evidence so far suggests disruption of pollination interactions in isolated plants causes a reduced reproductive output. This demonstration that plant aggregations and individuals isolated within arable fields are pollination limited has significant consequences, both for our understanding of the ecology of arable systems and for the development of practical conservation strategies.
In practical terms if pollination can limit the sustainability of arable plants then conservation strategies (particularly for the increasing number of species which are nationally and internationally rare) need to mitigate against this by preventing effective isolation. The conservation strategies that currently exist focus on other aspects of these plant's life-histories and do not recognise the potential importance of the spatial distribution of plant populations.

A new functional role for diversity in agroecosystems: resource pools and weed-crop competition

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A primary question in plant community ecology is how, given that plants share the same basic resource requirements, and that the most competitive species should exclude all others, can there be so many species coexisting within a given area. Several models have been proposed to account for plant coexistence, most involve resource niche differentiation and have considerable relevance to agroecosystems. Here we describe a new resource niche differentiation hypothesis and explain how it could be used to model the competitive interactions between weeds and crops across a range of agricultural management systems.

The basic tenants of the hypothesis are that (1) agricultural systems are unique in that management practices, such as the choice of crops, use of fertilizer, planting of cover crops, crop rotation, and weed management are the primary sources of inputs to the soil, and (2) these inputs directly or indirectly become soil resource pools from which crops and weeds derive nutrition. Therefore, management practices that alter the nature and diversity of soil resource pools should be expected to influence the intensity of competition between weeds and crops. This model leads to the novel prediction that along a gradient of increasing cropping-system diversity, the relative strength of weed-crop competition should decrease. Similarly, the degree to which crops and weeds overlap in their niche breadth (determined by species-specific functional traits for resource acquisition) will determine the extent to which weed-crop competition weakens as resource pool diversity increases, and vise-versa.

While there have been no direct tests of this hypothesis in agricultural systems, we highlight evidence from the applied ecological and agricultural literature that provides strong support for various components of this model. We propose that this model may account for the apparent difference in crop tolerance to weeds in organic systems relative to conventional systems. We also report on a recent agricultural experiment examining the effects of crop diversity on yields and weed communities that supports the predictions of the model and shows that as row-crop diversity increases incrementally from continuous monoculture (single crop-derived resource) to a six crop-species rotation (multiple crop-derived resource pools), the slope of the relationship between corn yield and weed biomass shifts from strongly negative to strongly positive.

This model provides testable hypotheses regarding the intensity of weed-crop competition. Validation of this model would have important implications for (1) the development of weed thresholds that are context specific, (2) integrated pest management strategies that aim to reduce weed competition, and (3) understanding factors that regulate diversity across agricultural landscapes.

Session 2:

Landscape, field margins or farming systems; what matters most for arable biodiversity

Effects of organic farming on plant diversity in crop and grass fields at different spatial scales

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Agri-environment schemes such as organic farming aim to mitigate against declining trends in farmland biodiversity. However, its efficiency may vary among different habitats within a farm and across different spatial scales. Here, the enhancement of plant diversity by organic farming was tested using a whole-farm approach.

Thirty-two paired organic and conventional farms were studied in England. On each farm, three cereal and three grass fields were selected and plant surveys were conducted in the centres, edges and margins of the fields three times between May and August in 2007 and 2008. Plant diversity was quantified at three spatial scales (field, farm, region). To quantify the efficiency of organic farming across different spatial scales, Hedge's g was calculated, which is a standardized measure of the effect size making comparisons independent from absolute species numbers possible.

The majority of the total 301 plant species was found in margins (252 species) followed by crop fields (205 species) and grass fields (199 species). Plant species richness of field margins did not differ between farming systems and bordering habitat-types. Strong management and location effects were found in crop fields, with higher plant species numbers in organic fields and in the field edges. In contrast, species richness of organic grass fields did not differ between edges and centres and was similar to edges of conventional fields. These results were consistent across all spatial scales.

The highest efficiency of organic farming in enhancing plant diversity was found in the crop fields, with Hedges' *g* varying from 0.22 to 1.61, whereas effect size in grass fields and margins was moderate (-0.03 – 0.21 in grass fields; 0.00-0.08 margins). Comparisons of Hedges' *g* across scales showed highest values at the regional scale and lowest at the farm scale for both crop and grass fields, whereas no substantial change was observed for margins.

These results highlight the conservation value of field margins and crop field edges for plants. Organic farming mainly enhanced plant species richness in crop fields and this best at a regional scale pointing to a considerable heterogeneity among organic farms.

Weed species diversity in energy cropping systems: potentials and threats

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Results from a large research project on cropping systems for energy plants ("EVA") in Germany will be presented. The main objective of the project is the comparison of various cropping systems for the agricultural production of energy crops under different soil and weather conditions in Germany. The project will provide information about the economic, ecological and energetic effects of the tested systems and highlight systems which are "optimised" in terms of these three target variables. To investigate and quantify the effects of different crop rotations, on-farm field experiments were performed in three particular regions in Germany. In every region five crops with potential for biogas use were investigated between 2005 and 2007. In each year the weed flora was analysed on 10 fix plots in every crop over the vegetation period. The data were used to feed a model approach to assess crop rotation effects for regionalised cropping sequences.

Crop rotation effects on the weed vegetation are related to the architecture of the crop stand during the growth period as well as the attraction of pollinators by the weed. Energy crop rotations in which these properties vary widely across the crops, provide the highest weed species richness. When energy crops are grown in monocultures, the weed flora is reduced to 20 to 25% of the regional potential diversity. The early harvest of cereal energy crops as green biomass for silage prevent the ripening of seeds for one third to one quarter of the cereal weed species. This diversity reducing effect can partly be compensated by integration of late harvest crops into the crop rotations. Monocultures and cropping systems dominated by cereals result in biodiversity losses in the long run.

Our investigations allow for a quantification of the contribution of particular crops to the regional γ-diversity for the weed flora and the weed flora diversity in particular energy crops. Regarding ecological evaluation criteria, we can conclude, that different crops within energy crop rotation address separate functional groups of weeds even when there is no difference in species richness. Species numbers or richness do not reflect structural and functional changes within the weed flora and seems to be an insufficient criteria to compare the effects either between energy crops and traditional crops or the differences between crop rotations in general. For this reason we suggest a multi-criteria evaluation schedule, which will be discussed.

Linking plant diversity and land use patterns in agricultural landscapes

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Planning successful agricultural conservation or agri-environment schemes requires a landscape scale perspective and an understanding of how biodiversity resources are distributed across landscapes. To contribute to this goal, we applied a GIS-based approach linking field sampling of plant communities to land use patterns in an intensively farmed region in Pennsylvania, USA. Agricultural in the region consists mainly of large scale grain-fed dairy operations, and the landscape is characterized by corn, soy, alfalfa, and small grain fields within a matrix of pastures, small woodlots, and early successional grasslands that serve as riparian strips. We used aerial imagery to stratify four study landscapes into digitized maps of four basic land use classes: arable fields, pastures, grasslands, and woodlots. We then used a nested plot design to survey plant communities and build species/area curves in a random subsample of four sites of each land use type in each landscape. We used this data to ask: 1.) What are the differences and variation in species richness and species composition across the four land use types?, and 2.) How is plant diversity partitioned within a landscape and within land use types into α, β, and γ components? Results indicate consistent differences in species richness and species/area relationships across land use types, but a broad range in community composition for each type. Most of the species richness within a landscape (γ-diversity) was found in the grassland and woodlot habitats (high α and β-diversity), but a high level of β-diversity for each land use type meant that many uncommon plant species also utilized the intensively managed arable field and pasture habitats. We encountered 377 species through sampling a total of only 6.4 ha, demonstrating that this approach is an efficient method for rapidly assessing plant diversity at landscape scales and linking diversity patterns to land use types.

Additive partitioning of weed species richness and diversity in rainfed cereal systems across multiple spatial scales

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Weed diversity is often related to local conditions, level of inter- and intraspecific competition and to crop and soil management. However, the landscape context may also be an important driver for plant species richness. Habitat heterogeneity and the proportion of natural vegetation in the landscape are the most influential factors. In this study the relationships between landscape complexity, local species richness, and diversity of arable weeds in cereal fields are analysed.

In spring 2008, 15 circular locations (500 m radius) were selected from a 1:25000 orthophotograph of La Segarra, a winter cereal region in Catalonia, Spain. The minimal distance between locations was 3 km. In each location, two randomly chosen winter cereal fields were surveyed for weed species richness and abundance. Abundance was estimated via vegetation cover and subsequent conversion to abundance. Species richness *H* was quantified as species per ha; species diversity via the Shannon indices *S*. La Segarra is characterised by a gradient in landscape complexity from structurally complex to simple (30–90% arable land). Natural vegetation in the surveyed landscape consisted mainly of evergreen oak and semi-deciduous oak forests (*Quercus ilex* and *Q. faginea*).

Additive partitioning was used to analyse weed species diversity. Variables were estimated in five quadrats in each of three habitats per field; field margins, headlands and crop field centres. For each, within- and between-community diversity was estimated at four scale levels (quadrate, patch, location and landscape). A patch is defined as the sum of all five quadrats per habitat type within a field. The additive partitioning model implies that the measure obtained as within-habitat diversity at a higher scale level is the combined effect of heterogeneity at various lower levels.

A gradient in weed species richness was observed between weed habitats; average species richness found in margins, headlands and crop centres was 15.32, 9.96 and 5.32, respectively. Richness for margins was estimated at 36, versus 21 and 12 for headlands and centres, respectively. Accumulated over all locations within the Segarra region the within-habitat richness was 248 species in margins, 146 species in headlands and 89 species in crop centres. Total within-landscape richness was estimated at 271.

The Shannon index *H* for within-habitat species richness was 2.63 for field margins, 1.91 for headlands and 1.34 for crop centres. Within-patch Shannon index *H* was highest in margins (0.17) and lowest in centres (0.09). Accumulated over all locations within the Segarra landscape, *H* was 2.01 for margins, which is higher than for headlands and crop centres. Within-landscape *H* was 5.89.

This study showed that, at a landscape level, field margins and headlands of cereal fields have an important role as refuges of agricultural weeds. The new agroenviromental schemes proposed for this rainfed cereal system should take into account the role of weeds as biodiversity indicators and the ecological significance of field margins where they are growing.

Financial support was provided by Ministerio de Educación y Ciencia (Project AGL 2007-60828).

Weed species richness depends on the spatial heterogeneity of the landscape mosaics.

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There is empirical evidence that the composition and structure of a given landscape can affect the distribution and long-term dynamics of the organisms that live in it. Weeds are no exception and it has emerged from studies comparing contrasted landscapes that weed species richness tends to be higher in complex landscapes e.g. Roschewitz et al. (2005). Yet, in these studies, landscape complexity is estimated by the proportion of arable crops in the landscape and no further evidence is provided as to which landscape elements affect positively the occurrence of weed species. To improve our understanding of landscape effects on weed communities, it appears important to identify (1) at what scale one can detect a landscape effect and (2) which variables describing landscape composition and/or structure affect weed species richness.

In this paper, we investigated how weed richness measured in 97 winter wheat fields located within a small agricultural region was affected by characteristics of the field itself (field size, preceding crop) and of the landscape surrounding each field at various radiuses (100m, 200m, 300m, 500m and 1000m). Landscape variables described its composition (proportion of spring crops, winter crops, woodlands, grassland, set aside) and structure (number of fields, number of land use types). AIC indicated that the variation in weed richness was better explained by landscape variables at the 200m radius. At that scale, we used hierarchical partitioning to measure the independent contributions of these variables and of field characteristics on weed richness. Two variables significantly affected weed richness. Weed richness increased significantly as field size decreased and as the number of fields within a 200m radius increased. The number of fields was negatively correlated with field size yet both variables had significant independent contributions.

Our results indicate that weed richness is higher in landscapes that have a finer grain, probably because these landscapes offer more heterogeneity in terms of habitat within cultivated parts and contain more crop edges that can shelter many weed species.

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Enhancing ecosystem service provision by floral biodiversity in long-term set-asides

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In Finland, green set-asides are included in agri-environmental scheme (2007-2013) for promotion of biodiversity. However, they are usually established by sowing a mixture of competitive grass species. For biodiversity, a more beneficial option would be the sowing of less competitive grass mixture with meadow plants. We studied the impact of seed mixture and mowing of set-asides on three ecosystem services: availability of seed- and chick-food for farmland birds and pollination.

A long-term set-aside experiment was established in southern Finland in 2003. The experiment was conducted on a clay soil as a strip-plot design with four replicates. The size of each experimental plot was 0.25 ha (50 m x 50 m). The treatments of experiment comprised on three seed mixtures (1) standard: *Trifolium pratense* - *Festuca pratensis* - *Phleum pratense*, 2) less competitive grass mixture: *Agrostis capillaris* - *Festuca ovina* and 3) less competitive grasses with twelve meadow plant species) and two mowing treatments (mowing yearly and no mowing). Samples on plants and seeds, pollinators and arthropods were collected in 2003-2006.

For the seed-food production, mowing had positive and the age of the set-aside negative impact, whereas the seed mixture had no impact but the interaction of year and seed mixture was detected. The highest chick-food production (measured by total catch of D-vac-sampler) was detected in standard seed mixture. However, species composition differed among seed mixtures and years; therefore superiority of seed mixture was depended on the arthropod group. Mowing reduced most the number of Dipteras. Species richness of pollinators increased throughout the four-year experiment in all treatments. Pollinator species richness and abundance were highest during the whole experiment in the seed mixture containing meadow plants but the difference to the other seed mixtures decreased during the last two years. This was largely explained by increasing abundance of *Cirsium arvense* in the unmown treatments. The experiment showed that the benefits of applying alternative seed mixtures vary between ecosystem services. This suggests that the promotion of each ecosystem service requires specific management.

Poster session:

Landscape, field margins or farming systems; what maters most for arable biodiversity

"Weeds in need" – a new conservation scheme for Germany's arable wild plants

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1. Background: Since the mid 20th century, land use intensity in Central Europe has tremendously increased due to technically improved cropping systems and the use of agrochemicals. This process resulted in a large-scale homogenization of agricultural habitats, leading to severe losses in many species of the segetal flora, which comprises around 350 species in Germany. Together with wetland habitats, segetal communities represent the most threatened plant communities in Germany.

2. Objectives: The Georg-August-University of Göttingen along with project partners (Research Institute of Organic Agriculture and German Association for Landcare) are developing new concepts for the conservation of the segetal flora, which are aimed at establishing long-term reserves even outside protected areas. The project is divided into a feasibility study (2007-2008) and the implementation phase (2009-2012), which has recently been granted.

3. Methods: We screened the available literature, but also tapped a number of non-formal sources to compile an overview of the few sites that still host diverse communities of arable weeds. In parallel, governmental protection schemes were reviewed and the major shortcomings were identified.

4. Results & Discussion: Previous and (the few) ongoing conservation projects aimed at ensuring survival of selected species and not on the maintenance and management of genetic diversity within populations and communities, which is a prerequisite for allowing adaptation and species persistence in the long-run. Because agricultural production and species conservation schemes compete at least partly for the same spatial and economical resources - for instance in agro-environmental programmes with questionable effectiveness - the concept of "sanctuaries for segetal flora" was developed. A core aim is to establish 100 permanent reserves but we go beyond that with the ultimate goal to sufficiently protect the genetic diversity within each individual species.

5. Conclusions: The project thus aims at the establishment and long-term low-intensity cultivation of sanctuary fields for the preservation of a typical segetal flora in Germany, and the management of species' gene pools. It is assumed that the genetic diversity of segetal species can be maintained to a large extent by selecting sanctuary sites in different landscapes all over Germany. A "sanctuary field" in this context is a site with a typical floristic inventory of segetal communities, where long-term availability is secured by acquisition or leasing, and where cultivation is secured by a long-term funding strategy (20-30 years).

Weed diversity and species assembly across six IWM systems in prairie cropping systems

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Six integrated weed management (IWM) systems adapted to prairie crops were applied to a four-year wheat-oilseed rape-barley-pea rotation at Saskatoon and Watrous, Saskatchewan Canada. In each system, seeding rate and date, herbicide timing and rates, and tillage operations were selected to optimize weed management. Changes in weed communities were assessed by monitoring weed density, biomass, and seedbanks. Total weed density was similar across IWM systems and crops. Generally, the highest values for species richness, evenness (Shannon's E) and diversity (Shannon's H') were found in the no herbicide/high tillage system, and the lowest values in the high herbicide/zero tillage system. These diversity parameters were lower in pea compared to other crops. Principal response curves indicated a gradual increase of *Thlaspi arvense*, *Chenopodium album*, *Amaranthus retroflexus* and *Polygonum convolvulus* in the no herbicide/high tillage system. Winter and early spring annuals, and perennials increased in most systems but particularly in the low herbicide/zero tillage and medium herbicide/zero tillage systems. Weed seedbanks increased over time in all systems, suggesting that changes in management operations would be needed in order to reduce weed seed production.

Differences between weed communities under conventional and organic management

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In many European countries, big changes in land use, cropping systems and fertilizer application came about in the last century. Crop management has been intensified, and in weed control, herbicides started to be used to a large extent. In the Czech Republic, the significant decline of a mean number of weed species during last decades was noticed (PYŠEK ET AL. 2005).

In 2006-2008, the phytocoenological survey was carried out in selected farms in the Czech Republic. The farms applying conventional or organic farming management have been situated in different climatic and soil conditions. In total, 290 phytocoenological relevés were recorded in winter and spring cereals and root crops. The observations were focused on weed dominance. At each field, 1 phytocoenological relevé with unique size 100 m^2 was recorded. The influence of farming system on occurrence of some weed species was approved by multivariate analysis CCA in programme Canoco for Windows 4.5.

In CCA, the dependence of weed species occurrence on different farming management was considered as statistically significant. Different farming management explained 1.8 % of total variability. Conventional farming was characterized mainly by weeds having wide ecological amplitude (*Polygonum aviculare, Veronica persica*) and by volunteers (*Brassica napus* subsp. *napus*, *Helianthus annuus*). Majority of winter crops in crop rotations and application of higher herbicide doses caused higher occurrence of *Viola arvensis* which is tolerant to commonly used herbicides. Due to reduced soil tillage in conventional agriculture, *Bromus sterilis* is currently spreading, first of all in winter crops. Thanks to shallow soil tillage and not cutted meadows, higher occurrence of *Taraxacum* was recorded. In sugar-beet stands, weed beet (*Beta vulgaris*) was often noticed.
Under organic farming, occurrence of some species presented in Black and Red List of Vascular Plants of the Czech Republic (PROCHÁZKA, 2001) was noticed (e. g. *Adonis aestivalis*, *Coronopus squamatus*, *Odontites vernus*, *Stachys annua*). Many species more sensitive to herbicides (*Myosotis arvensis*, *Vicia hirsuta*, *Lycopsis arvensis*) were also found. In the fields with lower intensity of farming, perennial species *Stachys palustris*, *Mentha arvensis*, *Sonchus arvensis* occurred. Some species indicated the natural conditions of locality (e.g. *Scleranthus annuus* - acid soils in higher altitudes). Due to growing of catch crops and fodder crops in crop rotations, *Trifolium pratense* as a volunteer was recorded in a succeding crops.

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This study was supported by the grants NAZV 1R55010 and MSM 6046070901.

Diversity measures of weed communities regarding crop type and management

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During the last decades weed species richness in fields has decreased as a consequence of intensive farming practices. With respect to yield and functional biodiversity a combination of high species numbers and low dominances of weeds could be a good compromise. The objective of this research is to describe and analyse weed diversity according to crop type and management in an intensive large-scale agricultural region in northern Germany.
The survey was carried out on 170 plots randomly distributed in the district of Doberan in Mecklenburg-Western Pommerania. Both conventional and organic fields grown with prevalent crops were investigated. Per field herbicide abandoned and sprayed plots were arranged to determine species numbers and their relative dominance. In addition to vegetation mapping, management and field data were collected.
Both species numbers and Shannon indices showed significantly higher values in organic and herbicide abandoned plots compared to sprayed plots. Species richness observation shows the existence of long-persistent soil seedbanks. Unexpectedly there were no differences examining organic and conventional unsprayed plots. Presumably the management is of minor importance. The ratio of observed to maximum diversity, which quantifies as evenness how equal the community is, was also calculated. Very high variations in the unsprayed plots attest partly abundant competitive weed species. In contrast evenness of the sprayed plots is approximated 1.
The rate of change in species composition across habitats or among crop communities can be presented with β-diversity (after Whittaker 1972). Dissimilarity was most between the group of winter cereals and spring sown crops like sugar beet and maize. Winter cereals and summer cereals were more similar in their weed composition. This observation was confirmed through ordination by means of gradients taken place as Correspondence Analysis done in R [R 2.5.1, www.r-project.org].

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Effect of farming management on plant and arthropods community in dryland wheat fields

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The presence of a certain level of weed infestation is increasingly recognized as essential for maintaining farmland biodiversity, from both agricultural and conservation point of view (Altieri & Nicholls, 1999; Marshall, 2003). However, studies demonstrating that a higher weed abundance and richness do not imply an increase in phytophagous populations are required if we want to convince farmers to adopt low-intensity farming practices.

Four pairs of wheat fields differing in farming management (organic *versus* conventional) were selected to study the relationship between weeds and arthropods. Weed vegetation using the combined cover-abundance method of Braun-Blanquet, and the abundance and richness of arthropods by suction-sampling were recorded twice from May to July 2004. Weeds and arthropods were classified in functional groups. Total cover and, height and biomass crop were also recorded.

The abundance and richness of legumes and forbs were significantly higher in organically managed fields. Conversely, neither the arthropods abundance nor the family richness of any functional feeding group differed between organic and conventional fields. Our results indicate that arthropod's community is more influenced by indirect effects of the plant community structure rather than management intensity at field scale, so that arthropods are significantly enhanced in fields with high total cover and biomass.

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The weed composition in cereal fields reflects the agricultural intensity level in Aragón

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The objective of this work was to relate different environmental and agronomic factors with the weed flora in winter cereal fields of Aragón. Aragón is a region in North-Eastern Spain with very diverse landscape, geographical parameters and agronomical practices. From 2005 to 2007, 138 winter cereal fields were surveyed in 10 survey areas, which were different in terms of altitude, agronomic practices, etc. Weeds were identified and weed species' abundance was recorded. The number of weed species and Shannon's diversity index were calculated and a multivariate analysis was performed on the data relating the different parameters with the weed species composition.

From the 185 species found, most were dicotyledoneous (85%) and most annuals (74%). Four species were found in more than half of the fields: *Papaver rhoeas, Lolium rigidum, Avena ludoviciana* and *Convolvulus arvensis*. These species were found to be independent of the studied factors. However, most of the species were rare: 117 species were found in less than 10% of the fields and 37 species even in less than 1% of the surveyed fields. Some species were only found in fields with many species. *Alyssum* spp., *V. agrestis, P. argemone, Glaucium corniculatum, Alopecurus myosuroides, Erucastrum nasturtiifolium, Silene conoidea, Conryngia orientalis* and *Ranunculus arvense* only appeared in fields with more than 11 species. Opposite, *Equisetum arvense, Xanthium strumarium, Phragmites australis, Hordeum murinum, Malva sylvestris, Avena fatua, Rumex crispus, A. sterilis* and *Fumaria* spp. were found in the fields with lowest number of species richness.

The canonical correspondence analysis (CCA) showed that the different survey areas are the main variables responsible of explaining vegetation distribution. The possibility of irrigation and altitude are the next most relevant explanatory variables. As expected, the number of weed species and the Shannon diversity index were higher for the areas with low inputs in agriculture, which are located at higher altitude.

Centaurea cyanus as indicator of biodiversity

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Protecting or increasing biodiversity is a challenge for the scientists and requires the setup of biodiversity indicators. The agri-environment is particularly concerned because it is necessary to compromise between the agri-productivity and the preservation of ecological services. We chose to test if the cornflower, *Centaurea cyanus*, which is at present in a dynamics of rarefaction in the West of France, could fit to that purpose. Besides the fact that it is emblematic of the flora associated with cultures, it is easily recognizable by its blue flower. Our study tried to estimate if its presence indicates higher biodiversity.

Seven zones (40 fields) of the plain of Niort (Poitou) and 14 control fields taken at random were surveyed. Each zone contained, during the last three years, a noticeable population of cornflower in the central field while no cornflower was found in the adjacent fields. We recorded the frequency of individuals of all taxa in 32 2x2 m^2 quadrats. Diversity indices were calculated, and a multivariate analyze compared the similitude between the fields and the zones. The size of the fields, the rotations of culture and the agricultural history of each field were documented by a survey with the farmers.

The cornflower was not significantly associated with higher plant diversity in winter wheat and oilseed rape fields of the zones where it was located. Similarly, it did not indicated a more important floral diversity when it was present in the field. However, the biodiversity of the endangered flora typically associated with wheat (“messicole”) increased when the cornflower was present. We suggest that cornflower can be a potential richness indicator of the endangered flora associated with cultures. Correlation of its presence and specific cultivation practices is discussed.

The effect of saffron (*Crocus sativus*) and black zira (*Bunium persicum*) intercropping on weed flora and seedbank

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Intercropping is defined as the simultaneous growing of two or more crops in the same field. Few studies have attempted to determine the effect of intercropping on weed community structure. Therefore, a filed experiment was conducted from 1999 to 2005 to examine the long- influence of saffron (*Curcus sativus*) – black zira (*Bunium persicum*) intercropping on the dynamics of weed flora and seed banks. Mixtures were consisted of 0/100, 25/75, 50/50, 75/25 and 100/0 saffron/ black zira ratios, each planted at three densities of 30, 50 and 70 plant. m^{-2}. A split plot design based on randomized complete blocks with four replications was used. Densities were assigned to main plots with ratios constituted the subplots.

Despite density effects was variable the mixture ratios caused drastic species compositional changes in weed flora for which four major associations were recognized: 1- weeds preferring higher ratio of saffron in mixture e.g. grasses, 2- weeds preferring higher ratio of black zira in mixture e.g. Persian speedwell (*Veronica persica*), 3- weeds that were more abundant in 50/50 mixtures e.g. some species of Caryophillaceae; and 4- those weeds showing no specific pattern e.g. lambsquarter (*Chenopodium album* L.). In most cases the weed seedbanks responded to mixture ratios similar to weed flora. Seed density decreased as soil depth increased, leading to the accumulation of 66%, 22% and 12% of seeds in soil layers of 0-5, 5-15 and 15-25 cm, respectively. This information contributes to improve current understanding of how crop–weed communities are assembled and may help in developing weed management practices.

Establishment of vegetation in field margins left set-aside after different years in a dryland area in Aragón

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The drylands of the Monegros region (Aragón, North-Eastern Spain) is characterised by low-input extensive farming with scarce steppe vegetation. 8-meter strips surrounding the fields of a farm have been established in different years and natural vegetation was left set-aside to reduce erosion and to increase biodiversity. The objectives of this work were to describe the vegetation establishment in these strips comparing changes in time (2006-2008) and comparing stripes of different ages (set-aside in 2003 to 2007) with the vegetation inside the cultivated fields and to find out how many years are necessary to achieve a permanent vegetation cover.

The vegetation increase was especially high the first spring after set-aside. Number of species increased rapidly from around 4 species in the field up to 22 in the oldest strips. After two years of set-aside more than 14 species were found in several strips. However, some differences between margins were caused not only by the age of the strip but also due to the position of the strip in the landscape (more moisture, a worse soil quality, etc.). Most species found were annual dicotyledoneous plants. The proportion of perennial species increased from year to year and in the oldest strips even more perennial than annual species were found in 2008. Perennial grasses were the group of plants which was less frequent.

Shannon's diversity index changed within years, probably caused by the climatic conditions of each year. The highest value was generally found for the oldest strips (up to 2.5 in 2007) and the lowest for the fields (0.7 in 2008). Some species like *Cardaria draba* and *Fumaria* sp. were important only in fields, while perennial plants like different *Plantago* species and *Dactylis glomerata* were typical of the oldest strips left set-aside in 2003.

As a matter of conclusion, biodiversity increased gradually in the strips set-aside and the proportion of perennial species increased. It is still early to estimate how many years are necessary to achieve maximum diversity but we have observed in some margins that species composition can change in an important way already after 2 years of set-aside.

Spatial scale and intensity of species turnover in weed communities

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Species turnover, the change in species composition between sites, represents an important component of biological diversity, which is relatively poorly understood in intensively managed agro-ecosystems. However, knowledge of species turnover, or β-diversity, patterns and intensity in weed communities can help formulate hypothesis about mechanisms governing regional diversity.

Data on presence-absence of weeds were recorded in 202 fields covering five major crops and scattered across a 30-km^2 intensively managed agricultural landscape in an conventional cropping systems (Central-Western French). Matrices of similarity in species composition between all pairs of fields were computed and analysed with respect to corresponding matrices of geographical distances and size of neighbourhoods. Mantels tests were applied to determine the correlation between species similarity and geographical distance. Maps of species turnover were also supplied to detect areas of high vs low β-diversity.

We identified 142 weed taxa with a mean richness of 17 species per field. The similarity of species composition between fields shows considerable spread with a low average value indicating a high species turnover. On average, more than 50% of the species change from field to field. This value is relatively constant over all the geographical scale and no distance decay relationship has been found between species turnover and geographical distance. Maps of β-diversity do not show structures at the studied scales.These data show that agricultural landscapes are characterized by small mosaics of weed communities that present high turnover (low initial similarity at short distance), but these mosaics are repetitive on a higher scale (long distance), resulting in patterns where the species turnover on a local scale is not much larger than on the next higher scale.

The occurrence of alien plant species in field margins in Finland

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Agriculture facilitates the spread of alien plant species in terms of intentional and unintentional dispersal, and by creating and maintaining disturbed habitats (e.g. fields and field margins). These habitats are often more prone to the introductions of new species than natural ones, and may act as dispersal corridors. This study aimed exploring the occurrence of alien plant species in field margins and other semi-natural agricultural habitats in Finland.

We used data set of 631 vegetation plots (50 m^2 in size) representing 10 different semi-natural habitats and four distinct geographical regions in Finland. The data were originally collected for the monitoring study on the effects of the Finnish agri-environment support scheme in 2001 and 2005. The data were combined with data of ecological traits, mostly taken from BiolFlor database. The number of species and frequency were compared between habitats and geographical regions. The differences in ecological traits between the groups of native, archaeophytes and neophytes were tested with chi-square tests.

A total of 118 alien plant species were detected which comprised of 34% of total species number. Most of the alien species (77%) had been introduced to Finland before 1600 (i.e. archaeophytes) and minority after 1600 (i.e. neophytes). The mean number species and frequency of alien plant species were higher on road verges and field margins next to a road than on other habitats. In western Finland, less alien plant species was found than in other geographical regions. Only three neophytes (*Amelanchier spicata, Lupinus polyphyllus, Sambucus racemosa*) found in the study are regarded as an invasive plant species in Finland. The results suggest that alien plant species comprise an important part of the biodiversity of Finnish field margins and semi-natural agricultural habitats. The role of field margins as dispersal corridors for invasive alien plants is limited for certain species.

Changes of the weed flora during 20th century – a case study on the area of the Czech Republic

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Based on relevant botanical literature focused on flora of the area of Czech Republic we created a list of vascular plants that occurred as weeds on arable land during the period of 20th century. We compared the frequency of their occurrence at the beginning (Polivka, 1900-1904), in the middle (Dostal, 1950), and at the end (Kubat, 2002) of studied period. From the total number of 350 arable weed species, 9 species are already extinct (e.g. *Cuscuta epilinum, Heliotropium europaeum, Spergula linicola*), 9 others probably extinct (e.g. *Lolium temulentum, Vaccaria hispanica, Stachys arvensis*). 80 species are mentioned on current Red List as endangered ones. Main reasons of decreasing of their occurrence are in improved seed cleaning, use of herbicides and fertilisers, deeper and more intensive soil tillage, and other factors of agriculture intensification. The process of decreasing abundance is serious especially when taking into account that some of today rare species were very common at the beginning of 20th century (*Adonis aestivalis, Agrostemma githago, Bromus arvensis, Bromus secalinus, Filago arvensis, Misopates orontium, Odontites vernus*).

On the other hand, some new species occurred on arable land during this period and many of them became serious weeds in crop stands, like *Abutilon theophrasti*, *Amaranthus powellii*, *Beta vulgaris*, *Consolida orientalis*, *Panicum miliaceum,* and *Solanum physalifolium.* This fact is not always reflected by recently published floras – especially the weedy form of *Beta vulgaris* is not distinguished from cultivated beets.

Following weed species were classified as highly abundant during the whole period: *Amaranthus retroflexus, Anagalis arvensis, Apera spica-venti, Avena fatua, Capsella bursa-pastoris, Chenopodium album, Cirsium arvense, Convolvulus arvensis, Conyza canadensis, Elytrigia repens, Equisetum arvense, Euphorbia helioscopia, Fallopia convolvulus, Fumaria officinalis, Galeopsis tetrahit, Galium aparine, Geranium pusillum, Lamium purpureum, Myosotis arvensis, Papaver rhoeas, Raphanus raphanistrum, Senecio vulgaris, Sinapis arvensis, Solanum nigrum, Sonchus arvensis, Sonchus oleraceus, Stellaria media, Thlaspi arvense, Tripleurospermum inodorum,* and *Veronica arvensis.*

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Effect of glyphosate on weed occurence during the vegetation of GM maize

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Herbicide tolerance (HT) is the most frequently used trangenic trait in field crops. HT crops have been widely adopted by farmers which evokes the question how this weed control system influences the weed communities, especially their diversity.

Small plot field trials in Roundup Ready maize were conducted to obtain data on structural and temporal changes in weed community after application of glyphosate (GL) compared to conventional pre-emergence herbicides (CPH) and untreated control (UC). Herbicide efficacy and biomass production by individual species were assessed during the vegetation season in 4 week intervals.

Only five weed species (*Amaranthus retroflexus*-AMARE*, Chenopodium album*-CHEAL*, Echinochloa crus-galli*-ECHCG*, Mercurialis annua*-MERAN*,* and *Solanum physalifolium*-SOLPS*)* were present in maize which points out on low initial level of weed diversity in current farming systems. CPH affected the weeds strongly in the 3-weeks period after the sowing of maize so that these plots remained weed free except of MERAN which is naturally tolerant to CPH. At the same time, the weed dominace (soil coverage) was about 10 % and available fresh weed biomass was 58 $g.m^{-2}$ on plots UC and GL, composed mostly by AMARE, SOLPS, and ECHCG. After the treatment by GL, these weeds were supressed quickly within 2 weeks. New flush of weed emergence succeeds 3-6 weeks after application of glyphosate but newly emerged weeds were not able to compete with crop. Till the end of vegetation, they produced only 0.6 – 5.1 % of biomass compared to UC. Despite the high control effect of GL, the eveness of biomass production between newly emerged weeds was better than on CPH plot where strong weed shift was found in favour of MERAN, CHEAL and ECHCG as a consequence of different sensitivity of individual species and residual herbicide activity. Similar selection patterns are valid for all herbicides including GL. Usage of GL in HT crops in the framework of "Integrated Weed Management" allows to exploit its advantages – conservation of weeds at the beginning of vegetation when the food resouces are limited, and less potential to cause weed shift than CPH when it is used properly.

Acknowledgement:
Research was supported by the projects NAZV 1B53057 and MSM 6046070901.

Weed biodiversity in German oilseed rape fields

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Weed species richness and species composition on arable land are strongly affected by the grown crop as well as the applied cropping measures. Oilseed rape is on the most important field crops in Europe showing steady increases in cropping area and intensity during the last years.

Data were collected on the range of weed species occurring in rape fields, their abundances and their spatial allocation to verify the contribution of oilseed rape cropping to biodiversity in arable systems. Another objective is to evaluate the impact of site conditions and cropping measures on weed diversity in oilseed rape.

Between 2005 and 2007 1463 rape fields throughout Germany have been surveyed. In late autumn weed species and their densities were determined in herbicide abandoned parts of rape fields.
Based upon the additive partitioning approach of $\alpha + \beta = \gamma$ the contribution of α- and β-diversity to the total observed species richness of oilseed rape fields is analysed at three spatial scales. The smallest scale is represented by the rape fields investigated within a commune / municipality, the medium scale by communes / municipalities within a federal state and the largest scale by 10 federal states. The effects of selected site and management parameters on species richness, Shannon diversity and Evenness of the weed vegetation are analysed using multiple regressions and generalized linear models.
A total of 161 weed species from 33 plant families has been recorded during 3 years of weed monitoring showing considerable regional distinctions in their frequencies and densities. Weed species richness averaged 11 ± 3,5 (min: 0; max:26) species per site and was effected by rape sowing date, tillage intensity, soil quality and soil pH, field size and position of the investigated plot in the field, but not by investigation year. Similar trends could be observed for Shannon diversity whereas there were hardly any differences in Evenness indicating there are few unbalanced weed populations in rape and thus diversity is mainly affected by species number.

The biodiversity has a spatial distribution within a field

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Species richness and diversity indices have been used to provide information about the changes over time in the weed flora. Such studies measured the overall effects of the cropping practices on weed diversity, considering uniform weed composition and abundance throughout the field and assessing a numerical value for the entire field. However, these indices do not reflect structural aspects of communities. Structure is inherently scale related and spatial pattern of diversity may help in identifying niches for pest enemies, refuges for farmland wildlife or even local environmental heterogeneity. No information is available about spatial distribution of diversity at seed bank level and its variation over time. The object of this study was to evaluate the spatial and temporal variation of the weed seed bank biodiversity in a field under human disturbance and discuss the importance of considering the spatial structure in monitoring studies of biodiversity in agroecosystems.

The spatial structure of the seedbank of a cereal field was studied during 3 years. Soil samples were taken on a 10m $\times$ 10m grid pattern and seed bank species estimated by germination. Species richness *S*, Shannon-Wiener diversity index *H'* and Pielou's evenness index *J'* were assessed for each point. Spherical isotropic semivariograms were used to describe biodiversity spatially. Nugget and sill of semivariograms fitted to *H'* were similar between years, suggesting that the amount of spatially structured variation of diversity did not change between years; the distance of uncorrelated observations (range) decreased every year probably due to the reduction of the species patches by the effect of herbicides on the flora. Nugget and sill of semivariograms fitted to *J'* were more variable and range remained stable the second and third years. Areas of higher seed bank diversity within the field were identified, calling attention to the interest of considering the spatial pattern of the weed diversity when developing management strategies that harmonize crop production and conservation of natural resources.

Repeated surveys in Finland follow the changes of weed flora in spring cereal fields

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Crop production undergoes constantly changes that apparently affect the composition of weed flora in arable fields. Regular weed surveys are considered a valuable means of monitoring the response of weed flora to changes in agricultural habitats and practices. MTT has carried out three extensive surveys of weeds in spring cereal fields, the first in 1961-1964, the second in 1982-1984 and the third ten years ago in 1997-1999. For the moment, the fourth similar survey is going on in 2007-2009. Both conventionally and organically cultivated farm fields are examined in 16 regions in southern and central Finland.

The number of weed species per field is used as a measure of diversity. Altogether 160 weed species were found from the 690 fields surveyed ten years ago. Typically, as observed in 1997-1999, the average species number was about 25 in organically farmed field and some 10 species less in conventionally farmed field. In this respect, organic farming clearly promotes biodiversity at the farm scale but not so much at the national scale as the field area of organic cropping is only about 6% of the total Finnish field area. Moreover, the interest in organic cropping of spring cereals has decreased substantially in our survey farms. One evident reason for the transition back to conventional farming has been the increased weed infestation and particularly the problems with perennial weeds like *Elymus repens*, *Cirsium arvense* and *Sonchus arvensis*. In general, some other noxious species like *Avena fatua* and *Galium spurium* have become more frequent during the last ten years.

The current weed survey is part of the monitoring program of the Agri-Environment Support Scheme in Finland. The authorities are interested in the impact of certain subsidized measures, like organic cropping and sustainable use of fertilizers and pesticides, on biodiversity in agricultural areas. Weed flora with interactions to other trophic levels serve as indicator of agricultural intensity and sustainability. From the agronomic point of view, some recent trends in cropping practices, like direct drilling, obviously affect the composition of weed flora which has to be taken into account in weed management practices. The weed shift over the decades will be discussed.

Estimation the weed flora observed in the margin strips in the experimental site of Chizé

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The hypothesis that a higher weed diversity species was found in the margin strips of the cultivated fields was tested during two years on the experimental site of Chizé (West of France). This linear area of the field, between the crop and the boundary is generally less weeded and the competition with the crop is often lower than in the centre of the field.

Data on presence-absence of weeds were recorded in 202 fields in 2006 and on 139 fields in 2007 covering the major annual crops and scattered across a 30-km2 intensively managed agricultural landscape. In the centre of each sampled field, a star-shaped array of 32 quadrats of 2x2 m was positioned. The quadrats were separated from each other by distances ranging between 4 and 64 m in logarithmically spaced intervals. The weed species present in the margin strips was assessed over a length of 50 meters. Field surveys were carried out each year between March and June.

In 2006, a total of 172 weeds species was identified with an average of 24 species per field. In the centre of the field, 18 (from 5 to 36) species were identified per field when 14 species (from 4 to 32 species) were identified in the margin strips. No difference in terms of rare species (segetal weed) was observed in the margins strips. For the winter crops (wheat, rapeseed), the species richness increased slightly with the species observed in the margin strips. Furthermore, there was a strong relationship between the flora of the margin strips and the centre of the field in wheat and rapeseed, but this relationship is very low for spring crops (pea, maize, sunflower).

This last result could be explained by the date of soil tillage. For the spring crops, the margin strips are opened by the first soil tillage carried out in winter or in early spring. Then, this area is certainly slightly perturbed by the last tillage related to the sowing crop. For this reason species composition of the margin strips of winter and spring crops is slightly different.

Sown grass field margin strips: such a rich and biodiverse habitat!

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The reform of the Common Agricultural Policy (CAP) of 2003 established the principle of conditionality based on production aids. Therefore, in France, farmers are requested to grow grass strips, in the field margin, in priority along the rivers, in order to minimize pesticide flows towards surface water and to reduce soil erosion. Field boundaries are generally thought to enhance biodiversity in intensive agricultural landscapes. Characterizing the flora found in sown grass field margin strips is essential to identify the biological traits that are being favoured in these new habitats.

The aim of this study was to characterize the weed community of the sown grass strips. What is the species richness of this habitat? What biological traits could structure the weed communities? The study was carried out in Burgundy (Eastern France) on 24 sown strips and in Deux-Sèvres (Western France) on 53 sown strips. In both sites, flora assessments were carried out walking across a 500m² area of the grass strip (5 metres by 100 metres), listing the observed species. Various landscape factors such as the crop of the adjacent field or the types of pre-existing boundary (ditch, river, woodland, etc...) were noted. The BiolFlor Traits database (www.ufz.de/biolflor/index.jsp) and the Jauzein Flora of cultivated fields (1995) was used to characterise the life form of species.

In total, 187 species were identified in the 77 sown grass strips. Most of the margins were sown with grasses such as *Lolium sp.*, *Festuca sp.*, *Dactylis glomerata*. and legumes such as *Medicago sativa* and *Trifolium sp.*, sometimes in mixture. A few segetal weeds as *Legousia-speculum veneris* were observed. On average, there were 29.2 species per sown grass strips, without significant differences (Kruskall-Wallis test) between sites and types of boundary. Moreover, the flora was diverse. 89.9% of the species observed in the strips can also be found as “weeds” in fields with 48.9% of the species being frequently found in fields. Regarding the life form, 46.6% were hemicryptophyte and 42.1% therophyte. Finally, 43.3% were annual plants while 47.2% were pluriannual plants.

Herbicide stewardship for biodiversity

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SUMMARY: Weeds have been defined as "plants out of place", and it is difficult to justify their presence where the goal of farming is just efficient food production, objective fully justified by FAO objective to double food production by 2050. Another view is that weed presence in cultivated fields can contribute to biodiversity preservation, but no economic compensation directly linked to weed presence has been offered so far to European farmers.

Mechanical weed control is being presented as an answer to biodiversity decline, and loss of biodiversity is being raised as an issue for cultivation of genetically modified herbicide tolerant (GMHT) crops in the European Union, with the presumption that a more effective weed control could lead to disappearance of some adventitious plants. Although in the last 12 years GMHT have offered more flexible tools for weed control to American farmers in soybeans and other crops, very effective weed control can also be obtained with proper combinations of conventional varieties, selective herbicides, and repeated mechanical tillage or hand weeding operations. In this way, both GMHT varieties and broad spectrum herbicides are two additional new tools which should also be available for European farmers to avoid the socio economic consequences of lack of competitiveness.
If there is a genuine need to preserve native weeds, or a will to conserve biodiversity for threatened species, good agricultural practices for this goal should the compatible with the continued increase in efficient food production, regardless if we are dealing with conventional or with genetically modified crops. An option in some specific areas might be to use vegetation bands, for example as part of cross compliance measures or adjacent to watercourses and other sensitive areas, where –in exchange for appropriate compensation payments- the use of chemical and mechanical weed control could be restricted to enhance the presence of defined natural species. This approach would offer the following advantages versus whole field management:

a) Habitat expansion for species now limited to field edges
b) Farming efficiency in the rest (most) of the field would not be penalized
c) The bands would facilitate turns and access of machinery operations by farmers
d) Easier access for citizens visiting cultivated fields
e) The vegetation bands would help as green strips to reduce the risk of fertilizers or pesticides reaching courses of surface water.

Assessing changes in weed flora diversity due to climate change in Europe

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With the objective to describe the current state of weed flora diversity in eight, climatically different agricultural regions in Europe and to quantify the differences between them, a three years field investigation (N=210 fields) was carried out along a transect across Europe between South Italy and Finland. In each region three different field types were investigated: young fallows, extensively and conventionally used cereals fields (N=9 each). A total of 768 weed species was found and classified according to their bio-climatically origin (areal) and grouped into five major types of climate related distribution (origin): species originating from the i) cold, nordic area, ii) moderate warm, iii) intermediate between moderate warm and warm, iv) intermediate between warm and very warm area and v) indifferent origin. The share of these groups on the regional weed flora was related to the annual average temperature in every region to identify significant relations between climate, weed diversity and field types.

We found highly significant relationships between the distribution of the particular species groups along the gradient and the different field types (See tab.1).

Species groups according to bio-climatically origin	Significance level for the field types		
	fallow	extensive	conventional
1 – cool	R^2=0,8651	R^2=0,9554	R^2=0,8245
2 – moderate warm	R^2=0,942	R^2=0,9005	R^2=0,8447
3 – moderate warm to warm	R^2=0,9133	R^2=0,8633	R^2=0,7656
4 – warm to very warm	R^2=0,9862	R^2=0,9874	R^2=0,968
5 – indifferent	R^2=0,8361	R^2=0,9385	R^2=0,968

The gained relationships can be used to assess the consequences of different climate scenarios for particular regions regarding changes within and between the species groups. This is demonstrated with some examples. The advantage of this method is applicability for different regional weed floras and to integrate influences of the natural vicinity of arable land. This procedure allows predictions on potential changes regarding species groups, whereas predictions for single species are out of scope of this method.

Wildflowers volatile emission to entomofauna attractivity: some possible relations between flower shapes and phytochemicals

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In order to establish the interaction between wildflowers and pollinators, volatile emission analyses were carried out. Since phytochemicals are connected to the selective attraction of several flower-visitors we hypotyzed some possible plant strategies in these volatile emissions. The aim of this study was to investigate possible ecological roles of these volatile compounds. Fourteen wildflowers weed species were selected due to their high degree of pollination mutualism and even because they sometimes became rare in the several Mediterranean agroecosystems. The seeds of these species were collected in summer 2007 and grown in pots in spring. During the flowering phase the plants were analysed in laboratory. Volatile compounds were identified and quantified by SPME (Solid Phase Microextraction) and GS/MS (Gas Chromatography /Mass Spectrometer).
Living flowers were cut and immediately placed into a 10 ml glass vial properly sealed with tinfoil paper. When the vial had been saturated by volatile compounds, the SPME fibre coated with the extracting phase was introduced. After the extraction, the fibre was transferred to the injection port of the GC/MS, where the desorption of the analyte took place and analysis was carried out. The main phytochemicals found belong to the category of monoterpenes (such as α-pinene, limonene, myrcene in *Consolida regalis*), sesquiterpenes (such as β-cariophyllene, germacrene, cedrene in *Centaurea cyanus*), fatty acid derivates (such as exenal acetate, nonanal in *Anchusa hybrida*) and benzenoid compounds (such as in acetophenone in *Linaria vulgaris*). Since these volatile substances virtually have the double ecological role of attracting pollinators and repelling phytophages and/or pollen predators an attempt of decoding them has been carried out. From the first results there seems to be a relationship between the long calix of the several species which belong to the *Silene* genus (i.e. *S.armeria*, *S.vulgaris* and *S.alba*) and monoterpenes. Indeed these phytochemicals have a likely attractive function towards a specific category of pollinators (i.e. butterflies). Finally, the fragility of some species of wildflowers was discussed. It seems that they probably became rare as a result of their few flexible interactions with pollinators.

Emergence dynamics of sown wildflower strips in different Tuscany agro-ecosystems

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Biodiversity has declined in agricultural landscapes in recent decades due to agricultural intensification and other changes in landscape structure. To compensate, it is necessary to encourage wildflowers, insects, arthropods within the landscape, including small mammals and birds. In the European Union, agri-environmental set-aside programmes have been established to enhance the animal and plant diversity of farmlands since it is considered an important contribution to nature conservation in agro-ecosystems. The planting of wildflowers strips in these areas could be a crucial part of the strategy for enhancing biodiversity, especially regarding pollinators. An initiative to save some of the UK's rare bumblebee species was launched by Syngenta and used wildflower margins. This environmental restoration has been tried in Italy using two different planting strategies: a mixture of legumes (basis of the project at three experimental sites) and of native wildflower species (to compare with legumes). The sowing took place in October 2008. Seed mixtures were developed specifically for the pollinators foraging both pollen and nectar throughout spring and summer. Growth of these plants is critical for bees in their life cycle and it depends on the endogen (seed dormancy) and environmental (soil constraints) conditions for growth. In addition, the emergence rate of wildflowers is strongly linked to how well the plants fit in the ecological niche, particularly over early seedling competition with the un-sown weed species. The aim of this work was to analyze the emergence dynamics of several wildflower species that were sown at three experimental sites (Pisa, Lavoria and S. Luce). The emergence percentage of each species was determined from how well the emerged seedling patterns overlapped with the sowing density. A lower emergence rate occurred for species with smaller seeds, probably due to their higher seed dormancy and/or lower endosperm energy level. Indeed, this last parameter is critical during the heterotrophic growth phase when environmental biotic and/or abiotic stresses can occur. Finally, the agri-environmental performance of the legume and wildflower mixtures will be discussed.

Influence of traditional crop seed cleaning techniques on the presence of cornflower (*Centaurea cyanus* L.) and corn cockle (*Agrostemma githago* L.) in winter cereal fields

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During the last decades arable field flora biodiversity has decreased dramatically mainly due to herbicides and chemical fertilization. The influence of other factors is less known, but it may be crucial for some species. For example, "crop seed mimic" weeds, such as cornflower and corn cockle, almost disappeared from Italy probably due to improved seed cleaning techniques. Few relict populations are still present in mountainous agroecosystems.

The aim of this work is to understand if the presence of these populations is correlated to local crop seed management since they were found poorly in previous seedbank analyses.
Two different areas have been studied: Camporgiano (44°9'39"60 N, 10°20'4"92 E, Lucca, Tuscany) and Montesano (40°16'37"20 N, 15°42'19"80 E, Salerno, Campania). They are characterized by low-input agriculture based on winter cereals and pastures. Farmers sow their self-produced crop seed, cleaned with traditional equipments.
Six one-kilogram cereal seed samples were collected in both locations before and after cleaning. Weed seeds were extracted, identified and counted. Average densities (seeds/kg of crop seed) were calculated for single species and for their complex. The amount of cornflower and corn cockle seeds (seeds/ha) returned in the fields during sowing was estimated according to local sowing dose of 200 kg/ha for cereals.

Average total weed seed density before cleaning was 2768 seeds/kg (36 species) in Camporgiano and 1060 seeds/kg (36 species) in Montesano. These values were reduced after cleaning to 191 (13 species) and 87 seeds/kg (18 species) respectively.
In Camporgiano cornflower and corn cockle were present with 10 and 70 seeds/kg before cleaning and 1 and 2.5 seeds/kg after cleaning, with a estimated distribution of 200 and 500 seeds/ha during the sowing.
In Montesano only corn cockle seeds were present with 138 before cleaning and 21 seeds/kg after cleaning, so the estimated return of this species seeds during the sowing was 4200 seeds/ha.

We concluded that these traditional crop seed managements allow the distribution of cornflower and corn cockle seeds during the sowing and this may play an important role for the preservation of these local populations, specially for *Agrostemma githago* L. whose dispersal strategy is basically anthropochory.

Does the vegetation affect the activity/density of generalist predators of the pupae of the Olive fruit fly [*Bactrocera oleae (*Gmelin)]?

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Agroecosystem services provided by functional biodiversity can improve the system's sustainability. Green plants are primary producers and provide food, shelter and overwintering and reproduction sites to the fauna, and in particular to beneficial arthropods. Therefore, the field and field boundary vegetation can be considered an important elements in the biological pest control services of agroecosystems. Previous studies have correlated environmental factors, such as plant density and vegetation type with predator's population density and activity to explain their spatial patterns at landscape level.

In this study, we are interested in all aspects of biodiversity that can contribute to the suppression of the olive fruit fly [*Bactrocera oleae* (Gmelin)]. Predation of the olive fly pupae by ground dwelling generalist predators can contribute substantially to olive fly control. We hypothesized that vegetation composition and density affect the composition of the ground dwelling arthropods. More specifically, we hypothesized that the type of herbaceous vegetation in two differently managed olive groves has a bigger impact on ground dwelling arthropod predator composition and density than factors related to the position of the olive tree in the field in relation to field boundary type, border effects etc.

Therefore, the vegetation in two differently managed (intensive versus extensive) olive agroecosystem in the hills of Pisa (Italy) was investigated in 2008 to study its effect on the activity/density (a function of movement and density) of a promising group of the ground dwelling predators of the pupae of the olive fruit fly. In each field nine olive trees were selected in a regular grid. A pitfall trap was positioned under each tree to monitor periodically the ground dwelling arthropods. Vegetation composition and structure around each tree were characterized in June by determination of plant species cover in 12 systematically selected quadrates of 10 x 10 cm that were part of a grid of 50 by 80 cm. Vegetation structure in the field margins was characterized by a visual description of homogeneous parts of each margin.
Multivariate analysis will be used to classify the vegetation in homogeneous groups. The result of this classification will be used as an environmental variable in the ordination of the arthropod community composition. Classical statistical tests will be applied to further correlate arthropod communities to field and margin vegetation data and management. Results showed a positive correlation between the rove beetles density and the vegetation cover ($r = 0.5042$).
Reports on the role vegetation with predators are limited on few publications and somehow generalized, hence further research are needed.

Assessment of twenty-five North American perennial plant species for pollinator conservation

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Supplementing agricultural landscapes with floral resources may be an effective means of conserving insect pollinators. Although pollinators utilize crop flowers for energy and nutrients, they frequently forage beyond the crop bloom period and require alternate food sources. Supplementing field edges with plant species whose flowering periods are staggered may thus provide a constant, though varied source of pollen and nectar through the growing season.

To identify suitable plant species for pollinator conservation efforts in the Mid-Atlantic region of the United States, a set of twenty-five species was first selected based on the following criteria: (1) perennial forbs, (2) native to the state of Pennsylvania, (3) upland species tolerant of full sun and moderate drought, (4) non-aggressive habit, (5) varying bloom periods, (6) floral morphology accessible to at least some bee genera, and (7) commercially available. The selected species, which represent ten plant families and twenty-three genera, were established in four randomized complete blocks at the Russell E. Larson Agricultural Research Center in Rock Springs, PA, USA.

To determine the relative attractiveness of each plant species to the local pollinator community, physical collections of pollinators were coupled with timed observations to estimate bee abundance and species composition. Collections were taken from all plants using a vacuum system every two weeks from early May until mid-October 2008. Observations of pollinator visits to flowering individuals were made on alternating weeks during the same calendar months.

Early analysis of the observation data has indicated that *Eupatorium perfoliatum*, *Monarda fistulosa*, and *Symphyotrichum novae-angliae* attracted the greatest number of bees overall. Further analysis will identify the most attractive plants at different dates during the growing season. In addition, identification of the collected pollinators will elucidate flower preferences among pollinator species.

Developing an understanding of the associations between plants and pollinators will be an important step in developing pollinator conservation measures for agricultural systems in Pennsylvania and other regions of the United States.

Carabid beetles are more abundant in a no-till organic cropping system

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Abundance and richness of carabid beetles are often enhanced in organic systems or in systems using reduced tillage. The objective of this study was to measure the combined effects of tillage (moldboard plow, chisel plow, no-till) and cropping system (conventional, organic) on carabid beetle populations in spring barley underseeded with red clover in 2007 at La Pocatière, Québec. The experimental design was a strip split plot with four replicates. Tillage treatments had a 20 year history (established in 1987). Carabid beetles were sampled monthly during the growing season (June-September) in two pitfall traps positioned in the center of the plots. Carabid beetles were identified to the species level and counted. Four species accounted for 99% of captured carabid beetles. *Harpalus rufipes* was the dominant species (74%). Carabid richness was highest in June and decreased over time ($p < 0.001$). Species richness was generally greater in organic than in conventional systems ($p = 0.07$) but was not affected by tillage ($p = 0.44$). Tillage effects on carabid abundance varied according to cropping system ($p = 0.02$) and sampling date ($p = 0.06$). Carabid beetles were more abundant in no-till than in tilled treatments in the organic system but not in the conventional system. These tillage effects were observed mainly in July. Results suggest that carabid beetles responded more to no-till than to the organic system. However, this trend may change as the organic system "matures" over time.

Session 3:

Weed Seed Predation

Effects of tillage and irrigation in cereal fields on weed seed removal by seed predators

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To evaluate the potential consequences of changes in crop management on natural weed control by seed predators, seed removal was investigated and seed predator populations monitored in irrigated (*N* = 3) and rain fed cereal fields (*N* = 6). Of the dryland fields, half was conventionally tilled and the other half no-till. Seed removal was followed from April 2007 until June 2008, using Petri-dishes and exclosure cages. Population of harvester ants were estimated by direct nest counts; rodent populations by Sherman live traps.

Seed removal in irrigated cereals, mainly by granivorous rodents, *Mus spretus*, was low. Seed removal in dryland cereals, mainly by harvester ants, *Messor barbarus*, was high from mid April to mid October, and is expected to cause a strong weed suppressive effect. Seed removal was higher in no-till than in conventional fields and corresponded to differences in harvester ant nest densities. Because tillage buries surface seeds, weed seed will remain exposed to predators longer in no-till than in conventional fields. Consequently, in this dryland area weed pressure should decrease in the absence of tillage.

The results indicate that the increase in the percentage irrigated land from 44% to 70% in the province of Lleida due to an imminent expansion of the irrigation network, will lead to increased weed pressure and increased dependency on and use of herbicides, because the highly effective harvester ant, *M. barbarus*, is lost and replaced by less effective granivorous rodents. The adoption of no-till in dryland cereals should decrease weed pressure. However, more knowledge is required regarding the circumstances under which harvester ants may cause crop damage in order to balance benefits and costs.

Financial support was provided by Universitat de Lleida, Generalitat de Catalunya (FI PhD grants), Ramón y Cajal grant (RYC-2006-000697) and Ministerio de Educación y Ciencia (Project AGL 2007-60828).

Diverse consumption of insects and weed seeds by granivorous omnivores.

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Arthropod granivores are a significant source of post-dispersal mortality to weed seeds within cropland, but nearly all are best considered as omnivores with distinct preferences for seeds and insect prey. Because both weed ecologists and entomologists rely on these omnivores as bases for integrated pest management, it is important to understand how these insects respond in their consumption of one class of pest (e.g., insect pests or weed seeds) when the other becomes more available. We established two treatments containing high or low densities of *Setaria viridis* seeds within alfalfa fields, and measured several responses of granivorous entomophages. Granivore populations in the two treatments were monitored for 1 wk after the establishment of the treatments, with collections made from barrier-linked, dry pitfall traps every 8 hr. Granivorous insects were frozen until they could be subjected to gut content analysis. The effect of seed density on the diets of predators was established using microscopic gut content analysis, and by subjecting the gut contents to a monoclonal antibody that specifically binds to proteins from dipteran prey. Seed removal rates were confirmed in the high seed density treatment using seed dishes. Crickets (*Gryllus pennsylvanicus* and *Allonemobius* sp.), along with a diverse community of carabids, were the most abundant granivores captured. The diets of these insects included both plant and insect material, and granivore populations responded differently to the availability of seeds. This work indicates that populations of predators of insects are affected by the availability of weed seeds. The implications of these patterns for the biological control of insects and weed seeds are discussed.

Post-dispersal seed predation of 7 weed species increases with vegetation cover

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Weed seed predation is an important process in agro-ecosystems for two reasons: First, weed seeds are used as a trophic resource by various animals including several endangered species[1]. Second, seed consumption reduces the size of weed populations, which in turn may decrease the need for curative weed control[2]. In previous studies, seed predation rates were found to be highly variable. Among the multitude of possible factors causing this variation, vegetation cover, crop species and crop management were highlighted as they may positively or negatively affect the habitat quality of seed predators by altering the microclimate on the soil surface, the presence of alternative food items or the protection against carnivores[1,3].

We tested the impact of vegetation cover (estimated by canopy light interception) on post-dispersal seed predation of 7 common annual weed species (and artificial plastic seeds for control). We placed seed cards (seeds glued on sandpaper[4]) in annual crops (spring barley, no crop) and perennial crops (lucerne, cock's-foot, fescue, and a mixture of perennial crops) with and without a cutting treatment (forage mowing) to increase the variation of vegetation cover *within* the crop species. Each crop modality was replicated 4 times in a randomized complete block design. Seed cards were exposed either in 12mm vertebrate exclusion cages, or in 1mm total exclusion cages (2nd control), or without any cage (open). Each trial lasted two weeks and was repeated three times in 2008 (April, May, July).

Overall predation rates on open seed cards averaged at 28%, 8%, and 40% for the three trial periods, respectively. The 12mm-exclusion cages strongly reduced the mean predation rates (8%, 3%, and 8%). There were virtually no accidental seed losses (0-2% in 1mm-cages, 0-4% for artificial plastic seeds). We observed a significant positive relation between vegetation cover and weed seed predation rates. This is in line with other published results[3]. There were significant differences between the crop modalities tested but large parts of this variation was explained by vegetation cover. As expected, cutting had a negative impact, particularly in lucerne, where cutting reduced the predation rates nearly to the low level of bare soil. We observed a clear preference order of the 7 weed species tested: (*Viola arvensis* Murray ≈ *Alopecurus myosuroides* Huds. ≈ *Sinapis arvensis* L. > *Chenopodium album* L. > *Anagallis arvensis* L. ≈ *Galium aparine* L. ≈ *Stellaria media* L. >> plastic seeds), which is consistent with our previous studies[5]. Nevertheless, the positive impact of vegetation cover was very similar for all 7 weed species tested. One generalist or different specialist predator species/guilds might thus be favoured by crop vegetation cover. This knowledge may be used to design cropping systems favouring the conservation of seed predators and their *access* to the weed seeds[2,3].

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Over-winter predation of *Abutilon theophrasti* and *Setaria faberi* seeds in arable land

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To improve understanding of weed population dynamics in arable fields, we used sham and full exclosure cages to determine the influence of crop habitats on predation of *Abutilon theophrasti* (velvetleaf) and *Setaria faberi* (giant foxtail) seeds in 2-year (corn-soybean) and 4-year (corn-soybean-small grain + alfalfa-alfalfa) crop rotation systems during three over-winter periods between 2005 and 2008. Mean predation rates varied from 61 to 91% among years, and varied from 31 to 99% among crop habitats across years. Crop habitat influenced seed predation and the influence was similar for the two weed species. Mean *A. theophrasti* predation ranged from 31% in the 2-year soybean habitat in the first year to 99% in the 4-year alfalfa habitat in the second year. Mean *S. faberi* predation ranged from 31% in the 2-year soybean habitat in the first year to 97% in the 4-year alfalfa habitat in the second year. Predation of both species was highest in the 4-year alfalfa habitat in all three years. The 2-year and 4-year soybean habitats had less predation of both species than the other crop habitats. No significant differences in predation were observed for either species among the 4-year alfalfa and 2-year and 4-year corn habitats in any year. Results indicate that substantial numbers of weed seeds could be removed during cold periods of the year, and suggest that a combination, or interaction of, cover and substrate factors influence seed predation rates. To maximize the contributions of seed predators to weed population regulation, future research should further examine the influence of physical habitat complexity on seed predators, their habitat requirements, and the characteristics of cropping systems that encourage predation, particularly during over-winter periods.

Temperature and seed predation rate in ground beetles (Carabidae)

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In the field, intensity of invertebrate seed predation, largely exerted by ground beetles (Carabidae), varies with the course of the year. A factor contributing to this variation is the fluctuating temperature. In this study we investigated the effect of temperature on the rate of seed consumption in *Pseudoophonus rufipes* and *Harpalus affinis*, two abundant seed predators in agro-ecosystems. Ten males and females were put at six constant temperatutes and provided with surplus seed of dandelion (*Taraxacum officinale*), and their consumption was recorded during 4 consecutive days. Smaller *H. affinis* consumed less seeds (average 12.2 seeds d^{-1}) than larger *P. rufipes* (29.0 seeds d^{-1}), and within each species smaller males consumed significantly less seeds than larger females. However, in proportion to the number of seed eaten *H. affinis* consumed significantly more seeds per unit body mass than *P. rufipes*. In both species seed consumption increased with temperature and was 2.4-3.4 times greater at 30 than 10 °C. Using a linear relationship base temperature for seed consumption (0.4 °C in *H. affinis* and 6.5 °C in *P. rufipes*) and increment of seed consumption per 1 °C increase above this threshold (0.7 and 2.8 seeds $individual^{-1}$ day^{-1}, respectively) were calculated. These parameters enable to calculate average daily consumption of each species at temperatures ≤20 °C while above this limit increasing consumption with temperature may be unaffected by temperature.

Supported by grant no. 521/07/0978 of the Grant Agency of the Czech Republic.

Density-dependent predation of weed seeds in Iowa corn field

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Seed predation can cause substantial losses of newly produced weed seeds and can thus be important in regulating weed densities. The impact on weed population dynamics is greatest if predation acts in a directly density-dependent manner. We investigated the effect of between-patch variability in seed density on seed removal.

Artificial weed seed patches were created by broadcasting *Setaria faberi* at low (1000 seeds m^{-2}), medium (4500 seeds m^{-2}) and high densities (9500 seeds m^{-2}) over 25 $\times$ 25 m areas within three corn fields in August 2006. Changes in giant foxtail seed densities were evaluated 3 and 7 weeks post-application, using soil surface sampling. Observations of seed predation rate (seeds $seed^{-1}$ $week^{-1}$), using seed cards and exclosure cages, activity-densities of invertebrates using pitfall traps, and population estimates of rodents using Sherman live traps, were conducted to understand and explain the dynamics of seeds on the soil surface.

Three weeks after seed addition, seed predation was strongly and inversely density dependent. After seven weeks, the net response since the start of the experiment exhibited only a weak inverse density-dependence. This means that between 3 and 7 weeks after seed addition, the response had reversed from inverse to almost direct density dependence. During the August-October period, seeds in corn fields were mainly consumed by invertebrates. The most abundant granivorous invertebrates were crickets, *Gryllus pennsylvanicus* and *Allonemobius allardi*, and carabid beetles, especially *Harpalus pensylvanicus*. The insects appeared unable to detect and respond numerically to weed patches, resulting in inversely density-dependent predation, which favours the persistence of weed patches. The granivorous prairie deer mouse *Peromyscus maniculatus bairdi* was present, but contributed little to overall seed losses in autumn.

Results of this study indicate that weed densities in corn fields currently are not regulated through directly density-dependent seed predation, because the time between seed shed and seed movement into soil is too short for invertebrates to respond to and level out spatial differences at the scale of weed patches. However, our results suggest that delaying crop harvest and tillage may provide invertebrate predators more time to attack weed seeds, and may allow for subsequent predation by vertebrates, which would be directly density-dependent.

Financial support was provided by the USDA National Research Initiative (Project 2006-35320-16548).

The role of seed predation in establishment of *Taraxacum officinale* (dandelion) plants

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Our earlier study revealed that more than 90 % of dandelion *Taraxacum officinale* agg. seeds disappeared before seedling establishment. Carabid predation was the major factor suspected of mortality of seeds but effect of seed inviability and seedling predation have not been estimated. The study of seed predation and seedling establishment was therefore continued using methods enabling to break mortality into particular components and determine its temporal and spatial variation.

Three year experiments made at a moist shaded and a dry exposed site were used to determine the survival of seeds. Seed was exposed in twin arenas of 33 cm^2 area separated by a distance of 3 cm of which one was protected from and the other exposed to predation. The "protected" arena was surrounded by a plastic collar 4.5 cm high of which 2 cm was in the soil, the "exposed" arena was surrounded only by a 2 cm high plastic collar completely inserted into the soil. Each pair of arenas was covered by a wire mesh cage protecting the arenas from vertebrate predation and a rubber mesh screen that let water pass through but shielded the plots from naturally dispersed dandelion seed. Experiments, each consisting of 10 cages, were repeated at about 1 monthly intervals starting from mid-May, through the vegetative periods 2004-2006. The abundance in the field (pitfall traps) and the seed and seedling consumption in the laboratory were determined for the main groups of predators - ground beetles (Coleoptera: Carabiade), terrestrial isopods (Isopoda: Oniscidea) and molluscs (Gastopoda: Pulmonata). On average, 28 and 48 % of the seed did not germinate and 43 % and 35 % succumbed to predation at the moist and dry site, respectively. Surprisingly, there was no seasonal trend in the rate of seed consumption. Ground beetles (particularly *Amara* spp.) and terrestrial isopods (*Armadillidium vulgare*) were efficient and dominant seed predators. Of the established seedlings on average 88 % was killed at the moist site and 32 % at the dry site, largely by slugs (*A. lusitanicus*). In total seed mortality, seed and seedling predation killed on average 98 % of dispersed dandelion seed at the moist site and 87 % at the dry site, respectively.

Supported by the project No. 526/09/1436 of the Grant Agency of the Czech Republic.

Comparing methods to measure the effect of weed seed densities on seed predation rates in cereals

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Distribution patterns of weeds -and their seeds- in arable fields is often patchy meaning that there are areas with low and high densities within the same field. The primary objective of this study is to determine if and how seed predators respond to areas (patches) containing high and low seed densities in order to predict if they will be able to regulate weeds in arable fields. We hypothesized a direct density dependent response. A secondary objective is to compare methods to estimate the response of predators, namely by offering seeds on seed cards, in petri-dishes and by repeated soil sampling of seeds distributed over the soil surface. The latter method is the most realistic but very labour-intensive, and it would be advantageous if it could be replaced by one of the less intensive methods.

In April 2008 we conducted a 16-day experiment in three irrigated cereal fields near Vilanova de Bellpuig, Lleida (Catalonia, Spain). In each field, one 15 m x 15 m patch was seeded with either 0, 2500, 5000 or 7500 seeds/m² of *Lolium multiflorum* Lam. Seed cards were exposed in the field for 7 days; seeds in Petri-dishes were exposed for 5 days and soil surface sampling was done prior to seed addition and at termination of the trial.

Results obtained with the seed cards and Petri-dishes suggest an inversely density dependent response to seed densities in two of the fields, while there was a density independent response in the third field. Seed predation in the third field was also much lower. The range of the offered seed densities was wide. The amount of seeds offered in the highest density treatment may have satiated the predator community present causing a different response than anticipated. However, the above results need to be compared with results obtained by soil surface sampling.

Rodents were the main seed predators. *Mus spretus* and *Apodemus sylvaticus* were active during the experiment in the three and two fields respectively, as confirmed by Sherman live traps.

Financial support was provided by Ministerio de Educación y Ciencia (Acciones integradas Project No. HA2007-0033), Universitat de Lleida, Generalitat de Catalunya (FI PhD grants), Ramón y Cajal grant (RYC-2006-000697) and Ministerio de Educación y Ciencia (Project AGL 2007-60828).

Poster Session:

Weed Seed Predation

Comparing methods of seed exposure

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Various methods are used to estimate pressure of seed predators in the field. The comparison of commonly used methods is of prime importance. This study investigate possible bias brought to observed seed predation levels by commonly used methods of seed exposure, with combination of two types of substrate in laboratory. The methods used are: i) seeds presented on moist filter paper; ii) seed card placed on moist filter paper; iii) seed card placed on sieved moist garden soil; iv) seed plasticine trays on moist filter paper; and v) plasticine trays on sieved moist garden soil. *Stellaria media*, *Capsella bursa-pastoris* and *Poa annua* were used as model species of seeds and two carabids (Coleoptera: Carabidae: *Amara aenea, Pseudoophonus rufipes*) and two terrestrial isopods (Isopoda: Oniscoidea: *Armadillidium vulgare, Porcellio scaber*) were used as model granivores. 50 seeds were exposed for a period of three days, and seeds were replenished daily if consumption exceeded 50%. Total seed consumption was standardized over dry body mass of each individual and compared for each treatment using ANOVA for each species separately. We found significant differences between methods in most cases, although the results were not entirely consistent across treatments. Seed consumption was generally highest on a filter paper and seed cards placed on top of soil, while predation on plasticine trays was consistently lower compared to seed cards. Only carabid *A. aenea* showed no response to the method of seed exposure in case of *S. media* and *P. annua*. The observed differences will be compared with the field data.

Supported by the project No. 521/07/0978 of the Grant Agency of the Czech Republic.

Long term population development of weeds in a crop rotation with emphasis on surface losses of weed seeds

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A long term experiment (rotation beets - winter wheat - winter barley) was conducted from 1981-1999 in Germany to evaluate the effect of different chemical weed control intensity in cereals and the influence of nitrogen fertilization on the population dynamics of weeds (Gerowitt & Bodendörfer 1998).
By counting plants at least six times per year, analysing the seed bank and estimating the seed production it became possible to contain the not direct measured influences on weed population dynamics to the term between seed shed and the entrance in the seed bank of the soil, the losses during the exposure of the seeds on the soil surface. It is supposed losses in this stage are due to seed predation and microbial activity.
The database allows profound analyses of long term effects by cultivation intensity on weed abundance and composition at a scale of plant species and societies. For *V. arvensis* the population development is well described and modelled (Gerowitt & Bodendörfer 1998 + 2001), but for other species and on a scale of plant societies further investigation is needed.
Results are presented using open source free ware “R” to do the statistical analysis and visualisation.

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Effects of seed density and background seed density on post-dispersal seed predation of weeds in barely field.

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Six sequential field experiments were conducted in 2007 in a barely field in Mashhad, NE of Iran to determine the effects of seed density, background density and their interactions on post-dispersal seed predation. Four weed species (*Avena ludoviciana, Hordeum spontaneum, Sinapis arvensis and Rapistrum rugosum*), three seed densities (50, 100 and 150 seeds dish^{-1}) and two background seed densities (with and without) were arrange in a factorial randomized complete block design. Seed predation was significantly different among species. *S. arvensis* which had the smallest seeds (1.95 mg seed^{-1}) had the highest seed predation (50.30 %). It was followed by *A. ludovociana* (19 mg seed^{-1}), *R. rugosum* (7.5 mg silicula $^{-1}$) and *H. spontaneum* (24 mg seed^{-1}) respectively. It seemed that seed predation was affected by seed size except for *R. rugosum* because of the presence of hard siliculas. In all species, seed predation was significantly different between dates of sampling and seed density except for *H. spontaneum* between the 4th and 5th sampling weeks and at densities of 100 and 150 seeds dish^{-1}. The highest seed predation occurred in 6th week in *S. arvensis* (56.27%) while *H. spontaneum* in the first week of the experiment had the lowest seed predation (20.97%). Background seed density significantly influenced seed predation. In all species, seed predation was higher in high background seed density treatments. Seed predation of all species was affected by interaction among densities and background density but such significance was not observed for *H. spontaneum.* The highest and lowest seed predation was observed in *S. arvensis* at 150 seed dish^{-1} with background seed density and *H. spontaneum* with no background density at 50 seed dish^{-1} respectively (81.54% vs. 19.35%). Results showed that for species with high preference, density alone did not have any effect on seed predation but in general background seed density promoted higher seed predation.

Weed seed predation potential of *H. pensylvanicus* in northeastern U.S. cropping systems

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Conservation of weed seed predators may help reduce weed infestations and reduce reliance on the need for both cultivation and chemical weed control. This research investigated the feeding preference of *H. pensylvanicus* to three summer annual weeds and it potential as a weed seed predator in several different cropping systems. Weed species seed preference experiments were conducted using *Setaria faberii*, *Chenopodium album*, and *Abutilon theophrasti*. The activity density of *H. pensylvanicus* was monitored in several cropping systems having different crop species and levels or timing of soil disturbance and seed predation was assessed during the growing season.

H. pensylvanicus consumed *S. faberii* and *C. album* seed, but not *A. theophrasti* seed. When given a choice amongst the three weed species, *H. pensylvanicus* preferred seeds of *S. faberii* and *C. album* equally over *A. theophrasti* seed. *H. pensylvanicus* consumed both newly dispersed and field aged seeds, but when given the choice, preferred newly dispersed seed. *H. pensylvanicus* activity density peaked in early August and activity density was unaffected by cropping system early in the summer. Cropping systems with little to no soil disturbances had equal or greater activity density than frequently disturbed treatments. Seed predation rates averaged between 38 to 63% and peak predation occurred in early summer and then again in late July and August. These results indicate *H. pensylvanicus* does show preference among weed species and prefers newly dispersed seeds over aged seeds. *H. pensylvanicus* may have less tolerance for one cropping system over another, but may tolerate specific crop types during specific times of the year. Several seed predators influenced the field predation results in this study, so future research should focus more on the effect of food preference and timing of disturbance on a host of potential seed predators.

Different strategies of pre-dispersal seed predators in flower heads of Cirsium species

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One of the significant factors causing seed mortality on the mother plant is pre-dispersal predation which has been intensively studied in many Asteraceae (KOPRDOVÁ and MARTINKOVÁ 2006). Pre-dispersal predators could limit thistles propagation to new niches. Flower heads of thistles contain the most varied, specific and well-known insect fauna of any part of the plant. They present rich source of food, packed with achenes, and their inhabitants are protected from vertebrate predators by the tough spiny bracts. Importance of pre-dispersal predators of thistles is well documented (SKUHROVEC et al 2008).

Our study has focused on the occurrence and diversity of seed-feeding insects (pre-dispersal seed predators) in flower heads of four thistle species (*Cirsium arvense*, *C. palustre*, *C. oleraceum* and *C. heterophyllum*). The diversity level was discussed in connection with insect life strategies, phenology and diversity of the host plants. The main goals of our study were: (1) to find out the occurrence of pre-dispersal seed predators, (2) to compare the strategy of pre-dispersal seed predators, which use thistle flower heads for their development and (3) to evaluate the utilizability of pre-dispersal predators as significant biological control agents of thistles.

We determined seed-feeding species belonging to these insect families: Diptera: Tephritidae, Diptera: Cecidomyiidae, Coleoptera: Curculionidae, Lepidoptera: Tortricidae, Hymenoptera: Eulophidae, Eurytomidae, Pteromalidae. Each pre-dispersal predator species has different attack strategy and the way of seed consumption. The most effective seem to be weevils (Curculionidae) (their larvae do not attack only seeds, but also the receptacle) and/or a combination of two and more bioagents which together create multiple stresses on the plant (e.g. Tephritidae + Tortricidae in *C. palustre*).

Next studies will be focused on the effects of pre-dispersal predators on the weight and germination of all seeds categories (riped, unripe and damaged), and the studies will compare thistles with their associated insects from geographically different localities. All this knowledge can be used as basal data for biological control of weeds.

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Research was supported by grant of the Ministry of Agriculture (Mze ČR) CZ0002700601 and by the project No. 521/07/0978 of the Grant Agency of the Czech Republic.

LIST OF PARTICIPANTS