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Importance or *Ludwigia grandiflora* as invasive weed on meadows and pastures in Western France.

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ABSTRACT: In flooded meadows, Large Water Primrose (*Ludwigia grandiflora* ssp. *hexapetala*) has become an invasive weed since years in many Western marshes. Settlement occurs both by cuttings and seedlings. Our purpose was (i) to assess progressive colonization in three sites and (ii) to show adaptive traits of *Ludwigia* "terrestrial forms" using another site with a strong moisture gradient, and (iii) to get recommendations for managers. (i) In the Natural Regional Park of Brière, colonization occurred through dykes. The first appearance was probably due to a dirty dredging engine. In Mazerolles polder, it was due to flooding and was increased by pumping in colonized dykes with much fragmentation. In Apigné meadow bad drainage led to colonization by *Ludwigia*. Field maps assess progressive colonization on many areas. (ii) Adaptation to land conditions led to reduced biomass of the whole plant and increased ratio between roots and stems. Cumulative stem length was only 21 cm in dry conditions, while it reached 2064 cm in aquatic forms. After settlement, plants are able to survive for years provided there is some remaining moisture in the soil. (iii) As a consequence for managers, barriers limiting dispersion of cuttings should be established in dykes but also along the hydraulic network leaving reed strips. Flooding events should lead to careful field survey to pick up the cuttings. The main problem is when fertile seeds are dispersed all over the area as in Mazerolles. No prevention exists, thus attempts of destroying *Ludwigia* mats are experimented.

KEYWORDS: *Ludwigia*, wetlands, colonization, land form, management

1 INTRODUCTION

Water Primroses (*Ludwigia grandiflora* ssp. *hexapetala* and *L. peploides* ssp. *montevidensis*) are increasing worrying weed problems all over France (Dutartre et al., 2007; Lambert et al., 2010). Their increasing colonization towards Northern France is accompanied by expansion on land areas due to flooding and cutting and/or seed dispersion. Their land forms colonize meadows and pastures in marshes: at present (spring 2011), they affect more than 500 ha in Pays de Loire and Bretagne regions (Haury et al., unpubl. data).

Our aims were: (i) to assess progressive colonization in three quite different sites and (ii) to point out adaptive traits of *Ludwigia* "terrestrial forms" (iii) to get recommendations for managers.

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2 SITES AND METHODS

2.1 Sites

We studied *Ludwigia* distribution and adaptations in three sites in Western France where we recorded its terrestrial forms (fig. 1): (i) PNR Brière (52,000 ha), including peatlands and marshes (area: 25,500 ha), (ii) Mazerolles polder (750 ha), and (iii) a wet meadow which has become submersed area due to bad drainage, near Apigné gravel pits (around 1 ha). Detailed presentations of these wetlands are given respectively in Cucherousset et al. (2008), Maisonneuve (2003), Coudreuse et al.(2009) and Haury et al. (2008).

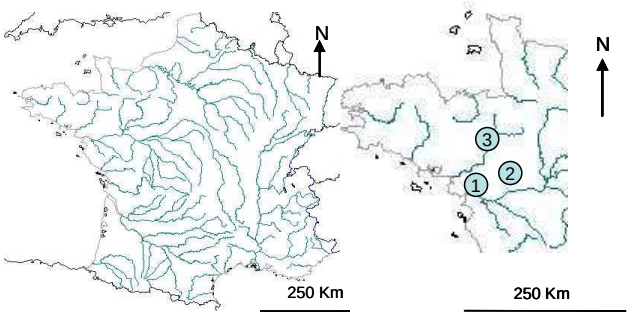


Figure 1. Study sites.
1: Brière; 2: Mazerolles Polder; 3: Apigné meadow

2.2 Methods

Mapping was done considering field surveys either by walking or boating in Brière in late spring, by field walking in both other sites in late summer. Presence or absence and density were recorded and drawn in the field on hard maps to be sure of plant colonization. Then the surfaces were integrated within a GIS system, allowing calculation and giving yearly maps of *Ludwigia* colonization both in dykes and on pastures and meadows.

Standing biomass was obtained picking up plants in five 0.25 m² quadrates in particular sites.

Three plants were collected in each site to measure morphological paramameters: stem and root length, roots/above ground biomass. In Apigné meadow four different moisture conditions were surveyed: from aquatic biotope up to dry one, never submersed.

3 RESULTS

3.1 Historical records of Ludwigia *distribution*

In Brière, *Ludwigia grandiflora* was absent before 1993 and was firstly recorded in a dredged dyke in 1994 (colonization was probably due to a dirty dredging machine that operated here at that time). From the dyke, that invasive plant reached progressively low meadow areas when flooding and began to invade the whole area except dense reeds and upper parts of the meadows (fig. 2).

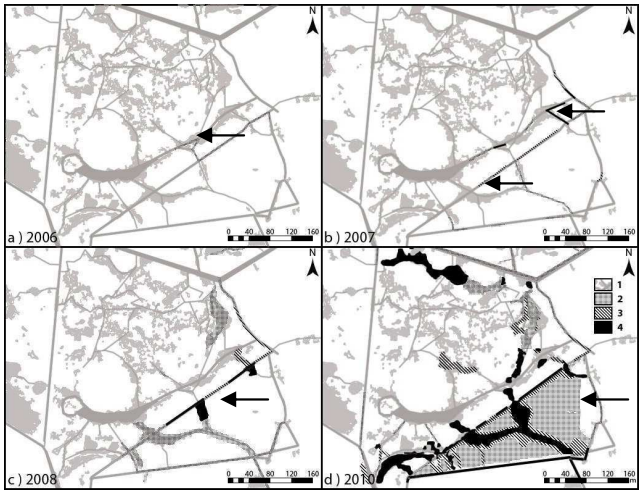


Figure 2. Successive states of colonization in Aines meadow (2006-2010).

Legend: 1: uncolonized dykes and low areas; 2: small and isolated patches of *Ludwigia*; 3: contiguous patches; 4: dense populations of *Ludwigia.*

In Mazerolles, colonization began around 1999 and was increased and accelerated by pumping in already colonized dykes, leading both to fragmentation of plants and dispersion. Unless some dredging practices occurred, occasional management was done to regulate the plant.

In Apigné meadow, colonization began after the formation of a small pond due to lack of surface drainage (2008): *Ludwigia* was introduced from neighbouring gravel pits and settled since beginning of 2009, forming terrestrial populations when water level decreased.

3.2 Present status of colonization

Historical records of *Ludwigia* distribution in Brière (fig. 3) point out such progressive colonization of many areas. *Ludwigia* is mainly found in outlying areas and along the main rivers and dykes.

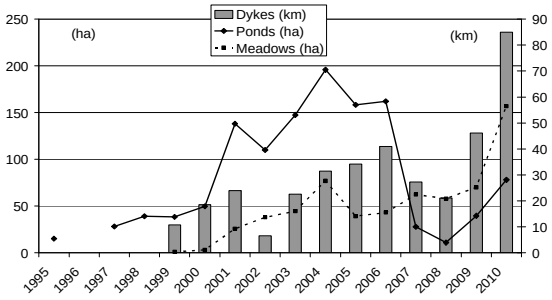


Figure 3. Progressive colonization of different habitats in Brière.

Five steps have been observed (i) no *Ludwigia* before 1993, (ii) a first maximum of meadows and ponds in 2004 with almost 200 ha of colonized ponds, (iii) a decrease (2005-2006) maybe due to hand removal, (iv) a minimum in 2008 with only 15 ha of colonized ponds, but also a large amount of wet meadows and the present step (v), with increasing figures for all biotopes. These data are the balance between natural expansion and hand removal which began in 2004-2005, but becomes financially less intensive now.

We can notice regular increase of *Ludwigia* on low parts of meadows from dykes and ponds, that was observed since 2000.

3.3 Biomass and morphology

Unless Mazerolles and Brière are peaty marshes, standing biomass is different between these areas (fig. 4), with more than 2 kg of dry weight per m² in Brière and less than one kg in Mazerolles.

In both sites, maximum biomass is obtained at late summer.

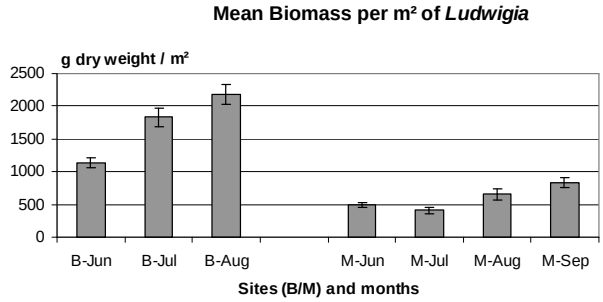


Figure 4. Mean dry biomass per m² in Brière (B-months) and Mazerolles (M-months) (mean of 5 quadrates with standard errors).

There is a huge phenoplasticity for *Ludwigia* regarding both aquatic and terrestrial forms. Such plasticity appears regarding individual weight, roots/above ground parts, stem length and root length (Table 1). A general reduction of stem/root ratio with increasing dryness is obvious as well as reduction of individual length (stem and roots)

Table 1: Phenological adaptations of *Ludwigia* in land conditions (mean obtained with three individuals).

	Mean stem length (cm)	Mean root length (cm)	Ratio Stems/ Roots
Apigné very dry site	21	76	0.28
Apigné medium site	675	669	1.01
Apigné wet site	354	339	1.04
Apigné aqua-tic site	2065	1438	1.44
Brière peaty dry site	29	143	0.21

Differences in content of water appear between terrestrial and aquatic forms (Table 2).

Table 2. Percentage of dry weight comparing terrestrial and aquatic forms.

Sites	% Dry weight
Apigné very dry site	46.7
Apigné medium site	25.7
Apigné wet site	29.7
Apigné aquatic site	7.4
Mazerolles dry peaty site	15.3
Mazerolles aquatic site	12.8
Brière peaty dry site	22.0
Brière aquatic site	16.2

3.4 Fertility

Populations of *L. hexapetala* are sterile in Brière (no fruiting), all over the site.

They are fertile in Mazerolles, with many formed fruits. On the collected fruits in 2009 and 2010, seeds have been separated, and *ex situ* germination experiments have been done, giving respectively 15 % and 18 % of seed germination, pointing out that seeds are able to keep their germination ability for several years.

In Apigné, few fruits have been formed in 2009 and 2010. Fruiting occurred very late in 2010, thus only 9 seeds were collected, with no observed germination.

4 DISCUSSION

4.1 Colonization and production

Colonization in the three sites occurs when flooding leading to cutting and fruit and seed dispersion all over the area during winter. Connectivity is increased with current, when no barriers exist.

In Brière, huge time heterogeneity in production appears and makes the managers' decision and work very difficult. Between year differences can be due to climatic differences with cold and rainy spring leading to late growth in 2007 and 2008 explaining decrease in 2007 and observed minimum in 2008 (because mapping is performed in late spring).

In Mazerolles, colonization and production are still increasing, making experiments of ecological restoration very important.

In Apigné meadow, between 2008 and 2010, colonization increased but favoured by dry summer in 2010, a farmer ploughed the meadow leading to form many cuttings in the area mow entirely colonized.

Production and standing biomass in terrestrial biotopes are low in Mazerolles while they are comparable to many aquatic conditions in Brière (Lambert et al., 2010).

Causes of such differences in production could be due to observed superficial rooting in Mazerolles, while it is deeper in Brière, unless both sites are peaty meadows.

4.2 Morphological adaptations

Plants adapt to stress by reducing their water content, individual biomass and above ground

biomass versus roots. Other parameters have been observed but not measured: reduction of leave shape, internode length, creeping structure.

Rooting is a key phenomenon to explain such adaptations to ensure positive water budget in dry conditions.

4.3 Fertility and genetics

Causes of observed differences in fertility between Brière, Apigné and Mazerolles remain unknown.

Climatic differences between Apigné and other sites can explain late fruiting in Apigné, either in the meadows or in gravel pits.

Genetics could explain such differences: there is possible genetic homogeneity of *Ludwigia* in Brière clonal population *vs* mixed populations in Mazerolles. Dandelot et al. (2005) found that *L. hexapetala* is decaploid and mainly outcrossing with probably a genetic self incompatibility. Fruitful populations could be only obtained when crossing populations of different origins.

4.4 An increasing problem without present solution: some implications for managers

Terrestrial forms of *Ludwigia* cause an increasing problem for managers as well as farmers, because invaded areas in meadows and pastures cannot be accepted for EU environmental grants.

It is only possible to pick up *Ludwigia* during flooding. At present, no efficient removal method is known for meadows when they are out of flood.

Thus, only prevention can limit new colonization. Recommendation against dispersion can be made towards managers: keep reed belts along dykes, avoid digging too many ditches in the meadows as they are preferential way of dispersion. Barriers inside dykes to collect cuttings are presently tested in Brière. Mapping and regular survey are compulsory to take off new cuttings or plants when they are still small and poorly rooted.

4.5 Some future research topics and experiments.

More precise measurements on terrestrial forms should be performed to describe terrestrial adaptations.

About fertility, genetic mechanisms should be explored too, and working at population level becomes compulsory

Some restoration experiments are in process in Mazerolles but not very successful presently. It is possible to destroy *Ludwigia* mats and sow Graminaceae, but herbs are destroyed by winter flooding and remaining *Ludwigia* begins its growth much before meadow plants.

5 CONCLUSION

The present papers focuses on terrestrial forms of Water Primroses as an increasing and worrying weed problem for wetlands.

Many questions appear when studying the topic, involving multidisciplinary research: genetics, plant and population biology, hydrology. Applied research is also necessary to answer the practical questions: How much? Where? How to manage?

In any case, collaboration between scientists and managers remains compulsory to solve that problem.

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