European Weed Research Society

14th EWRS Symposium

17 – 21 June 2007 ■ Hamar – Norway

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XIV European Weed Research Society Symposium
Hamar, Norway 18-21 June 2007

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Rationale

The European Weed Research Society is an international organization, which was established in 1975. It is open to everyone who has an interest in weed research and related topics. Its members come from governmental, commercial, university and independent research organisation: all have a particular interest in the many different aspects of weed science and its technology.

The 14th EWRS symposium
This symposium is the latest of a long and historical series of conferences that gather scientists, researchers and technicians to present and discuss the latest obtained knowledge on a broad range of weed science topic

The symposium venue is Hamar, Norway, at Scandic Hotel, which offer an excellent frame for the event with all modern conference facilities and its nice and functional appearance. Hamar is located less the 2 hours with train or bus s form Oslo, the capital in Norway.

Symposium Proceeding
This book contains the official abstracts of oral and poster presentations at the symposium in addition to programme and list of participants.

Contents

Programme at a glance

	Saturday 16-june	Sunday 17-june	Monday 18-june	Tuesday 19-june	Wednesday 20-june	Thursday 21-june
07:30			Registration and poster set up	Registration and poster exhibition	Registration and poster exhibition	Registration and poster exhibition
08:00						
08:30			Opening ceremony	Session 3	Session 4	Session 6 - continued
09:00	EWRS Scientific Committee Meeting	EWRS Executive Committee Meeting + Course on Statistical Assessment of Dose-response Curves + Herbicide Resistance Workshop	Opening lecture: Stephan Moss (UK)			
09:30						Session 7
10:00			Coffee break	Coffee break	Coffee break	Coffee break
10:30			Session 1	Session 3 - continued	Session 4 - continued	Session 7 - continued
11:00						
11:30				EWRS General Assembly	Session 5	
12:00						
12:30				Lunch		Final session
13:00			Lunch		Lunch	
13:30				Excursion 13.15 – 20.15		Lunch and good bye
14:00			Poster session		Session 5 - continued	
14:30						
15:00					Poster session and Coffee	
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16:00		Meeting WR* Editorial Board				
16:30					Session 6	
17:00		Meeting NRs**				
17:30						
18:00		Registration and poster set up				
18:30			Dinner		Dinner	
19:00						
19:30						
20:00		Welcome party	WG meetings		WG meetings	
20:30						
21.00				Symposium Dinner and entertainment		
00.00						

* WR= Weed Research

** NRs= EWRS National representatives

Saturday 16 June

09.00 – 18.00 **EWRS Scientific Committee Meeting**

Sunday 17 June

09.00 – 16.00 **EWRS Executive Committee Meeting**
09.00 – 17.00 **Course Statistical Assessment of Dose-response Curves**
13.00 – 19.30 **EWRS Resistance Working Group meeting**
16.00 – 17.00 **Meeting of Weed Research Editorial Board**
17.00 – 18.00 **Meeting of EWRS National Representatives with EWRS Board**

16.00 – 19.00 Registration & posters set up
19.00 *Welcome party*

Monday 18 June

07.30 – 08.30 Registration & posters set up

Opening session Chair: Marco Quadranti (CH)

08.30 – 08.35 Welcome address by the **Mayor of Hedmark County**, **Siri Austeng**
08.35 – 08.50 Welcome addresses by the **Research Director in Bioforsk, Nils Vagstad,** the **Director of Plant Health and Plant Protection division, Ellen Merethe Magnus** and the **Chairman of LoCom, Jan Netland.**
08.50 – 09.00 Welcome address by **EWRS President, Marco Quadranti**
09.00 – 09.45 **Stephan Moss (UK) -** Opening lecture: Weed Management: is it a case of trying to predict the unpredictable?
09.45 – 10.00 Discussion

10.00 – 10.30 *Coffee break*

Session 1 **Invasive plants and biological weed control**
Chair: Christian Bohren (CH) & Paul Hatcher (UK)

10.30 – 11.00 **Michael Browne (NZ) -** Keynote paper: Bringing authoritative invasive species knowledge to decision makers, weed scientists and practitioners (conservation practitioners and communities).
11.00 – 11.20 **Imre Beres (HU) -** Distribution and harmful effect of common ragweed (*Ambrosia artemisiifolia* L.) in Hungary
11.20 – 11.40 **Christian Bohren (CH) -** Control of Ambrosia artemisiifolia: disrupting lifecycle to exhaust seedbank in infested areas
11.40 – 12.00 **Renè Sforza (FR) -** Evaluation of the first augmentative biological control against *Euphorbia esula*
12.00 – 12.20 **Maurizio Vurro (IT) -** Delivery of mycoherbicides through drip irrigation systems

12.20 – 13.00 Discussion

13.00 – 14.00 *Lunch*
14.00 – 15.30 **Poster session** *and coffee*

Session 2 **Chemical weed management**
Chair: Svend Christensen (DK) & Per Kudsk (DK)

15.30 – 16.00 **Svend Christensen (DK) -** Keynote paper: Intelligent weed control technologies
16.00 – 16.20 **Milena Simic (RS) -** Weed suppression by plant arrangement of maize
16.20 – 16.40 **Pentti Ruuttunen (FI) -** Environmental risks of long term use of pesticides in Finnish potato fields
16.40 – 17.00 **Marija Arsenovic (US) -** The IR-4 Project: Update on herbicide registration in speciality crops in the United States
17.00 – 17.20 **Domínik Dicke (DE) -** Use of remote sensing for detecting herbicide injury in maize at early growth stages
17.20 – 17.40 **Marleen Riemens (NL) -** Predicting sublethal effects of herbicides from greenhouse data on terrestrial non-crop plant species in the field
17.40 – 18.00 Discussion

18.30 – 20.00 *Dinner*

20.00 – 21.00 **Working Groups meetings (parallel sessions)**
- Germination and Early Growth
- Physical and Cultural Weed Control
- Biological Weed Control
- Weeds and Biodiversity
- Weed Management in Arid and Semi-Arid Climate

Tuesday 19 June

07.30 – 08.30 Registration & poster exhibition

Session 3 **Crop-weed interactions and non-chemical methods**
Chair: Bo Melander (DK) & Francesco Tei (IT)

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09.00 – 09.20 **Frencesco Vidotto (IT) -** Evaluation of damage caused by spring tine harrowing in maize
09.20 – 09.40 **Kjell Mangerud (NO) -** Criteria for improved weed harrowing in cereals
09.40 – 10.00 **Marjolein Kruidhof (NL) -** Weed suppression by cover crop residue material - exploration and optimization
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10.30 – 10.50 **Martin Williams (US) -** Competitive interactions between sweet corn (*Zea mays*) phenotypes and wild proso millet (*Panicum miliaceum*)
10.50 – 11.10 **Clarence Swanton (CA) -** An alternative view of plant competition
11.10 – 11.30 Discussion
11.30 – 12.30 **EWRS General Assembly**
Chair: Marco Quadranti, EWRS President

12.30 – 13.15 *Lunch*
13.15 – 20.15 **Excursion**
21.00 – 24.00 *Symposium dinner*

Wednesday 20 June

07.30 – 08.30 Registration & poster exhibition

Session 4 — Weed temporal and spatial dynamics

Chair: Lammert Bastiaans (NL) & Ilse Rasmussen (DK)

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09.00 – 09.20 **Bastiaan Brak (UK) -** Evaluating the effect of weed management strategies on long-term weed population dynamics using a modelling approach
09.20 – 09.40 **Joel Torra (ES) -** PRIM (Poppy Resistant Integrated Management): a bio-economic model for Papaver rhoeas in the North-East of Spain
09.40 – 10.00 **Therese With Berge (NO) -** Spatial resolution for site-specific weed control in cereals
10.00 – 10.30 *Coffee break*
10.30 – 10.50 **Bo Melander (DK) -** *Apera spica-venti* growth under the influence of tillage, crop rotation and chemical control level
10.50 – 11.10 **Jose Gonzales-Andujar (ES) -** Habitat fragmentation and weed dispersal: A spatially explicit agricultural landscape model
11.10 – 11.30 Discussion

Session 5 — Herbicide resistance in weeds and crops

Chair: Baruch Rubin (IL) & Anne Thompson (UK)

11.30 – 12.00 **Marie-Pierre Plancke (CH) -** Keynote paper: Glyphosate-resistant weeds: a technical review and management recommendations
12.00 – 12.20 **Stevan Knezevic (US) -** Herbicide tolerant crops: 10 years later
12.20 – 12.40 **Baruch Rubin (IL) -** Herbicide-resistant weeds, a threat to the dry land farming in Israel
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13.00 – 14.00 *Lunch*

14.00 – 14.20 **Ron Marshall (UK) -** Resistance to acetolactate synthase (ALS) inhibiting herbicides in UK populations of *Alopecurus myosuroides* (black-grass)
14.20 – 14.40 **Christophe Délye (FR**) **-** Fitness variation associated with herbicide-resistant acetyl-CoA carboxylase alleles in black-grass (*Alopecurus myosuroides* Huds.)
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15.00 – 16.30 **Poster session** *and coffee*

Session 6	**Weed Biology** Chair: Andrea Grundy (UK) & Maurizio Vurro (IT)
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17.20 – 17.40	**Kirsten Tørresen (NO) -** Effect of previous environment on regrowth of *Elymus repens*, *Cirsium arvense* and *Sonchus arvensis* in autumn
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20.00 – 21.00	**Working Groups meetings (parallel sessions)** • Invasive Plants • Crop/Weed Interactions • Weed Management Systems in Vegetables • Optimisation of Herbicide dose

Thursday 21 June

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09.10 – 09.30	Discussion

Session 7	**Biodiversity and weed communities** Chair: Paolo Bàrberi (IT) & Bärbel Gerowitt (DE)
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10.00 – 10.20	**Stanislava Koprdova (CZ) -** Biology of pre-dispersal seed predators of two knapweed species, *Centaurea stoebe* and *C. scabiosa* (*Asteraceae*)
10.20 – 10.40	**Federica Graziani (IT) -** Post-dispersal weed seed predation by vertebrates and invertebrates in organic and conventional cereal fields
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11.10 – 11.30	**Jukka Salonen (FI) -** Effect of rotational fallows on weed communities of subsequent crops
11.30 – 11.50	**Kristin Goerke (DE) -** Weeds in oilseed rape in Germany – status and assessment of changes
11.50 – 12.10	**Christian Andreasen (DK) -** Flora changes in Danish arable fields
12.10 – 12.30	Discussion

Final Session	Chair: Marco Quadranti (CH)
12.30 – 12.50	Summary of the scientific programme - **Paolo Bàrberi**, EWRS Scientific Secretary
12.50 – 13.00	Presentation of the venue of 15th EWRS Symposium, June 2010
13.00 – 13.10	Concluding remarks - **Marco Quadranti**, EWRS President
13.30 – 14.30	*Lunch and good bye*

Weed Management: is it a case of trying to predict the unpredictable?

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For effective weed management, a farmer or advisor needs to predict the likely outcome of different strategies so that rational decisions can be made. Critically, weed management advice needs to be tailored to the individual field situation. While weed research has improved our ability to provide advice on the impact and control of weeds at the generic level, it is questionable what real advances have been made at the individual field level. In the UK, most arable farmers use a crop consultant, who typically advises on 4,000 – 10,000 ha of arable crops and charges €15 ha^{-1}. Even if an advisor allocates 1000 hours a year to advice on weeds, that equates to only 6 – 15 minutes ha^{-1}. Consequently, the amount of time that can be spent, cost effectively, on any individual field is very limited. Although much research has been conducted on Precision Agriculture, Integrated Weed Management and Modelling, it is unclear how much impact this has had in terms of better advice at the individual field level.

Hence the question should be asked - how far can we go in refining weed management advice to make it more applicable at the individual field level? For example: 1. Predicting yield loss caused by weeds. Problem – how can weeds density and distribution be assessed cost effectively over large areas? 2. The benefit of different cultivations on weed control. Problem – with such a huge choice of cultivation equipment, method of use (depth and speed) and soil conditions, how can we predict the effect of cultivation on a field scale? 3. The emergence pattern of weeds and herbicide timing. Problem – how can weed seed bank dynamics be determined cost effectively? 4. The rate of development of herbicide resistance. Problem – how can the initial incidence and subsequent selection pressure imposed by herbicides be determined in an individual field?

There may be a risk of diminishing marginal returns in many areas of weed research, where additional research delivers only marginal improvements in weed management. It might be better to recognise some of the practical limitations, and not pursue a policy of trying to achieve unrealistic precision.

Critical issues that need to be addressed are: 1. The problem of scaling up research results from small plots to field situations. 2. A lack of appreciation of the true financial cost of obtaining information, such as weed density, distribution and dynamics, at a field scale. 3. The drive by some funders for perceived 'scientific quality' at the expense of practical application. 4. Weed researchers becoming disengaged from practical agriculture.

In future, an increasing population, a finite land area, the consequences of global warming and demand for biofuels will require increased crop production. A recent review (Oerke, 2006) indicated that weeds cause the highest potential crop losses (34%), with insect pests and pathogens being less important (losses of 18% and 16%). Weed research has a bright future – but only if it places greater emphasis on practical weed management. The following questions should be asked in relation to any weed research project. What is the aim of this research? How are the findings going to help in managing weeds? Who is going to ensure the results of this research are used? What impact is this research likely to have in practice?

Session 1

Invasive plants and biological weed control

ORGANISERS

Paul Hatcher, United Kingdom

Christian Bohren, Switzerland

Bringing authoritative invasive species knowledge to decision makers, weed scientists and practitioners (conservation practitioners and communities)

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A weed is a plant growing in a place where it does not belong. A non-native or alien species refers to a species occurring outside of its natural range. Of 2721 non-native species identified in an 'Audit of non-native species in England', terrestrial plants were by far the largest category; flowering plants (angiosperms) made up 73% of the total (1798 species). The Convention on Biological Diversity defines an invasive alien species (IAS) as an alien species whose introduction and/or spread threaten biological diversity. The Millennium Ecosystem Assessment (called for by the United Nations Secretary-General in 2000) lists invasive species as one of five direct drivers of biodiversity loss at the global level. Over the past decade weed research directions have moved towards prevention and control with an increased focus on the environmental and social effects of weeds and on sustainable management. The need to transfer weed research information to where it can be applied is imperative. The IUCN SSC Invasive Species Specialist Group (ISSG) plays a leading role in bringing authoritative invasive species knowledge and experience to decision makers, conservation practitioners and communities around the world and, now to weed scientists. The ISSG aims to increase awareness about IAS and to facilitate access to information and expertise about IAS impacts on biological diversity and about prevention, control and eradication options. The Global Invasive Species Database (GISD), which is managed by the ISSG, is increasingly recognized as a standard source of invasive species knowledge and information. The GISD features current research and innovations in prevention and management as well as reports about IAS management operations. The importance of information exchange in the fight against invasive alien species will be discussed using case studies.

Distribution and harmful effect of common ragweed (*Ambrosia artemisiifolia*) in Hungary

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Ambrosia artemisiifolia L. (common ragweed) was reported for the first time from Hungary in 1888 and then again in 1910. By the 1920s, it has become established in some parts of Hungary and has started to spread in the country. According to the Hungarian Weed Surveys in wheat and corn fields, *A. artemisiifolia* occupied the 21st position on the list of the most widespread weeds in 1950, then became the 8th on the list in 1970, the 4th in 1988, and since the early 1990s, it has been the most widespread weed in Hungary. Currently it is present on more than five million hectares of agricultural land. 700'000 ha is heavily infested with common ragweed. *A. artemisiifolia* occurs in all crops and causes the highest yield loss in sunflower. Based on our surveys, 32-37% of sunflower fields is covered by *A. artemisiifolia*.

The main problems associated with the presence of *A. artemisiifolia* in Hungary are as follows: yield losses in agriculture (approx. 130 million euro per year), problems with the export of some agricultural products, human health problems, environmental protection issues, including its impact on biodiversity in protected areas, and its impact on tourism because it has become abundant in some of the most frequented touristic areas such as Lake Balaton.

Its biological characteristics greatly contribute to its spread. *A. artemisiifolia* has a good competitive ability in agricultural fields. In a replacements study, the yield loss in *Lupinus albus* reached 38%, when the proportion of *A. artemisiifolia* and *L. albus* was 3:1. In additive field experiments in maize, 26 *A. artemisiifolia* plants m^{-2} caused 71% yield loss.

In sunflower, *A. artemisiifolia* at densities of 1, 2, 5 and 10 plants m^{-2} caused 7, 11, 25 and 37% reduction in sunflower yield, respectively. *A. artemisiifolia* can be adapted to many different environmental conditions but its light requirement is high. In the intensive growth stage 6 hours shading per day considerably retarded its development and entirely prevented the flower and seed formation. Its sublethal water saturation deficit (WSD_{subl}) is high, over 70%. This means that the leaves can loose 70% of their water content without irreversible injuries. Beside good drought tolerance and competitive ability, continuous germination under field conditions, morphological and genetic variability, the appearance of the atrazine resistant biotypes and allelopathy can also contribute to its rapid spread.
Approximately 15-25% of the Hungarian citizens are allergic to ragweed pollen. In addition, the plant can cause contact dermatitis and the volatile oils of its pollen may cause photosensibility of the skin.

A. artemisiifolia can be controlled with a number of herbicides in agricultural fields. Mowing is a useful control method in rural areas, roadsides and other places. Biological control methods were also taken in consideration in Hungary. A microcyclic monoecious rust, *Puccinia xanthii*, known to infect *A. artemisiifolia* in the USA only, was proposed as a classical biocontrol agent of *A. artemisiifolia* in Europe based on the data in the literature. However, field surveys conducted in 2002-2003 in the USA and Canada could not locate any specimens in the field. Currently, we propose a North American oligophagous leaf-eating beetle, *Ophraella communa*, to be studied as a potential biocontrol agent of *A. artemisiifolia* in Europe. This work was supported by courtesy of Hungarian National Research Found (OTKA No. T046841 and T049093).

Control of *Ambrosia artemisiifolia*: disrupting lifecycle to exhaust seedbank in infested areas

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Infestation with common ragweed (*Ambrosia artemisiifolia*) has been increasing in the western part of Switzerland in several agricultural fields and along road sides for some years. It arrived in the Geneva region with the exchange of agricultural machines from France. Ragweed seeds reach private house gardens and public greens as contamination in bird seed grain. Single plants were mostly found during 2006, throughout the entire settlement area of Switzerland.

Up to 12% of the human population suffers from allergies (hay fever, asthma) to Ambrosia pollen in infested areas. A very low concentration such as 5-10 pollen spores m^{-3} of air are sufficient to trigger allergic reactions in sensitive patients. The bloom from July to October, initiated by day length, elongates the allergic season for patients. Ragweed propagates by seeds only. Federal authorities have recently declared *A. artemisiifolia* as an undesirable plant. All types of feedstuff put into circulation must be free from ragweed seeds. Ragweed control should aim to disrupt the life cycle of the plant, in order to gradually exhaust the seed bank in the infested sites. According to first experiences, ragweed quickly develops sprouts from the base of the stem if it is cut or treated with a non-systemic herbicide. These sprouts develop a smaller number of viable seeds, while an untouched mature plant produces several thousands of seeds. Agroscope Changins-Wädenswil ACW has developed strategies to control ragweed. In arable fields as well as along traffic lines, chemical, mechanical and combined methods have been tested.

The efficacy of herbicides was tested in field trials. Some soil-applied herbicides showed the best activity when applied in spring; but when applied in autumn no efficacy was observed. Contact herbicides such as glufosinate killed all green parts of the plant, but could not prevent sprouting of side stems. Efficacy seems to depend on growth stage of ragweed; clopyralid applied in the 2-6 leaf stage killed ragweed totally, but applied in bloom, it allowed ragweed to produce seeds. Results of a growth stage herbicide efficacy trial in the glasshouse are presented. It was observed that certain herbicides did not prevent the production of seeds if they are applied late, but the viability of these seeds was reduced.

To test the viability of seeds having survived an herbicide treatment or being produced after mechanical or chemical control, we developed a method to break seed dormancy. We kept seeds mixed with humid sand at 4 °C for 5 weeks. Germination rate was about 80-90 %.

In a 3 years trial with different mowing dates, we could show that one mowing early in September could prevent the production of viable seeds and therefore interrupt the life cycle of the species. Before the end of August ragweed seeds were not yet mature in the Geneva region but sprouts developed male flowers and pollen after cutting while female flowers remained empty. Mowing after the middle of September did not prevent ragweed producing viable seeds, and these were released during mowing.

Combination of treatments, including mowing in spring and herbicide application later on could be more effective than a single control method. An early cut could reduce pollen production and a late herbicide treatment could control the sprouts, preventing seed production. This combination could be important for road services, giving them a method for disrupting the plant's life cycle. Trials on optimization of the two methods are on-going and we present the first results of combined trials of mowing and herbicide application.

Evaluation of the first augmentative biological control against *Euphorbia esula*

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Euphorbia esula L. subsp. *esula*, commonly named leafy spurge, is indigenous to Eurasia where it is present in wild and cultivated areas. In the Saône Valley (France), it has been reported as a serious problem since the 1990s when farmers and practitioners noticed its unusual spread in pastures. Currently, it infests 3,500 ha of flooded grassland and could hamper the management of the meadows, affecting plant and bird diversity.

As a way of control, insects can be used to augment an indigenous population on a weed with few ecological concerns since they will fall to their original level if release is stopped. In that regard, since 2003, we made extensive surveys to collect natural enemies in leafy spurge stands with different trapping methods, i.e. sweep net, mouth aspirator and D-vac. The objective was to select the best candidate in terms of feeding impact, behaviour, field occurrence, for proceeding to an augmentative biocontrol programme.

Seven indigenous natural enemies, including a rust, were observed on *E. esula*. Insects were mainly collected from leafy spurge belonging to different families, i.e. Chrysomelidae ; Cerambycidae, Cecidomyidae, Sphingidae, and Sesiidae. Of which the cerambicyd beetle, *Oberea erythrocephala*, and the cecidomyid fly, *Spurgia* sp. were particularly studied. Natural infestations of *O. erythrocephala* larval stage ranging from 11 to 26% led us to consider this beetle as a first choice candidate. In order to build up artificial beetle populations, we reared it out on an artificial medium that is commonly used for root feeders. Five field-collected larvae were put together in one container, and observed until adult emergence. In Spring 2006, 100 field collected and artificially reared adults were released on a 10 m^2 plot covered with leafy spurge. A plot receiving no insects was a control. Damage and infestation rates were compared to controls, and will be detailed in our presentation. In addition, choice and no-choice tests were estimated, using different impact classes from 0 to 5, with *E. esula* and *E. palustris*, a protected native plant. Feeding impact and oviposition behaviour were observed. Results show a clear preference of the beetle for *E. esula* in terms of feeding damage as classes 3 and 4 were obtained, and not over class 2 for *E. palustris*. In conclusion, there is a significant impact of *Oberea* on *E. esula* and a clear preference for the beetles to feed and lay eggs on leafy spurge in a choice test. The interest of *Oberea* for marsh spurge is nearly nill in case of a no-choice-test because no laying was observed, and leaves feeding was very light .

Considerations about the future use of *O. erythrocephala* for augmentative release is discussed, together with preliminary results obtained for 2007.

Delivery of mycoherbicides through drip irrigation systems

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Drip irrigation is an efficient approach to watering that is growing in popularity. Drip irrigation systems deliver water to the crop using a network of mainlines, submains, and lateral lines with emission points (drippers) spaced along their lengths. Each dripper supplies a precisely measured and controlled uniform volume of water. Besides the advantage of a strong reduction of water usage, the application of chemicals and nutrients through these systems takes advantage of a uniform and precise distribution. A further possible application of the drip systems could be in the application of biocontrol microorganisms to the soil to protect the root systems.

One of the main problems in releasing microbial biocontrol agents is to find suitable methods of application that allow the uniform distribution of the agent at the desired site and in the desired amount. An advantage of using propagules of soil-borne pathogens, which normally infect at or below the soil surface, as biopesticides, is that the propagules may be more protected from environmental extremes or factors such as wind and UV radiation (which can negatively affect the uniformity of distribution and viability of conidia) so that they may persist and give residual control. As conidia can vary in size, length, and shape, they may not pass through the irrigation system, or their viability could be compromised by the physical passage through the drippers.

A pilot system has been designed in a greenhouse using dripper lines, drippers, filters and other tools commonly used in irrigation and precision agriculture, to evaluate their suitability for applying and distributing microbial biocontrol agents. Both thin- and thick-walled dripper lines, with different dripper spacing, and working at different pressures or at different flows were used, giving a wide range of the most used models of irrigation systems. Among the species tested, conidial suspensions of *Fusarium oxysporum* and *F. solani,* two promising agent proposed for the biological control of *Orobanche ramosa*, were used.

Experiments were carried out distributing known amounts of conidial suspensions through the irrigation systems, and then measuring the volume and CFU of the suspensions coming out of the drippers. None of the dripper lines or drippers clogged during the applications, demonstrating that the conidia can pass through the system without any problem, regardless of their size. The viability of the conidia, measured as CFUs at full capacity of the lines during the treatments was also without variation and was not influenced by the kind of conidia supplied. The CFUs at full capacity proved to be on average more constant along the line compared to the total CFUs. This suggests that some turbulence may occur at the beginning or at the end of the cycle, and that the system works well when it reaches full capacity.

The uniform and precise application of microbial particles close to the weed can have a positive influence on the success of biological control treatments. A further advantage could be the minimization of the applied doses, and then the reduction of the costs of the treatment. The use of systems or of technologies which are usually available in agriculture could have an influence in the acceptability of biocontrol agents by the farmers, and in the enlargement of their market.

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Establishment & initial impacts of *Gratiana boliviana* (Chrysomelidae), a biocontrol agent of *Solanum viarum* (Solanaceae) in the USA

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Solanum viarum Dunal (Solanaceae) is a perennial weed, originally from southern Brazil, northeastern Argentina, and Paraguay, that has been spreading throughout southeastern United States at an alarming rate since it was first detected in south Florida in 1988. *Solanum viarum* has invaded more than 400,000 hectares of improved pastures, agricultural lands, and state parks in eleven states (Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, Pennsylvania, South Carolina, Tennessee, Texas, and Puerto Rico). The rapid spread in the southeastern United States can be partially attributed to the great reproductive potential and highly effective seed dispersal by cattle and wildlife such as deer, feral hogs, raccoons, and birds that feed on fruits. The potential range of *S. viarum* in the United States can be extended even further based on studies of the effects of temperatures and photoperiod conducted by researchers in controlled environmental chambers. This invasive exotic weed was placed in the Florida and Federal Noxious Weed Lists in 1995. Although it is very difficult to estimate the real (direct and indirect) economic losses due to this invasive weed, Mullahey (unpublished data) estimated at US $11 million the annual production loss to Florida ranchers in 1993. This figure does not include vegetable-crop losses caused from pathogens transmitted by insect-vectors from *S. viarum* infested plants. Management practices for *S. viarum* are mostly based on chemical herbicides in combination with mowing practices. These control measures only provide a temporary solution, and are relative expensive. A biological control project on this highly invasive non-native weed was started in 1997 by the University of Florida in collaboration with Brazilian and Argentinean researchers. The South-American leaf beetle *Gratiana boliviana* (Spaeth) (Coleoptera: Chrysomelidae) was approved for field release in May 2003, and its release in Florida began in summer 2003. Currently, more than 80,000 beetles has been released in 25 counties in Florida, 2 counties in Georgia, 2 counties in Alabama, and 1 county in South Carolina. Evaluation of the feeding effects of the beetles on twenty marked *S. viarum* plants at each monitored site and changes in the number of beetles (immature & adults) on the plants have been made since 2003 in at least 5 of the release sites. The beetles got established in all the release sites in Florida. Beetle dispersal have been within relatively short distances and it is based on plants availability with annual beetle dispersion ranging from 1.6 to 16 km/year from the release sites. Visual estimation of the impacts of the beetles on *S. viarum* plants varied from 50 to 100% plant defoliation, and a significantly decreased in fruit production from 10-55 fruits per plant, when beetles were released in 2003-04, to zero or few (1-4) small fruits/plant after a 2 year period in at least five of the release sites monitored. The follow-up studies have been including observations on possible effects, if any, on closely related plants growing in the release area, and up to know none non-target effects have observed on plants growing in the proximity or mixed with *S. viarum*.

Global knowledge and partnership in resolving European problems – relevance and application to invasive plants

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An increase in contact, travel and trade between Europe and other continents in the last three centuries has brought great benefits through the introduction of many species that have improved the livelihoods of Europeans, productive (crops, livestock), protective (hedge plants, medicinal plants) or aesthetic (flowers, pets), but has also introduced challenges in managing those species that have proved harmful (plant pests, animal/human diseases), and been subsequently classified as invasive.

The 21st Century faces yet more challenges, through increased globalization of trade and climate change, both of which could increase the incidence of invasive plants entering Europe, and influence the management of those already having an impact. Invasive species threaten biodiversity, food security, health and economic development. Their importance and management are now widely accepted globally, spreading across governments, non-governmental organizations, and development assistance groups. Globally, the cost of damage caused by invasive species has been estimated to be € 1.6 trillion per year, close to 5% of global gross domestic product.

The exchange of scientific information and knowledge, therefore, is important in efforts to understand these species, to increase their benefits and reduce negative impacts. Many of the worst European weeds are exotics, and most are not problems in their native range. Whilst there is wealth of existing knowledge on why these species are classified as invasive and thus weeds, extended knowledge sharing and harmonization initiatives will aid decision making in Europe in the selection of control mechanisms or deciding management strategies.

The growth of the internet and the potential for universal access to information introduces opportunities for the creation of an informed and authoritative platform for invasive species knowledge. Recognising the importance of coherence and authority in invasive species information CABI and U.S.Departement of Agriculutre, in partnership, have initiated and created an international Development Consortium to bring together, and make available, global information on invasive species. Novel and powerful information technology, based on the existing experiences gained from the development of the Crop Protection Compendium (CPC), will be used to develop the world's most comprehensive multimedia knowledge base, the Invasive Species Compendium (ISC).

The ISC will serve as a platform for more efficient decision-support for exclusion, early detection and eradication, and management of invasive species. Already more than 300 full and interlinked datasheets, a review of key topics and a multiple-entry identification key for invasive plants from the CPC have provided the start point for the ISC. Partnerships are key and an over-riding objective is to compile, strengthen and unify existing invasive species databases and other information resources, which are currently highly scattered. CABI and USDA are strengthening and building partnerships, bringing in the enormous respect and expertise reflected in the Global Invasive Species Information Network (GISIN), and the Global Invasive Species Programme (GISP), and looking to closer partnerships with the European and Mediterranean Plant Protection Organisation (EPPO) and FAO. This international initiative is growing and seeks new partners.

Ambrosia artemisiifolia – a quick reaction to an invasion of Switzerland

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Common ragweed (*Ambrosia artemisiifolia* L.), a species from North America, is now an invasive species in several European regions such as the Balkan states and Hungary, the Po Valley in Italy and the Rhône-Alpes region in France. Common ragweed was presented at the 12th EWRS Symposium in Budapest as a new and very problematic weed in Hungary. It was predicted that this weed will cause in the near future big problems for agriculture in other European countries. In infested European regions people begin today to suffer from allergies as the quantity of pollen in the air increases. This increase of pollen is caused by an enormous and fast propagation of ragweed in infested areas and a rapid distribution to non-infested areas.
Results of a 2005 survey on presence of ragweed in Switzerland were confirmed in 2006. *A. artemisiifolia* is present mostly as single plant stands in the entire settlement area of the country, introduced basically by bird seed grains.

In the western part of Switzerland, it has also been introduced by agricultural machines, such as harvesters, from France and is now present in several agricultural fields and along road sides. With soil movements, traffic and transport of goods, ragweed seeds are distributed to all zones of human activities. An information campaign of the research station Agroscope Changins-Wädenswil (ACW) initiated manifold activities against ragweed in Switzerland. Highly motivated people control their gardens and help to curb the invasion.

Federal authorities have declared *A. artemisiifolia* as an undesirable plant. In 2005 the Federal Department for Economic Affairs adapted the ordinance on animal feedstuff with the restriction that all type of feedstuff put into circulation must bee free from ragweed seeds. 2006 the Federal Council amended the ordinance on plant protection and declared *A. artemisiifolia* subject to official control. Agricultural advisory services are now forced to control every focus of contamination in the fields because of the invasive behaviour of common ragweed.

Since 2003, Agroscope ACW has been performing efficacy trials with herbicides registered in Switzerland. These results were published in agricultural journals. We have also carried out mowing trials since 2004. We assessed plant regeneration and seed production after various dates of cutting. First observations show that a unique cut in the first half of September can break the plant life cycle and prevent seed production. Next years trials aim to prevent both, pollen and seed production. For the general public we recommend eradicating common ragweed by hand wearing gloves – and a mask and as soon as it flowers – and putting it immediately into the garbage bag, if up to 20 plants are found. A focus of > 20 plants should be eradicated immediately by specialists. Composting of ragweed is not allowed. The sites must be controlled in the following year.

The poster shows the actual distribution of *A. artemisiifolia* in Switzerland. It also demonstrates legal aspects and the concerted action in the country as well as the control methods given to the public.

Impact of tillage on *Commelina benghalensis* L. management

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Commelina benghalensis L. (a.k.a. tropical spiderwort or Benghal dayflower) is an exotic invasive weed that poses a major threat to agricultural production in the U.S.A. *C. benghalensis* is listed as a U.S.A. federal noxious weed and was identified among the world's worst weeds, negatively affecting 25 crops in 29 countries. Studies were conducted at the University of Florida, West Florida Research and Education Centre, Jay, FL, and at the University of Georgia, Tifton, GA, U.S.A. in an area naturally infested with *C. benghalensis* to determine the effect of tillage and herbicides on management of *C. benghalensis*. Peanut and cotton were grown under two tillage regimes: 1) conventional tillage which included use of a moldboard plough, disk and field cultivator prior to planting and; 2) reduced tillage which included use of a strip-till implement fitted with an in-row subsoil shank, closing discs, and rolling baskets. The strip-tillage operation left at least 50% of the soil surface undisturbed. Cotton in the study area was treated with the herbicides pendimethalin applied preemergence followed by metolachlor plus glyphosate applied early postemergence to cotton with three to four leaves. Peanut was treated with pendimethalin preemergence followed by metolachlor plus gramoxone early postemergence. Mid-season weed counts indicated a lower *C. benghalensis* density in the conventional tillage area (3 plants m^{-2}) compared with the strip-tillage area (60 plants m^{-2}) in both cotton and peanut. In a second study three levels of tillage prior to cotton planting were compared. In a second study, three levels of tillage prior to cotton planting were compared. In addition to conventional and strip-tillage, an intermediate level of tillage (para-tillage) was included. *C. benghalensis* density increased as level of tillage decreased (conventional tillage = 3 plants m^{-2}, para-tillage = 9 plants m^{-2}, strip-tillage = 17 plants m^{-2}). A third study was conducted to evaluate the depth of emergence of *C. benghalensis* seedlings. Soil cores were collected and 100 seedlings without any true leaves were used to evaluate the depth of emergence, based on the position of the seed relative to the soil surface. Seedlings emerged from depths ranging from 0.1 to 6.5 cm and averaging 2.02 cm.

Shoot and root system responses of the invasive aquatic plant *Myriophyllum aquaticum* to hydroregime and nutrient availability

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Myriophyllum aquaticum (Vell.) Verdc. (Haloragaceae), once introduced as ornamental aquarium plant species, is known for more than 20 years in European waters. About 10 years ago it has become a problematic species in Western and Southern Europe, clocking irrigation and drainage channels and becoming locally dominant in native vegetation. In a series of rhizotron experiments, allowing non-destructive measurements of root system development over time as well as measurements of above ground biomass, we looked at above and below ground growth responses of this species to three water levels (10 cm above soil surface to create anoxic soil conditions, completely drained soil with aerobic conditions, and a water level 20 cm below soil surface creating intermittent conditions) and high (humic soil with 56 mg NO_3-N per kg soil and 20 mg extractable P per 100 g soil) or low (2/3 sand, 1/3 humic soil with 18 mg NO_3-N per kg soil and 4.5 mg extractable P per 100 g soil) nutrient availability under Central European climatic conditions. Total biomass increased with increasing water level from 5 g dry weight per plant (g_{DW} plant^{-1}) under drained to 16 g_{DW} plant^{-1} under flooded conditions as well as shoot (from 4 to 15 g_{DW} plant^{-1}) and root biomass (from 0.5 to 1.4 g_{DW} plant^{-1}). Total shoot length of *M. aquaticum* increased from 250 cm per plant to 840 cm per plant with increasing water level under high nutrient availability and from 80 to 190 cm under low nutrient availability. Low nutrient availability increased root:shoot ratio from 0.09 to 0.16. Root system development of *M. aquaticum* showed a large plasticity with respect to water level and nutrient availability: Plants showed a shallow, laterally spreading root system when growing in flooded soil and a narrow but deep growing root system when cultivated under drained conditions. Root growth rate under drained conditions was 1 cm per day. Root aerenchyma increased with increasing soil water level from 17% growing on drained soil to 28% in shallowly flooded soil. Shoot aerenchyma was higher on humic soil (20%) than on sand-humic mix (16%). Global change models postulate a climatic scenario for Central Europe with increasing temperatures and increasing water level fluctuations. Eutrophication of European wetlands as a result of diffuse nutrient sources originating from agriculture, industry and traffic has already caused changes in wetland ecosystems. The preference of *M. aquaticum* for nutrient rich sides and its ability to grow not only submerged as an aquatic species but also emerged in shallow water and even as a terrestrial plant on drained soil enables this species to be a potent invader of Central European wetlands and waters.

Response of four potential invasive New World helophytes to different hydroregimes and soil temperatures

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Introduction of non-native plants is one of the major aspects of global change. One source of introduction is for use as ornamental plants. In our study we looked at the responses of four North American species used frequently as ornamental plants in garden ponds and aquariums to changes in hydroregime and soil temperature to get information about the preferred growth conditions under Central European climatic conditions. *Ludwigia grandiflora* (Onagraceae)*, Lobelia cardinalis* (Campanulaceae)*, Pontederia cordata* (Pontederiaceae)*,* and *Saururus cernuus* (Saururaceae) were cultivated in pots with three different water levels: a) drained, b) water level at 15 cm below soil surface (medium), and c) water level 5 cm above soil surface (high). In additional experiments the four species were cultivated in containers with a water level at 5 cm above soil surface with three different substrate temperature regimes: a) ambient, b) 5 °C above ambient, and c) 10 °C above ambient. The four species differed in their preferred hydroregime and temperature response. *Ludwigia grandiflora* and *S. cernuus* increased total biomass with increasing soil temperatures by 15% and 19% respectively. Total biomass of *P. cordata* was twice as high growing under increased soil temperature compared to the ambient soil temperature regime, probably due to a 25% increase in CO_2-net assimilation rates in this species with increasing soil temperature. In *L. cardinalis,* total biomass decreased with increasing soil temperature (-33%), as well as net assimilation rates. All four species perform slightly better under medium to high water levels than on drained soil: *L. grandiflora* increased total biomass by 33%, *L. cardinalis* by 45%, *P. cordata* by 56%, and *S. cernuus* by 32%. In *L. grandiflora, L. cardinalis,* and *S. cernuus* CO_2-net assimilation rates increased with increasing water level. *Pontederia cordata* CO_2-net assimilation was not influenced by water level. However, all species were able to grow also under drained conditions. While *L. cardinalis,* in its native range pollinated chiefly by hummingbirds, invested more than 25% of its total biomass into inflorescence biomass and only 15% into rhizomes and shoot bases, the other three species invested much more biomass (55 – 70%) into rhizomes and shoot bases, and therefore vegetative reproduction. While *L. grandiflora* is already on its way to spread out in Central Europe, *P. cordata* and *S. cernuus* are only known from a few locations in Central Europe. But with increasing temperature and water table fluctuations under the predicted global change scenarios, these two species could also become invasive. For *L. cardinalis* there are no field records at the moment, probably mainly due to the lack of effective pollinators.

A bioherbicide system for torpedograss management in Lake Okeechobee, Florida: summary of three years of field trials

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Torpedograss is one of many invasive weeds that displace native plants in Florida wetlands and choke shallow lakes such as the Lake Okeechobee. Torpedograss is difficult to control because of its tolerance to chemical herbicides and its ability to regrow from rhizomes following chemical control, mowing, or burning. Use of host-specific pathogens as bioherbicides may provide an effective nonchemical option to manage this troublesome weed. We have developed a novel strategy to control weedy grasses by using three fungi indigenous to Florida, *Drechslera gigantea, Exserohilum longirostratum*, and *E. rostratum*, which are applied either alone or in a mixture. In efficacy trials conducted in a greenhouse, *Drechslera gigantea* was highly effective against torpedograss (*Panicum repens*). Thirty-six different species of crop plants grown in Florida and the USA, 22 other cultivated, and native or naturalized plant species were tested, and found to be unharmed by both the individual pathogens tested and a mixture of the three pathogens. Therefore, the bioherbicidal use of these fungi would not pose any threat to non-target plants grown in the vicinity of treated areas. Given the susceptibility of torpedograss to the bioherbicide system, we have evaluated the long-term efficacy of the bioherbicide system to manage torpedograss over three years (2002-2004) under field conditions, and integrate the bioherbicide system with chemical control being practiced in Lake Okeechobee, FL. In summary, the bioherbicide system effectively controlled torpedograss under field conditions over a period of nearly 2 years (20 months; 2 to 3 applications per year), and weed control is selective i.e., it does not harm other desirable native species tested in greenhouse, and those found at the field site. The bioherbicide could be integrated with chemical herbicide application (single application of Arsenal at 64oz/A; dry or wet soil conditions at field site, followed by 2 applications of the bioherbicide in the following year). Natural recruitment of native plant species occurred in bioherbicide treated torpedograss plots. Chemical herbicide (Arsenal at 64oz/A applied aerially once) application was not selective to torpedograss, and killed all vegetation present at the field site. Regrowth of both torpedograss and natives occurred about 6 months after chemical application. But, bioherbicide application following chemical application controlled torpedograss selectively, allowing the natives to remain healthy and allow for natural recruitment. Revegetation with some selected native species (plant species that are fast growing, and competitive to torpedograss) will possibly help reclaim the field site treated with bioherbicide alone or in combination with a single application of chemical herbicide. We are currently seeking help from any agency or industry partner to license the technology from University of Florida to get the bioherbicide registered and made available for large-scale use.

Preventing introductions of exotic vascular plant species to Alaska

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Alaska, known for vast wilderness, is being irrevocably changed by invasive plants. The number of exotic plant species in Alaska increased 60% since 1968. Exotic plants causing impacts to Alaska ecosystems include *Melilotus alba*, *Viccia cracca*, and *Hieracium aurantiacum*. However, the number of invasive plants in the Alaska flora is still low compared to more southerly regions. Prevention is the most cost-effective strategy to negate impacts from additional invasive species. Because exotic species can reach Alaska through a number of different pathways, it is important to know the importance of each to determine the pathways to regulate first. Two pathways were studied: 1) Soil shipped with ornamental plants; 2) weeds in imported hay and straw. Stores selling ornamental plants and hay and straw were surveyed to determine origins and amounts sold. For ornamentals, 3 containers were obtained from 53 sources. Soil samples from each container were incubated under greenhouse conditions. Seedlings that emerged were counted and identified at anthesis. Soils contained 0–167 seedlings L^{-1}. Mineral soil contained more weed seedlings than artificial potting soil (22 vs. 1 seedling L^{-1}). To determine the number and species of exotic plants entering Alaska through hay and straw, 3 bales of hay and straw were purchased from 31 import sources. Bales were screened over 0.6 and 0.3 cm mesh. Two 40 g samples of the resulting fines were collected from each bale, mixed with 750 g sterile potting soil and incubated in a greenhouse. Seedlings were counted and identified at anthesis. The number of weed seedlings in hay ranged from 0 to 3409 kg^{-1}. Fifty-one exotic species were found.

The weed supressive potential of the decay products of three marigold (*Tagetes* L.) species

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Allelopathic interactions between cultivated plants and weeds have been traditionally considered as harmful for the former. However, recent achievements in allelopathic studies has demonstrated that allelochemicals of cultivated plants could be succesfully used for weed control. This approach gains importance as farmers try to adopt alternative weeding techniques, which rely less on chemical herbicides. Among the species possible as donors of weed-suppressive allelochemicals are ornamental annuals of marigold species (*Tagetes* L.), which were shown to produce large amounts of biologically active secondary metabolites (flavonoids, phenolic acids, terpenoids, polythienyls) with fungicidal, bactericidal and nematocidal properties.

The aim of this study was to assess the weed-suppressive potential of the decay products of three ornamental species of marigold (*Tagetes erecta, T. patula, T. signata*) in dynamics using modeling laboratory and plot experiments. The latter was conducted on the plantations of lily (*Lilium* × *hybrida*) monoculture at "M.M. Gryshko" National Botanical Garden (Kyiv city). The soil for the laboratory experiment modeling decomposition of marigold phytomass was collected from between the rows of lily monocultures in early spring. Immediately after addition of marigold phytomass to the soil and afterwards regularly (within a period of 7 days) soil samples were collected and tested for allelopathic activity by the direct bioassay method. The duration of the laboratory experiment was 140 days and the plot experiment lasted 60 days. The microbiological analysis of the soil before marigold phytomass incorporation and at the end of each experiment was also conducted.

These studies showed that the weed suppressive effect of decay products of the marigold plants observed in the plot experiment correlated with the results of the laboratory study. The dynamics of the weed suppressive effect of decay products of the three marigold species in both experiments were characterized by a sharp increase of phytotoxic allelopathic effects during first 2 to 4 weeks of decomposition, with subsequent gradual decrease and change to stimulation. However, the degree and duration of each of the above phases differed depending on species of marigold.

Most species of weeds found on the experimental plots were sensitive to decay products of the marigold phytomass. High sensitivity to marigold decay products was shown by such widespread and noxious weeds as *Elytrigia repens, Convolvulus arvensis, Galinsoga parviflora, Portulaca oleracea, Capsella bursa-pastoris,* and *Stellaria media*. However, *Digitaria sanguinalis* and *Senecio vulgaris* were tolerant to the addition of decay products of marigold. Marigold decay products incorporated into soil did not affect the phytomass accumulation of lily plants. In the both plot and laboratory experiments decay products of *T. patula* and *T. erecta* were more effective against weeds than those of *T. signata*.

Microbiological analysis of samples of soil used in the laboratory and plot experiments showed that allelopathic excretions of the decay products of *T. patula* and *T. signata* considerably reduced soil infestation by micromicetes of *Fusarium* genus, which includes noxious phytopathogenic species, while decay products of *T. erecta* slightly affected these micromictes. We consider *T. patula* and *T. erecta* to be promising for utilization as weed suppressive mulches, while mulches of *T. patula* and *T. signata* are promising for control of soil infestation by micromicetes of *Fusarium* genus.

How *Conyza albida* (Willd. ex Sprengel) invades the crops and urban ecosystems in Greece

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The introduction of plant species to areas beyond their natural distribution has been a global phenomenon that poses critical problems for the conservation and management of many agricultural and natural ecosystems. The genus *Conyza* provides one of the foremost examples of the intercontinental plant invasions from the New to the Old World; *C. albida* (horseweed) is now among the most widespread species found in waste dumps, vineyards, orchards, and in natural ecosystems in a variety of biogeographic regions. In Greece, it is characterized by a rapid and vigorous growth in orchards, vegetables, alfalfa, and in no-tillage areas, while its high dispersal potential enables its establishment as a permanent weed of the urban landscape.

C. albida populations, from agricultural (alfalfa and apple orchard) and ruderal habitats, were sampled in September 2001. The plants were randomly collected from each population and measured for the following characters; inflorescence length, number of capitula per plant, mean number of achenes per capitula, mean number of achenes per plant, and the percentage of germinated seeds on each plant. Seedlings were transplanted during 2002 into pots and kept out in the field to overwinter at the rosette stage. At the end of their maturity the traits referred above were measured. The populations originating from the agricultural habitat had a larger inflorescence, greater seed set and seed germination than the ruderal ones. The populations differed among the different ecosystems in their life history traits suggesting that environment mainly determined the reproductive characters.

The invasion of horseweed in turfgrasses was evaluated through the study of the allelopathic influence of horseweed on the main turf species such as, *Poa pratensis, Lolium perenne, Festuca arundinacea, Pennisetum clandestinum* and *Dichondra repens*. The study included in vivo experiments as well as in vitro bioassays, evaluating the inhibitory action of horseweed's plant tissues on the growth and the radicle development of the turfgrasses. Inhibition of growth was found to be species-specific. The estimated reduction of target plant root biomass indicated that *P. pratensis* was more sensitive and *P. clandestinum* was the most resistant species to the horseweed's residues. The extracts from the dried horseweed residues significantly inhibited the root growth of all the species when they were tested in Petri dishes bioassays. The five species exhibited differential response to the increasing extraction rates and the inhibitory estimate for 50% reduction of root length (I_{50}) demonstrated further the sensitivity of *P. pratensis* and the tolerance of *P. clandestinum.* The occurrence of tolerant species should be used as a potential natural control on the dispersal of this highly invasive species.

Evaluation of *Alternaria cirsinoxia* for the biocontrol of *Cirsium setosum*

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Thistle (*Cirsium setosum* [Willd.] Bess.) is an extremely harmful and widespread perennial weed belonging to the Asteraceae. During the last few years, *Alternaria* species have been studied as potential biocontrol agents of this weed. There are many publications dealing with *Alternaria* spp. that were tested as mycoherbicides. For instance, *A. alternata, A. cassiae*, *A. eichhorniae, A. macrospora*, *A. helianthi* and *A. cirsinoxia* were successfully examined.

Almost 30 *Alternaria* species have been described as pathogens of plants from the Asteraceae (Simmons, 1997), apart from a group of non-specialised saprotrophs. Two representatives of the genus, *A. cirsinoxia* Simmons et Mortensen and *A. nattrassii* Simmons, are associated with *Cirsium* spp. They were found in North America and Europe, respectively. A strain of *A. cirsinoxia* from Canada was found to be a prospective biocontrol agent by Green and Bailey. Its host range was limited to species within the Asteraceae. However, it was primarily pathogenic on older, senescent leaves of *C. arvense* and did not produce spores in liquid culture. Within *Alternaria* species we isolated from leaves and stems of *C. setosum*, two ubiquitous non-selective pathogens, *A. tenuissima* and *A. infectoria,* were dominant. One fungal strain (C-363) isolated from *C. setosum* leaves collected in Kyrgyzstan was identified as *A. cirsinoxia*. This is the first report of this species from Eurasia. Our research goal was to assess the possibility of using the C-363 strain to develop a mycoherbicide. Strain C-363 of *A. cirsinoxia* was highly pathogenic on *C. setosum*. Inoculation of 10-mm leaf discs by a conidial suspension (10,000 conidia ml^{-1}, 10 l $disc^{-1}$) induced symptom appearance after 1 day and whole disc death after 3 days. Lower concentrations (1,000 conidia ml^{-1}) were less effective (< 0.01), but after 5 days the leaf discs died and sporulation of the fungus started. All four tested clones of *C. setosum* were equally susceptible to the pathogen (= 0.99). No difference in severity of necrosis was found between leaves inoculated on the upper or lower side and when leaves were untouched or wounded.
The infection of whole thistle plants was achieved by inoculation of 3-week-old plants with 2 ml of a suspension containing at least 1000 conidia ml^{-1}. The main target of infection was mature leaves. The youngest leaves always remained symptomless and were capable of subsequent growth.

The host range of *A. cirsinoxia* was tested by inoculating eight species, from four different families. Three of four species within the Asteraceae, *Cirsium setosum*, *Cichorium intybus* and *Arctium tomentosum,* were infected. However, the necrosis severity of non-host plants was lower than that of thistle ($p < 0.001$). Conidia of *A. cirsinoxia* did not infect *Sonchus arvensis* or plants from the Poaceae and Apiaceae. Treatment of tomato induced weak leaf blight with a severity of 9%, but the fungus was not isolated from necrotic spots.

The fungus had rapid growth on many media. Abundant sporulation occurred on V-8 or V-4 juice agar under NUV light. Conidium germination was observed within a wide range of temperatures: more than 95% of conidia germinated at 6-39 °C for 8 h. An optimal temperature is ca. 24 °C . Illumination did not influence the conidial germination rate.

In general, our results supported published data that *A. cirsinoxia* is an aggressive specialised parasite of thistle. However, treated plants can recover by developing new leaves. Thus *A. cirsinoxia* has limited potential as a mycoherbicide.

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Combined effects of herbicides and rust fungi on *Rumex obtusifolius*

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The rust fungus *Uromyces rumicis* (Schumacher) has been investigated as a potential biocontrol agent for the perennial grassland weed *Rumex obtusifolius* L. in Europe for a number of years. Although rust infection reduces plant growth, it does not kill the plant, cannot infect the young leaves, and causes only a moderate reduction in seed production. Thus, it is unlikely to be a successful biocontrol agent on its own. Therefore, studies were carried out to see if low doses of a number of herbicides could have a synergistic effect when combined with the rust fungus. Such effects have been shown, particularly with asulam, in some other systems.

Preliminary experiments looked at the effect of dicamba, asulam, thifensulfuron-methyl, fluroxypyr and triclopyr on *U. rumicis* germination in petri-dishes. When good (i.e. > 80%) rust germination was achieved then the herbicides at 1 in 81 dilution had no effect on germination rate. However, when only 50% germination was achieved the 1 in 81 dilution [all dilutions from stock concentrations of 5.6 g a.i. asulam l^{-1}, 12 g a.i. dicamba l^{-1}, 7.2 g a.i. triclopyr l^{-1},1 g a.i. fluroxypyr l^{-1} and 0.248 g a.i. thifensulfuron-methyl l^{-1}] dicamba, asulam and triclopyr increased germination to about 60%. With 15% natural germination, 1 in 300 dilution asulam, dicamba and thifensulfuron-methyl increased germination to 25-30%. However, all dilutions (down to 1 in 300) of these herbicides also increased the proportion of germinating spores with deformities, including the germ tube twisted round the spore, low growth, branched or doubled germ tube, twisted and knotted germ tube.

Therefore, the effect of a 1 in 300 dilution of asulam, dicamba and thifensulfuron-methyl on rust pustule density in the field was studied. *R. obtusifolius* plants were infected with *U. rumicis* at full strength (22.7 mg spores 15 ml^{-1} Fluorinert, and inert fluorocarbon carrier used previously to infect *R. obtusifolius* with this fungus), or 1/3rd or 1/6th strength spore suspension and sprayed 2 h later with the 1 in 300 dilution of the herbicide. After 8 days the pustule density on equal-aged leaves was measured. Although spore suspension dilution had a significant effect on rust pustule density, herbicide had no effect.

The effect of herbicide and rust fungus on the plants was investigated. Six-week-old plants were infected on all leaves with *U. rumicis*, using the full-strength solution above. One day later plants were sprayed to run-off with a 1 in 300 dilution of the stock solution of asulam or thifensulfuron-methyl. Plants were harvested after 2 months, and root and shoot dry weight measured. Rust infection alone produced a 46% reduction in root and shoot weight. Asulam alone produced a 9.5% decrease in shoot weight, and no effect on the roots; combined with the rust it produced a 65% reduction in shoot and 64% reduction in root weight. Thifensulfuron-methyl alone produced a 39% reduction in shoot weight and 17% reduction in root weight; combined with rust infection it produced a 62% reduction in shoot weight and 65% reduction in root weight. In both cases, the effect of the herbicide was additive to that of the rust infection, and no synergistic effects were observed.

In conclusion, a number of herbicides, applied in very low concentrations, were able to stimulate spore germination of *U. rumicis* otherwise showing a low germination rate. However, this effect was reduced by the increase in germination abnormalities observed with application of herbicides. In the field, low doses of asulam, dicamba and thifensulfuron-methyl did not affect pustule density, and low doses of asulam and thifensulfuron-methyl showed an additive effect with that of the rust on reducing root and shoot weight of *R. obtusifolius*. Thus, these herbicides have some potential to be included in the spore suspension used to treat *R. obtusifolius* plants.

Evaluation of the fungus *Ascochyta sonchi* for biological control of *Cirsium arvense* and *Sonchus arvensis*

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Cirsium arvense (Canada thistle) and *Sonchus arvensis* (sow thistle), perennials from the family Asteraceae, are common troublesome weeds worldwide. The control of these weeds with chemical herbicides and mechanical practices is difficult due to their vigorous root regeneration capacity. The development of more ecological cropping systems has intensified interest in the biological control of these weeds. Fungal pathogens from thistles were collected in different regions of Russia and Former Soviet Union and were screened for possible biocontrol activity. The fungus *Ascochyta sonchi*, causal agent of brown leaf spot disease of both thistle species, was selected and evaluated as a biological control agent for them. Solid state fermentation with *A. sonchi* on millet was used to obtain conidia. A preliminary controlled environment study of the pathogenicity of 17 isolates of *A. sonchi* from some regions of Russia and Moldova, using leaf disks, resulted in identification of seven of the most pathogenic isolates. We selected one *A. sonchi* isolate (17.46) from Leningrad region (north-west of Russia), three isolates (32.54.1-3) from Voronezh region (central part of European Russia) and two isolates (m-7 and m-8) from Moldova to study their degree of pathogenicity on two different Canada thistle clones (G-1 and C-2). Clone G-1 reacted similarly to all isolates of *A. sonchi* (the mean necrotic leaf disk area was higher than 50% on 7 day after inoculation). *A. sonchi* strains m-7, m-8, 32.54.1 and 32.54.2 showed a high degree of pathogenicity on all clones. The degree of pathogenicity of the isolates 17.46 and 32.54.3 was significantly reduced on the C-2 clone compared to G-1. It is known that Canada thistle ecotypes are distinguished by their reaction (from resistant to moderately susceptible) to *Puccinia obtegens*. To overcome differences in ecotype susceptibility a mixture of spores of different isolates should be applied. In greenhouse conditions, isolate 17.49.3 (recovered from *Sonchus arvensis*) and m-8 (recovered from *Cirsium arvense*) led to a high (up to 100% on 7 day after inoculation) necrotic leaf surface of *S. arvensis* and *C. arvense*, respectively. Both strains at cross inoculation damaged as the species from which they had been isolated, and alternative ones. With a 48-h leaf wetness period and at a concentration of 2 x 10^6 spores ml^{-1}, the first necrotic lesions were observed on leaves 2 days after inoculation. Seven days after application the strain m-8 killed 40% of Canada thistle plants (3-weeks old) and strain 17.49.3 killed 75% of sow thistle plants. However, in semi-field trials the disease severity in the thistles caused by both strains was low (5-25%). Their pathogenicity was not significantly enhanced by higher conidial inoculum concentration (1 x 10^7 spores ml^{-1}) and inoculum formulations that contained 10% rape oil. Further search and selection of more aggressive isolates is needed. This work was supported by the grant ISTC 2939.

Comparative investigations of life cycle, regeneration capacity, growth and photosynthesis of four invasive aquatic plant species

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In the last decades, a number of alien aquatic plant species has become established in West- and Central Europe. Some species do not cause any problems for the native flora and the human use of water bodies (e.g. for fishing, shipping, rowing and swimming), but other species have become a serious problem. Four of these invasive aquatic plant species (*Crassula helmsii* (Kirk) Cockayne, *Hydrocotyle ranunculoides* L. fil., *Ludwigia grandiflora* (Michaux) Greuter & Burdet and *Myriophyllum aquaticum* (Velloso) Verdc.) were investigated in 2005-2006. Life cycles of *H. ranunculoides* and *L. grandiflora* reveal that this species are not evergreen in most cases. In spring, both species grow up from stem fragments and roots. Under protected circumstances, if the water is not covered by ice, particularly *H. ranunculoides* generates small underwater shoots and sprouts in spring from these small over wintered plants. *Myriophyllum aquaticum* over winters either as a submerged plant or the plant grows up from fragments in spring. Only *Crassula helmsii* is a real evergreen species. Species show significant differences in the capacities to regenerate from single leaves, nodes with attached leaf, and nodes without attached leaf. While *L. grandiflora* and *M. aquaticum* show a high regeneration capacity, even by developing new shoots from single leaves, *H. ranunculoides* and *C. helmsii* do not show this ability. All tested species have the ability of forming new shoots from single nodes (with or without leaves), even if this ability is different between the tested species. Species differ in relative growth rates (RGR), especially with respect to nutrient availability. RGR of *H. ranunculoides* was 0.005 g g^{-1} d^{-1} with low nutrient availability and 0.132 g g^{-1} d^{-1} with high nutrient availability, which was significantly higher than maximum growth rates of the other tested species. Species differenced in temperature and light optima of net assimilation rates (µmol CO_2 per hour and dry weight [µmol CO_2 * h^{-1} g dw $^{-1}$]):

- *Hydrocotyle ranunculoides* leaves reach maximum photosynthetic rates of up to ~ 3500 µmol CO_2 * h^{-1} g dw $^{-1}$ (25 – 35 °C and light saturation ~ 800 µmol photons m^{-2} s^{-1}),
- *L. grandiflora* up to ~ 2200 µmol CO_2 * h^{-1} g dw $^{-1}$ (25 – 35 °C and light saturation at ~ 700 µmol photons m^{-2} s^{-1}),
- *M. aquaticum* ~ 400 µmol CO_2 * h^{-1} g dw $^{-1}$ (27 – 37 °C and light saturation at ~ 900 µmol photons m^{-2} s^{-1}) and
- *C. helmsii* up to ~ 200 µmol CO_2 * h^{-1} g dw $^{-1}$ (23 – 30 °C and light saturation at ~ 300 µmol photons m^{-2} s^{-1}).

In this regard, *H. ranunculoides*, *L. grandiflora* and *M. aquaticum* has to be considered as species preferring high light intensity and high temperatures, whilst *C. helmsii* was negatively affected by intense sunlight. Considering the presented results, we assume that *H. ranunculoides, L. grandiflora,* and *M. aquaticum* will profit from the predicted climate change scenarios with increasing temperatures and become invasive also in Central Europe. *Crassula helmsii* is at least locally invasive in Central European waters.

Introduced plant species in the surroundings of the Belgrade (Serbia) urban area

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The floristic investigations carried out in the last few decades in different parts of the Belgrade suburban area showed an increase in number of non-indigenous plant species (Bogojevic, 1968; Tomanovic, 2004). Recently, a total of 120 taxa of alien vascular plants with domination of *Asteraceae* (22 species) were found in the whole urban and suburban territory of Belgrade (Tomanovic, 2004). Among them the most invasive species are *Ambrosia artemisifolia* L.*, Asclepias syriaca* L.*, Reynoutria japonica* Houtt. and *Sorghum halepense* L. These non-native species caused the quantitative and qualitative floristic changes, especially in the natural steppe fragments in the north-eastern part of Belgrade. In this region 335 plant species have been recorded recently (Jakovljevic, 2006) in comparison to the previous data of 433 species (Bogojevic, 1968), being the loss of 22.5%. According to the present analyses there are 32 introduced species, while 6 of them are recorded for the first time in Belgrade urban and suburban localities (*Lycium barbarum* L., *Maclura pomifera* (Rafin.) C.K. Schneider, *Mahonia aquifolium* (Pursch.) Nutt., *Morus nigra* L., *Solidago gigantea* Aiton, *Triticum aestivum* L.). The introduced species, especially invasive ones (*S. halepense*, *A. artemisifolia,* etc.), caused not only the floristic changes of vegetation and disturbance of suburban ecosystems diversity, but also the habitat degradation in general. Comparative analyses of distribution pattern of already confirmed and newly found species, native and non-native ones, showed a rate of the introduced or alien plant species 10 times higher then earlier. Considering the natural steppe characteristics of the investigated area, a remarkable decrease (approximately 50%) was found in species of Pontic-South Siberian origin (*Astragalus contortuplicatus* L., *Astragalus onobrychis* L., *Euphorbia nicaensis* All. subsp. *glareosa* (Pallas ex Bieb.) A.R. Sm., *Potentilla cinerea* Chaix ex Vill., etc.) and a conspicuous increase of Cosmopolitan species (*Galium aparine* L., *Malva sylvestris* L., *Sonchus arvensis* L., *Setaria glauca* (L.) Beauv., etc.) (5-times bigger now). We observed minor changes in the number of species of transitional Mediterranean-Continental and Central European type of distribution. These qualitative floristic changes in investigated area indicate the trends of habitat to uniformity with domination of cosmopolitan and introduced species.

Invasive species in Hungary in context of investigations and research

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In Hungary, the change of weed flora was continuously surveyed by the National Weed Surveys since 1947. On this basis it can be concluded, that the number of weed species decreased, but the importance and dominance of invasive alien species have highly increased.

Out of the 2400 plant species of Hungary, 700 are considered to be neophytes. They were introduced into Europe since 1492, after Columbus had discovered America.

The majority of neophytes (ca. 600 species) are not a real threath, because they remain limited in small populations (e.g. *Senecio inaequidens* DC.), or they disappeared quickly after their first appearance (*Amaranthus spinosus* L.*, Mimulus guttatus* FISCH. Ex DC.) in Hungary.

Plant invaders originated mainly from North-America (e.g. *Ambrosia artemisiifolia* L.*, Conyza canadensis* (L.) CRONQ.*, Amaranthus spp., Asclepias syriaca* L.). Ten percent of the neophytes (71 species) are considered as invasive alien species. Thirty three species are able to change the characteristics of both the natural flora and agro-ecosystems. *Amaranthus retroflexus* L.*, A. Chlorostachys* Willd.*, C. canadensis, Cyperus esculentus* L.*, Iva xanthiifolia* NUTT.*, Panicum ruderale* (KITAG.) LYSOV*, Sorghum halepense* L. are able to transfer only on arable land. 19 % of the invasive aliens in Hungary belong to the Phanerophyta (e.g. *Ailanthus altissima* MILL.*, Robinia pseudo-acacia* L.*, Acer negundo* L.), 23 % belong to Hemikriptophyta (e.g. *Phytolacca americana* L.), 10 % belong to Geophyta (e.g. *S. halepense, A. syriaca*), 3 % belong to Hemitherophyta (e.g. *Oenothera biennis* L.) and 46 % belong to Therophyta (e.g. *A. artemisiifolia, C. canadensis, Echinocystis lobata* MICHX.). 28% and 11% of the invasive species belong to Asteraceae and Gramineae, respectively. 61% of the invasive species belong to other 28 families, but at most 3 species per family.

The main questions for the research on plant invasions are the following: 1. Which characteristics make the species suitable for invasion, 2. Different resistance of the plant associations to invasion, 3. Harmful effects of the invasive species, 4. Protection possibilities to control invasive species.

Enhanced import, opened borders (travelling, tourism, international trade), the lack of natural enemies, global warming, ecological and green corridors (artificial and natural streams, flood-plains, dams, roads, railways, forest belts) do participate in the invasion processes. Most plant invaders are dangerous to ecological balance of biotic communities, nature conservation areas, to our rare and protected plant species and biological diversity. They can cause human health problems (e.g. pollen allergy of *A. artemisiifolia, I. xanthiifolia*). Invasive weeds may considerably reduce crop yields. Their indirect harmful effect as alternative hosts of plant pests and pathogens may also be important.

In Hungary, we have investigated in many invasion studies the relation between invasive ability and biological characteristics of weeds. A long germination periode under field conditions, broad ecological amplitude, high phenological and genetical variability, high biomass production, considerable vegetative and generative reproduction, low proportion of the self pollination, seeds/achenes spreading by wind and human activitites, considerable competitive ability, good drought tolerance, resistance to herbicides and allelopathy are the main characteristics to favour invasion. Prevention of their future spreading, national and international contacts, provisions of law, planting of native trees (against *A. altissima*), regular soil cultivation (against Hemikryptophyta and *Solidago* species), agrotechnical methods (e.g. crop rotation, stubble treatment), mechanical methods (removing, mowing, grazing etc.), chemical and biological methods as well as combined treatments may be effective for the control of invasive alien species.

Peculiarity of weed risk assessment for Ukraine

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The present urgent ecological problems in Ukraine are the decrease of biological diversity and phytopollution. Both of these problems are closely related to each other and to the problem of anthropogenic disturbance of natural vegetation. Therefore they should be solved simultaneously. Unfortunately, in Ukraine such an approach is absent. The researchers of a temporary joint group from Institute of Botany of the National Academy of Sciences and Institute of Plant Protection of Ukrainian Academy of Agricultural Sciences did the first complex research in this field in 2005. We assessed the risks from invasion and distribution of potentially dangerous species of weeds (PDW) on the territory of Ukraine**.** It was conducted under orders of State Inspection on quarantine weeds in connection with the oncoming acceptance of Ukraine into Worldwide Trade Organization (WTO).

The analysis of PDW showed, that the systems of quarantine of weeds in European and Mediterranean Plant Protection Organization (EPPO) and the ones in Ukraine are somewhat different. They are based on the different approaches to quarantine of weeds, and because of this**,** the objects of special attention for EPPO and Ukraine are different. In Ukraine the emphasis is made on the avoidance of invasion of quarantine weeds**.** Not enough attention is paid to phytosanitary monitoring. EPPO gives more importance to monitoring and regularly publishes the results in Internet as Alert-lists. As quarantine organisms pest and diseases are given the most attention. The ecologically dangerous species of weeds are given considerable attention in Western Europe. Ukraine has a national list of quarantine species of weeds, and the legal system of quarantine measures to objects of external and internal quarantine has been designed. At that**,** the accent has been made on species dangerous to agro ecosystems. Such approach, is justified, as in Ukraine the portion of arable lands is rather high and reaches 60-80 % of the total territory exceeding a critical limit of 30-50 %. On the other hand, the following important circumstance has been neglected: for stable operation of agro ecosystems it is necessary that 50-70 % of territory should be under natural ecosystems. The fact that invasive flora of Ukraine includes 830 species, out of which about 100 are noxious weeds including quarantine ones**,** makes the problem of low occurrence of natural vegetation more acute. Some of these invasive species form steady, often monodominant communities on transformed ecotopes, which are displacing indigenous vegetation and delaying restoring successions. Therefore it is rather urgent for Ukraine to solve the problem of PDW (including phytosanitary monitoring) and to determine ecologically dangerous weeds, threatening natural biodiversity, many branches of national economy, and human health. Forecasting of the distribution of invasive plants in modern changeable conditions is rather difficult – it is the ecological problem. Nevertheless, the methodology of forecasting of ecological risk from these weeds has not yet been worked out completely. We consider EPPO schemes of the analysis of phytosanitary risk (offered by EPPO in 2001) to be focused entirely on estimation of diseases and pests. However, they are far from being perfect. The confirmation of this is the interesting publication of Fokin (2005), who compared the results of risk assessment for invasive, quarantine and indigenous species of pests and received rather close values. Besides some paragraphs are very difficult to use for the analysis of weeds.

Based on the mentioned above, we consider the following to be necessary:) monitoring of rates of spread and aggressiveness of potentially dangerous weeds; b) adaptation of introduction methodology, which is traditionally used by botanical gardens; c) adaptation of the schemes of EPPO with the purpose to create forecasting mathematical models. Such models would allow to provide potential geographic ranges and possible danger of invasive weeds on the territory of Ukraine.

Eradication of Giant Hogweed Sosnowskyi (*Heracleum sosnowskyi*) in Latvia

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Heracleum sosnowskyi Manden is an invasive species that has very rapidly entered the flora of Latvia. *H. sosnowskyi* is a native of the Caucasus, that was introduced into Latvia as a cultivated plant in the middle of the 20th century for silage. By the 1980s, this hogweed began to escape from cultivation and became naturalized in Latvia. This period was the beginning of changes in farmland ownership, from collective to private, which seriously altered the normal management systems. Today the spread of *H. sosnowskyi* in Latvia is out of control, primarily targeting wastelands, roadsides, forest margins and riversides. The total area in Latvia contaminated with *H. sosnowskyi* is approximately 13 000 ha.

The sap of *H. sosnowskiy* is phototoxic, which is the main and most compelling reason for controlling the spread of this plant. The leaf and stem sap contains furocoumarins and when it comes into contact with skin and exposed to ultraviolet light, usually in form of sunlight, the furocoumarins are activated to phototoxic derivatives and causes severe skin burning.

The field trials were carried out from 2002 to 2004 at two sites in Latvia: Barkava (56°45'N, 26°30'E), and ekava (56°49'N, 24°16'E). All fields were covered with naturalized *H. sosnowskyi* stands. The soil in Barkava and Kekava test plots were sandy loam.
Trials were grouped into four treatments:

1. Mechanical methods: different soil tillage methods, depths and timing of soil tillage (ploughing, milling, sharing-ploughing, rotary harrowing and plough harrowing) in Kekava; cutting in Kekava and Barkava; mulching in Barkava.
2. Chemical methods: treatment with herbicides at different rates, concentrations, spraying time and combinations. The following herbicides were used: Roundup (glyphosate 360 g L^{-1}), MCPA (750 g L^{-1}), Bnvel 4S (dicamba 480 g L^{-1}), Granstar (tribenuron-methyl 750 g kg^{-1}), Piramin Turbo (chloridazon 520 g L^{-1}), Stomp (pendimethalin 330 g L^{-1}), Milagro (nicosulfuron 40 g L^{-1}), Zencor (metribuzin 700 g kg^{-1}).
3. Biological methods: sowing of annual ryegrass, fodder radish, buckwheat (Barkava).
4. Complex methods: soil tillage + spraying of Roundup (Kekava), spraying of herbicides + cutting (Barkava).

In the two geographical sites different plot sizes and machinery were used.

Weed cover was scored as a percentage and then was converted to a 9-point scheme: 0% = 1 point, 0 - 2.5% = 2 points, 2.5 - 5% = 3 points, 5 - 10% = 4 points, 10 - 55% = 5 points, 15 - 25% = 6 points, 25 - 35% = 7 points, 35 - 67.5% = 8 points, 67.5 - 100% = 9 points. Field trials were successful when the incidence of *H. sosnowskyi* was at the 0-1 point level.

In Barkava the trials were followed by this crop rotation: natural stand of *H. sosnowsky* → green manure plants → barley → spring wheat.

Successful reductions of *H. sosnowskyi* are based on knowing the biological and ecological habits of the weed. In open areas best results were achieved by herbicidal methods with a double herbicide application of glyphosate and tribenuron-methyl during early growth stages. In protected areas mulching and cutting of adult plants in full flower effectively reduced numbers of *H. sosnowskyi* plants, but these methods are time consuming and expensive. Following any control treatment, it is necessary to restore the natural plant community or to initiate new crop production in cleaned areas.

Host specificity and impact studies of *Chromatomyia ramosa*, a candidate for biological control of *Dipsacus* spp. in USA

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Two teasels of European origin, *Dipsacus fullonum* L. and *D. laciniatus* L., have become invasive weeds in the United States. They were most likely introduced in contaminated seed of cultivated teasel, *D. sativus* (L.) Honckeny, between the 18th and mid-20th centuries, when this plant was a minor crop used in textile processing. Biological control is considered an appropriate strategy against invasive teasels in the U.S., especially since the family Dipsacaceae is exclusively Old World and contains no major economic species. Thus, the risk of non-target attack by biological control agents is expected to be very low. Tests were conducted on *Chromatomyia ramosa* (Hendel), a European leaf-mining agromyzid fly that is a candidate for biological control of invasive teasels. Field testing was conducted to determine whether *C. ramosa* infestation contributes to a significant reduction in teasel seed production. Teasel rosettes with symptoms of *C. ramosa* infestation were identified in the field at three locations in southern France and a single control plant without symptoms was chosen at random for each infested plant. Plants were followed until seed set, whereupon their seedheads were collected, air-dried, counted, and weighed. No significant differences were found in comparisons between fly-infested and symptomless teasel plants for number of seedheads per plant, number of seeds per head, number of seeds per plant, total weight of seeds per head, and total weight of seeds per plant. However, a significant ($p < 0.0001$) correlation was shown to exist between seed count and seed weight. Thus, in future experiments seed may simply be weighed rather than counted. In addition, observations were made on the interaction between the fly and the plant. Host-specificity was tested in growth-chamber oviposition experiments with teasel plants and 16 other closely related or economically important plant species. Adult male and female flies reared from pupae dissected from field-collected plants were placed in cages containing all test plants, including the target plants, *D. fullonum* and *D. laciniatus*. Fly behavior was observed and recorded on the different plants and all plants were regularly inspected for symptoms of larval infestation (i.e. leaf mines). Senesced leaves from all plants were dissected and inspected for the presence of *C. ramosa* eggs, larvae, or pupae. In these host-specificity experiments, mines were only observed on *D. fullonum* and *D. laciniatus*. Further testing will include no-choice host-specificity tests (i.e. without the target species present), as well as further impact testing with refinements made to testing protocols as the results of these impact tests were thought to be confounded with fly oviposition behavior.

Initial eradication of *Lysichiton americanus* from the Netherlands

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Lysichiton americanus (Hultén & H.St.John) or Skunk cabbage is an ornamental plant, belonging to the *Araceae* and originating in North America. It is a striking inhabitant of wet forests and bogs with large yellow flowers which appear in April and huge shiny leaves throughout the growing season. It overwinters with a large corm, or short rhizome, which is positioned deep in the soil (up to 25 cm). Propagation is by seed. Seeds are dispersed by water and animals, and may survive five years in the soil.

L. americanus has been imported and grown as an ornamental in Western Europe for a long time; the exact date of the first introduction is not known. The species has escaped from cultivation or gardens? in several countries, and has naturalized in the United Kingdom, Ireland, Germany, Switzerland, France, Norway and Sweden.

The European and Mediterranean Plant Protection Organisation (EPPO) has conducted a pest risk analysis and concluded that the species presents a risk to biodiversity that warrants action. The Dutch Plant Protection Service received word from a local botanist of a small feral population in 2004 and decided to attempt eradication. The botanist undertook an extensive survey and no more locations were found. Interviews with the owner indicated that the population likely descended from a nursery for water plants at the location, abandoned around 1950. Since then the location has returned to nature. It is now a dense willow thicket with well-developed natural vegetation below. Only the old overgrown ditches show the land was once cultivated. The site is inaccessible because of the thicket, but also because the site is flooded during a considerable part of the year. Geologically it is an old silted-up oxbow of the river IJssel. The site is part of a large manor.

Under phytosanitary law owners are normally ordered to carry out prescribed official measures at their own cost and risk, because phytosanitary risks are considered to be normal risks in agriculture. This model is not likely to work for nature reserves. These lands are maintained largely through public subsidies. Because of this situation we decided to take a very different approach. We explained the situation to the owner and concluded with him that there was a common problem that needed to be solved, and that he would co-operate. Next we found a local nature conservation volunteer group to be willing to take on *L. americanus*. The whole process of discussion and organization took almost half a year. In December 2004, when the water level was sufficiently low to allow access, our volunteers were ready and eradication started. Though it was frosty the plants were still recognizable, but finding them was difficult because of the terrain. Digging them out was equally challenging, because water-saturated clay does not co-operate. Removed plants were carried to the road for further transport and destruction (deep burial on dry ground). We finished half the site and decided to continue in March. That had to be delayed to mid-June because of high water levels. Inspection showed that the part we did in December showed no regrowth, and that we had not overlooked small plants. Because *L. americanus* may regenerate from a seed bank we will inspect the site every year till we have an accumulative free period of five years. Only then shall we conclude that eradication has been successful.

For slow growing plants with a long generation time like *L. americanus* the method of manual removal by volunteers turned out to be suitable: slow in organization, but very effective in execution on small locations, with negligible damage to the site.

Impact of *Lantana camara* invasion on environment and economy of India

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Invasive species are a growing problem for the world both ecologically and economically. The impact of invasive species on native species and ecosystems has been immense. In India *Cytisus scoparius* L. (destructed mountain grasslands of Western Ghat range in southwest India), *Chromolaena odorata* L. (affected the tree species regeneration in the Biligiri Rangan hills Temple sanctuary, Karnataka), *Eupatorium adenophorum* Spreng. (out competed the native vegetation in Meghalaya), *Lantana camara* L. (affected the tree species regeneration in the Vindhyan dry deciduous and Kumaun Himalayan forest), *Mikania micrantha* H.B.K. (reduced crop yield, plant diversity and forest regeneration in the Western Ghat region), *Mimosa invisa* Mart. (foliage damaged the heart and liver of elephants and rhinos inhabiting in the Kaziranga National Park), *Parthenium hysterophorus* L. (replaced native vegetation and affects the nutrient pools and processes of the invaded area), *Prosopis juliflora* DC. (out competed native species in Rann of Kachchh) , *Eichhornia crassipes* Mart. and *Pistia stratiotes* L. (eliminated other aquatic flora due its profuse growth and choked water bodies for e.g. Keolodia National Park, a major Indian waterfowl sanctuary) have posed a serious threat to the invaded areas.

Out of these species *L. camara* is considered among the ten most important invasive species in the world and in India. This species was also recognized as the most important invasive species, at the Indo US Science and Technology forum workshop, 2006 held at Jim Corbett National Park, India. The study from Banaras Hindu University, India is pertinent to the ecological and economical impact of *L. camara* in the region. The impact of this species on the environment is immense as it affects the biodiversity of the region where it invades and substantially alters the ecosystem processes which culminates into changed economy of the region (for e.g. invasion of *L. camara* in the Jim Corbett National Park, India). The impact on economy by this species is evident. The cost of impacts caused by *L. camara* are eventually irreversible and this would be as severe as for e.g. it affected the food chain in the Jim Corbett National Park. Various aspects of invasion related to ecology and economy of *L. camara* have been summarized in this study to give insight into the problem of *L. camara* invasion. It is emphasized that environmental consequences of *L. camara* invasion, particularly on the economy of the Vindhyan Highlands of India are little understood and further studies are needed to fulfill this knowledge gap.

Potential effects of fire on seed germination and seedling emergence of Spanish broom (*Spartium junceum*) and Chaste tree (*Vitex agnus castus*)

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The introduction of several plant species to areas beyond their natural distribution has been a global phenomenon that poses critical problems for the conservation and management of many agricultural and natural ecosystems.

Spanish broom (*Spartium junceum* L.) and Chaste tree (*Vitex agnus castus* L.) are two of the most important native shrubs in arid and semi arid Mediterranean regions, being noxious invasive species for those areas. Seeds of these species were randomly collected from ruderal habitats in Greece, in August 2004. Laboratory and greenhouse experiments were conducted in order to investigate the germination rate of untreated seeds and seeds subjected to several hot air treatments. The subsequent emergence of the seedlings was also recorded.

The selected experimental temperatures are likely to be reached at the soil surface or the first few centimetres below ground in bush fires. The germination experiments revealed that dry heat can either promote or inhibit seed germination. A hot air treatment of 110 °C (and secondly 80 °C) was significantly the most stimulative for *S. junceum* seeds resulting to germination rate of 84% (74 %, respectively). In contrast, hot air heating of *S. junceum* seeds at 170 °C for 5 min resulted to significantly lower (27%) germination rate than 140 °C for 5 min (54%) and untreated seeds (69%). In the case of *V. agnus castus*, the temperatures of 140 (72%) and 110 °C (69%) were the most effective ones, resulting to significantly higher germination rates than the untreated seeds (48%) and seeds subjected at 170 °C for 5 min (46%).

The clearly harmful effects of high temperatures were also observed on seedling emergence. A temperature of 170 °C resulted to significantly lower percentages of seedling emergence (53% for *S. junceum* and 60% for *V. agnus castus*) compared to untreated seeds (73 and 76% respectively). Our results also indicated that the emergence rates of untreated *S. junceum* and *V. agnus castus* seeds were relatively satisfactory (73 and 69 %, respectively). However, dry heating at 80 °C or 110 °C for *S. junceum* and 110 °C or 140 °C for *V. agnus castus* contributed to the further optimization of seedling emergence (80-83 %).

Conclusively, this study is a preliminary attempt towards investigating the crucial action of heat on the depletion of seed bank by promoting massive seed germination and seedling emergence. The study may help to understand the potential use of fire as a management tool for the effective control of invasive woody plants, like Spanish broom and Chaste tree. Thus, fire could be taken into account as an effective control method of local seed bank and germination rate of these two invasive plants in Mediterranean-type ecosystems and other arid and semi-arid regions.

Distribution of *Iva xanthifolia* in the area of Kostinbrod

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The invasion and spread of alien weeds in Europe created serious ecological, economical and, in some cases, human health problems. Some annual alien species behave invasively in new territories. After introduction mostly by men – they invade quickly and spontaneously their new habitat. *Iva xanthifolia* (Nutt.) is one of the most troublesome weed species that represents a potential risk of invasion in Europe. This species originates from North America. It invades ruderal communities and crops and colonizes new habitats in urban environments. In 1996, *I. xanthifolia* was for the first time established in Bulgaria, in the region of Kostinbrod, Sofia district, along railway tracks and roadsides. The species was possibly introduced with contaminated maize crop seeds imported form USA in 1994. Today, *I. xanthifolia* is a common ruderal weed species in the area of Kostinbrod. It has been spread rapidly by organic manure, birds, people and irrigation water. The species was observed 2006 in more than 15 locations in and around Kostinbrod on urban territory, cultivated and uncultivated areas as riversides, arable fields, ruderal and others habitats on an estimated total area of about 110 ha. Our investigations showed that this species occurred in communities with:

a) in the area of riversides: *Amaranthus hybridus* L.; *Bidens frondosa* L.; *Carduus acanthoides* L.; *Chenopodium album* L. and *Chenopodium urbicum* L.; *Daucus carota* L.; *Conyza canadensis* L.; *Polygonum* spp.; *Sinapis* spp.; *Urtica dioica* L.; *Lactuca serriola* L.; *Xanthium strumarium* L.; *Rumex crispus* L. The density of *I. xanthifolia* ranged from 50 to 130 individuals per m^2.
b) in ruderal habitats: *A. hybridus*; *Matricaria* spp.*; C. acanthoides*; *C. album* and *C. urbicum*; *Conium maculatum* L.; *Datura stramonium* L.; *D. carota*; *X. strumarium*; *Setaria pumila* Schultes.; *C. canadensis*; *R. crispus*; *Elytrigia repens* (L.) Gould; *L. serriola*; *Hordeum murinum* L.; *Sinapsis* spp.; *Echinochloa crus-galli* (L.) Beauv. The density of *I. xanthifolia* ranged from 50 to 620 individuals per m^2.
c) in arable fields: potatoes: *Matricaria perforata* Mérat; *C. album*; *X. strumarium*; *Setaria glauca* auct. and *E. crus-galli*; in maize: *A. hybridus* and *Amaranthus retroflexus* L.; *C. album*; *X. strumarium*; *S. glauca*; *E. crus-galli*. The density of *I. xanthifolia* ranged from 14 to 64 plants m^2.

The rapid propagation of *I. xanthifolia* is attributed to its features: high seed production with max. 105 000 seeds per plant which could remain viable in water and soil over an extended period of time (31 months in water and 5-8 years in soil), a high competitive ability and some allelopathic effects on the growth of *C. canadensis*, *C. maculatum* and *Lepidium sativum* L. In pot trials we investigated on intraspecific and interspecific competition between *I. xanthifolia* and some crops as peas, sunflower and maize, and some weeds as *Sinapsis arvensis* L., *X. strumarium*, *C. maculatum* and *C. album*.

Results of the experiments showed: i) the intraspecific competition affects mainly the leaf area, the weight of leaves, stems and roots of *I. xanthifolia*; ii) *I. xanthifolia* had a strong negative effect on the growth of *C. maculatum*; iii) on the contrary, *X. strumarium* was competitively superior to *I. xanthifolia*; iv) *I. xanthifolia* was a serious competitor to sunflower, maize and peas.

The competitive ability of investigated crops decreased with increase in density of *I. xanthifolia*.

Ambrosia confertifolia management in Israel

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Most of the Invasive alien species are recognized as one of the leading threats to biodiversity that imposes enormous costs on agriculture, forestry and other human enterprises, as well as human health. Accelerated international trade and tourism enhances the spread of invasive species, allowing them to overcome natural geographic barriers. The majority of crop species used in agriculture are alien species. *Ambrosia confertifolia* L. - also known as burr ragweed - is one of the most aggressive perennial noxious weed threatening the agricultural area in Israel. *A. confertifolia* is a member of the COMPOSITAE family and known also for being an allergenic plant for people, who suffer from asthma or other breathing sicknesses, causing its eradication more urgent. This weed was found for the first time a few years ago along the Alexander River in Heffer valley, and is nowadays infesting more than 1000 ha of river banks, field crops and subtropical orchard. Heffer valley is located in the fertile Sharon Plain of Israel; therefore the invasion of such noxious weed is very risky to field crops and orchards in this area. *A. confertifolia* propagates by seeds, underground rhizomes and re-vegetation of previous year above-ground shoots. New plants grow also from vegetative buds which develop on the root stocks. Tillage can redistribute vegetative buds during few weeks, facilitating the rapid spread of the plant. Shoots of burr ragweed will grow from root buds, emerging during April with silvery-grayish foliage. During late July or early August bloom begins. Male flowers are borne on the tip and upper portion of the flowering branch. Clusters of burs sprout from the female flowers further down the rhachis. Development of a national strategy for limited area should be the first practical step after useful information applied to local farmers and agro - extension service in formulating an eradication plan of alien species. There are some major steps for dealing with invasive alien species: prevention, early detection and information, eradication and control. When prevention has failed, eradication is the preferred action. Eradication can be a successful and cost-effective solution as long as the non-indigenous species is not yet widespread. Successful eradication programs in the past have been based mainly on a combination of mechanical and chemical control methods. The eradication of *A. confertifolia* is rather difficult due to its propagation ability, generative, vegetative, dry root sprout) huge biomass and the fact that it grows mainly along river banks. In order to prevent its further spread, a three years eradication program has been initiated in summer 2006 and will continue during 2007 and 2008 fiscal years. Mechanical control is not efficient due to the high re-growth capacity of *A. confertifolia*. Furthermore, since human labor is rare and expensive, and physical methods are of limited value, the chemical control option is often the only effective solution for prevention and eradication of such weed. Effective chemical control of burr ragweed requires timely application of systemic herbicides that will be translocated to the root system. *A. confertifoli*a plants in Heffer valley were sprayed with a tank mixture of 2,4-D or fluroxypyr with glyphosate at field rates of 1%, 1% and 3% (V/V) respectively. Highly effective knockdown of the weed was achieved, lasting for two to three month only, whereas glufosinate-ammonium (2%, V/V) resulted in a poor control. The use of systemic hormones, such as 2,4-D, fluroxypyr or triclopyr on a large scale is hazardous to broadleaf crops especially when applied during the hot season (July and August). Current situation shows that at least three annually consecutive applications of the above mentioned herbicides are needed in order to reduce the re-flowering ability during the long vegetation period, and control the weed. The coming spring will dictate the efforts needed to prevent the spread of *A. confertifolia* to other regions in Israel.

Phytotoxic metabolites produced by *Phyllosticta cirsii*, a potential biocontrol agent of *Cirsium arvense*

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Canada thistle (*Cirsium arvense* L.) is considered one of the worst weeds of temperate areas because the plant reproduces by resistant rhizomes and by wind-blown plumed achenes. The common methods of control are very expensive and unable to restrain the weed diffusion. For these reasons, alternative methods of control, including the use of plant pathogens as well as of their toxic metabolites, have been proposed. *Phyllosticta cirsii*, a fungus isolated from *C. arvense* leaves in Russia, has been considered as a potential candidate for the biological control of this weed.

In order to ascertain the potential production of toxins and the best cultural conditions for their production, a strain of *P. cirsii* was grown on four different liquid mineral media and incubated at the dark at 25 °C. The biomass of fungus and the toxicity of the culture filtrates were determined at 1-week intervals up to 9 weeks in still conditions and at 4-day intervals up to 20 days in shaken conditions.

The culture filtrate having the highest phytotoxic activity was obtained growing the fungus on M1D medium. It was submitted to preliminary chemical purification by extraction with organic solvent at different pH and dialysis. Consequently, the culture filtrate was exhaustively extracted with ethyl acetate at pH 4.5. The crude organic extract, having a high phytotoxic activity, were purified by step by CC and TLC on direct and reverse phase. Four metabolites (preliminarily named CC1; D3A; G2; G4) were isolated as pure homogeneous compounds, and one of them (G4) was produced in larger amounts (about 10 mg L^{-1}). Thanks to preliminary spectroscopic investigations (1H and 13C NMR) it is possible to suggest that the toxins could be new metabolites structurally correlated each other.

All the compounds were biologically characterized by testing their phytotoxicity to leaves, the zootoxicity to brine shrimps and the antimicrobial activity to fungi and bacteria.

A puncture assay on *Cirsium* leaves was used to test the phytotoxic activity of the pure compounds. Droplets (15 µL) of toxin solutions were applied to the surface of punctured leaves, kept in moistened chambers for 2 days. The main compound (G4) showed the highest phytotoxic activity, causing large areas of necrosis, resembling those caused by the pathogen. The toxin was also tested on leaves of several mono- and dicotyledons.

Moreover, the toxicity of G4 was also evaluated to protoplasts obtained by *Cirsium* leaves. The toxin at 10^{-4} M caused a 50% reduction of the cell vitality.

The antifungal and antibacterial activities of the four metabolites were tested respectively on *Geotrichum candidum* and *Lactobacillus sp*. (Gram +) and *Escherichia coli* (Gram -). All the pure compounds were tested at concentrations up to 100 µg $disk^{-1}$. Only the main metabolite, even when tested at 5µg $disk^{-1}$ had an antiobiotic activity only on *Lactobacillus sp*., whereas the other three metabolites were not toxic at all.

The zootoxicity of compounds was evaluated using the brine shrimp (*Artemia salina* L.) larvae mortality assay. Only G4, tested at 10^{-3} M caused 100% larvae mortality. All the compounds at 10^{-4} M had only a weak activity on larvae.

Further studies on the biological and chemical characterization of the fungal metabolites are in progress.

Session 2

Chemical weed management

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Intelligent weed control technologies

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There is a growing worldwide need for development of innovative technologies applicable for biological systems according to the global demand for food and food quality and the increasing awareness of the impact of agriculture on environment and climate changes. In this context we define intelligent weed control technologies as the integration of domain knowledge about weeds and weed control requirements and the enabling technologies e.g. Information and Communication Technology (ICT), Global Navigation Satellite Systems (GNSS), Geographical Information System (GIS), computer vision and robotics.

Herbicide and sprayers were key technologies in the innovation of weed control in the last century. Knowledge about weeds and weed control are therefore dominated by research related to the biological, environmental and agronomical impact of herbicide application and spraying technologies. Further innovation of weed control applying intelligent weed control technologies requires a paradigm shift in research toward species adapted control measures, site specific weed management, realtime monitoring of crop and weeds and the integration of the environmental and agronomical demands in control-loop of the sprayer, weeding tool etc.

The key note addresses of the state-of-art and the main challenges for research and innovation of intelligent weed control technologies:

- The relationship between weed species distribution, aggregation and the spatial and temporal optimal control unit
- The remaining obstacles in real time identification and monitoring of weeds
- SWOT analyses (***S***trengths, ***W***eaknesses, ***O***pportunities, and ***T***hreats) of alternative control measures using the enabling technologies ICT, GNSS, GIS, computer vision and robotics
- The need for research and development

Weed suppression by plant arrangement of maize

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The crop yield loss due to weeds is mainly explained in terms of competition. Competition is a dynamic process and beside interspecies, intraspecies competition almost always occurs. The intensity of crop competition is mostly defined by the population density and the spatial arrangement of plants. In a completely uniform crop stand with the equal distance between plants competition against weeds will start earlier than in the conventional row cultivation, while intraspecies competition will occur later. Effects of the plant arrangement i.e. the uniformity of crop plants on the weed infestation level have been investigated in cereal crops more than in maize as a row crop. The aim of this study was to estimate the influence of different spatial arrangements of maize plants in the combination with herbicide low rates on the weed biomass and the crop yield. The plant arrangement was achieved by the combination of different row distances and spaces between plants with the same maize population density. Field experiments were performed on sandy loam soil at the Maize Research Institute, Zemun Polje, Serbia, during the 2004-2005. The three-replicate experiment was set up according to the split-split plot RCB design. Main plots encompassed the following spatial arrangements of maize: a) row space 70 cm and 25 cm between plants in the row; b) row space 50 cm and 35 cm between plants in the row and c) row space 35 cm and 50 cm between plants in the row. The maize population density was the same at all spatial arrangements (57,143 plants ha^{-1}). Subplots consisted of three herbicide rates that included a pre-emergence application of isoxaflutole+acetohlor at a full rate (1500 g ha^{-1} +1536 g ha^{-1} a.i.), half a rate (768 g ha^{-1}+ 750 g ha^{-1} a.i.) and without a herbicide application. Sub-subplots included different maize maturity group hybrids of: H_1-ZPSC 434 (FAO 400), H_2-ZPSC 578 (FAO 500) and H_3-ZPSC 735 (FAO 700). Average data for all hybrids are presented. The weed samples were collected a month after the herbicide application (June) and the weed fresh weight of all species per one square meter area was measured in each experimental plot. The maize grain yield was measured at the end of a growing cycle and calculated with 14 % of moisture. The data were processed by the analysis of variance using Genstat Discovery edition 2.0, while differences of means were tested by the LSD-test. The average values for two years are presented.

According to obtained data, the spatial arrangement of maize plants had no significant effect on average values of the weed fresh weight. Nevertheless, the weed fresh weight declined over smaller row distances and was, on the average, the lowest at the 35-cm row distance (1456.2 g m^{-2}). The herbicide application significantly affected the weed fresh weight. Average weed fresh weights were the smallest in the full rate treatment (101.3 g m^{-2}). According to a statistical analysis, the interaction of the spatial arrangement and the herbicide rate also significantly influenced the weed fresh weight. The best result in weed control was obtained in the treatment with a full herbicide rate at the 35-cm row distance (83.4 g m^{-2}). The maize grain yield was also affected by investigated parameters. The significantly higher grain yield was observed in the variant with the herbicide application (12.9 and 13.0 t ha^{-1}). The maize grain yield did not differ significantly between treatments with a full and a half rate of herbicides, over all variants of row distances. Also, a row distance had a positive effect on maize production and the highest grain yield on the average was observed at the 35-cm row distance (12.4 t ha^{-1}). Gained results indicate that it is possible to successfully control the weed infestation level if maize is grown under conditions of the altered plant arrangement with the herbicide application. In such a way, maize plants are more competitive against weeds and even lower amounts of herbicides could be applied.

Environmental risks of long-term use of pesticides in Finnish potato fields

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In northern weather conditions the degradation of pesticides is expected to be slow, but there are only little research data available. Potato is typically grown on light soils and is treated with many pesticides that are known to be quite persistent and/or prone to leaching. The objective of this research project was to obtain knowledge about the behaviour of the herbicides metribuzin and linuron and the fungicide fluazinam in soil in Finnish potato fields in order to estimate environmental risks. The main research approaches were monitoring of pesticide residues, pesticide fate simulations and various analyses of soil microorganisms and their activity. Pesticide residues in soil were monitored in 2004-2006 in three potato fields (mouldy fine sand, fine sand and mould soils) in Southern Finland with a long-term monoculture of potato. Recommended doses of pesticides were used. The weather conditions in the three trial years varied widely. The growing season 2004 was very rainy and rather cool, while both the temperatures and the precipitation in 2005 were close to normal, and finally the growing season 2006 was exceptionally warm and dry. The soil samples for residue analyses were taken with hand-operated soil bores at the depths of 0-5 cm, 0-20 cm, 20-40 cm and 40-60 cm. Residues of fluazinam, linuron, metribuzin and the metribuzin metabolites metribuzin-desamino (MDA), metribuzin-desaminodiketo (MDADK) and metribuzin-diketo (MDK) were analysed. Only the residue analyses of the samples from 2004 and 2005 have been completed. So far the data indicate that fluazinam degrades rather rapidly at first, but a small amount of residues does not seem to degrade before the start of new applications in the next season. By contrast, the herbicides do not seem to accumulate in the soil. The half-lives of the herbicides were in accordance with the literature: linuron, DT50field 26-57 days (literature 13-82 days) and metribuzin, DT50field 20 days (literature 9-107 days). Linuron and metribuzin seem to leach more easily below the ploughing depth than fluazinam especially in soils low in organic matter. Particularly in the mould soil it was typical that in early spring the residues were higher than in the previous autumn. Linuron and metribuzin were also easily dissolved into surface runoff in the spring. The occurrence of metribuzin metabolites was very rare in the soil samples, but all metabolites were found in the surface water. The Swedish MACRO 5.0 model was chosen for the pesticide fate simulations, which will be completed after the residue results of the 2006 samples are available. In a winter simulation laboratory trial the pesticides degraded slowest in frozen soil (-7 °C), faster in conditions of repeated melting and freezing (+5 °C/ -7 °C), and fastest at +5 °C. The microbial functional diversity was assessed by an enzyme activity kit comprising of ten fluorogenic soil enzyme activity measurements. The microbial activity and biomass were estimated by soil basal respiration, nitrification activity, ATP and fungal biomass by ergosterol content. The toxicity of pesticides was studied with luminescent bacteria tests. Especially herbicides seemed to increase enzyme activities in microcosms, but decreases were observed in soil with plants. Fluazinam appeared to be extremely toxic to the luminescent bacteria. None of the pesticides affected the ergosterol content of the soil. Metribuzin reduced the nitrification activity of the soil. The microbial studies of the field experiment in 2006 confirmed many of the results of the laboratory tests. The wholeness of the environmental risks of the studied pesticides will be estimated when the residue analyses and the simulation studies have been completed later in 2007.

The IR-4 project: Update on herbicide registration in specialty crops in the United States

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The IR-4 Project is a publicly funded effort established in 1963 to support the registration of pest control products on minor or specialty crops. The IR-4 Mission is to provide pest management solutions to growers of vegetables, fruits, ornamentals, and other specialty crops. People who benefits from IR-4 are minor crop growers, food processors, and consumers. IR-4 develops data for submission to the EPA to support the regulatory clearance of new crop protection chemicals on minor food and ornamental crops and assists in the maintenance of existing product registrations. IR-4 provides help in the development and registration of biopesticides and expedites new pest control technologies for minor crops. As the Food Quality Protection Act (FQPA) of 1996 threatens to restrict or eliminate many long-standing pest control products, IR-4 is focusing on "reduced risk" and safer chemistry to ensure that producers of specialty crops have an adequate number of pest control products, both traditional and biopesticides. The IR-4 Project continues to actively work to provide growers with weed control options despite a climate in which there are fewer herbicides to evaluate. IR-4 has worked cooperatively with Canada in the development and exchange of food crop residue and performance data since 1996. Residue trials have been conducted in Canada as a regular part of joint studies. In addition, data packages developed for U. S. registrations have been provided to the Pest Management Regulatory Agency (PMRA) of Canada in support of MRLs that allow use in Canada and for MRLs that supports the importation of U. S. agricultural products. Recently, the Canadian government provided federal funding which allowed Agriculture and Agri-Food Canada and the PMRA to give Canadian producers better access to minor use and reduced risk-products and to help increase their international competititivenes. A Minor Use Program similar to IR-4 was created in 2002 in Canada and has been named the Pest Management Centre. In addition, under the North American Free Trade Agreement (NAFTA), the governments of Mexico, Canada, and United States formed the Technical Working Group (TWG) on Pesticides in 1996 to develop a coordinated pesticides regulatory framework among NAFTA partners to address trade irritants, build national regulatory/scientific capacity, share the review burden, and coordinate scientific and regulatory decisions on pesticides. IR-4 has been an active member of the TWG to support specialty crop issues. Recognizing the need and considering the work IR-4 has already contributed to the international concerns, IR-4 is uniquely position, with the expertise in specialty crops to be more involved in global pesticide/herbicide regulation harmonization.

Use of remote sensing for detecting herbicide injury in maize at early growth stages

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Negative side effects of herbicide applications on agricultural crops have been described in various publications. Vitality and yield losses caused by herbicides may be the result of wrong application timing, incorrect herbicide rates, treating unregistered susceptible cultivars or of stressful environmental conditions. However, in practical farming early information on crop damages are urgently required to arrange management strategies (e.g. fertilisation). At industry level both, plant breeders as well as plant protection companies require early information on response of crop varieties to herbicides in order to evaluate wether or not cultivars are susceptible to herbicides of interest.

Experiments were conducted in 2002, 2005 and 2006 to determine if sulfonylurea type herbicide injury in maize can be detected using remote sensing at early growth stages.

In 2002, 12.5 g/ha Rimsulfuron in 300 l water/ha was applied site-specifically under stressful environmental conditions at locations with more than 5 grass weeds * m^{-1} within a 5.8 ha maize field, when maize had reached the 4-leaf stage. A multispectral image of the field was recorded by the *QuickBird* satellite 25 days after herbicide treatment. The *Normalized Difference Vegetation Index* (NDVI), a vitality measure, was calculated throughout the entire field. At harvest, a yield map was recorded.

In 2005 and 2006 the influence of *Rimsulfuron* and *Nicosulfuron* on vitality and yield of susceptible compared to unsusceptible maize cultivars was tested. Therefor, defined rates of *Rimsulfuron* and *Nicosulfuron* were sprayed in susceptible and unsusceptible maize cultivars at Research Station Dikopshof near Cologne (2005) and on a practical farm near Erkelenz, Germany in 2006 in cooperation with a plant protection company. Multispectral images from the experimental designs of the respective years were taken via airborne remote sensing after herbicide application. At the same times, vitality was assessed via rated stunting by assignment of staff.

In 2002, the treatment map for site-specific weed control corresponded closely to the reflectance pattern in the multispectral satellite image. NDVI values, recorded 25 days after herbicide treatment, were significant lower in the treated compared to the untreated areas. Herbicide treated areas corresponded closely with low yield classes. In 2005 and 2006 NDVI and yield were significantly lower in the susceptible compared to the unsusceptible cultivars. Observations on crop vitality from rated stunting by staff corresponded to the vitality values (NDVI) measured with remote sensing.

Rated stunting relies on human observers. So it is firstly influenced by individual mistakes and secondly it cannot generally be scaled up from the research plot scale to entire fields.

By contrast, remote sensing allows discrimination of herbicide injury in maize in (1) entire fields and (2) in a numerical manner. This methodology provides more information compared to classical experimental designs and thus potentially cheapens costs in field trial operations.

Predicting sublethal effects of herbicides from greenhouse data on terrestrial non-crop plant species in the field

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The assessment of risks posed by herbicides to non-target terrestrial higher plants is essential for the protection of biodiversity, within the plant kingdom as a whole and particularly in agro-ecosystems. Several tiered approaches to assess these risks have been proposed. However, a number of very relevant factors to consider during risk assessments are not discussed in these proposals: plant development stage, reproduction and recovery of plants. Other relevant factors are differences in sensitivity between monocotyledons and dicotyledons, between field and greenhouse grown plants, and between individuals and vegetations. These risk assessment protocols are based on single species experiments in greenhouses and may therefore under- or overestimate risks.

The focus of this study was to gain more insight into these factors, especially in the possibility of predicting effects in the field based on greenhouse data. Therefore, we grew four non-crop plant species (*Chenopodium album*, *Stellaria media*, *Poa annua* and *Echinogloa crus-galli*) in the field as well as in the greenhouse. They were grown both as individual plants as well as in mixtures with four additional species (*Elymus repens*, *Panicum milliaceum*, *Solanum nigrum*, and *Centaurea cyanus*) and tested for their sensitivity to sublethal doses of glufosinate ammonium and tepraloxydim. We tested their response during different developmental stages, and investigated their reproduction and recovery. The results differed with plant life stage: young plants were 25 to 83% more sensitive than older plants ($p<0.05$), and recovery differed between the species. Biomass was less affected than seed production. Seed production did not differ between younger and older plants ($p=0.972$), whilst germination and emergence of seeds was not reduced if the maternal plants were treated in an early stage ($p=0.820$). However, they were reduced up to 52% with increasing concentration if plants were treated in an older stage ($p<0.001$). The results suggest consequences at the population level. Even when only marginal effects on the biomass of non-target plants are to be expected, their seed production and thereby survival at the population level may be negatively affected. When grown in a mixture, small plant species were sheltered from the herbicide treatment by the larger species in the mixtures. At higher doses this beneficial effect did not always remain visible. It became unfavourable for *S. media* for example, to grow in a mixture at higher doses. This was probably the result of a stronger reduction in its competitive ability in comparison to the other species. Therefore, results from single species experiments can not be directly translated to effects on these species grown in mixtures. Furthermore, a relationship between the effects on greenhouse and field grown plants was found in this study. The log- transformed $ED_{10,20,....,90}$ values from the greenhouse data were linearly related to the log- transformed $ED_{10,20,.....,90}$ values of the field data ($p<0.001$) for each single grown species.

When assessing the risk of a compound in non-target areas, predicting the amount of deposited product in such an area is of great importance. We propose a methodology that combines dose response curves, the relationship between greenhouse and field grown plants and a droplet drift model to estimate the risk of herbicides on higher terrestrial plants in non-target areas. The methodology is called Effects of Pesticides on Plants model (EPOP) and can make use of several endpoints such as biomass, seed production and species composition. The model can be used as an extension of the tiered standard for risk assessment as proposed by EPPO.

Winter wheat competition against wild oat (*Avena ludoviciana* L.) as influenced by wheat variety and seeding rate

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A study was conducted in 2004-2005 to determine the effect of wheat varieties and increasing seeding rate would reduce the effect of wild oat on winter wheat. the experiment included 2 wheat varieties (Rooshan and Niknejad), 3 wheat seeding rate (recommended)(150 and 135 kg/ha for Niknejad and Rooshan, respectively), recommended+25% and recommended+50%) and 4 Wild oat densities (0, 25, 50 and 75 plant m^{-2}) in a Factorial trail based on a randomized block design with 4 replications. Tiller m^{-2}, plant height(cm), spike m^{-2} , spikelets $spike^{-1}$, number of grain per spike, 1000 grain weight(g), Wild oat height (cm), Biomass (kg ha^{-1}), grain yield (kg ha^{-1}) and growth indexes for wheat and Wild oat was recorded. Seeding rate and variety had no effect on Wild oat density. Rooshan (120 cm)(wheat cultivar) reduced mature Wild oat Biomass by 7% compared with Niknejad (95 cm)(wheat cultivar) on average of all wheat density. Niknejad had more yield than Rooshan at 3 wheat seeding rate and Wild oat interference. Number of tillers per plant, number of spikelet and number of spike m^{-2} had highest correlation with yield. Results of this study indicate that in weedy farm optimum seeding rate for Rooshan was the recommended rate and recomenmended +25% for Niknejad. From a practical point of view, Niknejad in weed free and weedy farm may be better than Rooshan.

Spring control of *Alopecurus myosuroides* Huds. in conditions of South-West Poland

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In Poland *Alopecurus myosuroides* Huds. is often found in ruderal habitats. As the weed of cultivated field it only occurs in some region of Poland. As early as in the end of 60's *A. myosuroides* was observed in cereal fields on Kujawy region (central part of Poland). In the end of 80's its mass occurrence was noted in cereals in Vistula River Delta. In the last several years increase of *A. myosuroides* occurring - especially in south-west Poland - is observed.

This study examines the results of *A. myosuroides* control in winter wheat in the spring time.

The field experiments were conducted in the years 2004-2006 in winter wheat. The aim of the conducted trials was evaluation of the herbicides efficacy against *A. myosuroides* and their influence on the yield of winter wheat.

The method used to conduct the experiments was the randomized blocks, in three replications, on fields of 20 m^2. All of them were situated in productive fields of winter wheat, in the area of Lower Silesia region (south-west part of Poland).

In the experiments, 7 herbicides contain iodosulfuron, fenoxaprop-P-ethyl, propoxycarbazone sodium, sulfosulfuron, chlortoluron, and mixtures of isoproturon + diflufenican and iodosulfuron + mesosulfuron were selected. All of tested herbicides in the spring was performed.

Herbicides were applied with a knapsack sprayer "Gloria", at a pressure of 0.25 MPa and an application water volume of 250 $l \cdot ha^{-1}$.

The herbicides efficacy was measured on the base of the fresh weight reduction in comparision to untreated.

The fresh weight of weeds was measured 5-6 weeks after application from 3 random chosen places of each plot (3 x 0,25 m^2). The aboveground part of the plants was cut and weighed.

The trials were harvested by the field mini-combine Nurserymaster Elite Z 035 at the GS of full ripeness.
The field trials showed that efficacy of *A. myosuroides* control was dependent on the applied herbicide. At the moment of herbicide application, *A. myosuroides* was at the growth stage (BBCH=23-25) and therefore not all of tested herbicides were efficient.

The application of propoxycarbazone sodium, fenoxaprop-P-ethyl and mixture of iodosulfuron + mesosulfuron reduceded the fresh weigh of *A. myosuroides* with more than 90%. Application of sulfosulfuron and chlortoluron was less efficient. These herbicides reduced the weed weight between 82-85%. The lowest level of control (63-76% efficacy) was obtain with iodosulfuron and isoproturon + diflufenican mixture.

The yields from untreated plots was 2.52 $t \cdot ha^{-1}$., which were between 2.69 to 4.00 $t \cdot ha^{-1}$ lower than in the plots treateted with herbicides. The significance differences of winter wheat yielding by statistical analisys were confirmed ($LSD_{(0,05)} = 0,487$).

The higest yield 6.04-6.52 $t \cdot ha^{-1}$ was measured with the treatment of fenoxaprop-P-ethyl, propoxycarbazone sodium and iodosulfuron + mesosulfuron mixtures. The plots treated with sulfosulfuron and isoproturon + diflufenican provided a yield level of 5.91-5.92 $t \cdot ha^{-1}$.
The lowest yield 5.48-5.75 $t \cdot ha^{-1}$ was measured after application chlortoluron and iodosulfuron was observed.

Effects of different weed control strategies on durum wheat (*Triticum durum Desf.*) yield and quality

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Durum wheat (*Triticum durum* Desf.) is a traditional crop in the Mediterranean environments, where is concentrated about 60% of the world production. In Southern Italy this crop finds optimal conditions and is able to give good quality productions, even though it needs correct growing practices. Effective weed control is recognized, both by researchers and by farmers, as a "key aspect" in the growing of durum wheat. However, public concern about the environmental impact of herbicides, requires to optimize chemical control using integrated or organic strategies. The correct use of agronomic strategies, such as fertilization, that are able to reduce infestation and crop-weed competition, are recommended to improve the weed control effectiveness and safeness.

The aim of this research was to study the effects on durum wheat (cv Simeto) yield and quality of different weed control strategies (chemical and mechanical) combined with different fertilization techniques. In a field located in Noicattaro (Apulia – Southern Italy), previously cultivated with processing tomato, the following strategies were compared: 1) mineral fertilization + mechanical weeding; 2) mineral fertilization + chemical weeding; 3) mineral fertilization localized on the row + chemical weeding; 4) mineral fertilization localized on the row + mechanical weeding; 5) organic fertilization + mechanical weeding.

Mineral fertilization consisted in 1.0 q ha^{-1} of P_2O_5 e N respectively applied at sowing and at shooting. Chicken manure, applied at sowing (33.0 q ha^{-1}), was used as organic fertilizer.

Due to the very scarce presence of grass weeds, tribenuron methyl (Granstar, 15 g ha^{-1}) was sprayed for the chemical weeding, whereas a finger-harrow was used for the mechanical control. Weeds were controlled at the beginning of wheat tillering. A completely randomized block experimental design with 4 replications was adopted and the significance of differences between treatments was determined by Duncan's multiple range test (alpha = 0.05).

The most spread weeds were: *Urtica urens* L., *Veronica hederifolia* L., *Stellaria media* (L.) Vill., *Lamium purpureum* L., whose total covering indexes (estimated using Brown-Blanquet method after 20 days from the treatments) were 99.4 – 0.2 – 7.1 – 99.4 – 88.8 %, respectively in the plots treated with the strategies 1 – 2 – 3 – 4 and 5. The lowest covering indexes were observed in the plots in which mineral fertilization was combined with chemical control. Similar trends were obtained considering the infestation level of each weed species. Grain yield ranged from 58.6 q ha^{-1} to 40.1 q ha^{-1} whereas protein content from 9.9 to 9.0 %. The statistically lowest results were obtained in the plots where chicken manure was applied and weeds were controlled mechanically. In these last plots, non-vitreous grain percent was the highest (97.5 %) and significantly different from those obtained with the other treatments in which data varied from 23.7 and 32.5 %. All the chemically fertilized plots, gave results not statically different one from each other. With concern to the other quality parameters (hectolitre weight, 1000-grain weight, ash) no sensible differences were found. It was possible to conclude that chemical weed control showed more effectiveness. However, for the level and type of infestation that was found in the experimental field, no quantitative or qualitative difference was observed between plots chemically fertilized, regardless the techniques (localized application or not). On the contrary, yield loss and quality decrease was observed in the plots fertilized with chicken manure and mechanically weeded.

Phytotoxicity assessment of selected herbicides in some minor crops in Poland

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Camelina sativa, Fagopyrum esculentum, Phacelia tanacetifolia and *Papaver somniferum* are some examples of minor crops cultivated in Poland, however there are no registered herbicides for these crops. The objective of the present study was to investigate the phytotoxic effect of some herbicides on *Papaver somniferum, Camelina sativa, Fagopyrum esculentum* and *Phacelia tanacetifolia*. Field experiments were carried out in the years 2004-2006 at the Institute of Plant Protection in Poznań. The experimental plots were designed as randomised blocks with four replications. Phytotoxicity assessment was visual and expressed in percent.

The following active ingredients were tested in *Camelina sativa*: trifluralin incorporated into the soil and metazachlor + quinmerac applied after sowing, in the autumn at the 3-4 leaf stage or in the spring, after start of vegetation. Trifluralin and metazachlor + quinmerac applied at the 3-4 leaf stage and in spring were the most selective herbicides. Herbicides assessed in *Fagopyrum esculentum* were: linurone, flurochloridone, napropamide all applied after crop sowing and clomazone + metazachlor, propoxycarbazone sodium, metazachlor + clomazone applied at the 3-4 leaf stage. The most severe crop injuries were observed with linurone, flurochloridone at the higher doses, clomazone + metazachlor and propoxycarbazone sodium. The other treatments only caused insignificant, temporary crop injuries that did not affect yields. Weeds in *Phacelia tanacetifolia* were controlled by using linurone, metamitrone and by lenacil. All herbicides were incorporated into the soil. The most selective compounds were linurone and lenacil. Herbicides tested in *Papaver somniferum* were clomazone, chlortoluron, florasulam, carfentrazone ethyl, isoxaflutole and mesotrione at different times of application. Results indicate that the best weed control and best selectivity were observed following application of mesotrione. Susceptibility of the crops varied between years hence further studies are necessary. In summary, the results indicate that some of examined herbicides could be recommended for weed control in minor crops in the future.

Integrated weed management in stone fruit orchards

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Difficult-to-control weeds such as *Amaranthus retroflexus*, *Chenopodium album*, *Polygonum* ssp., *Stellaria media*, *Cirsium arvense*, *Elymus repens*, *Echinochloa crus-galli*, *Sorghum halepense*, *Digitaria sanguinalis*, *Setaria* spp., *Cynodon dactylon* increasingly infest stone fruit orchards. The concept of integrated management weeds control is based on "threshold tolerance" which means the highest number of weeds, with no injury effect on the trees or economic yield loss. In the context of sustainable agriculture, the integrated management of weeds in stone fruit orchards need to be carried out combining agro-technical, biological and chemical methods with control and organizational means. This study presents some weed control data from the apple orchard of RDIPP in Bucharest. To achieve satisfactory weed control and taking into consideration the compelling ecological demands for environmental protection, we included both agro-technical (weeding, scything, mulching) and chemical methods (glyphosate). The purpose of the study was to replace the exclusive use of herbicides leading to increasing problems with perennial weeds because of the high effect on annual weeds.

The results of this study lead to the conclusion that both agro-technical and chemical methods assured a good weed control of 80%. Although the weeds control was not completely diminished, the three consecutive scythings kept the weed infestation at an acceptable level. The weeds were unable to store sufficient nutrient reserves to survive the winter. On the mulching plot, a very good weed control could easily be obtained at a low cost. Besides a good weed control, particularly on perennial weed species, mulching also had a fertilizing effect, contributing to the organic enrichment of the ground. The only herbicide used was glyphosate due to its low toxicity to beneficials, its low persistence in soil and no residues in the harvested fruits. The herbicide was applied using equipment developed by the National Institute of Mechanical Agriculture. The best results were obtained with two applications of 3 l ha^{-1}; one when the perennial grass weeds were 15-20 cm tall, and a second application when the soil was re-infested.

Herbicide control of Velvetleaf (*Abutilon theophrasti*) in sugar beet

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Abutilon theophrasti is one of the most significant and the fastest spreading invasive weeds in the Czech Republic at the present time. It has mischievous impact especially in sugar beet stands. Main reason of this fact is practically zero efficiency of conventional herbicide control methods. Velvetleaf is very tolerant to most of commonly used herbicides in sugar beet (desmedipham, phenmedipham, ethofumesate, etc.).
Field herbicide experiments were carried out in years 2004 – 2006 on experimental station in Prague. These experiments were broadening previous greenhouse experiments, which were carried out in years 2002 – 2003 and they are described in: Jursík et al. 2004.

A week before sowing of sugar beet, seeds of *A. theophrasti* were scarified by H_2SO_4 and subsequently were incorporated into soil profile (5 cm). Density of sugar beet got round 120 000 plants.ha $^{-1}$ and density of *A. theophrasti* ranged between 10 and 40 plants.m^{-2}.

Aim of experiments was checking of efficacy of herbicide Safari 50 WG® (*triflusulfuron*) and herbicide tank mix Safari 50 WG + Lontrel 300® (*clopyralid*) on *A. theophrasti.* Both of herbicides were used in recommended doses for sugar beet in the Czech Republic (*triflusulfuron*: 0,15 g.ha^{-1} a.i., and *clopyralid*: 60 g. ha^{-1} a.i). Herbicide Betanal Expert® (*desmedipham* + *phenmedipham* + *ethofumesate*) was chosen as a standard treatment. Application of herbicide was carried out 2 - 4 times, in dependencies on growth stage (BBCH) of *A. theophrasti*.

These experiments showed out the good efficiency of *triflusulfuron* (85 – 95 %) which was used in all terms of treatment (3 - 4 times in dependence on weather of year and weed density). However, this favorable efficiency was achieved only when the first treatment (T1) was applied in early growth stages of velvetleaf (cotyledonous leaf) and second treatment (T2) followed about week. If T1 was carried out later or if interval between T1 and T2 was too long, efficacy markedly declined. Nevertheless, despite of right herbicide application timing, plants of velvetleaf often regenerate and then they may continue in growth (yield loss 0 – 60 %) and subsequently start to reproduce (till 1000 seeds.m^{-2}), especially in lacunary canopies of sugar beet. It is also important to increase crop competition ability, e.g. by increasing LAI (leaf area index) of sugar beet, minimize canopy gaps and maintain healthy sugar beet leaves. When the competition ability of the sugar beet is high, velvetleaf plants that are injured by herbicides can not regenerate.

Slightly higher efficiency than *triflusulfuron* (90 – 97 %) was achieved by combination of *triflusulfuron* + *clopyralid.* This herbicide combination showed favorable efficiency as well only if it was applied at least 3 times and T1 was applied in early growth stages of velvetleaf and T2 followed about week. Yield loss and generative production of *A. theophrasti* were similar as by *triflusulfuron* alone (0 – 55 %, resp. 0 – 1.000 seed.m^{-2}).

Efficiency of standard Betanal Expert® was almost zero and *A. theophrasti* induced marked yield loss (75 - 85 %). Seed production of *A. theophrasti* was very high (10.000 – 20.000.m^{-2}), markedly higher than on untreated control (2.000 – 5.000.m^{-2}), where other weeds (mainly *Chenopodium album, Amaranthus retroflexus, Echinochloa crus-galli*) competed.

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Combining mechanical and chemical methods of broad-leaved weed control in spring cereal

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Mechanical weed control allows farmers to reduced or even eliminate herbicide use. In cereal crops mechanical weeding is not widely used because many farmers believe that it can reduce yield. Mechanical methods of weed control in cereals are usually practiced up to 4-6 leaf stage, with an increasing risk of damaging the crop when applied later.

Four field experiments were conducted in 2001, 2002 and 2003 to determine the influence of mechanical treatments combined with herbicide application on weed control and yielding of spring cereals (wheat and barley). The experimental design contains following treatments: (1) herbicide at recommended dose; (2) herbicide at 1/2 or 1/3 recommended dose; (3) cross-harrowing two times; (4) cross-harrowing four times; (5) cross-harrowing two times and second treatment of herbicide at low dose (two or three days after harrowing); (6) cross-harrowing four times and second treatment of herbicide at low dose (two or three days after harrowing). A check plots received no harrowing and herbicide treatment. Harrowing was made with tine weeder and herbicide (mixture of tribenuron methyl at the rate of 11,25g ai/ha as recommended dose with surfactant at 0,1%) treatment with field experimental sprayer delivered of spray volume of 280 l/ha. During the chemical treatment broad-leaved weeds were at the 1-4 leaf stage and crops at the 4-6 leaf stage. A randomised complete block design with a four replications and a plot size of 16,5 m^2 was used. Herbicidal efficacy was evaluated by fresh weight of weeds harvested ca. 3-4 weeks after treatment. Data collected included as well as cereals density (two trials), weight of 1000 grain and grain yield.

Results of the mechanical treatments showed that only harrowing did not significantly reduce weed infestation as compared with chemical weed control. It is important, that environmental conditions are optimum when harrowing. Warm, windy and sunny conditions, as well as dry weather during and following harrow, will reduce reestablishment of weeds, as the weeds will dry out before they can re-root. Generally, optimum conditions for mechanical weed control during and several days after treatments were observed in the experiments. Although the environmental condition was satisfactory weed control was poor. In some trials no significant effects were observed even after cross-harrowing two and four times. In some cases weed harrowing resulted in the highest weed fresh weight and density. Considering only mechanical weed control, better results were obtained by two times harrowing than four times. Generally, harrowing alone showed a low efficacy on weeds and probably caused secondary germinations of annual weeds such as common lambsquarters that emerge from shallow soil depths (less that 2 cm). A combination of mechanical weed control and herbicide at reduced dose may be a compromise versus choosing one single method. Herbicide applied at 1/2 or 1/3 of the recommended dose as second treatment gave nearly 90% control of the most important weed species (common lambsquarters) in years with optimum environmental conditions, but much lower effect in season with wet and higher rainfall several days after treatment. Due to the short interval between harrowing and spraying, in some cases, results were not satisfactory probably because weeds were covered by soil. Chemical weed control alone resulted in the highest efficacy. In all trials cereals tolerated post-emergence use of a harrow and herbicide treatments. Highest crop yields were obtained with chemical treatments and combinations of chemical methods with all harrow types.

Seeds production of *Chenopodium album* in spring wheat and spring barley field experiments sprayed with lower herbicide doses

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Field experiments were carried out in the years 2001-2003 at the Institute of Plant Protection in Poznań (Poland). The aim of the research was to determine the effect of reduced herbicide dose applications on broadleaved weeds control (*Chenopodium album, Viola arvensis* and *Matricaria inodora*). Infestation was assessed 4 weeks after the last herbicide treatment. Before crop harvest *C. album* fresh weight, seed biomass and seed number were investigated. *C. album* is a very common weed in all regions of Poland and is recognized as the dominant weed species in spring cereals.

Tribenuron methyl and mecoprop + MCPA + dicamba were applied at the recommended rate and at 2/3 and 1/3 of the recommended rate in spring wheat and in spring barley. The doses of tribenuron methyl were 11,25, 7,5 and 3,75 g a.i ha $^{-1}$ and of mecoprop + MCPA + dicamba 450 + 300 + 60, 300 + 200 + 40 and 150 + 100 + 20 g a.i ha $^{-1}$. Spring cereals were cultivated at two crop densities (spring wheat: 400 (D1) and 250 (D2) seeds ha $^{-1}$; spring barley: 200 (D1) and 100 (D2) seeds ha $^{-1}$). The purpose of reducing crop density was to increase weed competition. Both herbicides were applied at the beginning of tillering (BBCH 21-22) and at the end of tillering (BBCH 28-29). Treatments were applied using the plot sprayer with: TeeJet XR 11003 nozzles, 230 L ha $^{-1}$ of water volume, 0.2 MPa of pressure.

Data revealed a higher seed production in the control plots at low crop density. Average seeds mass in spring barley (D1: 44.4, D2: 88.5 g m $^{-2}$) was higher than seed mass in spring wheat (D1: 42.2, D2: 73.2 g m $^{-2}$). A 100% reduction in *C. album* seeds reduction was observed following application of recommended herbicide rates at the end of tillering. A reduction in herbicide dose at the beginning of tillering led to lower seed mass reductions than at the late application time. Tribenuron methyl applied at all doses and mecoprop + MCPA + dicamba at full dose and 2/3 of the recommended dose at BBCH 28-29 and optimum crop density caused a 100% reduction of *C. album* seed production. In spring barley mecoprop + MCPA + dicamba was less effective in reducing seed production than tribenuron methyl. *C. album* seed production where herbicides were sprayed at lower doses did not affect the quality of spring cereal grain. Seeds of *C. album* collected from herbicide treated plots weighed less than the ones collected from the control plots.

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Non-inversion tillage affects herbicide activity

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The activity of prosulfocarb, pendimethalin and flupyrsulfuron was examined in soil samples collected during two growing seasons at four farms practising non-inversion tillage. In each field a surface sample (0-2.5 cm) and a reference sample (0-20 cm) simulating the soil composition following ploughing was collected. If the farmers were practising no tillage farming with direct seeding an undisturbed soil sample was collected using stainless steel tubes. Herbicide activity was assessed in pot experiments using *Apera spica-venti* as test plant. Applied pre-emergence herbicide doses had to be increased by a factor 1.5 to 5 in the 0-2.5 cm soil samples compared to the 0-20 cm soil samples. The differences in activity were less if herbicides were applied post-emergence at the 2- to 3-leaf stage. Herbicide activity was lower in undisturbed soil samples compared to the 0-2.5 cm soil samples. K_d values were determined for prosulfocarb and flupyrsulfuron using soil samples from three of the farms. K_d values were significantly higher in the 0-2.5 cm soil samples reflecting the observed differences in herbicide activity.

In a series of glasshouse pot experiments the influence on herbicide performance of straw residues on the soil surface was examined. Wheat straw was cut into 1 cm pieces and amounts of straw corresponding to 1 and 3 tonnes per ha were placed at the soil surface. The efficacy of pendimethalin and flupyrsulfuron was significantly reduced and more so with 3 than with 1 ton straw per. ha. Five mm rain 1 DAT did not improve the performance of pendimethalin suggesting that the rain did not wash off the herbicides from the straw residues.

Effects of site-specific and conventional herbicide application on spatial and temporal variability of *Cardaria draba* (L.) population

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Intensive field surveys of *Cardaria draba* were conducted in two growing seasons (2005-2006) at two saffron (*Crocus sativus* L.) fields (field *a*: broadcast treatment and field *b*: patchy treatment), located in Boshrooyeh (33° North latitude, 57° East longitude), Razavi Khorasan, Iran. Geostatistical techniques were used to characterize the spatial and temporal variability of *C. draba* density and results were used to design precise herbicide application. The density and spatial distribution of *C. draba* varied with year and fields. The *C. draba* density maps calculated by kriging and was employed to estimate the percentage of surface susceptible to be treated with a site-specific herbicide treatment based on a weed threshold value of 13 shoot m^{-2}. Before herbicides application, in two years, *C. draba* density data showed moderate spatial dependence at both fields (47.6%-72.6%). Weed control was higher using broadcast than patchy application of herbicide in both years. In patchy control method, herbicide application was reduced by 42 and 26 percent compared to broadcast method in 2005 and 2006, respectively. In patchy herbicide method, the area exceeding the economic threshold was increased from 58 in 2005 to 74 percent in 2006, however under broadcast application treatment it was increased from 34 percent in 2005 to 67 percent in 2006. This indicated the lower weeds population increase under patch method (16%) compared to broadcast method (33%). Our results showed that the efficacy of weed control was higher in patchy than broadcast herbicide application method.

The weed density as affected by reduced herbicide dosages in spring barley fertilised with different nitrogen rates

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In conventional agriculture, the use of herbicides represents a risk of environmental pollution. Reduction of herbicide dosages may decrease impact on the environment and lead to more sound agriculture practice. The objective of the present work was to evaluate the effects of reduced herbicide dosages on weed density in spring barley.

The experiment ran from 2001 until 2004. The local spring barley variety 'Ansis' was sown in the field at the State Stende Cereal breeding institute in North-western Latvia. The soil was a loam with a pH of 5.9, organic matter of 2.0 %, level of exchangeable phosphorous is 256 mg kg^{-1} and potassium 161 mg kg^{-1}. Four levels of nitrogen, 0 (control), 60, 90, 120 kg ha^{-1}, in the form of complex mineral fertilizers (N18: P9: K9) were applied at sowing. The plants were treated with two different herbicides at BBCH growth stage 26 – 29. The herbicides were used at full, ½ and ¼ of recommended dose. Tribenuron-methyl (Granstar, DuPont) was aplied at 0, 3.75, 7.5, 15.0 g a. i. ha^{-1}; dichlorprop- P + MCPA + mecoprop-P (Duplazan Super, Nufarm UK Limited) at 0, 0.5, 1.0, 2.0 kg a. i. ha^{-1}. Annual dicotyledonous weeds were counted before and four weeks after the treatment. The effect of the herbicide treatments (*T*) was calculated by as where A is the number of weeds before treatment and B is the number of weeds after treatment. The effect of the treatments was characterized as very low if lower than 20 %, low when between 20 and 40 %, medium when between 40 and 70 %, high when between 70 to 85 % and very high when above 85%. The objective of the study was to evaluate how the different nitrogen rates and herbicide dosages affected weed density in spring barley.

The density of annual dicotyledonous weeds in 2001, 2002, 2003 and 2004 varied a lot and was on average 84 weeds m^{-2}, 181 weeds m^{-2}, 24 weeds m^{-2}, and 182 weeds m^{-2}, respectively. The reason of this discrepancy may be explained by variations in the weed seed bank at the experimental site and different weather conditions. The most commonly found weeds were *Thlaspi arvense* (L.), *Chenopodium* spp. and *Polygonum convolvulus* (L.), particularly in 2004. Other species like *Viola* spp., *Lamium* spp., *Spergula arvensis* (L.), *Capsella bursa-pastoris* (L.), Stellaria media (L.), *Matricaria inodora* (L.), *Galeopsis* spp., *Fumaria officionalis* (L.), *Galium aparine* (L.), *Lapsana communis* (L.), were found at densities lower than 10 weeds m^{-2}. The effect of herbicides on annual dicotyledonous weeds increased with the amount of nitrogen fertilizer. In the control plots, the effects of dichlorprop- P + MCPA + mecoprop-P and tribenuron-methyl were medium for full and ½ doses and very low for ¼ doses. In the treatments receiving 60 N kg ha^{-1} the effects of both herbicides at full and ½ doses was medium, while ¼ dose of dichlorprop- P + MCPA + mecoprop-P had a low effect and tribenuron-methyl had a very low effect. In the treatments receiving 90 and 120 N kg ha^{-1} both herbicides showed medium effect irrespectively of herbicide dose. The four year experiment showed that reduced herbicide dosages control annual dicotyledonous weeds well at high N rates.

The effect of four experimental adjuvants on glyphosate phytotoxicity in seven grass- and broadleaved weeds

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The addition of adjuvants to aqueous solutions of water-soluble glyphosate salts, either to the original formulation or later by tank mixing with it, is commonplace in current agricultural practice because of their ability to improve the performance characteristics of this herbicide. In these terms, adjuvants can be useful tools when considering a rational and dependable use of herbicides based in decreasing herbicide rates without sacrificing herbicide effectiveness. The effect of the experimental adjuvants LI 144 (a lecithin + methyl esters of fatty acid + non ionic surfactant based product), LI 700 (a lecithin + propionic acid + non ionic surfactant based product), ADE 702 (an all-green adjuvant based on Soya lecithins, a solvent coming from beet industry, and a surfactant coming from wheat straw and beet industry) and ADE 804 (a 70% rapeseed methyl ester concentrate with an emulsifier coming from wheat straw) on the effectiveness of a commercial glyphosate formulation (Asteroide 36% p/v, EC) applied at a 150 L ha^{-1} carrier volume using a precision lab sprayer. Grass weeds *Alopecurus myosuroides*, *Avena fatua*, *Digitaria sanguinalis*, *Lolium rigidum*, and broadleaved weeds *Chenopodium album*, *Conyza albida* and *Conyza bonariensis* grown in growth chambers with a 14-h photoperiod at 24 C day/18 C night temperature were used as experimental models. Half effective doses (ED_{50}) were recorded 28 days after treatment. Dose-response assays carried out under laboratory-controlled conditions showed a differential response to adjuvants depending on the weed species studied. Therefore, weed species such as *L. rigidum*, *D. sanguinalis*, and *C. bonariensis* showed no positive response to the presence of adjuvants in the tank mixture, with ED_{50} values ranging from 64.7±14.35 to 82.6±5.53 g a.i.ha^{-1} (*L. rigidum*), 37.5±4.70 to 82.5±5.01 g a.i.ha^{-1} (*D. sanguinalis*), and 15.2±2.08 to 71.4±10.16 g a.i.ha^{-1} (*C. bonariensis*), with control values of 53,2±3,31, 28,6±9,41,and 17,8±1,51 g a.i.ha^{-1}, respectively. On the contrary, all the adjuvants assayed succeeded in increasing the effect of glyphosate on *A. fatua*, being ADE 702 (170.8±22.85 g a.i.ha^{-1}) and LI 700 (173.3±9.77 g a.i.ha^{-1}) the most effective ones compared to glyphosate alone (474.7±30.11 g a.i.ha^{-1}). LI 700 also increased the herbicide effect in both *A. myosuroides* (168.6±10.48 g a.i.ha^{-1}) and *C. albida* (18.8±6.78 g a.i.ha^{-1}) when compared to non-additivated mixtures (278.8±9.47 and 52.7±8.05 g a.i.ha^{-1}, respectively), while LI 144 managed to improve herbicide results in *C. albida* (19.4±1.97 g a.i.ha^{-1}) as well. *C. album* was extremely susceptible to glyphosate and its mixtures, controls showing ED_{50} values of 7.23±1.24 g a.i.ha^{-1}. In these terms, all the adjuvants tested resulted in ED_{50} values well below the minimum dose assayed (5 g a.i.ha-^{1}). Interestingly, an antagonistic effect was observed in two of the three refractory species, where ADE804 (71.4±10.16 g a.i.ha^{-1}, *C. bonariensis*) and LI700 (82.5±5.01 g a.i.ha^{-1}, *D. sanguinalis*), displayed values significantly higher than controls. Our data support the thesis of a species-dependant relationship between adjuvant and herbicide improvement, suggesting LI700 and LI144 as the most effective products, and *A. fatua* as the most susceptible weed species to the presence of the adjuvants assayed in the tank mixture.

Shikimate accumulation in nine weedy species following glyphosate application

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Glyphosate controls many weedy plant species and the mechanism of action causes shikimate to buildup due to the blockage of the EPSPS enzyme. Nine weedy plant species were selected for examination to determine the changes in shikimate concentrations in plant shoots from 1 to 6 days after glyphosate application. The objectives of this study were to provide background shikimate concentrations under field conditions, to correlate shikimate buildup to plant growth parameters, and to compare shikimate fluxes in different plant species. All plants except soybeans were susceptible to glyphosate in this field. Species included *Brachiaria platyphylla, Trifolium repens, Polygonum pensylvanicum,* glyphosate-tolerant *Glycine max, Xanthium strumarium, Conyza canadensis, Ambrosia trifida, Ambrosia artemisiifolia, Chenopodium album,* and *Amaranthus palmeri.* Background shikimate concentrations from untreated plants were usually orders of magnitude lower than in treated plants, although *B. platyphylla* and *A. palmeri* had higher background levels. Shikimate concentrations in glyphosate tolerant soybeans were low (<50 ug/g fresh weight), which was expected. Plant height measurements indicated a range in plant growth from 0.25 cm per day for *T. repens* to 2.2 cm per day for *A. palmeri*. There was no obvious correlation between plant growth in untreated plants and shikimate concentration in treated plants. Shikimate accumulation patterns were divided into three general groups. One group had increased concentrations and then a steady concentration at < 4000 ug/g fresh weight; these plant species included *C. album, B. platyphylla,* and *X. strumarium.* This first group also had relative standard deviations < 20%, which was lower than other species. The second group had increased shikimate concentrations and some variability to a stable level at a higher concentration of > 4000 ug/g fresh weight. These plant species included *A. artemisiifolia, T. repens*, and *C. canadensis*; this group had relative standard deviations of 20 to 30%. The third group of plants had overall lower levels of shikimate accumulation and the concentration peaked at 2 or 3 days after treatment, then declined. Plant species in this group included *A. trifida, A. palmeri*, and *P. pensylvanicum.* This last group also had higher relative standard deviations of 33 to 35%. Glyphosate resistance in other populations in the United States has been confirmed in three of these species, *C. canadensis, A. palmeri,* and *A. artemisiifolia*. *C. album* and *A. trifida* are suspected of having glyphosate resistance in some populations. There appears to be no relationship between shikimate accumulation patterns in these plant species, which would provide an indication of future propensity to develop glyphosate resistance.

Use postemergence grass herbicides to manage wood small-reed (*Calamagrostis epigeios* (L.) Roth) in oak forest plantation

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When Hungary joined the European Union sethoxydim, which was the most widely used herbicide against *Calamagrostis epigeios* in sessile oak forest plantations, was removed from the market. It was necessary to change technology therefore we examined the efficacy of eight active ingredients in five trials against *C. epigeios*. We carried out four small plot trial with knapsack sprayer in sessile oak plantations. We treated *C. epigeios* in the beginning of May, when it was 40-50 cm high in 2002 and 2003, 30-35 cm high in 2004 and 30-40 cm high in 2006. The control treatment was sethoxydim at 0,375 and 0,5 kg/ha. We examined the control possibilities of *C. epigeios* by aerial application in turkey oak forest plantation. All tested herbicides were totally selective in sessile oak and turkey oak.

Propaquizafop at 0,12; 0,15 and 0,2 kg/ha and quizalofop-P-ethyl at 0,125; 0,15 and 0,175 kg/ha provided very poor control and at the tested rates these herbicides cannot be recommended against *C. epigeios* at the examined growth stages. Quizalofop-p-tefuril at 0,12 and 0,14 kg/ha was significantly less effective than the standard herbicide in small plot trials. Quizalofop-p-tefuril at 0,06 kg/ha provided adequate result by aerial application, i.e. the effect was much better than in small plot trials. Clethodim at 0,195 kg/ha, fluazifop-P-butyl at 0,225-0,3 kg/ha, haloxifop-R-methylester at 0,162 kg/ha and cycloxydim at 0,3 kg/ha controlled *C. epigeios* satisfactorily. With aerial application quizalofop-p-tefuril at 0,06 kg/ha can also be applied.

The response of *Pastinaca sativa* and *Echinochloa crus-galli* to some graminicides

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Parsnip (*Pastinaca* sativa L.) is a minor crop in Poland, but its cultivation area is growing rapidly, since the roots became the material for processing and fresh market as well.

The main annual grasses affecting the vegetable crops, including parsnip, is in Poland barnyardgrass (*Echinochloa crus-galli* (L.) P. BEAUV), which usually appears in large amount from the half of May and the beginning of June and could determine a threat for parsnip plantations. The usually long time of parsnip emergence causes that weeds competition is risky for parsnip cultivation, especially at the first part of its vegetation period.

This report describes the results obtained from control of this grass species and the reaction of parsnip to graminicides such as: propaquizafop (100 $g \cdot l^{-1}$), fluazifop-P-butyl (150 $g \cdot l^{-1}$), cycloxydim (100 $g \cdot l^{-1}$), quizalofop-P-tefuryl (40 $g \cdot l^{-1}$), chletodym (120 $g \cdot l^{-1}$) and quizalofop-P-ethyl (50 $g \cdot l^{-1}$).

The trials were undertaken (2002-2004) in Skierniewice, Poland. Field experiment design was randomized complete plots, in 4 replications and with plot size 12.15 square meters. Parsnip (*White Star* cv.) were sown between 22-28th April of each year. Graminicides were applied postemergence at the 3-6 leaves stage of parsnip and at the 4-6 leaves stage of *Echinochloa crus-galli*. The boom plot sprayer with fan nozzles Tee-Jet: DG 11002 VS, at the pressure of 0.4 MPa and 200 $L \cdot ha^{-1}$ water volume was used. The visual assessment of grassweed control efficacy was carried 1, 2, 3, 4 weeks after graminicides application. Phytotoxicity to the crops was evaluated four times, simultaneously with grassweed control. The influence of graminicides on yield of parsnip roots was estimated. Chlorophyll content in leaves of parsnip was determined by SPAD 501 gauge, 18-21 days after graminicides application.

The date obtained from the experiments allow us to a draw a conclusion that in general, all graminicides at rates adjusted for *Echinochloa crus-galli* control showed the very good efficacy level, amounted up to 100%. There were practically no differences between biological activity of graminicides, especially during last two evaluations. However, the results of barnyardgrass control obtained by individual graminicides during the fourth evaluation showed the following results: propaquizafop at the rate 80 $g \cdot ha^{-1}$ – 99.8% of damage, fluazifop-P-butyl (150 $g \cdot ha^{-1}$) – 97.4%, cycloxydim (150 $g \cdot ha^{-1}$) – 99.8%, quizalofop-P-tefuryl (32 $g \cdot ha^{-1}$) – 98.2%, chletodym (96 $g \cdot ha^{-1}$) – 99.3% and quizalofop-P-ethyl (50 $g \cdot ha^{-1}$) – 99.4%. Graminicides presented fast action of barnyardgrass damage process and a long-lasting biological activity, however after application of cycloxydim and chletodym the regrowing of small amount of *Echinochloa crus-galli* was sometimes observed. Phytotoxicity symptoms on parsnip plants were almost not noticeable, with the exception of slightly and temporary brighter spots on plant leaves, which disappeared about 3 weeks after the application. The measurements of chlorophyll content in parsnip leaves proved that graminicides at all treatments did not cause this factor and positively influenced the yield of parsnip. The yield received from all graminicide treatments was relatively at the similar level and was significantly higher in comparison to the untreated plots.

Investigating possibility of some selective herbicides tank mixture in wheat fields in controlled conditions

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To study the possibility of tank mixture of 2,4-D SL 62%, 2,4-D plus MCPA SL 67.5%, bromoxynil plus MCPA EC 40% and MCPA plus dichloprop-p plus mecoprop-p SL 60% with clodinafop propargyl EC 80% and fenoxaprop-p-ethyl EW 7.5% an experiment was conducted in 2005-2006. this green house experiment was conducted as a randomized complete block design with three replications. Treatments consisted of tank mixture of 2,4-D at 1.5 L/ha, 2,4-D plus MCPA at 1.5 L/ha, MCPA plus dichloprop-p plus mecoprop-p at 2.5 L/ha and bromoxynil plus MCPA at 1.5 L/ha with clodinafop propargyl at 0.8, 1 and 1.2 L/ha, and fenoxaprop-p-ethyl at 1, 1.2 and 1.4 L/ha, tribenuron methyl DF 75% at 20 g/ha plus clodinafop propargyl EC 80% at 0.8 L/ha as reference standard herbicide, and dual purpose herbicides iodosulfuron-methyl-sodium plus mesosulfuron- methyl WG 6% at 350 g/ha plus non-ionic surfactant at 0.2% (v/v) and sulfosulfuron at 26.6 g/ha plus non-ionic surfactant at 1 L/ha, were studied in control of wild oat, ryegrass, downy brome, hairy wetch, high mallow, black bindweed. Results indicated that tank mixture of MCPA plus dicloprop-p plus mecoprop-p at 2.5 L/ha with clodinafop propargyl at 0.8 L/ha, and bromoxynil plus MCPA at 1.5 L/ha with clodinafop propargyl at 0.8 to 1 L/ha satisfactorily controlled broadleaved and grass weeds. Fenoxaprop-p-ethyl could not satisfactorily control grass weeds, however, its tank mixed form had some synergistic effects on broadleaved weeds. Tank mixing 2, 4-D and 2, 4-D plus MCPA with clodinafop propargyl and fenoxaprop-p-ethyl, respectively, reduced grass herbicides efficacy. None of herbicide treatments could control downy brome except for sulfosulfuron.

Future trends in authorisations for minor uses of herbicides

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Over the last 15 years chemical weed control in Europe has come under increasing pressure, which has been particularly noticeable in minor crops. Many minor crops have but few authorised herbicides, and some have now no (complete) herbicide programme. Many crops can only be grown with the aid of a sufficiently effective herbicide toolbox, though non-chemical methods are often possible and continue to be developed.

In 1993 the European Directive 91/414 came into force, which was the beginning of a harmonised review of all existing active ingredients. All member states started to use the Uniform Principles for a harmonised product authorization. As it turned out many active ingredients did not have the complete dossier to allow evaluation under the new criteria or uniform principles. This meant that ca 87 herbicides on the market in 1993 were not notified for review and withdrawn from the market for all uses. From the remaining herbicides ca 83 are still under review. Eleven new herbicides have a provisional authorisation. Since 1993, 29 new herbicides came to market and have been included in the Annex I of Directive 91/414, whereas 65 existing ones have been included. Exact figures change continuously as the reviews proceeds. Minor uses suffered even more than major uses, because there is little economic incentive for the further development of dossiers, and by tradition minor use dossiers have often been incomplete in most Member States. Inclusion in Annex I means that one or at most a few chosen (major) uses are acceptable, and that further uses (including most, if not all minor uses) may be evaluated and authorised. This process is costly and often uneconomic to industry. As a result developments are slow and few new uses are authorised while old ones still disappear. Directive 91/414 will be succeeded by a new Regulation, now in discussion. In the draft there is little so far that offers hope for the future of minor uses because the specific rules proposed remain practically unchanged. A further reason is found in the demands of the Residue Regulation harmonising all MRL's in the EU and making sure that the needed residue data are available and up to standard.

Industry has seen many mergers and is operating in an agricultural world market that demands the crop protection industry to be mean and lean. This means that marginally profitable active ingredients and uses are not maintained. Again, it is the minor uses that suffer most. The herbicide discovery and development sector has been hard hit since the mid-nineties when herbicide tolerant crops (mostly Roundup Ready) came to market and quickly overran the soybean, cotton, rapeseed and maize markets in the Americas. Development of these technologies has been slower elsewhere, but except for Europe this technology still conquers vast new markets in Asia. That meant less potential market for traditional herbicides and fewer herbicides that might fill niches in minor crops. Currently there are few new herbicides in the pipeline and virtually no new mode of action.
Minor uses will have to do with fewer herbicides, which will increase the risks of resistance and will increase the needs for alternative weed control systems. The potential minor uses will often not been developed by industry alone, but by conglomerates of growers organisations, governments and industry. This may either lead to national protection because growers are organised on national scales and will demand data protection, or possibly to the further development of European groups devoted to common development of authorised uses for all member Sates. In that case European organisation and funding similar to the USA IR4 organisation would be necessary.

Effect of low-rate herbicide treatments on weed biomass and yield of sugar beet

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Herbicides are widely used to improve weed control in sugar beet (*Beta vulgaris var. saccharifera Aleph*.) which is poorly competitive against weeds. Nowadays, mostly due to environmental reasons, herbicides are usually used after sugar beet emergence. Mixture of post-emergence, broad spectrum herbicides have to be applied to control the wide range of weed species in sugar beet crops. Increase awareness of the enviromental damage caused by use of herbicide has aroused grate interest in reducing ther rates as much as possible. One of the way to diminish the herbicide input in sugar beet is to apply reduced herbicide doses at early growth (cotyledon) stage of weeds, when the first seed leaves start to appear. In order to low rates to be effective the first herbicide treatments have to be followed by additional application in relatively short intervals (7-15 days) when each new weed flush appear. This paper reports the results of a two year field study designed to determine the influence of different herbicide rates on fresh weed biomass and yield of sugar beet. All herbicide treatments, except standard (full dose) were used in low rates varying from 1/3 to 2/3 of standard rate and repeated three to five times during vegetation. Tank-mixed herbicide treatments consisted of herbicides desmedipham, phenmedipfam, ethofumesate, herbicidal oil and metamitron. Herbicide quizalofop-p was added to control annual grasses in all treatments. To improve *Ambrosia artemisiifolia* control herbicide clopyralid was added in some treatments. Treatments 1 and 2 were determined by the growth stage of the first emerged weeds and applied 23 days after sowing date in the first year of research and 30 days in the second year when sugar beet was in cotyledon stage. Treatment three was applied at stage of first true leaves of sugar beet with rates reduced by 1/3, and standard treatment (treat. 4) when sugar beet was at 4 leaves stages with full doses. Sprayings were applied at a water volume equivalent to 200 l/ha. Treatments were replicated four times in a randomised complete block design. Plots were 3,3 m long with 10 rows of sugar beet (15 m^2). Weed control was expressed as percent reduction in fresh weed biomass compared to the untreated control. Measuring was done in July when the weeds were in maximum growth stage. Sugar beet was hand harvested from the central six rows in each plot in October each year. The data were anylsed with ANOVA and LSD test. In both years there were similar weed density. The main weeds present in order of average density per m^2 for both years were *Echinochloa crus-galli* (20), *Solanum nigrum* (10)*, Ambrosia artemisiifolia* (7), *Chenopodim album* (6) and *Ch. polyspermum* (6). Compared with herbicide treatments significantly more fresh weed biomass (85%) and the lowest crop yield (93 %), in both years, occured on untreated check. All treatments gave acceptable weed control which ranged from 80-95 % reduction in weed flora. There was no significant difference in fresh weed biomass between herbicide treatments. Crop yield was not significantly different between herbicide treatments. Although there was no statistical difference between herbicide treatments the best average weed control (95 %) and the gratest average sugar beet yield (57 t/ha) were obtainted where herbicide combination desmedipham, phenmedipfam, ethofumesate, herbicide oil, and clopyralid were applied with residual metamitron reduced by half (treat. 2) compare with standard (full doses) treatment. Increasing the herbicide dose did not obtained better results in weed control and crop yield. This clearly indicate the financially benefit of weed control when appling repeated below-labeled herbicides rates after sugar beet emergence. This approuch should have particular positive effect on enviroment, although it was not the aim of our research.

Assessment of the tank mixture of mesotrione and pethoxamid efficacy for weed control in maize

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Weeds are one of the most important factors in maize (*Zea mays* L.) production. Therefore, weed control is an important management practice for maize production that should be carried out to ensure optimum grain yield. Mesotrione is a new callistemone herbicide that inhibits the HPPD enzyme (p-hydroxyphenylpyruvate dioxygenase) and introduces a new naturally selective tool into weed-management programmes for use in maize. Mesotrione provides control of the major broadleaved weeds, and it can be used in integrated weed-management programmes depending on the grower's preferred weed-control strategy. At post-emergence rates mesotrione provides naturally selective control of key species that may show triazine resistance e.g. *Chenopodium album* L., *Amaranthus* spp., *Solanum nigrum* L., as well as species of weed that show resistance to acetolactase synthase (ALS) inhibitors e.g. *Xanthium strumarium* L., and *Sonchus* spp. In all cases, a grass herbicide is still needed. Pethoxamid can be used for grass and broadleaf weed control in maize. Grass weeds controlled include *Echinochloa crus-galii* (L.) Beauv., *Digitaria sanguinalis* (L.) Scop., and *Setaria* spp. Up to new regulations of UE in some cases that both herbicides may replace the use of atrazine. The objective of this research was to determine the effect of the grass and broadleaves weed control by different mixture rate of mesotrione plus pethoxamid applied postemergence in maize. Field trials were conducted using maize (var. Fido) grown at the Brody Research and Education Station of Agricultural University of Poznan, during the 2005 and 2006 growing season. The trials were complete, randomised block design with four replicates and individual plot sizes of 2,8 m x 10 m. Mesotrione (Callisto 100 SC) and pethoxamid (Successor 600) as the tank-mix were used at different rates (150+1800, 100+1800, 100+1500 g.ha^{-1} and 150 g.ha^{-1} mesotrione only). Treatments were applied at 4-6 leaves (BBCH 14-16) of the maize growth. There was no phytotoxicity observed on maize after herbicide treatments. The main weeds present in the untreated plots in all trials included *Echinochloa cruss-galli*, *Chenopodium album*, *Viola arvensis* Murray, *Geranium pusillum* L., *Polygonum aviculare* L., *Polygonum convolvulus* L. and *Veronica hederifolia* L. Herbicide mixture provided higher levels of ECHCG control (98-100%) than mesotrione was used alone (86%). The data were analysed and there was no significant difference between 100+1500 and 1800 g.ha^{-1} rates of mesotrione plus pethoxamid. In the postemergence trials, the broadleaf weeds, except *Ch. album,* were not well controlled by the mesotrione-alone treatment. The addition of pethoxamid to mesotrione significantly improved the control of broadleaf weeds. Control of *G. pusillum* was effective with lower rates of mesotrione plus pethoxamid (100+1500 g.ha^{-1}). Mesotrione applied alone was less effective on *P. arvensis* and *P. convolvulus* (50 and 63% control, respectively). Understandably, herbicide mixtures provided higher levels of both species control than when used mesotrione alone. Results indicated 88-90% control of *P. arvensis* and 98-100% control of *P. convolvulus* when mesotrione and pethoxamid was applied at the rate 100+1500 g.ha^{-1} only. *V. arvensis* was more effective controlled when mesotrione and pethoxamid tank-mixture were used at higher rates e.g. 150+1800 g.ha^{-1}, respectively. Mesotrione and mesotrione plus pethoxamid treated plots were always among the highest yielding as compared to untreated plots. Any redactions in cob and grain yield were always associated with high weed fresh matter yields indicating that it was the weed competition that lead to reduced yield and not herbicide phytotoxicity.

Evaluating the efficacy of some newly registered "dual purpose" herbicides for weed control in maize (*Zea mays* L.)

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There are very few herbicide options available for weed control in maize in Iran. Field experiments were conducted in 2005 at the research fields of Plant Protection Research Institute in Ahvaz, Kermanshah, Karaj, and Varamin, to evaluate maize yield response and control of weeds with nicosulfuron at 40, 60, and 80 g a.i./ha, foramsulfuron at 337.5, 450, and 562.5 g a.i./ha, rimsulfuron at 5, 7.5, and 10 g a.i./ha as "dual purpose" herbicides, and 2,4-D plus MCPA as reference standard. The experimental design at all locations was a randomized complete block with four replications. Naturally occurring weed populations were used in the experiments. All herbicides were applied at the three- to six-leaf stage of maize. Results indicated that nicosulfuron and foramsulfuron at the highest dose provided satisfactory control of broadleaved and grass weeds in maize. Results also showed that weed control efficacy of 2,4-D plus MCPA was equal to those of nicosulfuron and foramsulfuron in case of some weed species and locations; in these cases the new "dual purpose" herbicides were advised because they gave the opportunity to control grass weeds as well. Rimsulfuron, however, could not generally act acceptably in this respect. Application of nicosulfuron at 80 g a.i./ha resulted in the highest maize yield after the weed-free check except for Kermanshah. At Ahvaz, Karaj, and Varamin, grain yield of nicosulfuron at 80 g a.i./ha treated plots were 6275.0, 7647.5, and 8095.0 kg/ha, respectively. At Kermanshah, however, the highest grain yield among all treatments was obtained with foramsulfuron at 562.5 g a.i./ha (10560.0 kg/ha). 2,4-D plus MCPA plots had the lowest grain yield among all treatments. This could be attributed to the spectrum of weed control with this herbicide, since the grass weeds escaped control where maize was sprayed with 2,4-D plus MCPA. Grain yield in plots treated with rimsulfuron was lower than the other two "dual purpose" herbicides, which could be attributed to lower weed control efficacy of this herbicide. Altogether, results of these experiments showed that 2,4-D plus MCPA could be replaced by nicosulfuron at 80 g a.i./ha since it gave an acceptable control of broadleaved weeds while it provided satisfactory grass weed control. This would especially be beneficial from an ecological point of view since application of "dual purpose" herbicides allowed to reduce the use of herbicide. Rotational application of 2,4-D plus MCPA, nicosulfuron and foramsulfuron at the highest dose could also be suggested in order to prevent evolution of herbicide resistant weeds.

Study on weed control efficacy of some newly registered herbicides in wheat (*Triticum aestivum* L.)

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Introducing new herbicide options is a prerequisite for a successful weed management program in wheat. Field experiments were conducted at three research stations of Plant Protection Research Institute, Iran, in 2003-2004. Treatments consisted of 2,4-D plus carfentrazone-ethyl at 300, 350, 400, and 700 g/ha, florasulam plus flumetsulam at 50, 60, and 70 ml/ha, bromoxynil plus MCPA at 750, 1000, and 1500 ml/ha, solid 2,4-D at 700, 900, and 1400 g/ha, all as newly registered herbicides, 2,4-D plus MCPA and tribenuron methyl as reference standard herbicides, and a full-season weed free check. Herbicides were sprayed at wheat tillering. Naturally occurring weed populations were used in all experiments. Results were different in terms of weed control. At Karaj, results indicated that 2,4-D plus carfentrazone-ethyl at 400 g/ha, and bromoxynil plus MCPA at 1500 ml/ha could significantly improve weed control efficacy compared with tribenuron methyl as reference standard herbicide. At Bostanabad and Kordkouy, however, the new herbicides 2,4-D plus carfentrazone-ethyl and florasulam plus flumetsulam did not act better than older herbicides, although they were more satisfactory at Kordkouy compared with Bostanabad. At these locations 2,4-D plus MCPA and bromoxynil plus MCPA at 1500 ml/ha controlled weeds better than other herbicide treatments. These results indicated that herbicide efficacy is dependent not only on herbicide itself but also on other factors such as climatic conditions. In general, the new herbicide florasulam plus flumetsulam could not provide acceptable weed control at most cases. Grain yield was significantly affected by herbicide treatments. At Karaj, grain yield of the full-season weed free check (4616.0 kg/ha) was ranked third after tribenuron methyl (4699.6 kg/ha) and 2,4-D plus carfentrazone-ethyl at the lowest dose (4624.3 kg/ha) treated plots. This could be attributed to the possible damage of hand weeding to the wheat crop. It was also observed that the results obtained for grain yield did not agree with those obtained for weed control, which was due to crop damage caused by 2,4-D plus carfentrazone-ethyl at this location. At Bostanabad and Kordkouy, however, the plots treated by 2,4-D plus MCPA and bromoxynil plus MCPA at 1500 ml/ha produced the highest grain yield (4005.0 and 1605.0 kg/ha, respectively) after the full-season weed free check which were in agreement with results obtained for weed control. Generally, rotational application of bromoxynil plus MCPA at 1500 ml/ha and tribenuron methyl or 2,4-D plus MCPA is proposed to prevent the evolution of resistant weeds.

Efficacy of weed control for wheat (*Triticum aestivum* L.) using tank mixture of 2,4-D plus MCPA with clodinafop-propargyl

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Field and greenhouse experiments were conducted in 2003-2004 to study weed control and winter wheat response to tank mixtures of 2,4-D plus MCPA with clodinafop propargyl. The field experiments were conducted at Yazd and Oroumieh, Iran, with factorial combinations of 2,4-D plus MCPA at 0, 975 and 1300 g a.i./ha, with clodinafop propargyl at 0, 64, 80, 96 and 112 g a.i./ha in four replications under naturally occurring of weed populations. A series of greenhouse experiments was also conducted to further evaluate the effect of these tank mixtures on weed control; however, each herbicide mixture was considered as one treatment and the experiment was established in a randomized complete block design with four replications. In the field experiments, herbicides were applied at wheat tillering while in the greenhouse experiments they were applied at the beginning of tillering stage and at four-leaf stage of grass and broadleaved weeds, respectively. Significant differences were observed among different tank mixtures of 2,4-D plus MCPA with clodinafop propargyl at all locations and in case of all weed species. Generally, results indicated synergistic effects between 2,4-D plus MCPA and clodinafop propargyl. Broadleaved and grass weed populations and biomass control efficacy increased with most tank mix combinations, although the goodness of control was also dependent on weed species. Clodinafop propargyl either applied alone or tank mixed with 2,4-D plus MCPA failed to control rye (*Secale cereal* L.) and downy brome (*Bromus tectorum* L.). This could be attributed to the ability of these two weed species to metabolize this herbicide. The best tank mixture with regard to weed control efficacy and environmental concerns was 2,4-D plus MCPA at 975 g a.i./ha with clodinafop propargyl at 96 g a.i./ha which was in agreement with the results obtained from greenhouse experiments. The results of visual rating at 30, 40, and 50 days after herbicide applications (DAT) in greenhouse experiments showed that the effectiveness of herbicide treatments increased with time, i.e. the highest visual weed control was obtained at 50 DAT. Wheat grain yield was also increased by tank mixing clodinafop propargyl with 2,4-D plus MCPA. The highest grain yields at Yazd (4172 kg/ha) and Oroumieh (6432 kg/ha) were obtained in plots treated by 2,4-D plus MCPA at 975 g a.i./ha with clodinafop propargyl at 96 g a.i./ha, and 2,4-D plus MCPA at 1300 g a.i./ha with clodinafop propargyl at 64 g a.i./ha, respectively. These could be attributed to wider range of weed control using tank mixtures. As a result and with regard to both weed control efficacy and wheat yield, 2,4-D plus MCPA at 975 g a.i./ha with clodinafop propargyl at 96 g a.i./ha treatment is advised. In addition, results showed that in order to prevent clodinafop propargyl efficacy reduction due to tank mixing with 2,4-D plus MCPA, its application dose should be increased by 32 g a.i./ha from its recommended dose (64 to 67 a.i./ha).

Weeds and weed management in lettuce

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The EWRS Working Group "Weed Management Systems in Vegetables" was established with the aim of collecting and disseminating information and results on weeds and weed control strategies in vegetables, identifying gaps in knowledge and defining new research projects. So far the working group has published reviews on onions, tomatoes, carrots, peas and cabbages. Information about key weeds, new weeds or species that have recently become problematic, effect of competition, weed management programmes in integrated and organic production, approved herbicides and those currently undergoing registration for use in lettuce grown in Germany (D), Italy (I), Jordan (HKJ), The Netherlands (NL), Poland (PL), Portugal (P), Slovenia (SLO), Spain (E), Switzerland (CH), Turkey (TR) and United Kingdom (UK) was collected.

Although the majority of the lettuce crop is grown as an outdoor spring-summer crop (E 37000 ha, TR 20000 ha, I 18000 ha, D 12500 ha, UK 7000 ha, HKJ 1900 ha, CH 1700 ha, NL 1300 ha, PL 600 ha, SLO 350 ha,), early and late productions are obtained by non-woven materials (fleece), clear/white plastic mulch, row covers and greenhouse cultivations to satisfy year-round consumption. Black polyethylene and black biodegradable plastic (Mater-Bi) mulching are usually preferred where weed control is a priority in comparison to yield earliness. Lettuces are mainly transplanted as modules, but may be also direct-drilled. The weed communities are typically very species rich and their composition is highly variable in relation to climate, soil and crop period. Weeds that are most problematic in lettuce are those that are taxonomically related and not controlled by herbicides, in particular, *Galinsoga* spp., *Anthemis* spp., *Matricaria* spp., *Senecio vulgaris* and *Sonchus oleraceus.* However, *Capsella bursa-pastoris, Diplotaxis* spp., *Fumaria officinalis, Papaver rhoeas, Veronica* spp., *Viola arvensis, Stellaria media*, *Urtica urens, Chenopodium* spp. and *Poa annua* may also be key weeds in early cultivations whilst *Amaranthus* spp., *Polygonum* spp., *Portulaca oleracea, Digitaria sanguinalis* and *Echinochloa crus-galli* may occur in late cultivations. Some species are becoming important: *Rorippa sylvestris* in CH, *Abutilon theophrasti, Galinsoga parviflora, Xanthium spinosum, X. strumarium* in P, *Aethusa cynapium, Bidens tripartita* in D, *Cruciferae* in SLO, and *Oxalis pes-caprae* and *Calendula arvensis* in I. Transplanted crops rarely suffer severe weed competition, but late maturing varieties and all drilled crops are particularly susceptible due to low initial growth rates. Typically there is no critical period of competition such that a single weeding 2-3 weeks after transplanting is sufficient to prevent yield loss. However, there is a zero tolerance of weeds that may hinder hand-harvesting or lead to contamination of minimally processed lettuces. Conventional weed control is based on herbicide application; options are restricted to trifluralin (I, UK, HKJ), chlorpropham (I, UK, NL), pendimethalin (E, I, UK, D, CH, HKJ), propachlor (I, UK), propyzamide (E, I, UK, D, CH, P, PL, SLO), carbetamide (NL), benfluralin (E, I), chlorthal (E, I), oxadiargyl (E), oxadiazon (I), oxyfluorfen (HKJ) and graminicides (E, I, P, D, SLO, HKJ). No pre- or post-emergence/transplanting herbicides are registered in TR. In CH, flufenazet 0.6 L/ha applied immediately before planting showed a total control of *Galinsoga* spp. Common strategies for organic production are false seedbed technique, mechanical (i.e. split-hoeing and/or finger weeding) and manual weeding; planting on ridges and use of starch-based biodegradable mulches are increasing. Further and more detailed information can be found in the WG web site at www.veg.ewrs.org

Perspectives of mixed spring grain crops and legumes growing and their protection against weed vegetation

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One approach to increase the supply of protein in Belarus is to cultivate cereal crops and pulse crops together, but high weed infestations prevent the growing of these crop mixtures. Herbicide application in crops consisting of cereals and legumes in mixture is complicated due to different selectivity patterns of cereals and legumes to herbicides. Generally soil herbicides are better tolerated than foliar active herbicides.

Research carried out in the experimental fields of the Belarussian Institute of Plant Protection showed that the following herbicides applied after sowing but before crops emergence provided good control in a crop of oat (cultivar Bug) and blue lupin (cultivar Mirtan): Prometrex, WP (promethrin) at 1,0-1,5 kg ha^{-1} (72-96 % weed control), Stomp 33% EC, (pendimethalin) at 2,0-3,0 l ha^{-1} (72 -97 % weed control) and Racer 25% EC (flurochloridon) at 1,0-1,5 l ha^{-1} (86-90 % weed control). In a mixture of barley (cultivar Gonar) and lupine (cultivar Pershatsvet) the most effective herbicides were (applied after sowing but before crop emergence): Gesagard SC (prometryne) applied at 1,5 l ha^{-1} (56-77 % weed control), Sencor WDG (metribuzine) at 0,3 kg ha^{-1} (60-86 % weed control), Marathon (pendimethalin + isoproturon) at a 3,0 l ha^{-1} (60-93 % weed control), Stomp 33% EC at 3,0 l ha^{-1} (60-98% weed control) and Racer 25% EC at 1,0 l ha^{-1} (67-98 % weed control). Due to the reduced weed infestation reliable yield increases were obtained.

Influence of herbicides on grain quality in winter wheat varieties

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Research on herbicide use in cereals has shown that despite the unquestionable role of herbicides in eliminating weed competition, they can also have an influence on the quality and chemical composition of the grain. In the present work the influence of six herbicide combinations on the content of protein and gluten, the falling number and sedimentation index have been analyzed in the winter wheat varieties Finezja, Pegassos, Turnia, Sukces, Clever, Nutka and Tonacja .

The analyzed grain samples came from experimental fields in Kro cina Mała near Wrocław (Poland), grown in the years 2003-2005 at Experimental Station of Institute of Plant Protection in Trzebnica. The experiment was conducted as a split-block design with four replications and a plot size of 16,5 m^2 (15 m^2 of crops). The plants were treated with recommended dosages of herbicides in the spring during the tillering phase. The following herbicides were used: Atlantis 04 WG (iodosulphuron + mesosulphuron) + Atpolan 80 EC (paraffin oil); Attribut 70 WG (propoxycarbazone) + Sekator 6,25 WG (iodosulphuron + amidosulphuron); Huzar 05 WG (iodosulphuron); Gold 540 EC (2,4-D + fluoroxypyr); Chwastox Trio 540 SL (mecoprop + MCPA + dicamba) and Mocarz 75 WG (dicamba + tritosulphuron). The control sample came from fields, where no herbicides were applied. The result is shown as the average from the three years of the experimentation.

The quality of the winter grain varied significantly during the years of the experimentation. As for the qualities analyzed, the most valuable grain was collected in the year 2003. Regardless of the weather conditions, the grain quality was most influenced by the genetic characteristics of the varieties, whereas the application of herbicides resulted in slight but positive changes in the analyzed parameters of quality. Following herbicide application the content of protein tended to increase compared to the control sample. The most significant increase was observed in Finezja, Turnia and Sukces treated with Gold 540 EC, and Turnia treated with Atlantis 04 WG + Atpolan 80 EC and Attribut 70 WG + Sekator 6,25 WG. The yield of wet gluten and sedimentation index was comparable to that of the control samples in the majority of the grain samples. Only a small decrease of the gluten content was observed in Finezja treated with Chwastox Trion 540 SL, whereas all varieties treated with Gold 540 EC showed an increase. It was noticed that the falling number depended on the environmental conditions and the herbicides used. Nevertheless, all the herbicides analyzed increased the falling number, especially in Pegassos, Nutka, Sukces and Tonacja. The results of the experiment have shown that herbicide treatments did not adversely affect grain quality and by influencing some of analyzed parameters in some cases it even improved the nutritional value.

Cuscuta campestris (Ynck) and *Cuscuta epithymum* (Murr.): serious problems in alfalfa in Serbia

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Alfalfa is a major forage crop, grown in an area of some 30,000 ha in Serbia. Apart from weeds, which are a permanent threat, large areas of this crop also become infested by parasitic flowering plants of the genus *Cuscuta*.

In this investigation we found two species, *Cuscuta campestris* (Ynck) and *Cuscuta epithymum* (Murr) in alfalfa. Both species normally infest young as well as established alfalfa crops. The occurrence of *Cuscuta* spp. over large areas results from a practice widespread among Serbian farmers to saw their own seeds from infested plots (because of high seed prices on the market) without scouring them in the decuscutator. *Cuscuta* spp. control is further limited by an insufficient choice of sound control solutions. To improve *Cuscuta* spp. control in alfalfa, we conducted tests in a growth chamber and in the field. Seeds were germinated in a growth chamber experiment on filter paper supplemented with various concentrations of herbicides: propyzamide 1.5, 1.0, 0.5 and 0.25 mg kg^{-1} and imazethapyr 0.2, 0.15, 0.1, 0.05 and 0.025 mg kg^{-1}. The purpose was to determine whether the two herbicides affect the germination of *C. campestris* and *C. epithymum*. The trials were done in triplicate and no effect of any concentration investigated was recorded. There was no difference between control and treatments. The results were similar in the preemergence tests of propyzamide and imazethapyr effects on germination and emergence of *Cuscuta* spp. and alfalfa in plastic pots. Propyzamide was applied at 1.5 and 2 kg ha^{-1} rate and imazethapyr at 0.15 and 0.2 kg ha^{-1}. Neither herbicide was found to affect *Cuscuta* but phytotoxicity to alfalfa was high, especially in the imazethapyr treatment, where no germination was recorded. Slightly less severe phytotoxicity, but still high, was found in propyzamide treatment. This method of control was therefore assessed as inappropriate. Methods of control were tested against dodder already forming haustoria on alfalfa plants in growth chamber and field experiment. Alfalfa was first grown into an optimal stage, and then infested with *Cuscuta* spp. In both cases, the following herbicides were tested: propyzamide at 1.5 and 2 kg ha^{-1}, imazethapyr at 0.2 kg ha^{-1}, imazethapyr at 0.15 kg ha^{-1}+ diquat-dibromide at 0.28 kg ha^{-1}, diquat-dibromide at 0.42 kg ha^{-1}, glyphosate-IPA at 0.48 kg ha^{-1}, and glyphosate IPA at 0.290 kg ha^{-1}+ diquat-dibromide at 0.140 kg ha^{-1}. The herbicides were applied in 400 l ha^{-1} of water. The activity was monitored by daily inspection of the crop and *Cuscuta* spp.

High efficacy was found in treatments with imazethapyr and glyphosate IPA, slightly poorer with the imazethapyr+diquat-dibromide combination, and very poor with all others. Relatively slow dodder development, insignificant flowering and predominating absence of seed formation were taken to be acceptable results. Such data contradict a current practice of recommending the use of propyzamide for *Cuscuta* spp. control as its efficacy in this trial was unsatisfactory, as well as that of diquat-dibromide. Regarding selectivity, no significant phytotoxicity was found in the field. Transient damage was found in diquat-dibromide treatment, but the herbicide fully destroyed alfalfa in the growth chamber. In conclusion, propyzamid and glyphosate IPA can be successfully used against *Cuscuta campestris* and *Cuacuta epithymum*, both independently or in combination.

Adjuvants enhance herbicide micro-rate efficacy in sugar beet

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Sugar beets are sensitive to competition from weeds, and effective weed control with herbicides requires multiple, timely applications of several products in combination. Optimum weed control with standard herbicide rates is often achieved at the expense of sugar beet injury. Also recommended herbicide combinations are relatively expensive.

Field trials were conducted for 3 yr (2004-2006) to determine sugar beet tolerance to and efficacy of conventional herbicides applied at micro-rates, either with or without various oil-based adjuvants. The recommended standard herbicide treatment, which was applied without supplemental adjuvant, was phenmedipham + desmedipham + ethofumesate (Betanal Progress AM 180 EC) + triflusulfuron (Safari 50WG) at 90 + 90 + 90 + 15 g ai/ha, respectively. The micro-rate herbicide combination, which was applied with and without supplemental adjuvant, included: phenmedipham + desmedipham + ethofumesate at 30 + 30 + 30 g ai/ha (Betanal Progress AM 180 EC) + triflusulfuron at 4.5 g ai/ha (Safari 50WG) + clopyralid at 33 g ai/ha (Lontrel 300 SL) + lenacil at 160 g ai/ha (Venzar 80 WP). Adjuvants evaluated with the herbicide micro-rate combination were applied at 1.5 L/ha and included two commercial methylated seed oil adjuvants with various emulsifiers (Adpros 85 SL and Olbras Super 90 EC), one basic-pH methylated seed oil adjuvant that raised the spray mixture pH above 7 (Atpolan BIO 80 EC), and one adjuvant based on emulsified free fatty acids from winter rape oil (Olbras 88 EC). All herbicide-adjuvant combinations were applied broadcast and sequentially at the cotyledon stage of emerging weeds using a CO_2-pressurized backpack sprayer equipped with four TeeJet 11002 flat-fan nozzles and calibrated to deliver 170 L/ha at 250 kPa. Plots, four row wide (4 x 0.45 m) and 10 m long, were arranged in a randomized complete block design, and treatments were replicated four times.

To achieve adequate weed control, micro-rate and standard-rate treatments required four sequential applications. Sugar beet was infested mostly with *Chenopodium album*, *Galium aparine, Solanum nigrum, Viola arvensis, Cirsium arvense,* and volunteer *Brassica napus*. The micro-rate treatments applied with adjuvants provided excellent weed control (between 96 to 100%, depending on years) that was equal to the standard-rate treatment applied without adjuvant. All tested adjuvants greatly and similarly increased efficacy of the herbicides applied as micro-rate treatments. Sugar beet injury from the micro-rate herbicide combination applied with any adjuvant evaluated was generally 2 to 6%, which was substantially lower than generally 7 to 15% injury by the standard-rate herbicide. Yields of sugar beet root and extractable sugar following the micro-rate herbicide combination applied with any adjuvant tested were similar to the standard-rate treatment applied without adjuvant. The cost for herbicides and adjuvants was generally 42 to 45% less with the micro-rate than the standard treatment.

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Weed control in new forest plantations in Israel

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Jerusalem pine (*Pinus halepense*) occupies the majority of the forest plantations in Israel for more than 80 years. Along with this species there were several other pines, e. g., *P. pinea*, and *P. brutia*. The "European" forest established at the early days of the 20th century faced a long term of unsuitable eco-conditions, caused dramatic change in the plantation characteristics started several years ago. The pine trees in the Mediterranean regions are replaced by native broadleaf species, e.g., *Ceratonia*, *Olea*, *Zizipus*, *Amygdalus*, *Acer*, *Quercus*, *Pistacia*, *Rhamnus* etc. Weed management in semi arid forest plantations is rather complicated task due to lack of rains, short winter and rapid growing season. Spring and summer are dry and temperatures are around 35 ^{0}C. Winter 2004/5/6 precipitations in the Israeli coastal-plain were 756, 508 and 561 mm, respectively. Almost all the newly-planted tree species replacing pines are very susceptible to triazine herbicides and to most other pre-emergence, soil-applied herbicides. Simazine (1.5 - 2.0 kg a.i./ha) and sulfometuron-methyl (25-50 g a.i./ha) used in the last 30-40 years as the common tool for weed control along with mechanical equipments provided reasonable and economical solution. The ban on atrazine and simazine use imposed by the EEC facilitated the search for environmentally safer herbicides. In order to face these challenges, field experiments were carried out in order to evaluate the potential efficacy as well as the influence of several herbicides on a variety of tree seedlings during their first stage of growing. The field experiments were placed in a new plantation of native dicot species and last for three consecutive years (2003/4-6). The examined herbicides were applied early winter after the first major rain as a single annual treatment supplemented by single weed mowing during the summer. Of all the herbicides tested during the long experimental period, no one exhibited reasonable control when applied alone. We found that either a pre-mix of propyzamid + oxyfluorfen (428+550 g a.i./ha - 'AMIR'), isoxaflutole (187 g a.i./ha) or flurochloridone (0.5 kg a.i./ha) tank-mixed with propyzamid (0.5 kg ai/ha) gave good weed control for 4 to 5 months. Propyzamid is an essential component in this management due to its ability to control grass weeds. Annual grasses especially *Bromus* spp. and wild oat were the main weeds present in most of the treated plots, and were the major reason for tree growth inhibitions. Diflufenican (375 g a.i./ha) and isoxaben (375 g a.i./ha) failed to maintain the desired weed-free plots as compared to the above mentioned herbicides.

Effects of reduced herbicide doses in spring cereals in Latvia

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In Latvia, herbicide application in often the only plant protection activity in cereal crops. Because pesticide use can have negative influence on the environment many European Union countries have implemented pesticide reduction plans. There are two ways to reduce pesticide usage: to use reduced dosages of pesticides or not to apply pesticides at all. Many investigations show that it is possible to use herbicides in reduced dosages without substantial yield losses.

Field experiments have been carried out since 2001 to develop a Latvian prototype of the Danish decision support system model "PlanProtection Online/Weeds" and to test its efficacy under Latvian conditions. Spring barley (cultivar Balga) was grown on a sod podzolic sand loamy soil with neutral pH, medium humus content and medium content of phosphorus and potassium. Soil tillage was traditional: autumn ploughing and presowing tillage with roto-tiller. Sowing was done with a experimental sowing machine "Hege". Sowing rate was 400 germinable seeds per m^2. Mineral fertilizers were applied before sowing assuming a yield of 5 t ha^{-1}. Six herbicides, tribenuron-methyl, amidosulfuron, dicamba + triasulfuron, MCPA 750, dichlorprop-P + mecoprop-P + MCPA and fluroxypyr, were applied at the tillering stage (BBCH 23-30) at three dosages: full recommended dosage (1/1N), one half (1/2N) and one quarter (1/4N) of the full-recommended dosage. Weed assessments were done on the day before spraying, and 6 weeks after spraying. Assessments were done by placing a 0.25 m^2 ring at three sites per plot identifying weed species and counting the number of weeds per species. At the second assessment weed fresh weight were also measured. Assessments were done in fixed places. Weed infestation in both 2001 and 2002 was medium, on average 54 -86 weeds per m^2. There were a total of 23 weed species before spraying but only 4- 5 of them occurred at a density higher 1 plant m^{-2}. The most common species were *Chenopodium album* L., *Lamium purpureum* L, *Cirsium arvensis, Galeopsis* spp., *Thlaspi arvense* L., and *Veronica arvensis* L. Almost 60 % of all weeds were at 2-4 true leaf stage at the time of spraying.

Results show that all herbicides had a good (>85 %) effect on some of the weed species even when applied at reduced dosage. Reduction to 1/4N was effective for tribenuron-methyl in 2001; reduction to 1/2N was effective for dicamba + triasulfuron in 2001 and dichlorprop-P + mecoprop-P + MCPA in 2002. There were no significant differences if spring barley grain yields between herbicide dosages.

Optimization of weed control with post emergence herbicides in maize under conditions in the Ukraine

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Maize is extremely sensitive to weed competition. Thus, weed control in maize is one of the key elements in modern production system. In many countries maize producers use herbicides for weed control, however agricultural practices in the EU countries are moving towards a reduced dependence on chemical weed management. This is achieved not by omitting the use of herbicides, but by means of improved application technologies, synthesis of new herbicides and adjuvants and accurately defined strategies as cultivation of maize is not possible without effective weed control. The objective of this research was to investigate the effectiveness of mesotrion used alone or in mixture with metolachlor, terbuthylazine or nicosulfuron in maize.

Field trials were conducted in 2005 and 2006 at the Feed Research Institute of UAAS. The soil was a grey wooded type with 2.2-2.4 % organic matter content and pH of 5.2-5.5. The trials were carried out using a plot size of 25.2 m^2 (4.2 x 6m) and 4 replications. The pre-emergence spraying was carried out the day after sowing. The post-emergence application took place when crop and grass weeds were at the1-3 leaf stage and broad-leaved weeds were at the first true leaf stage. Herbicides efficacy was assessed 30 days after treatment (DAT) and at crop harvest by measuring the above-ground weed fresh weight. The results showed that pre-emergence application of mesotrion at 144 g. a.i. ha^{-1} provided 81 % control of mono and dicotyledonous weeds. Application of tank mixtures of 120 g. a.i. ha^{-1} mesotrion + 1200 g. a.i. ha^{-1} metolachlor resulted in 90 % weed control. We found that mesotrion also showed a high activity when applied post-emergent. Application of mesotrion (120 g. a.i. ha^{-1}) provided 100 % control of *Amaranthus retroflexus, Chenopodium album* and *Galinsoga parviflora*. The tank mixture of mesotrion (72 g.a.i.ha^{-1}) + nicosulfuron (30 g.a.i.ha^{-1}) resulted in 94 % control. The herbicides combinations nicosulfuron + prosufuron and mesotrion + metolachlor + terbuthylazine provide highly variable control of broad-leaved weeds and grasses in maize. Inclusion of ammonium nitrate into the spray solution of nicosulfuron and rimsulfuron allowed reduction of the herbicide doses of 25-30 % without any loss in efficacy.

Session 3

Crop-weed interactions and non-chemical methods

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Rumex species in Europe and the conversion to organic agriculture – problems and solutions

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Docks (especially *Rumex obtusifolius* and *R. longifolius* in northern Europe) are important perennial weeds of grassland throughout Europe. In this paper we compare and contrast problems of dock infestation in the UK, Norway and Switzerland, the management techniques currently used, and research into dock control. In the UK, research into farmer's perceptions of dock problems and control indicates that whilst docks can be a problem, farmers usually target docks in parts of the farm system where they are vulnerable and it is practical and cheap to do so. It is clear that a range of approaches will work best over a period of time. Docks are generally managed through the whole rotation by preventing them from seeding and reducing the vigor of or killing the tap root. In grasslands, a competitive grass sward is sown, a silage rather than hay cut taken, poaching is avoided and docks are usually cut or grazed (e.g. with sheep). Manual removal at targeted stages of rotation is also a proven method, but labour intensive. Topping specific patches with mowers or strimmers is a common mechanical method. Research into *Rumex* biocontrol has concentrated on the use of the chrysomelid beetle *Gastrophysa viridula* and the rust fungus *Uromyces rumicis*. Neither will control docks on their own although the combined agents can produce an additive effect. Several farmers have expressed an interest in using *G. viridula*, and some have reared the beetle or translocated it. In combination with quick reseeding with *Lolium perenne*, the beetle can give effective control of young *R. obtusifolius* seedlings. In Norway, docks are a challenge in all grassland cropping systems and are perceived as a true bottleneck in the development of grassland-based organic production. *R. longifolius* is more common than *R. crispus* and *R. obtusifolius* in Norway, and has been little studied. With the exception of herbicide testing there has been little recent research on docks in Norway, but in one study the biology and ecology of all three species was compared, showing differences in root biomass production and development during stem elongation as well as basic information about root ecology and regeneration. In a recently initiated project, important factors that influence the severity of dock infestation, studies on the weak points in dock growth, and evaluation of biological control of docks and a synthesis of various measures to control these weeds were included. The return on the project has been stressed in terms of increased organic production of meat and dairy products in Norway. In Switzerland, organic farming has increased rapidly and this increase is projected to continue. Two recent surveys amongst farmers have identified *R. obtusifolius* as the most important obstacle to conversion to organic grassland management. Other docks are also considered problematic, such as *R. alpinus* on disturbed mountain pastures. *R. obtusifolius* infestations can reduce the feed value of the sward by up to 30%. Numerous physical control methods have been tested but none of them proved to be economically or ecologically feasible. Figures recorded on an experimental farm suggest that an extra 48 hr labour ha^{-1} is needed to control *R. obtusifolius*. The amount of time Swiss farmers are prepared to put into management is often very high, some farmers devoting 1000 man-hours yr^{-1} to dock control alone. However, this level of management is not feasible for all farms; any reduction in the effort necessary to control docks would be an important advance. Biological control is a logical tool here to integrate into a holistic organic management strategy for docks. In conclusion, no completely satisfactory strategy to control docks especially in organic farming systems exists to date. The most promising approach appears to be a combination of different management methods including biological control.

Evaluation of damage caused by spring tine harrowing in maize

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In organic maize cropping systems weeds are a major issue that need to be addressed appropriately in order to get a satisfying crop performance. In such cultivation systems, weed management mainly relies on preventive methods (e.g. crop rotation) and on direct methods (flame weeding, spring tine harrowing, etc.). Direct interventions may result in poor selectivity resulting in significant crop injuries when treating the whole crop both in broadcast and row-planted crops. To assess crop injuries caused by mechanical interventions, two field experiments were carried out in 2004-2006 in maize. In the first experiment (2004-2005), a split plot design was set up with three cropping systems as main treatments, and weed management strategies as subplots. The compared systems differed in terms of soil fertility management and were: CON) conventional (reference); FYM) use of organic farmyard manure; GRM) use of green manure and intercropping. A stale seedbed was adopted both in FYM and GRM to reduce weed pressure. The following weed management strategies were compared: A) spring tine harrowing twice (at 2-3 and 4-5 leaves stage) followed by inter-row hoeing (in FYM and GRM) or post-emergence herbicide application (CON); B) manual weed removal all season long; C) no weed control. Mechanical weed control effects on maize were assessed in terms of crop yield, crop biomass, crop leaf area, crop height and crop density several times in the growing season. Significant effects of weed management were only 20-30 days after spring tine harrowing. The largest differences between treatments A) and B) ranged from 12% to 30% and were observed for biomass and leaf area. No differences on yield were recorded between weed-free and spring tine harrowed plots. Generally, highest efficacy of mechanical weed control (treatment A)) and highest crop biomass were recorded on the FYM system. In the second experiment (2005-2006), the following treatments were applied in five maize varieties, traditionally cultivated for human consumption in Italy: A) spring tine harrowing twice (at 2-3 and 4-5 leaves stage) followed by inter-row hoeing and ridging (at 9-10 leaves stage); B) manual weed removal all season long; C) as treatment A) but supplemented with manual removal; D) untreated. Effects of mechanical treatments and weed infestation on varieties were assessed as in the first experiment. In addition, yield components (number of kernles per ear, 1000-seed weight, final ear density), grain volume weight and number of European corn borer [*Ostrinia nubilalis* (Hübner)] tunnels per ear were also recorded. In general, weed control treatment effects on the main growth parameters could be ranked in the order B)>A)>C)>D) for all varieties. When averaging all varieties, yield recorded in treatment A) was significantly lower (about 10%) than that recorded in treatments B) and C), while no differences were observed between treatments B and C. This suggests that competition from weeds escaping control affects crop performance more than the mechanical damage. In general, low yielding varieties showed the largest differences between treatments in terms of plant growth and yield.

Criteria for improved weed harrowing in cereals

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The objective of the ongoing study is to obtain new knowledge to provide a fundament for improving weed harrowing in organic cereal production as well as optimising weed harrowing as an alternative for herbicides in conventional farming. Results from field experiments on three locations during three years will be presented and discussed. The experiments included the factors: a) different manufactures of spring tine weed harrows, type of tines and used with different aggressiveness (adjusted through tine working depth and speed); b) cereal developmental stages; and c) soil types (locations) and conditions as well as weed infestation levels. The project included new experimental equipment including a specially constructed 1.5 meter wide harrow, which made it possible to treat many small sub-plots. Cereal yield and quality, number and dry matter weight (biomass) of weeds, and soil water content, soil share strength, and soil penetration resistance were recorded. The resulting intensity of the harrowing operation was measured using digital pictures taken before and after harrowing to give an estimate of cereal coverage of the soil. Pre-emergence harrowing and harrowing at early 1-leaf crop stage reduced in general weed number and biomass compared to untreated control. The mean weed reduction over locations and years was about 40%, but this reduction was not always significant different to control plots. In one year, harrowing at those early stages gave an increase in weed number and biomass, presumably because of rainy weather after harrowing. In general, pre-emergence harrowing and harrowing at early 1-leaf stage increased crop yield compared to untreated, but harrowing at such stages occasionally also resulted in small yield reductions. We conclude, however, that this early harrowing should be carried out every year. Weed harrowing once, either at 2 or 3-4 crop leaf stages, also gave decreased weed number and biomass, but no clear influence on cereal yield. Therefore, harrowing at these late stages is an opportunity, if weather conditions do not allow weed harrowing at earlier stages. The combination of pre-emergence harrowing and harrowing at 3-4 leaf stage gave a significant reduction of weed number and biomass compared to untreated control. In general, harrowing twice gave increased crop yields, but the differences were only significant at one of the locations. The potential benefit of a second harrowing at the 3-4 leaf stage depends on the weed situation, number and biomass, as well as crop competitiveness. Our results have indicated that the threshold for weed harrowing may be around 300 annual weeds m^{-2}, but more knowledge is needed for verifying the level of total number and species. If the number of weeds is less, weed harrowing twice gives a significant reduction in weed number, but not an increase in yield compared to only one weed harrowing at an early growth stage. Furthermore, our results indicate that the different types of harrows and tines will not work properly on all soil types. On light soils, all of them gave satisfying results. However, a normal tine (X 7mm bent Einböck or a X 10mm long straight CMN) is not rigid enough on soil types that build a soil crust after rain. An X 8mm bend Einböck tine, however, was better at breaking a soil crust and thereby improve cereal plant emergence on such soils. On the other hand, it is important not to adjust such tines too aggressive when no crust is present. Another trial showed that a straight tine will pick up less stones on stony soils than a bent one will do, stones which might damage the combiner during combining. Our results from one of the locations (medium light soil with stones) showed that yield as well as reductions in weed number or biomass m^{-2} was not affected by tine type.

Weed suppression by cover crop residue material; exploration and optimization

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In organic farming systems, weed control is recognized as one of the main bottlenecks and a major reason for conventional farmers not to convert to organic production. System-oriented approaches for ecological weed management are needed and cover crops might form an important component of such an approach. In this study, it was investigated whether cover crop residue incorporation in spring can inhibit germination and early growth of weeds. Additionally, options for maximization of the allelopathic effect of cover crops were investigated by focussing on three consecutive stages: i) the production of allelochemicals in cover crops, ii) the release and persistence of allelochemicals in the soil and iii) the response of germination and early growth of target weed species and crops to the uptake of allelochemicals. As different plant families are known to produce different categories of allelochemicals, the study was conducted with winter rye, winter oilseed rape and alfalfa. A first screening of extracts of winter rye, winter oilseed rape and alfalfa plants in petri dish bioassays showed significant allelopathic effects. The temporal pattern of allelopathical activity of cover crop residues in spring was characterized by a linear decline for winter rye and a steep decline at the onset of the flowering stage for winter rapeseed, whereas for alfalfa no specific pattern was observed. The experiment clearly demonstrated that mechanical injuring of field-grown cover crops in spring enhanced the allelopathic activity per unit biomass of all three cover crop species. Though systemic induction of secondary compounds by mechanical damage has been reported for young plants grown under conditioned circumstances, this is the first time that induction of allelochemicals was observed for more advanced, field grown, plants. However, the increase in allelopathic activity per unit biomass after damaging was often just sufficient to compensate for the loss of plant material resulting from damage. This implies that mechanical damaging of cover crops before residue incorporation is of little significance for farming practice. Release, persistence and distribution of allelochemicals in the soil are another important determinant of efficacy and can be influenced by cover crop residue management and rainfall. Different options for pre-treatment (cutting, crushing, grinding) and incorporation of cover crop residue material were compared. Ground winter oilseed rape material was most effective in inhibiting emergence of fast-germinating species. Furthermore, inhibition of emergence from winter rye residues left on the soil lasted longer than inhibition of emergence from residues mixed through the upper layer of the soil. An accidental heavy rain shower (22 mm) shortly after incorporation of cover crop residue material in one of the field experiments generated a strong suppression of several weed species. This phenomenon was confirmed in a number of pot experiments. Sensitivity of different weed and crop species to allelochemicals varied markedly. A strong negative relationship between seed size and vulnerability to allelochemicals, as earlier reported for laboratory assays was confirmed in our field experiments. This offers potential for selective application of this strategy in large-seeded field crops. Further investigation revealed that the synchronization between the germination pattern of a weed species and the release of allelochemicals is of major importance. Based on the previously described observations, it was hypothesized that irrigation might thus be a useful means for optimization of this weed management strategy, through a stimulatory effect on the release of the allelochemicals.

Competitive interactions between sweet corn (*Zea mays*) hybrids differing in canopy architecture and wild proso millet (*Panicum miliaceum*)

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Variation in canopy architecture among crop cultivars influences competitive interactions with weeds, both in terms of the crop's ability to endure competitive stress (i.e. 'crop tolerance') and the crop's ability to suppress weed growth and fecundity (i.e. 'weed suppressive ability'). Commercial cultivar development is primarily focused on traits that are not necessarily associated with crop competitiveness. Our research team, charged with improving weed management in vegetable crops, is systematically exploring biologically based approaches to favour the crop over the weed. Of particular interest is sweet corn, one of the most popular vegetable crops in North America. Sweet corn is grown mainly under rainfed conditions in the north-central USA and under irrigation in the arid western USA. Thus, many of our field studies have been conducted in both regions. Weed management systems in sweet corn are characterized by extensive use of soil-applied herbicides, many facing increased regulatory scrutiny (e.g. triazines). Recent studies indicated that over one-half of commercial sweet corn fields suffered yield losses due to weed interference, and *Panicum miliaceum* (wild proso millet) is one of the most abundant and fecund weed species in the crop. Although sweet corn hybrids vary extensively in plant type, the implications of sweet corn canopy architecture on crop/weed interactions were until recently unstudied. Our initial research on this topic identified significant variation among three hybrids in several canopy properties relevant to competition, including height, light interception, total leaf area index (LAI), and vertical LAI distribution. Using *Panicum miliaceum* as a model weed species, certain hybrids were on average 28% or 81% more weed suppressive than other hybrids in western and north-central USA, respectively. Weed fitness was negatively correlated with LAI at crop anthesis (-0.48 to -0.63), intercepted light at harvest (-0.51 to -0.56), and LAI at the 120 to 150 cm height (-0.51 to -0.55). Crop tolerance also varied among hybrids with higher yield loss parameter estimates in the north-central USA compared to the western USA location. When 23 sweet corn hybrids with a broader range of plant types were examined to further define the significance of canopy variation in competitive interactions, crop tolerance was positively associated with late-season canopy architecture traits, including late-season height, late-season light interception, leaf area near anthesis, shoot biomass near anthesis, and time to maturity. In contrast, weed suppressive ability was positively correlated with traits that characterized early canopy development, including seedling vigor, early-season upright leaf angle, early-season light interception, and early-season LAI. Based on these results, we hypothesize that both early development of the crop canopy and final canopy architecture are important to the competitive abilities of sweet corn, operating independently via weed suppressive ability and crop tolerance, respectively. These observations have significant implications to weed management. We observed that efficacy of sub-lethal doses of herbicides depended in large part on the degree of weed suppressive ability exerted by sweet corn plants. A more competitive hybrid increased herbicide efficacy under sub-optimal conditions and enhanced the success of reduced herbicide doses. Sweet corn traits conferring competitive canopy architecture make small, consistent contributions to weed management. Growing commercially-available hybrids with canopies that are competitive with weeds or breeding for hybrids with more competitive canopy architecture offer tangible improvements to weed management systems in sweet corn.

An alternative view of plant competition

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Weed competition with crops has been viewed traditionally as a process driven by limiting resources. Based on this approach, crop yield losses have been attributed to the degree of available resources captured by weeds. An alternative view of plant competition would be to consider limiting resources as an effect of competition rather than the cause.

In this study we hypothesize that maize seedlings detect the presence of weeds through changes in the R/FR ratio. Experiments were designed to insure that no direct competition occurred for light, water and nutrients. Maize seedlings were grown hydroponically and exposed to changes in the R/FR ratio caused by light reflectance from the leaf surface of redroot pigweed (*Amaranthus retroflexus* L.). Exposure to R/FR caused by the presence of weeds delayed leaf appearance. Differences in leaf tip number between weed-free and weedy treatments ranged from 0.3 at the 9-leaf tip harvest ($P = 0.001$) to 0.6 of a leaf tip at the 11 and 15 leaf tips stage of maize growth ($P < 0.0001$, $P < 0.0001$ respectively). Root dry weight was 5.44 g versus 4.65 g ($P < 0.001$), and 19.04 g compared to 16.46 g ($P < 0.01$) in the weed-free treatment versus weedy at the 11 and 15 leaf tip stages, respectively. Shoot dry weight was also reduced in the weedy treatment compared to the weed-free ($P = 0.0008$). Lighter stem dry weights were observed beginning at the 9 leaf tip and continuing through to the harvest at the 15 leaf stage of maize growth. Interestingly, despite having differences in height, leaf number and shoot dry weights no differences were detected in leaf area at any sampling time. This evidence suggests that once maize seedlings have expressed an early shade avoidance response caused by the presence of weeds, they are constrained phenotypically during later stages of growth and perform suboptimally in terms of biomass accumulation.

The influence of different cultivation methods on weed infestation and growth and yield of transplanted leek

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Crop production using no-tillage is common in many cultivated crops. Cover crops used as an organic mulch can improve soil structure, reduce soil erosion and nitrate leaching, enhance soil nitrogen availability, especially in case of legume species and inhibit weeds emergence. However, it also may have a negative influence on by absorption of soil moisture and allelopathic activity. In the present studies, the influence of three cultivation methods on weed infestation and growth and yield of transplanted leek was tested and evaluated. Leek was cultivated in a conventional way (without cover crops), with cover crop residues left on the soil surface and cover crop residues cut and incorporated 10-12 cm into the soil. The experiments were designed as a split-plot with 4 replications arranged in blocks, the plot size being 9 m^2. Field trials were conducted during the years 2003-2005 on pseudo-podzolic soil containing 1.3-1.5% of organic matter with pH=6.5. Cover crops (rye and hairy vetch) were sown in the autumn, and desiccated with glyphosate (1.8 $kg \cdot ha^{-1}$ + adjuvant) and crumbled or cut and incorporated into the top layer of the soil in spring. Leek was planted at the end of May. In the experiments weed species infestation and yield of leek and some morphological features were evaluated. Rye and hairy vetch used as cover crops produced high amounts of biomass. Cover crop residues left on the soil surface produced over 45 tons of fresh biomass per hectare at the end of April and three weeks later, before cover crops were cut - 53.2 $t \cdot ha^{-1}$. Amount of residue biomass was more important for weed suppression than residue type. The results showed different weed infestations associated with the cropping systems. Density of weeds in leek grown without cover crops was higher than in the systems having cover crops. In the cover crop free system, weed infestation after planting of leek was higher than in both systems with cover crops, but lower weed coverages were observed at the end of the growing season. Weed coverage in leek grown without cover crops and evaluated 41-47 days after planting, was almost three times higher than in the systems where cover crop residues had been left on the soil surface. Dominating weed species infested leek at different levels. *Galinsoga parviflora* covered 23% of the ground in leek grown without cover crops, 13.5% in cover crops being cut and incorporated into soil, and 3.2% with cover crop residues desiccated and left on the soil surface. *Chenopodium album* covered the ground by 7.8, 13.4 and 2.4%, respectively, and *Thlaspi arvense* by 10.6, 1.8 and 1.1%, respectively. The growth of leek was affected by cropping system. The plants grown in cover crops residues left on the soil surface grew tallest (average height 84.6 cm), 13 cm taller than in cover crops residues cut and incorporated into the soil. Chlorophyll content in the third leaf of leek was measured by chlorophyll meter SPAD-501. Leek grown in cover crop residues left on the soil surface had a higher content of chlorophyll in the leaves compared to the other systems. Leaf Area Index (LAI), determined by Sun Scan Canopy Analyzer, was highest in the system with cover crop residues left on the surface. The highest level of relative variable chlorophyll fluorescence, determined by Mini PAM fluorymeter, was obtained in leek cultivated in conventional way. Method of cultivation caused differences in the yield of leek. Cover crop residues left on the soil surface increased the yield of leek compared to conventional cropping. In the system with cover crops cut and incorporated, leek yield was lower than in the other methods of cultivation. The system with cover crop residues left on the soil surface is the most promising for leek cultivation.

Improvement of the competitiveness of Iranian winter wheat cultivars against *Avena fatua* during 1956-1995

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To evaluate genetic improvement in yield of wheat (*Triticum aestivum* L.) bred from 1956 to 1995, a field experiment was carried out at Arak, Iran, in the 2001-2002 growing season. Six winter wheat cultivars with different era of releases (Omid 1956, Bezostaya 1969, Azadi 1979, Ghods 1989, Alamot 1995 and Alvand 1995) were sown with and without *Aven fatua* L. A 2 by 6 factorial arrangement based on randomized complete blocks design was used and each treatment was replicated 3 times. Results showed an increasing trend for yield with a rate of 2.2 % yr^{-1} and 3.8% yr^{-1} under weed free and weedy conditions, respectively. The more yield increasing trend under weedy condition indicates an improved competitive ability of new cultivars. Harvest Index (HI) and biomass were increased from old cultivars to new cultivars. 74% of the yield gain could be explained by an increased HI, whereas 26% of the remaining yield improvement attributed to the biomass increases. There were no differences between cultivars in extinction coefficients (*K*) and Radiation Use Efficiency (RUE). However, weedy condition reduced RUE significantly. RUE showed an upward trend with the year of release and increased by the rate of 0.77% yr^{-1} and 0.14% yr^{-1} under weed free and weedy conditions, respectively. Averaged RUE of 1.3 g MJ^{-1} (in terms of absorbed photo-synthetically active radiation, APAR) and 0.83 g MJ^{-1} were estimated in weed free and weedy conditions, respectively. Leaf area index (LAI) was the only component that decreased over time.

Exploring the role of soil nitrogen on crop-weed competitiveness

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Soil nitrogen (N) is considered an important driver of crop-weed competition, yet the mechanisms involved have been only partially explored, especially with respect to early growth dynamics when competitive hierarchies are initiated. This study was conducted to: i) comparatively characterize the effect of different N levels on biomass accumulation, height and leaf area for maize (*Zea mays* L.) and four important weed species of the north-eastern USA (*Amaranthus retroflexus* L., *Abutilon theophrasti* Medic., *Setaria faberi* Herrm. and *Chenopodium album* L.); and ii) explore the possible influence of differential N responses on competition. Under glasshouse conditions, plants were grown in separate pots filled with sand and irrigated with nutrient solution at four N concentrations (0.2, 0.5, 2, 5 M L^{-1}) until 57 days after emergence (DAE). Except for *S. faberi* which was unresponsive to N, the relative biomass growth rates (RGR) of maize and the broadleaf weeds were positively and similarly affected by increasing N. Path analysis indicated that the effect of N on plant height and plant leaf area was primarily explained through changes in shoot biomass (=0.86*** and =0.96***, respectively), which for this early growth period was jointly determined by seed size (=1.57***) and RGR (=1.41***). RGR responses to N were strongly linked to changes in leaf chlorophyll index (=0.73***) rather than to changes in the ratio of leaf area to plant weight (=0.14ns). This analysis highlights three major points: i) the equivalent importance of seed size and RGR on plant biomass accumulation during early growth; ii) a strong allometric relationship between plant biomass, leaf area, and height; and iii) that N affects biomass accumulation mainly through changes in chlorophyll index and thus presumably through changes in the net assimilation rate, rather than through changes in allocation (i.e. leaf area:plant biomass, shoot:root). To infer the impact of N availability on maize-weed competitiveness, plant biomass and height were contrasted as a function of maize size. With respect to the broadleaf weed species, maize had a similar biomass advantage across the N treatments. However, nitrogen influences on the biomass-height allometry decreased the height advantage for maize over *A. theophrasti*, *C. album* and *A. retroflexus* at lower N levels. In contrast to the broadleaf weeds, *S. faberi* maintained its biomass growth and had improved competitive position relative to the maize at lower N. Considering that height and its influence on the vertical leaf area distribution within the canopy are important factors for light competition and for the establishment of plant hierarchies, we propose that differential height responses to soil nitrogen availability could be a contributing factor to the relative position within those height hierarchies, thus affecting the final outcome of crop-weed competition.

The influence of undersown red clover and mechanical treatments in the autumn on some creeping perennial weed species in cereals

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Cover crops are included in cropping systems to achieve various ecological benefits. In stockless organic cereal systems, nitrogen is commonly supplied by undersowing a legume shortly after sowing of cereals. Retarded growth of annual weeds is considered as an additional benefit of using cover crops. There is, however, less knowledge on the influence of undersown cover crops on the growth of perennial weeds. This issue was addressed in a field experiment at Ås in southeast Norway. For obtaining an experimental field with uniform distribution of the perennial weed species, root fragments of *Cirsium arvense* and *Sonchus arvensis* and rhizomes of *Elymus repens,* were transplanted by hand in the spring of 2001. A split plot design with 3 replications was initiated in 2002 and continued until the autumn of 2006. Barley undersown with red clover versus barley alone composed the two main plot treatments, except in 2006, in which barley was grown without red clover in the whole field. This was combined with four sub-plot mechanical treatments in the autumn: 1) untreated control; 2) mowing; 3) rotary tilling and 4) shallow ploughing plus harrowing. The autumn treatments were only carried out in 2004 and 2005. Number of weeds was counted at different dates throughout the growing season, and weed biomass was assessed just before harvest. Preliminary results indicate that red clover undersown in barley, compared to barley alone, reduced the biomass of established stands of *S. arvensis* by 50%, 42% and 13% in 2004, 2005 and 2006 respectively. The effect on *E. repens* varied from +10% in 2004 to -42% in 2005 and -50% in 2006. There was no suppression on established stands of *C. arvense* (+10%, 0 % and +70%). Of the autumn mechanical treatments rotary tilling and shallow ploughing most effectively retarded the growth of perennial weeds, especially *C. arvense* and *E. repens*. Rotary tilling and shallow ploughing reduced mean weed biomass for 2005 and 2006 of *C. arvense* by 80% (rotary tilling) and 40% (shallow ploughing), and *E. repens* by 77% and 89%, respectively. Mowing and shallow ploughing reduced mean weed biomass for 2005 and 2006 of *S. arvensis* most effectively, with a reduction of 62% for both treatments. Although the results need more attention before detailed recommendations can be given, the study indicates clearly that the effect of different mechanical treatments in the autumn depend on weed species.

Effect of crop row spacing and environmental factors on weed development

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Crop stand structure can affect microclimate of crop and soil upper layers and so crop and weed development. A field experiment was carried out in 2006 in Central Bohemia, Czech Republic to study the effect of spring wheat (*Triticum aestivum* L.) row spacing on abiotic environmental factors and weed phytocoenoses. Using a randomized block experimental design with 4 replicates, spring wheat was sown on May 11 at 0.125 and 0.25 m row width. Samplings at weekly intervals were performed to determine crop and weed above-ground dry biomass, crop stages (BBCH scale). Photosyntheticaly active radiation (PAR, mol d^{-1}), air temperature (by Minikin QT sensor, EMS Brno, CZ) at 0.10 m height inside the crop, soil temperature (by Minikin TT, EMS Brno, CZ) at 0.05 and 0.10 m depth, soil water potential (MPa) at 0.05-0.072 m (by Microlog SP + Watermark 200SS-X, EMS Brno, + Irrometer, USA) were recorded at 15-minute intervals throughout the crop cycle; also rainfall (rain-gauge SR03 Fiedler, CZ, mm) was measured. The average daily values of the weather data between two biomass samplings were used for the statistical evaluation of the results. Crop row width affected weeds emergence and growth: weed biomass was higher in the crop sown at 0.25 m than at 0.125 m row width (e.g. at the end of crop heading, above-ground weed biomass was 410.7 kg ha^{-1} with wider rows and 171.2 kg ha^{-1} with narrower ones). On the contrary crop biomass was lower at 0.25 m than at 0.125 crop row width. There was a highly significant linear relationship between PAR values at 0.1 m height above ground inside the crop canopy and wheat biomass (i.e. PARt = 30.37-0.00239*biomass production) observed from the beginning of tillering (i.e. 21 BBCH stage) to the early milk crop stage (i.e. 73 BBCH stage). Weed growth was positively correlated with the transmitted PAR through crop canopy. Row width did not affect air temperature inside crop canopy, soil temperature, and soil water potential. As a conclusion, since wider crop rows caused lower crop biomass production and higher transmitted PAR through crop canopy, and weed biomass production was mainly influenced by the PAR availability, traditional wheat row spacing (i.e. 0.125 m) adopted in conventional agriculture systems was proved to be more competitive against weeds than wider row spacing (i.e. 0.25 m) proposed in organic systems.

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Weed control by mechanical means in organic soybean and maize

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Weeds are a major constrain in organic production, because of the paucity of valid and appropriate tools for their management. A two-year experiment (2000-2001) was carried out in Turin (Po Valley – Italy) to test several non-chemical methods for weed management in organic maize and soybean. A split plot design was used for both experiments with two soil tillage systems for seedbed preparation as main-plot treatments and weed control practices as sub-plot treatments. The two tillage systems compared were mouldboard ploughing and minimum tillage (disk harrowing), both combined with the application of a stale seedbed. Weed control practices in maize were: a) 2 flame weedings (with maize at 2-3 and 5-6 leaf stage, respectively) combined with inter-row hoeing; b) 2 spring tine harrowing (at 2-3 and 5-6 leaf stage, respectively); c) 2 inter-row hoeing (at 2-3 and 8-9 maize leaf stage, respectively) combined with one ridging intervention at the second hoeing. In soybean, weed control treatments consisted of 2 spring tine harrowing applied in combination with 3 different row spacing (15, 30 and 75 cm) followed, in the case of the largest row spacing, by one inter-row hoeing pass. Untreated plots were included in the experiment, and the plot size was 360 m^2 (30m x 12 m). In all plots, weed density, weed control efficacy, and crop yield were assessed for both experiments. On average the efficacy of weed control exceeded 85% in maize and 78% in soybean, and was higher in ploughed plots than in disked plots. The effect of tillage system was more evident in soybean, in particular in the second year, and especially when weed control practices gave poor effects. Flame weeding and spring tine harrowing provided in maize an average control of 91% and 89%, respectively. In soybean, the weeding efficacy averaged 62%, 63% and 85% in 15, 30 and 75 cm row-spacing plots, respectively. Spring tine harrowing affected maize and soybean crop density by 3 and 8%, respectively. Flame weeding did not result in any density reduction but caused some burns on basal leaves of maize and a slight growth delay compared to untreated plants. These effects were not any more noticeable 15 days after this intervention. The average crop yields obtained in the treated plots of maize and soybean were about 60% and 30% higher in comparison to the untreated plots, respectively. The highest yield was obtained with flame weeding in maize and with 75 cm row-spacing plots in soybean. The results of this study pointed out that the non-chemical weed management techniques tested have a promising potential in organic maize and soybean. Nevertheless it must be considered that the intervention timing is a crucial factor to have effective weed control together with crop selectivity.

Growth analysis of maize under different planting pattern and herbicide application rate

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An experiment was conducted in 2005 at the research field of Plant Pest and Disease Research Institute, Iran, to study the effect of different planting patterns in maize (*Zea mays* L. cv. SC 704) on herbicide consumption rate and crop growth. The experiment was laid out in a split plot design with four replications. Four planting patterns (one line on a row, two lines on a row, one line on the bed, and one line on a row and then replacing row by bed) were main plots, and atrazin plus allachlor, and EPTC (ethyl bis (2-ethylhexyl) phosphinate) both at recommended dose and 75% of the recommended dose were sub-plots. Naturally occurring weed populations were used in the experiment. Results indicated that planting pattern could reduce herbicide consumption rate. The full-season weed free check was ranked first in case of most studied traits. However treating maize with recommended doses of atrazine plus allaclor, and EPTC at 75% recommended dose could result in the highest yield, leaf area index, crop growth rate, total dry matter and leaf area index duration when maize was planted in two lines on a row, also bed was replaced by row. But, planting maize to one line on a row/bed produced the highest amount of the above-mentioned growth and yield traits when maize was sprayed with recommended doses only. The recommended doses of atrazine plus allaclor, and EPTC were applied under planting patterns of one line on a row and one line in furrow resulted in higher grain yield, physiological indices, but reductions of weed population and biomass. Leaf area and dry matter production shifted to upper parts of the maize canopy in atrazine plus allachlor at the recommended dose while plants which were planted in a furrow had a reverse relationship. This was caused by more interplant shading on leaves, which subsequently reduced the yield compared to atrazine plus allachlor and EPTC both at 75% recommended dose. Weed population and biomass percentages reductions were highest in planting methods of two lines on a row and one line in furrow and then changing furrow to row. In these treatments, however, no considerable differences were observed between herbicide treatments due to high negative effect of this planting method on weed interference. Altogether and with regard to the importance of integrated weed management and reducing herbicide consumption, healthier food could be produced by applying alternative patterns. Planting pattern is one of the management strategies, which helps improve crop competitiveness. Planting two lines on a row and changing bed to row could be served as the most suitable planting patterns in maize from a crop competitiveness point of view. Generally, it could be concluded that shifting from current maize planting method (one line on a row) could lower the herbicide dose needed to control weeds satisfactorily, which helps moving towards a more sustainable weed management program and a healthier environment.

Torsion weeding in field vegetables

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Physical weed control has been developed rapidly the last decade and today we have a wide range of methods available for weed control in most crops. In row-crops such as vegetables, there is however still a general need to develop the available technique in order to obtain more reliable effect in commercial production.

One of the most promising methods for in-row weed control is torsion weeding. It has become a valuable contribution to physical weeding due to its simplicity, low cost and usefulness in various crops.

However, there is a general lack of basic information concerning expected weed control effect, possible crop plant reduction, effect on yield and reduction of manual labour input. Thus, in a Swedish project carried out in 2003-2005 torsion weeding was tested in dill, carrots, field beans, red beets and sugar beets. Torsion weeding was used as a part of a physical weeding system comprising torsion weeding, inter-row cultivation and manual weeding. Three main weeding strategies were studied; A) row cultivation only; B) weed harrowing and row cultivation and C) row cultivation with torsion weeders. Strategy B and C were carried out at two development stages of the crop ('early' and 'late'). For example in carrots the torsion weeding started at 2-3 true leaves and 4-5 true leaves respectively, while in red-beet the treatment begun at the 2 leaf-stage and 4 leaf-stage. In total five treatment combinations were applied in each crop. The effect of the weeding systems was measured in terms of yield, manual labour input and weed control effect.

The weed control effect varied between crops; in beans 87-100 % of annual weeds could be controlled by torsion weeding starting at an early crop development stage. In carrots, the weed control effect was somewhat less pronounced, but still amounted to 56-66 %. The yields varied between years and treatments. In general, torsion weeding had a minor effect on yield compared to the standard strategy irrespective of treatment time.

Manual weeding could also be highly reduced by torsion weeding. As an example, the labour reduction was high in the beans, decreasing from 58 hours ha^{-1} using the standard strategy, to 18 h ha^{-1} with torsion weeding combined with inter-row cultivation.

The experiments clearly showed that torsion weeding can be used in vegetable crops without jeopardizing yields. Moreover, the technique will reduce input of manual labour and have a high weed control effect.
Results from the experiment will be published in detailed and also processed into recommendations for vegetable producers.

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Effect of weed density and relative time of emergence on potato yield

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Potato is one of the most important field crops in Iran and due its role in providing food and proteins for an increasing population area cultivation and yield of potato is increasing rapidly. Redroot pigweed (*Amaranthus retroflexus*) and lambsquarter (*Chenopodium album*) are highly competitive weeds that are widely distributed through cropping area of Iran and cause large potato yield losses. Field experiments were conducted in 2004 and 2005 in order to model the effect of *A. retroflexus* and *C. album* on potato. A split-split plot experimental design with 4 replicates was used to compare 2 weed species in main plots (*A. retroflexus* and *C. album*), weed density in sub-plots (2, 4 and 8 plants per meter of row) and relative time of weed emergence in sub-sub-plots (8, 4 and 0 weeks before crop emergence in 2004 and 0, 2 and 4 weeks after crop emergence in 2005). Hyperbolic and exponential models were used to model the effect of density and density-relative time of emergence of redroot pigweed and lambsquarter on potato yield:

$$Y_L = \frac{ID}{1+\frac{ID}{A}} \quad \text{(Cousens, 1985)}$$

$$Y_L = A*(1-\exp(-b*D)) \quad \text{(Calvo } et\ al.\text{, 1994)}$$

$$Y_L = \frac{ID}{e^{CT}+\frac{ID}{A}} \quad \text{(Cousens } et\ al.\text{, 1987)}$$

$$Y_L = \frac{ID}{e^{CT}+\frac{ID}{Ae^{-BT}}} \quad \text{(Fu and Ashley, 2006)}$$

where Y_L is percent yield loss, D is weed density (expressed as plant/meter of row), I is percent yield loss when $D \rightarrow 0$, A is the upper asymptote or maximum yield loss (i.e. when $D \rightarrow \infty$), b is the rate of change, T is the time of weed emergence relative to the crop, C is the rate at which I decrease exponentially as T becomes larger, B is the change rate of A with T. Corrected Akaike Information Criteria (AIC_C) was used to compare models.

The best model to represent density and density-emergence time effects was the hyperbolic model.

Parameters I did not vary between years for lambsquarter whilst for redroot pigweed decreased from 2004 to 2005, especially for first emergence time. In all cases parameter I estimated for redroot pigweed was higher than for lambsquarter. For redroot pigweed I at the three emergence times was 18.3, 11.7 and 7.4 in 2004 (that is 84.2, 58.3 and 83.0 % more than for lambsquarter) and 13.05, 7.12 and 4.4 in 2005 (i.e. 37.3, 20.1 and 54.8 % more than for lambsquarter).

Maximum yield loss (A) for redroot pigweed was bigger than lambsquarter in both years: in 2004 A at the three emergence times was 63.48, 60.25 and 57.65 for redroot pigweed and 57.19, 49.66 and 32.38 for lambsquarter.

According to the estimated parameters, redroot pigweed was more competitive than lambsquarter and crop yield losses were much higher when weeds emerge sooner than potato.

Influence of emergence time and density of mayweed (*Tripleurospermum inodorum* Sch/Bip) on winter wheat (*Triticum aestivum L*)

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Interplant competition for the capture of growth-limiting resources i.e. light, water and mineral nutrients exerts a strong influence on the performance of agricultural ecosystems. Most crop yield reductions caused by weeds are ascribable to competition for these resources and the success of decision-making programs for weed control relies on the ability to predict the effect of weeds on crop yield early in the season. To implement a decision-making program a reliable model for crop yield loss based on independent variables that are quick and easy to measure during the first weeks of the crop growing cycle is essential. Some authors have based their prediction on relative cover of the weeds. Despite the encouraging results already obtained further insight into the mechanisms which drive early plant growth could enhance our predictive ability. Weed-crop competition in real systems is a complex phenomenon because many factors (e.g. morphological and eco-physiological plant traits, relative weed emergence, plant density, weather conditions) contribute to the final outcome of the process. Mayweed is a major weed occurring in field on winter wheat where can induce yield losses and other problems at crop harvest.

Field experiments were carried out in 2003-2005 to study the effect of emergence time and density of mayweed on winter wheat yield. Winter wheat cultivar Albota was sown in 12.5 cm row apart and 450 plants m^{-2} on 1st October each year while mayweed seed were manually sown at six dates (i.e. 1, 15 and 30 October, 1, 10 and 20 April) and at 3 densities (i.e. 20, 40 and 60 seeds m^{-2} sown on 1st october); weed-free plots were included as checks. Experimental designs were a RCBD with 4 replicates with 25 m^2 plots. To define the influence of weed on crop plants relative ground cover (RGC), above-ground total dry matter (A-GDM) and growth rates (GR) were determined every ten days from crop emrgence to crop maturity both in wheat and mayweed; weight of 1000 grains (TGW) and volumetric grain weight (VGW) were determined on wheat samples at crop harvest. At each sampling, crop and weed plant were harvested in 1 m^2 per plot and oven dried at 105 °C for 8 h. Other weeds were controlled manually throughout the crop cycle. Results of the three years were averaged. Mayweed emergence occurred 7-10 days after sowing; weed emerged together with wheat when sown on 1st October. A non-linear regression analysis were performed for RGC, A-GDM and GR observed data in function of time.

Winter wheat yield and percentage loss varied depending on density and time of weed emergence. Wheat yield reduction was 18, 21 and 35 % for mayweed densities of 20, 40 and 60 plants m^{-2}, respectively. Increasing weed density decreased TGW from 51 to 44 g and VGW from 78 to 68 kg hl^{-1}. Size of mayweed plants was negative correlated with wheat size plants. When mayweed emerged at the same time with wheat (i.e. in 1st October-sowing time) weed interference was increased in comparison with later sowing dates. Mayweed RGC decreased with a delay of emergence: at the six sowing dates it was 68, 22, 21, 18, 11 and 8%, respectively).

The results obtained are important for a decision-making programme because: i) mayweed strongly competed with winter wheat plants every year; ii) weed caused wheat yield losses at a wide range of weed density; iii) high crop yield reduction was only when the weed emerged at the same time with winter wheat.

Weed problems in organic farming

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Guidelines for organic farming only offer limited use of weed control methods, fertilization and tillage, and thus weed infestations in organic crops often cause serious problems. Consequently, knowledge on biological traits of important weed species and options for preventive, cultural and direct weed control methods are crucial elements for weed management in organic cropping systems. This paper deals with the status of the major weed flora occurring in organic cereal crops (winter rye, winter triticale, and spring barley / oat mixtures) cultivated with and without intercrops (*Ornithopus sativus* in rye, *Lupinus angustifolius* in triticosecale, *Trifolium pratense* in barley/ oat mixture, and *Pisum arvense* in barley / oat mixture).The survey was undertaken at Kuryły (North-Eastern Poland) on rye complex soil in 2001-2004. The crops listed above covered 80% of the crops grown in the area and they were mainly used for fodder for the local stock. Moldboard ploughing once a year was the primary tillage method. Weeds were controlled by weed harrowing 2 or 3 times at the beginning of the growing season. The weed flora was examined using a quantitative method where weed species composition and number of individuals were recorded on a sampling area of 0.5 m^2 at four places of each cereal canopy (both without and with intercropping) before crop harvest. The number of different weed species recorded (24 to 32 in total) was much larger than normally seen in conventionally cropped cereals irrespective of whether the cereals were grown in pure stands or mixtures. However, weed density varied significantly between crops. Pure stands had 1.5 and up to almost 4 times more weeds than mixed stands: pure rye had 570 weeds m^{-2}, and rye intercropped with seradella had 224 weed plants ; pure winter triticale had 311 m^{-2} and 117 m^{-2} when intercropped with blue lupine; barley / oat mixture had 724 m^{-2} and 184 m^{-2} when intercropped with red clover, but when intercropped with field pea, 484 m^{-2} weed plants were recorded. Number of weed plants varied with year more in intercrops (SE 33.9-107.3) than in pure stands (SE 10.0-21.2). Such a high variability in mixed crops resulted from an uneven crop canopy as well as a low crop plant density. Intercrops also reduced the number of principal weed species. Depending on the intercrop, principal weed species made 47% to 69% of the entire infestation and without intercrop – over 80%. *Apera spica-venti* and *Setaria glauca* were the main species in winter cereals, and *Avena fatua* and *Setaria glauca* in spring cereals. In conclusion, cereals cultivated in pure stands are strongly infested by weeds. Intercropping can significantly reduce the density of individual weed species, but the reduction varies with year and does not provide sufficient weed control as such.. However, still a great number of weed plants may remain in the crops, even in intercropped crops, which would still pose a threat for future weed infestations. Thus, a wider spectrum of weed control methods is needed to manage weeds satisfactorily in organic cereals.

Mechanical weed control strategies in winter oilseed rape

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Some growers in Poland have considered using inter-row cultivation in row crops (maize) and especially in field vegetables as an alterative weeding method to herbicides. Inter-row cultivation can be used profitably when herbicides are also applied. The herbicide may become more effective and the amount can be reduced, particularly with band applications over the crop row. To provide adequate weed control in long-season crops, such as winter oilseed rape, mechanical weeding probably has to be applied more than once. The objective of this study was to evaluate inter-row hoeing as an alterative weed management system in winter rape. Two field experiments were carried out in 2004 and 2005 to evaluate the efficacy of several mechanical weed control methods. The treatments were: (1) in autumn, metazachlor +qiumerac (416 SC) with oil adjuvant applied at the half recommended dose at the 1-2 leaf stage of rape and a second treatment of inter-row hoeing at the 4 leaf stage of rape; (2) the same herbicide and second treatment of inter-row hoeing in spring (after start of vegetation); (3) the same herbicide and two treatments of inter-row hoeing (one in autumn and one in spring); (4) inter-row hoeing at the 4 leaf stage of rape; (5) inter-row hoeing in spring only; (6) inter-row hoeing twice (one in autumn and one in spring); (7) in autumn, metazachlor +qiumerac applied alone at recommended dose at the 1-2 leaf stage; (8) in autumn split-application of metazachlor + qiumerac with oil adjuvant, half the recommended dose early and then again half dose at the 1-2 leave stage of rape. The trial was a randomised complete block design with four replicates and a plot size of 16,5 m^2. Inter-row hoeing was done in the rape crop at 25 cm row spacing. Four weeks after the last treatment (before flowering of winter rape), weeding efficacy was determined by assessing weed density and weed fresh weight. Weed biomass and yield of winter oilseed rape were statistically analysed using an ANOVA, and means were compared by Tukey test. The results from a two-year field study showed that the best treatment for the control of broad-leaved weeds was achieved by combining chemical and mechanical weeding. In both seasons, weed fresh weight was reduced by 75-79% and 37-76% with treatments (1) and (2), respectively. Treatment (3) was the most effective and gave 69% (2004) and 92% (2005) reductions of weed biomass compared with the untreated plots. Herbicide application at low dose combined with one or two inter-row hoeing showed equal or even better efficacy as standard chemical treatment. Herbicide applied alone at recommended dose (7) gave satisfactory effect on weeds only in 2005 (78% reduction). Considering only mechanical weed control, the best results were obtained by two-time inter-row hoeing i.e. in autumn and in spring (6). In this case results were similar to chemical treatment with herbicide applied at half recommended dose. The inter-row hoeing alone used in autumn (5) at the 4-leaf stage of rape was the least effective among the mechanical weed control methods. There were no differences in the tolerance of rape plants to mechanical treatments and when combining mechanical and chemical methods of weed control. Under normal weather conditions (as in 2005), crop yield was only slightly affected by weed control methods, and all experimental treatments gave similar yields. In contrast, results from second year showed that specific weather conditions can strongly affect the yield of tested control methods. The results of two-year experiments indicate that an optimal strategy for weed control in winter oilseed rape can be achieved with herbicide treatment applied at half the recommended dose at the 1-2 leaf stage of rape and by two treatments of inter-row hoeing (one in autumn and one in spring).

Effects of mulching and cover crop on weed population in citrus orchard in Cukurova Region of Turkey

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Turkey is one of the important citrus producer in the world. Weeds are serious problems as a result of intensive production in Cukurova Region of Turkey. The cover of weeds can be reached up to 49 % because of irrigation, mild climate and rainy weather in spite of weed control. The most preferable method for controlling weed in citrus growing areas is herbicide. But the chemicals cause significant problem such as herbicide resistant and pollution. Because of this all negative reasons, we investigated alternative weed control methods such as mulching and cover crop on weed population in this study. The experiments were conducted on a clay loam in newly established citrus orchard in Plant Protection Research Area at Cukurova University-Adana in 2004-2005. Common vetch (*Vicia sativa* L.) was chosen as cover crop between rows while black polyethylene (P.E.) and 3 different thickness black geotextile materials were used for mulching on rows. Thickness of P.E. mulch in 2004 and 2005 was 0.04 mm and 0.1 mm respectively. 0.38 mm, 0.58 mm and 0.72 mm were other geotextile mulch thickness both of years. Mowing, herbicide and weedy control were other applications on rows. In treatments randomized complete block design was used with four replications for cover crop treatment and five replications for mulching. Plot size was 145 m^2 for cover crop and 24 m^2 for mulching and other treatments on rows. Seeds of cover crops were sown 140 kg ha^{-1}. Cover crop treatments included weedy check. Mulch materials were applied in rows 160 cm apart. When the cover of weeds reached 15 % herbicide (Glyphosate) was applied at 6000cc ha^{-1}. Mowing treatment was applied when the weeds lenght reached at 20 cm. 6 and 1 number a 1 m^2 quadrat was permanently placed for each plot of cover crop and mulch treatments respectively. After emergence, weeds were counted at 15 days intervals at the quadrats and % cover of weeds was determined at all plots. Lenght of *Vicia sativa* L. and dominant weed species was also determined. At the end of the vegetation of common vetch, biomass of *Vicia sativa* L. and weeds were determined. Common vetch and weeds were collected from one random 1m^2 quadrats within each plot and weighed, after that oven dried at 65 °C and weighed again. Soil and air temperatures were monitored hourly by a datalogger placed in the field. Soil temperature probes were placed at a depth of 10 cm. Since experimental area was newly established, fruit product was not determined, but length and stem thickness of citrus were determined. As a result of the experiment, cover crop supressed weed population 64 % and 38 % in 2004-2005 respectively. In mulching applied rows in 2004 and 2005 no weeds emerged any of geotextile material. On the other hand, P.E., herbicide and mowing, controlled the weeds in 2004; 99 %, 87 % and 17 %, in 2005; 99 %, 91 % and 18 % respectively. All mulch treatments increased soil temperature at 2 to 5 °C when compared to the nonmulched control. In experimental area 39 and 37 weed species were determined in 2004 and 2005 respectively. Mulching, herbicide and mowing more increase citrus lenght and stem thickness than weedy control. According to this data; weedy control, mowing, herbicide, P.E. mulch, geotextile (0.38 mm thickness), geotextile (0.58 mm thickness) and geotextile (0.72 mm thickness) increased citrus height respectively 13.6 %, 18.7 %, 30.4 %, 43.0 %, 35.3 %, 34.4 %, 37.2 % in 2004 and 35.6 %, 68.2 %, 79.8 %, 89.5 %, 88.2 %, 88.0 %, 82.8 % in 2005. All treatments of same order increased stem thickness respectively 29.6 %, 48.1 %, 52.4 %, 68.3 %, 73.4 %, 69.0 %, 60.5 % in 2004 and 43.1 %, 66.1 %, 105 %, 96.1 %, 99.8 %, 86.9 %, 90.7 % in 2005.

Mechanical and electrical control of *Cirsium arvense* in growing cereal crops in organic farming

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During last decades field thistle *(Cirsium arvense)* has been possible to control because of its sensitivity for phenoxyacetic acids and other herbicides. In organic farming, however, it is one of the most troublesome weeds. During the years of 1997 until 2000 field trials concerning mechanical and electrical control of field thistle were accomplished by the department of Ecology and Crop Production Science at the Swedish University of Agricultural Sciences and Swedish Institute of Agricultural and Environmental Engineering. The objective was to develop and test methods for thistle control in growing cereal (barley and oat). Mechanical control measures included cutting just above the growing crop (double knife mower and rotary mower), mechanical pulling of thistle (crushing tires and crushing rollers) and stripping (stripper rotor). Furthermore high voltage treatment (20 000 volt) and several manual measures such as pulling by hand, brush saw and thistle shaft were tested. The mechanical measures, as they were used in this experiment, have not proved to be efficient for thistle control. At some occasions they even promoted thistle growth. However the weather conditions were somewhat extreme at two of the three years, which caused very feeble crops. Results from trials with high voltage showed some effect on the thistle at more than one occasion. To keep in mind is, however, that this method requires rigorous safety arrangements because of the accident risk. Treatment with rotary mower just above soil surface and manual measures proved to be effective at most test situations. Besides the design of the mentioned equipments the results on the whole also rely on the weather conditions and the status of the crop as well as the thistle clone.

Weed control in organic farming – a study of *Sonchus arvensis*

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Control of perennial weed species such as *Sonchus arvensis* L. and *Cirsium arvense* (L.) Scop. is a great challenge in organic farming in Sweden. Many studies have been performed regarding weed control of *C. arvense* but rather few on *S. arvensis.* Knowledge of how the growth and development of *S. arvensis* is influenced by crop competition and mechanical disturbance is therefore scarce. In the Swedish research project 'Weed control in organic farming – a study of sow-thistle (*Sonchus arvensis* L.)', the effects of different levels of crop competition and different cultivation techniques on the abundance of *S. arvensis* were studied. The aim is to develop more efficient weed control methods for *S. arvensis* in organic farming. One experimental series was designed to investigate the weed control effects of short fallow in the spring combined with different green manure crops sown in the beginning of July. The short fallow techniques used were: disc harrowing, disc harrowing + ploughing, spring ploughing + disc harrowing. Summer fallow was also included in the experiment. The green manure crops used were: oats/peas (*Avena sativa* L./*Pisum sativum* L.), white mustard (*Sinapis alba* L.) and Italian ryegrass (*Lolium multiflorum* Lam., *L. italicum*). The control effects on *S. arvensis* were then evaluated in the following summer in spring cereal (oats, *A. sativa*). Results from the field experiment in 2006 showed significant weed control effects of all fallow techniques compared with the control plots. No significant differences could, however, be detected between the treatments. On average, 3% of *S. arvensis* plants survived in the treated plots compared with the control plots. This weed control effect is comparable to the effects of herbicide treatment. The results presented are based on one experiment only and it is rather difficult to determine whether the results are season-dependent. Therefore, further studies are required. A preliminary recommendation from the experiment is that short fallow combined with sowing of green manure crops seems to be a rather effective weed control method against *S. arvensis*.

The effect of relay cropping winter wheat on weed biomass, summer crop yields and risk of nitrogen leaching

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Relay cropping is defined as the growing of two or more crops simultaneously during part of the life cycle of each crop. Establishing more than one crop simultaneously can be used to reduce the need for auxiliary energy in crop production. Such a system may decrease the cost of cultivation, improve soil structure and reduce nitrogen leaching, but may also increase problems with pests and diseases. Varieties of winter wheat, with a strong demand for vernalisation before entering reproductive growth, can be sown in spring together with a summer annual, *i.e.* relay cropped, and be harvested the following year. The main challenge of the summer crop/winter wheat intercropping system is to find methods of management that minimise yield losses due to competition, pests and diseases. The aim of the present project is to evaluate the summer crop/winter wheat relay cropping system regarding its effect on weeds, energy inputs, available soil mineral nitrogen, nitrogen use efficiency and economic yields. The specific objectives of the first year of the presented investigation were to test the hypotheses that relay cropping of winter wheat reduces the amount of weeds in the summer crop and the amount of available soil mineral nitrogen at the end of the season from significant nitrogen uptake by the wheat in the autumn. Field experiments were established at three sites in Sweden in the spring of 2005. Treatments with winter wheat relay cropped in oats, peas or field beans were compared with treatments with summer crops only and winter wheat sown at conventional time. The crops were generally sown after ploughing and seedbed preparation, but in one treatment the winter wheat after peas was sown after stubble cultivation. The autumn-sown winter wheat was sown at time according to local practice. No fertilisers or chemicals were used. The undersowing of wheat reduced the amount of weeds growing in the summer crops including the yield of the summer crop significantly. The amount of weeds in spring crops with relay cropped wheat was only about 50 per cent of the amount in the pure summer crops. Depending on which summer crop that was used, relay cropping of wheat caused an average yield reduction of 331-882 kg ha^{-1}. The wheat biomass increased until the harvest of the summer crops, but was then reduced during the period between summer crop harvest and conventional time for sowing of winter wheat. There was, on average, 20 kg N ha^{-1} less soil mineral nitrogen late in autumn with relay cropped wheat than with wheat sown in sequence. We conclude that it is possible to reduce the amount of weeds at the harvest of peas, field beans and oats by undersowing winter wheat in conjunction with the sowing of the summer crop, but at a cost of reduced yield of the summer crop. The amount of soil mineral nitrogen is lower before winter in spring-sown rather than autumn-sown winter wheat.

Effect of late winter sowing on critical period of competition in maize

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The critical period for weed control identifies the phase of the crop growth cycle during which weeds must be removed to prevent yield losses. A four-year study in the Po Valley (northern Italy) evaluated the effect of maize sowing date on weed flora composition and competitiveness.

The experiments were conducted during 2001, 2002, 2003 and 2005. Maize was sown every year in late winter (early sowing) and also later in 2003 (traditional sowing). In order to evaluate the onset of the critical period (i.e. duration of tolerated competition, DTC) plots were left weedy for different times from crop emergence while to determine the end of critical period (i.e. weed-free period, WFP) plots were kept weed-free for increasing times. Weeds were removed at different times by hand: Weed emergence dynamics were recorded weekly in all plots and their cumulative emergence was modelled using a Gompertz function. DTC and WFP, based on 5% yield loss, were determined by fitting logistic and Gompertz equations to the relative yield.

The results showed that the early sowing date increases the importance of late winter and early spring emerging weeds (such as *Alopecurus myosuroides, Anagallis* spp., *Avena* spp., *Lamium* spp., *Kickxia elatine*, *Matricaria chamomilla*, *Picris* spp., *Poa* spp., *Polygonum aviculare, Polygonum convolvulus*, *Stachys annua*, *Stellaria media*, *Veronica persica*). The infestation in early sown maize is similar to the weed community in sugarbeet. Because of unfavourable temperature and humidity during emergence, the pre-competitive period is longer in the early sown maize than in traditionally sown maize. The delay in the beginning of the critical period makes control difficult with a pre-emergence herbicide and questions its usefulness. For example, pre-emergence herbicides with persistence of about one month are almost inactive when the pre-competitive period finishes (the early beginning of the critical period was 36 days after sowing in 2001). In this situation post-emergence control can be useful to control weeds. Weed density was very different in all the experiments and it was possible to find a relation between this parameter and the critical period: a scarce infestation seems to determine a shorter critical period later in the crop cycle. For example, in 2001 weed density was 97 plants/m^2 and the critical period (5% yield reduction) began 36 Days After Sowing (157 Growing Degree Days, GDD) and lasted only 3 days; in 2002 the weed density was 208 plants/m^2, the critical period began later (75 DAS, 384 GDD) and finished after 11 days; in 2005 weed density was higher (690 plants/m^2), the critical period began 50 DAS (201 GDD) and was the longest (22 days). 2003 was an unusual year, with a cold-dry spring and hot-dry summer. For both the early and traditional sowing dates it was not possible to identify a critical period because the critical point (intersection point between DTC and WFP curves) corresponds to less than 2% yield reduction. However, it is interesting that this critical point occurs almost on the same calendar date (i.e. 9 and 13 May in early and traditionally sown maize, respectively) and at about the same GDD sum (297 and 210), but at a very different time if expressed in DAS (63 and 24).

In conclusion, early sowing extends the period for sowing and harvesting operations and helps the farmer to improve management of the cropping cycle; on the other hand, early sowing lengthens the critical period reducing the efficacy of the pre-emergence herbicide (applied immediately after sowing), and therefore requires weed control strategies to be adapted. A possible solution might be to delay the pre-emergence treatment (for example by two weeks) or use only post-emergence herbicides, but in this case it is important to treat at the correct time, and the weather conditions could not been always suitable.

Effects of alternative cover cropping systems on weed population in tomato (*Lycopersicon esculentum*) and pepper (*Capsicum annum*)

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Vegetable growers have become significantly interested in alternative weed control methods due to public awareness about herbicide use. One alternative weed control method is to use cover crops that could be adopted by both conventional and organic vegetable producers. Field studies were conducted in tomato and pepper from 2004 to 2005 at the Black Sea Agricultural Research Institute experimental field in Samsun, Turkey. The cover crop treatments consisted of *Lolium multiflorum*, *Avena sativa*, *Secale cereale*, *Trifolium meneghinianum*, *Triticum aestivum*, *Trifolium alexsandrinum*, *Vicia sativa*, *Vicia villosa* and bare ground with no cover crop or any herbicide application. Treatments were arranged in a randomized complete block design with four replications. Cover crops were sown on 2nd November 2004 and incorporated into the soil on 5th May 2005 when they were flowering. Tomato and pepper seedlings were transplanted by hand on25th May in 2005. The broadleaved species *Sinapis arvensis*, *Abutilon theoprasti*, *Rumex crispus Lathyrus aphaca*, *Convolvulus arvensis*, and *Matricaria chamomilla* were the principal weed species seen. Although broadleaved weed species richness was greater than grass weed species richness in all plots, *Alopecurus myosuroides* and *Echinochloa crus-galli* had relative proportions of more than 7%. All cover crops established well, and *L. multiflorum* produced the greatest amount of biomass with 2,785 kg ha^{-1}. Biomass of *V. sativa, A. sativa, V. villosa*, *T. aestivum, S. cereale, T. alexsandrinum* and *T. meneghinianum* followed that of *L. multiflorum* in decreasing order. Cover crop biomass was positively correlated with the suppressive effects on weeds. Total weed biomass measured just prior to cover crop incorporation into the soil was significantly lower for *S. cereale* than for the other cover crop species. The number of weed species was lowest at 14 DAD (day after desiccating) and then increased at 28 and 56 DAD, and subsequently remained constant until harvest in both tomato and pepper. All cover crop plots except *T. alexsandrinum* had fewer weed species than the bare ground at 14 DAD. In subsequent evaluations, the effect of the cover crops on number of weed species was similar among treatments. Weed density varied among cover crops. *L. multiflorum* most effectively suppressed weed biomass, although weed density was higher in *V. sativa, A. sativa, V. villosa* and *S. cereale* there were no significantly differences among these treatments at 14 DAD. The suppressive effects of *V. sativa* and *V. villosa* residues on weed densities appeared at 28 and 56 DAD. The residues of these cover crops suppressed *Sinapis arvensis*, *Lathyrus aphaca*, *Portaluca olerecea*, *Veronica persica* and *Chenopodium album*. None of the cover crops residues controlled *Amaranthus retroflexus*, *Rumex crispus*, *Cirsium arvense*, *Euphorbia helioscopia*, *Cynodon dactylon*, *Cyperus esculentus*, *Cyperus rotundus* and *E. crus-galli* because these weeds are difficult to control even with herbicides. This research indicates that cover crops such as *V. sativa, A. sativa, V. villosa* and *S. cereale* could be used in integrated weed management programs to control some weed species at early growth stages of conventional or organic vegetable production.

Critical period of redroot pigweed (*Amaranthus retroflexuxs* L.) control in green bean (*Phaseolus vulgaris* L.)

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Two field experiments were conducted in Islamic Azad University of Tabriz, Iran, in 2004 and 2005 in order to determine the critical period of redroot pigweed control in green bean. The experimental design in both years was a randomized complete blocks with three replicates. To evaluate the onset of the critical period, redroot pigweed was seeded immediately after green bean sowing and then weed plants were removed after 2, 4, 6, 8, 10 and 14 weeks from green bean emergence; to determine the end of the critical period redroot pigweed plantlets at two-leaves stage were transplanted in weed-free green bean plots after 2, 4, 6, 8, 10 and 14 weeks from green bean emergence and then plots were left weedy until the final harvest; weed-free and weed infested plots throughout the crop cycle were included as checks.

Crop above-ground dry biomass, stem height, number of pods per plant and pod yield were determined at final harvest. Yield data were expressed as a percentage of the weed-free control. A logistic model was fitted to observed data from increasing duration of weed interference treatments while a Gompertz equation was fitted to observed data from plots with increasing length of the weed-free period.

Critical period of weed control was determined at yield loss levels of 5% and 10%.

Weed competition affected crop above-ground dry biomass, stem height, and pod number per plant.

Critical period of weed control was from 13 to 60 days after green bean emergence at a 5% yield loss level and 19 to 55 days at a 10% yield loss level.

Weed interference response to planting date and Chickpea (*Cicer arietinum*) varieties

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The effects of planting date and varieties of chickpea on weed interference were investigated in a two-year field experiment conducted under dry-farming principles from 2002-2004 at Agricultural Research Station of Kohdasht in Lorestan province of Iran. The layout was a factorial randomized block design with three replications. Treatments consisted of: a) weed interference at two levels, weed-free and weed infested for the entire growing season; b) three chickpea planting dates (autumn, winter and spring); and c) three chickpea varieties [ILC_{482}, *Hashem* and *Greet* (a local landrace)]. Weed densities at the autumn planting date were 3 and 7 times higher than those counted at the winter and spring planting dates, respectively. *Carthamus oxyacantha* and *Hordeum* were the principal weed species. Weed biomass at the autumn planting date was 2.5 times higher than those of the winter and spring planting dates. Based on a hyperbolic curve fitted to the data, chickpea maximum biomass and grain yield reduction due to weed competition were 91.8% and 77.5% respectively. Chickpeas planted in spring showed 66% and 89% reduction in dry matter and grain yield, respectively compare to the autumn planting. Grain yield reduction was mainly due to reductions in number of pods plant^{-1} (60% reduction) and 100 seeds weight (32% reduction). The reason for this yield reduction at the spring planting date is because the grain-filling period of chickpeas suffered from drought stress and high temperature conditions during the summer. Weed interference further magnified the yield reductions. Chickpeas when planted in winter did not suffer from drought stress and produced the highest grain yield. *Greet* was the best variety giving the highest grain yield irrespective of planting dates and weed infestation level. *Hashem*, however, generally produced the lowest yields. There was no interaction between planting date and chickpea variety. Although in weed free condition, yield potential of autumn and winter chickpea is higher than spring cropping, but seriousness of weed interference in autumn and winter cropping is very high.

Effect of wild mustard (*Sinapis arvensis*) and rapeseed (*Brassica napus*) densities on growth and yield of rapeseed in greenhouse

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Wild mustard shows a persistent seedbank, competitive growth habit, and high fecundity and causes high crop yield losses in Iran.

A greenhouse experiment was carried out to evaluate the effects of different densities of wild mustard and rapeseed on growth and yield of rapeseed. The experiment was performed in a completely randomized design with four replicates using replacement series in which wild mustard and rapeseed were sown at different ratios (i.e. 4:0, 3:1, 2:2, 1:3 and 0:4) in 30 cm pots. Weed was sown at a depth of 1 cm and crop at 2 cm. Measurements at plant maturity included plant height, number of branches per plant, number of siliques per plant, silique length and number of seeds per silique in rapeseed and plant height, silique length and number of seeds per silique in wild mustard. Relative yield (RY), relative yield total (RYT), relative crowding coefficient (RCC), and aggressivity (A) were used to assess the competitiveness of wild mustard with rapeseed.

Results indicated that the maximum height, number of branches per plant, number of siliques per plant, silique length and number of seeds per silique in rapeseed and the maximum height, silique length and number of seeds per silique in wild mustard was obtained in monoculture. The mean values of A and RY for rapeseed were greater than those of wild mustard which indicated that rapeseed was a more aggressive competitor and its competitive ability was greater than wild mustard. RYT was more than 1 in all the mixtures. This showed that rapeseed and wild mustard were exploiting the resources in different ways or somehow benefiting each other. RCC for $3_{rapeseed}$:$1_{wild\ mustard}$ was greater than for other ratios. RCC for $1_{rapeseed}$:$3_{wild\ mustard}$ was the lowest among all the ratios. RCC of rapeseed and wild mustard showed that rapeseed in this experiment was 2 times more aggressive than wild mustard and that rapeseed plants were engaged in intra-specific competition, while wild mustard plants were under the influence of inter-specific competition. There was a highly significant negative correlation between weed dry weight and rapeseed silique number per plant ($r = -0.96$) and seeds number per silique ($r = -0.95$).

Mechanical weed control in soybean: evaluation of efficacy and subsequent weed seed rain

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In row crops, although weeds between the rows can normally be controlled by ordinary inter-row cultivation (e.g. hoeing, harrowing), weeds in the row constitute a major problem. For intra-row weed control, most mechanical methods are based on old principles, but new implements and improved versions of old principles have emerged lately. However, limited reports on the effects of these implements are available. The aim of this study was to evaluate the efficacy of several mechanical inter- and intra-row weed control methods in soybean. Two field experiments were carried out in 2004 and 2005 in central Italy (42°57'N - 12°22'E, elev. 165 m) on a clay-loam soil (24.8% sand, 30.4% clay and 0.9% organic matter). Soya bean was sown in 0.5 m-spaced rows at a density of 40 plants m^{-2}; soft winter wheat was always the preceding crop. Experimental design was always a randomized block with three replications and a plot size of 45 m^2 (3 m width). For both trials, the following weed control methods were applied: 1) spring-tine harrowing (one pass at the "T_1" time); 2) spring-tine harrowing (two passes at the "T_1" and "T_2" time, respectively); 3) spring-tine harrowing (one pass at "T_1") + hoeing (one pass at "T_2"); 4) split-hoeing (one pass at "T_2"); 5) finger-weeding (one pass at "T_2"); 6) split-hoeing + finger-weeding (one pass at "T_2"). A common post-emergence herbicide programme was applied (bentazone 374.4 g a.i. ha^{-1} + fomesafen 104 g a.i. ha^{-1} + cycloxydim 200 g a.i. ha^{-1}) at the "T_2" time and untreated plots were included as checks. At the "T_1" time, crop was at the "one trifoliolate leaves" stage and weeds at the "2 true leaves" stage; at the "T_2" time, crop was at the "two trifoliolate leaves" and weeds at the "6 true leaves" stage. Four weeks after the treatments, the following parameters were determined: weed density, weed dry weight and weed ground cover. Furthermore, in 2005 weed seed rain was assessed using four seed traps per plot. At harvest, crop density and crop production was determined. All data were subjected to analysis of variance and treatment means were separated using Fisher's protected LSD at P = 0.05 level. Total weed flora was higher in 2004 than in 2005 with a ground cover in the untreated check of 263% and 128%, a density of 89 and 48 plants m^{-2} and a weed dry weight of 245 and 113 g m^{-2}, respectively. In 2005, the untreated check showed a total weed seed rain of 80,838 seeds m^{-2}. Herbicide application gave highest weed efficacy. Considering mechanical methods, harrowing + hoeing gave the best results with 67% to 94% weed reduction and seemed to be a good alternative to chemical control. Split-hoeing showed satisfactory results especially in 2005 with an efficacy ranging from 53% to 82%, while finger-weeding was effective only against weeds at early growth stages, and its efficacy was rather low, especially in 2004. The combination of finger-weeding plus split-hoeing did not improve weed control compared to split-hoeing alone. Harrowing alone gave very low efficacy, regardless of the number of treatments. When considering weed seed rain, the lowest seed number was observed with herbicide treatment (1,903 seeds m^{-2}). Harrowing + hoeing showed the lowest seed rain (18,408 seeds m^{-2}) among mechanical treatments. However weed seed rain appeared to be significantly correlated to weed dry weight (R=0.915). As a consequence, the best treatment should be able to obtain a high weed density reduction and to hinder the development of not-uprooted weeds, reducing their competitive ability and seed production. Mechanical and chemical treatments did not cause any significant reduction in soybean density. High crop yields were obtained with chemical control and harrowing + hoeing, without significant differences. In the other treatments, crop yield values were not significantly different from that of the untreated check.

Comparison between chemical and thermal weed control on hard surfaces in urban areas

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In urban areas, weeds can interfere with human activities in many ways. They can limit the visibility to car and motorcycle drivers, spoil the aesthetics of streets and squares, cause mechanical damage to hard surfaces and tarmac, cause pedestrian to slip or make walking difficult, facilitate vehicle skidding, obstruct urban drainage, and spread allergenic pollens. In Italy, herbicides and mowing machines (trimmers) are commonly used for weed control on hard surfaces in urban areas. To promote a new approach to weed management in such areas based on reduction of herbicide use, experimental trials on physical weed control on hard surfaces were carried out in 2004 by CIRAA E. Avanzi of the University of Pisa in the town of Livorno (Tuscany). Two weed management systems (physical and chemical) were compared on three types of hard surfaces (packed soil surface, gravel surface, and porphyry blocks). Four to six physical treatments (from April to October) were carried out using a knapsack flaming machine, while one chemical treatment was carried out in April with a hand-held sprayer using a herbicide containing 31% glyphosate (average rate: 18.6 kg a.i. ha^{-1}). Different initial weed cover was observed depending on type of hard surface, which ranged between 34% (gravel surface) and 90% (packed soil surface). Thermal treatments were considerably faster in their manifestation of effects on all surfaces. Ten days after treatment (DAT), total weed cover was reduced by ca. 50% on packed soil and gravel surfaces, and by ca. 85% on porphyry blocks. The effect of chemical weed control was particularly effective and durable on porphyry blocks, while on both packed earth soil and gravel no weed cover was observed at 45 DAT, but then weeds quickly re-colonised the sites afterwards. As a consequence, weed cover in glyphosate-treated plots from July to October 2004 ranged between 40 and 60%. Flaming allowed more consistent weed control throughout the season and resulted in a very low final weed cover. Working time and total costs were higher for physical than chemical treatments (+65% and +18% respectively). Although this difference is apparently relevant, the application of an ordinary physical weed management, based on flame-weeding performed regularly, can reduce working time and LPG consumption, and, at the same time, increase thermal treatments effectiveness. Follow-up activities include a two-year (2006-2008) series of trials on urban weed control in the cities of Livorno and Pisa, aimed to compare flame-weeding with chemical and mechanical (mowing) systems on different hard surfaces. Although this work is still in progress, results of the first 9 months indicate that weed communities in the chemical and mechanical treatments are more abundant and species-rich than that in the flame-weeding treatment. Potential of a new prototype of self-propelled flaming machine, planned and realised at the University of Pisa, for ordinary urban weed management is presently being tested in Livorno.

Influence of injection system on the effect of 'activated' soil disinfection on the weed seedbank

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Soil steaming is one of the most promising methods for preventive weed management in high-value (e.g. vegetable) cropping systems. This method reduces weed emergence during the crop cycle and thus seems particularly suitable for organic agriculture, where expensive hand weeding interventions are often required for sufficient intra-row weed control. The University of Pisa has been working on this topic since 1998 with the aim of planning, implementing and improving efficiency of versatile machines for soil disinfection based on the use of steam and activating compounds. Based on previous experience, a two-year (2005-2006) experimental trial was carried out to test the preventive weed control effect of three innovative steam injection systems developed for use by a track self-propelled steaming machine. The three injection systems were: (a) single bar for deep interventions (ca. 20 cm depth); (b) carter bar for shallow interventions (ca. 7 cm); (c) mixed system characterized by the concurrent use of both single and carter bars operated with a steam distribution ratio of 2:1, 1:2 and 1:1 between the upper and lower bar respectively. Treatments were carried out using steam alone or with two activating compounds (KOH and CaO), each distributed at two different rates (1000 and 4000 kg ha^{-1}). Treatments effects were observed both on an artificial weed infestation, achieved distributing ca. 450000 seeds m^{-3} soil of *Brassica juncea* (L) Czern (Indian mustard), and on the natural soil seedbank. After each treatment, soil temperature trend was measures with a specific device (PT 100 bifilar sensors connected to a data logger). Field emergence of *B. juncea* was sampled one week after soil disinfection on one 25 x 30 cm sampling area $plot^{-1}$ for a 10-day period. The effects of treatments on artificial and natural seed banks were analysed with the seedling emergence technique: four soil cores $plot^{-1}$ (10 cm diameter) were taken at three different depths (0-7 cm, 7-14 cm, and 14-21 cm) and placed in plastic tubs in an unheated glasshouse under optimum water regime. Emerged weed seedlings were periodically identified and counted over a 12 month-period. Results showed clear differences among the three injection systems. The single bar treatment was the most effective at the deepest soil depth (on average, between 14 and 21 cm depth, soil maximum temperature reached 65 °C with activating compounds and *B. juncea* seedbank density decreased by 91%). The carter bar treatment was the most effective in the surface soil layer (on average, between 0 and 7 cm depth, soil maximum temperature reached 63 °C with activating compounds and *B. juncea* seedbank density decreased by 96%). The mixed system was on average the most effective in terms of seedbank reduction in the whole treated soil volume (on average, between 0 and 21 cm depth, soil maximum temperature reached 52 °C with activating compounds and *B. juncea* seedbank density decreased by 84%). Similar trends were recorded in the first trial year for *Poa* spp. and *Oxalis* spp., the two most abundant species in the natural seedbank. Furthermore, the carter bar injection system allowed a significant reduction (-85% compared to the control) of *B. juncea* field emergence even without the use of activating compounds. This is an important result because it may extend the range of use of this machine to organic agriculture, where at present the use of CaO and KOH is forbidden. Complete suppression of *B. juncea* field emergence was obtained with use of the carter bar and of the mixed system (with 2:1 steam distribution ratio) at the maximum rate of both activating compounds.

Physical weed control in organic chicory and fennel cultivated in the Fucino Valley (Italy)

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In order to improve physical weed control strategies in organic chicory and fennel in comparison with the organic "traditional" crop management used at present in the Fucino Valley (one of the most important areas of chicory and fennel production in Italy), a field experiment was established in 2004 and 2005. Organic "traditional" weed control strategy includes a false seed bed technique performed by spring tine harrowing or rotary harrowing before chicory and fennel transplanting, and then followed by conventional hoeing and hand weeding after transplanting. The innovative strategy consisted of stale-seedbed technique, carried out by a 2 m wide rolling harrow (that was tested for the first time in the Fucino Valley) and flaming before transplanting, followed by innovative precision hoeing (realized by means of rolling harrow and precision hoe) and manual weeding after transplanting. For flame weeding, a specific operative machine equipped with four open flame rod burners each having a width of 0.5m was used. A specific precision hoe equipped with torsion weeder was modified to control weeds after transplanting. Number of hoeing and manual weeding interventions in "traditional" organic and innovative organic techniques were variable and related to the development of weeds. During the fennel and chicory cropping cycle, weed flora density and biomass were recorded; yields of the two crops were also determined. Moreover, work chain characteristics and manpower employed in weed control operations were measured. Innovative strategy conducted by flaming and organic "traditional" technique using spring tine harrowing or rotary harrowing produced similar weed control effects before transplanting. The weed population was lowered by 99% through pre transplanting operations both in 2004 and in 2005. On the contrary, weed control operations conducted after transplanting showed strong differences. In particular, precision hoeing controlled both inter and intra-row weeds quite successfully. Consequently, a reduction of the need for manual weeding was observed; this was particularly evident in chicory in 2005 (a 30% reduction of time compared with "traditional" technique) and on fennel in 2004 (a 15% reduction of time compared with "traditional" technique). Differences in fennel and chicory crop yield were observed under the innovative technique in comparison with the "traditional" organic strategy. The innovative system gave 16 % and 32% yield increases in chicory in 2004 and 2005, respectively, compared with the "traditional" weed control strategy. Similar results were observed for fennel yield in 2004 and 2005 (+30% and about +11% yield gains) when applying the innovative system.

Repeated clover undersowing as a strategy for organic grain production – effect on annual weed infestation

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For obtaining higher grain yields on stockless farms to meet future demands, a project was started in 2002 with the following objectives: Repeated undersowing of clover as a mean to: 1) increase grain yields; 2) improve field N balance; 3) mobilize soil mineral P and K; and 4) control weed. A four-year crop rotation field experiment was performed in Southeast Norway at two experimental sites, Apelsvoll and Kise, in 2002-2005. The main crops were oat and wheat alternating every second year. The undersown clover species, red clover (in oat) or white clover (in wheat), established in pure stands or in combination with ryegrass (two treatments), were compared with two different weed control treatments: the cereal crops in pure stand with or without weed harrowing. In addition, cereals undersown with ryegrass were included as a third control treatment. In two additional treatments, an only one year green manure (2003) was included as a N-supply during the four-year-period, one with red clover in pure stand and one in combination with timothy. When harvested at Zadoks 49, undersowing with pure clover resulted in 642 kg weed biomass ha^{-1} on average over the four years at Apelsvoll, but only 415 kg ha^{-1} at Kise, compared with 462 kg and 453 kg ha^{-1}, respectively, in the treatments with the cereal crop without undersowing. The green manure year 2003, resulted in a peak in weed biomass and grain yield in 2004, probably because of the N-supply from the green manure. The weed biomass was 1162 kg ha^{-1} at Apelsvoll, but only 511 kg ha^{-1} at Kise. In 2005, weed weights dropped to 617 kg and 317 kg ha^{-1}, respectively, at the two sites. The undersowing also resulted in an increase of the weed seed bank from 18,603 vs. 11,765 seeds m^{-2} down to 0.20 m soil depth in the controls without undersowing at the two sites, respectivly, and up to 19,449 seeds m^{-2} and vs. 15,184 seeds m^{-2} with undersowing. The increases were not significant. The number of annual weeds in undersowing with clover was 1080 vs. 646 plants m^{-2} at the two sites, respectively, compared with 1032 vs. 607 plants m^{-2} in the controls. The differences were not significant. The main crop with harrowing only, resulted in a significant decrease in weed number at both locations (680 vs. 465 plants m^{-2}, respectively). It can be concluded that the harrowing was not particularly effective, but sufficient to keep the soil seed bank on a steady level at both sites. Grain yield, however, decreased probably because of injuries caused by harrowing. The different results at the two experimental sites, may be explained by higher precipitation at Apelsvoll than at Kise (609 vs. 526 millimeter). But even more important, the Apelsvoll site was irrigated whenever necessary while Kise did not receive any irrigation. In concluding terms, repeated clover undersowing in four years gave higher total grain yields than only one of the four year with green manure. Regarding weed control, no benefit from the repeated clover undersowing was recorded. The increased nitrogen supply may have improved weed growth and thereby obscured suppressive effects from the undersown clover.

Management of perennial weeds in organic plant production – combining soil cultivation and cover crop competition

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To stabilize organic cereal production systems, it is necessary to control *Cirsium arvense* and other perennial weed species. The aim of the two presented experiments (I and II) has been to study the effects of applying mechanical treatments in spring combined with competition from a cover crop. In both experiments, we used the same mixture of cover crops; phacelia (*Phacelia tanacetifolia*), common vetch (*Vicia sativa*), red clover (*Trifolium pratense*) and Italian ryegrass (*Lolium multiflorum*). The first experiment (I) was arranged in a complete factorial split-plot design. Factorial combinations of the treatments (i) length of root fragments of *C. arvense* (5 or 10 cm), (ii) burial depth of the fragments (5 or 15 cm) and (iii) cover crop (with or without), composed the eight main plots and simulated different mechanical treatments and date of cutting the seven subplots. Use of cover crop was the single factor that most effectively reduced the gain of biomass of *C. arvense*. At the final harvest, combined treatment of deep root burial (15 cm), short root length (5 cm) and cover crop had reduced number of new shoots of *C. arvense* by 95% and root biomass by 97% compared to shallow burial and no cover crop. The minimum regenerative capacity of *C. arvense* was observed when *C. arvense* had developed 2 to 6 leaves in the treatment with cover crop and 4 to 8 leaves in the treatment without cover crop. In the second experiment (II), which had a complete factorial design, ± ploughing in autumn was combined with different fallow strategies in spring before sowing the cover crop. Disc harrowing during the fallow period was performed either 2x when fallow lasted for 3 weeks or 4x when fallow lasted for 6 weeks. Additionally, all combinations of ± ploughing in autumn and length of the fallow period were combined with ± ploughing before sowing the cover crop (all together 8 treatments). In two additional subplots, shallow ploughing preceded the autumn ploughing treatment (± ploughing). Preliminary results from experiment II, support in general the conclusions from experiment I. Combining soil tillage with the competition from a fast growing cover crop have potential for retarding perennial weeds. The classical approach for controlling *Elymus repens* was confirmed in this experiment, the longer tillage period the better weed control, and the tillage period should be proceeded by deep ploughing. Ploughing in the autumn gave no additional effect on couch grass. Best control of *C. arvense* was obtained with shallow ploughing in the autumn followed by a 6 week tillage period (3 weeks was not tested here) in spring and early summer and completed by ploughing before sowing the cover crop. In conclusion, the experiments showed that intensive soil tillage combined with competition from a cover crop gave promising results for managing perennial weeds. Due to the positive effect of moderate tillage operations, attention to other factors, such as nutrient supply, soil structure and energy use, may still be considered while a satisfying weed control is obtained.

Seed production in *Papaver rhoeas* affected by time of emergence and crop competition

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Papaver rhoeas L. is a major dicot weed in winter cereals in Spain with an extended period of emergence from October to April. Its high fecundity is the one of most remarkable biologic features. To understand how a weed will perform in various cropping systems, the baseline performance of plants growing without competition must be determined. There is limited published information on the biology of *P. rhoeas* under Mediterranean conditions. The objective of this work was to study how is reproduction affected by the time of emergence and the presence or not of cereal competition. With this purpose, during the seasons 2003/2004 and 2004/2005, *P. rhoeas* cohorts were established in a commercial cereal field in the north-east of Spain, with and without crop competition. Two autumn cohorts (without crop), two winter cohorts (with and without barley), and two spring cohorts (with and without barley) were established in the first season whilst two autumn cohorts (with and without crop), one winter cohort (without barley), and one spring cohort (without cereal) in the second season. At the end of each growing season, seed production was estimated for each cohort. No differences in seed weight (1000 seeds) were found between cohorts and years, and this parameter was used to estimate fecundity. In the season 2003/04, without barley competition, the October cohort produced 82854 seeds plant^{-1}, the November cohort 49343 seeds plant^{-1}, the January cohort 39394 seeds plant^{-1}, and the April cohort 6072 seeds plant^{-1}; with cereal, the January cohort produced 9116 seeds plant^{-1}, and the April cohort 739 seeds plant^{-1}. In the season 2004/05, without barley, the December cohort produced 99156 seeds plant^{-1}, the January cohort 15912 seeds plant^{-1}, and the April cohort 111 seeds plant^{-1}; with cereal, the December cohort produced 2525 seeds plant^{-1}. The number of capsules per plant ranged between 300 capsules plant^{-1} (October cohort without crop in season 2003/04) and 1 capsule plant^{-1} (April cohort without cereal competition in season 2004/05). The production of reproductive elements (seeds plant^{-1} and capsules plant^{-1}) was much higher without crop competition. Later emerged cohorts produced also much less seeds when compared with earlier emerged plants, both with and without barley. A contrast analysis of variance showed that these differences were statistically significant ($P < 0.05$). Between years, seed production was higher the first season ($P < 0.05$), probably due to the much drier season in 2004/05. The number of seeds capsule^{-1} showed a similar pattern as the previous variables, ranging between 2000 and 10 seeds capsule^{-1}. This data show the importance of cohort and crop competition on the fecundity and demography of this species. This information allows improve predictions of weed population dynamics and develop better strategies and future weed management models for Spanish farming systems.

Orobanche aegyptiaca management by catch and trap crops in tomato

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Application of catch and trap plants is a cultural and biological method for *Orobanche* soil seed bank reduction. Catch crop is a host crop that is parasitized and then removed before broomrape emergence; trap crop is a false host that stimulates broomrape germination but it is not parasitized.

A lab experiment was carried out to evaluate the effect of root exudates of 17 crops (wheat, barley, maize, broomcorn, flax, cotton, pinto bean, lentil, broad bean, pea, sugar beet, sesame, soybean, Berseem clover, alfalfa, pepper, sunflower) on *Orobanche aegyptiaca* seed germination. One hundred mg of *Orobanche* seeds were pre-conditioned and then placed in a Petri dish with 60 crop seeds for 2 weeks at 25 °C. A complete randomized experimental design with 4 replicates was used. Broomrape germination was measured. Berseem clover, flax, broomcorn, broad bean, pepper, pinto bean, soybean, sunflower, lentil, cotton, pea affected *Orobanche* seed germination.

A greenhouse experiment was carried out in 2005 in order to study different crop rotations effects on broomrape germination and identify the best crop as a trap crop for reducing *Orobanche* seed bank Using a RCBD with 4 replicates, 10-15 mg of *Orobanche* seeds mixed with substrate and crop seeds were sown in pots with diameter 0.30 m and height 0.30 m. The same 17 crops of the lab germination experiment were used. After 40 days from sowing, the crop plants were picked up from the crown and were replaced by 3 tomato (cv. Superstrin B) 7-leaves stage transplants; two tomato plants of three were removed after 10 days. *Orobanche* and tomato fresh and above ground dry weight and *Orobanche* stem number were recorded at the end of trial. Berseem clover was the strongest catch crop showing the highest *Orobanche* stem number of per pot (about 14) and fresh and dry weight (107.8 and 20.4 g per pot, respectively). Sunflower and pepper were weak catch crops: *Orobanche* stem number of per pot was 5.75 in sunflower and 2.75 in pepper respectively; *Orobanche* fresh and dry weight were 44.5 and 8.4 g per pot in sunflower and 19.7 and 3.2 g in pepper. Sugar beet, wheat, corn, sesame, barley and soybean had no stimulation effect on *Orobanche* germination. Broomcorn, Berseem clover, flax, pinto bean, cotton, lens, pepper, broad been, sunflower, and pea were effective in reducing weed seed germination. Flax and Broomcorn were strong trap crop whilst cotton, pinto bean, lens, broad bean and pea were weak ones.

Session 4

Weed temporal and spatial dynamics

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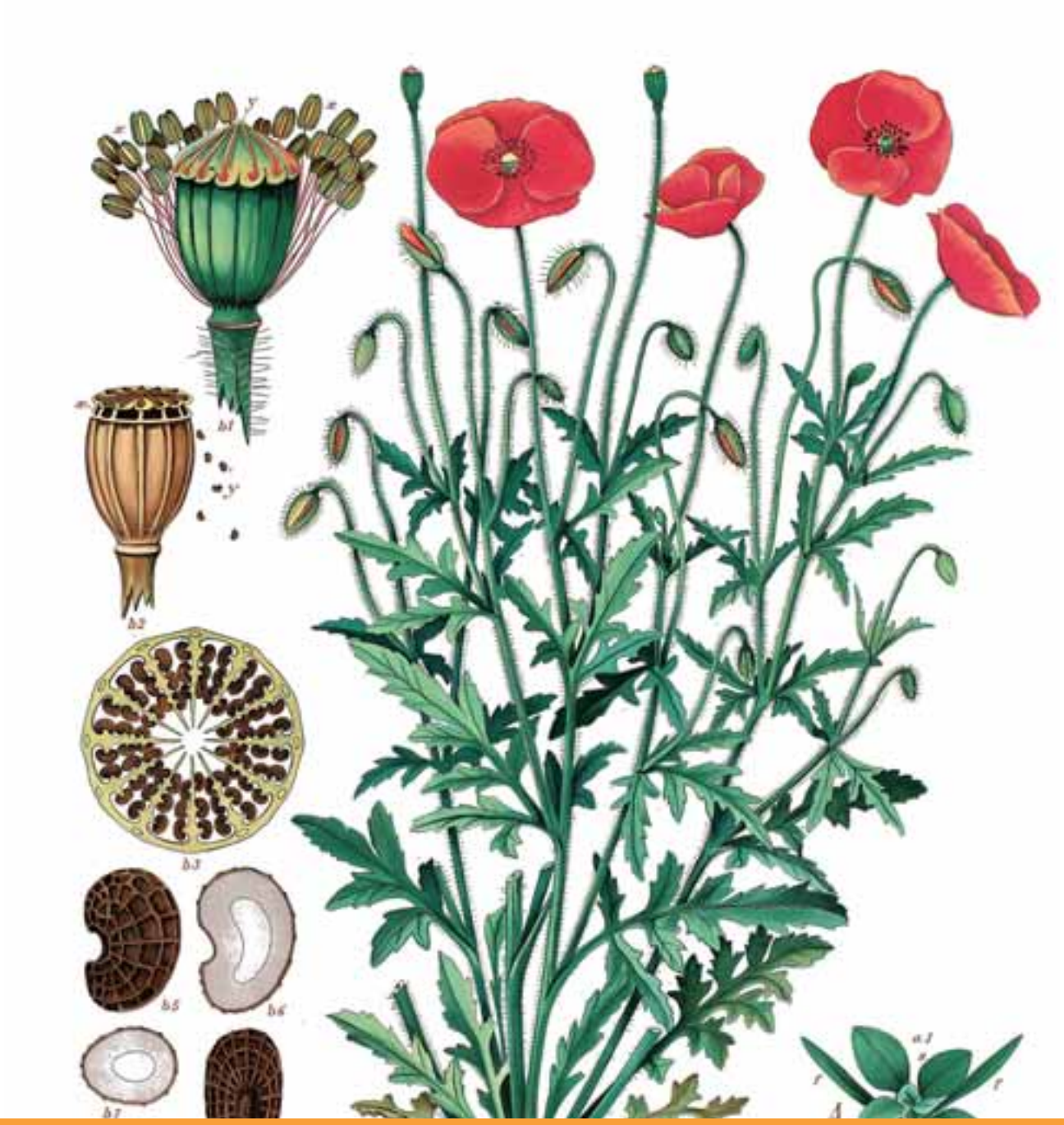

'All models are wrong – but some are useful' – a report from an EWRS workshop on modelling weed population dynamics

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A three-day workshop on modelling weed population dynamics partially sponsored by the European Weed Research Society (EWRS) was held in October 2006 at Research Centre Flakkebjerg. 24 participants attended the workshop from 8 countries, mainly Europe and USA. The aim of the workshop was to gather some of those active and interested in the field, i.e. most of the participants had either published papers on weed population dynamic models or had a model under development. By gathering these people, it was our hope to learn from each other and possibly benefit by increasing the knowledge and use of each other's work. The EWRS saw the workshop as an opportunity to interconnect some of the work going on in (at least) three working groups: Weed Seed Germination and Early Growth, Crop-Weed Interactions and Physical and Cultural Weed Control.

The preparations of the workshop were initiated by the keynote paper: "Field weed population dynamics: a review of model approaches and applications" presented by N. Holst at the EWRS Symposium in Bari, Italy, 2005, which has recently been published in Weed Research. In connection with this, a database with a bibliography of publications on weed population dynamic models was created, and is public online at http://www.blackwell-synergy.com/doi/abs/10.1111/j.1365-3180.2007.00534.x. At the workshop, ten weed population dynamics models were presented, and all of these were available on computers for the participants to try. Many of the models are freely available on the Internet, although some must be paid for, and some are still under development.

The themes discussed at the workshop were presented under five headings: 1. Using models for understanding weed biology, 2. Modelling tools for understanding the dynamics of weed populations, 3. Using models for prediction purposes and decision support, 4. Understanding basic spatial-temporal dynamics through use of models and 5. Model analysis. A common understanding at the workshop, in respect of the fact that no model can accurately show the complexity of the real world, was that "All models are wrong – but some are useful". Some important discussion points brought up at the workshop were related to application domain and model complexity. Are the models used to explain what actually has happened, or are they used for forecasting. It was decided that some of the participants will collaborate on a common publication on this subject. Another topic was the required level of complexity also phrased as 'How long do we keep on improving our models?' Does added complexity make the model more realistic, or does it just add errors? Aspects of these discussion points will be dealt with in more detail in the presentation at Hamar.
We also discussed how we could make better use of each other's work. In this regard it was decided to make a list of the presented models, including links to the models and where possible open source code, so that parts of generic models could be used by other modellers. In addition, a common database with parameters characterizing different life cycle stages of specific weed species was planned. Since participants agreed that this workshop was a very important opportunity for weed population dynamics modellers to convene, it was suggested that a new workshop should be arranged within 2-3 years, location depending on possibilities for sponsoring.

Evaluating the effect of weed management strategies on long-term weed population dynamics using a modelling approach

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The last decade has seen more concern about food safety and sustainable management of natural resources than ever before. One implication is a reduction in available herbicides, reflected in the recent EU pesticide review (EU 91/414). With fewer herbicides available to vegetable growers, there is a potential for certain weed species to escape control operations. As a result, these weeds may start to proliferate and the weed flora composition could change over time. Hence, there is a need to evaluate the effect of weed management strategies on the long-term development of the weed flora. Other factors known to affect weed abundance and composition include the density and composition of the seedbank, weather conditions and type of crop. Gradual changes in weed flora composition may be masked initially due to these factors and their possible interactions. Therefore, it's likely that an experimental approach would have to span a long period to be able to detect these changes. A modelling approach avoids this disadvantage. As parameters and individual models based on biological information are increasingly available for processes within the lifecycle, it seems valuable that these models are integrated into a weed population dynamics modelling framework. Quantifying the effects of different weed management strategies and testing these strategies using simulations in a weed population dynamics model will help in determining the probability of an increased weed problem. In addition, simulating different combinations and timings of weed management options should reveal the most suitable strategy to control the target weeds. The objective of this project was therefore to develop such a modelling framework, capable of simulating the impact of weed management strategies on long-term weed population dynamics. Ultimately, the aim of the model is to provide feedback to growers in the form of guidelines about weed management strategies. Common chickweed (*Stellaria media*) and scentless mayweed (*Tripleurospermum inodorum*) were chosen as the first weeds to be parameterised as relevant biological information was already available and because they have contrasting morphological appearances and life history traits. Where available, data from the literature was used and additional experiments were carried out if required. A detailed study was conducted to investigate the effect of plough and power harrow cultivations on the vertical re-distribution of seeds. The data were used to test the assumption that sequential cultivations can be modelled by multiplying the transition matrices for individual cultivation implements. To comply with the dynamic nature of the modelling approach, other experiments were conducted to explore the temporal sensitivity of plant processes including the phenological development of weeds and the relationship between weed biomass and seed production. The modelling framework is developed in MatLab and runs on a daily timestep with climate data and dates of weed management events as input. It consists of a series of linked sub-models, e.g. a depth-structured seedbank, a germination and emergence sub-model and a growth and competition model. Simulations will be conducted for a simple cropping rotation with one year of vegetable crop (carrot / onion) followed by multiple years of cereals (barley / wheat). Simulation results comparing the effect of different weed management strategies on weed population dynamics will be presented. For example, one scenario will explore the effect of timing and type of weed control after winter cereal stubble on the amount of viable seed that return to the seedbank.

PRIM (Poppy Resistant Integrated Management): a bio-economic model for Papaver rhoeas in the North-East of Spain

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A bio-economic model for *Papaver rhoeas* L. in dry-land cropping system in Spain was developed from a version of the resistance and integrated management (RIM) model for *L. rigidum* in Australia. The original model was extended to include four seed bank layers and simulate seed movement in the soil profile resulting from tillage. Different emergence rates and seed bank mortalities were included depending on soil cultivation and burial depth, and different weed management practices (herbicide and non-herbicide options) available to control this species were incorporated. Users of PRIM may specify the crop sequence (wheat, barley or fallow) and any feasible combination of the 43 weed treatment options each year over 20 years. Weed treatment options include selective herbicides (19), control options using non-selective herbicides (6), non-chemical treatments (17) and user-defined treatments (1). PRIM represents weed and seed bank population dynamics, weed-crop competition, weed treatment impacts (including phytotoxicity), agronomic details, and financial details. The model can be used to evaluate weed management scenarios by investigating the implications of different tillage, fallow and cereal rotational sequences and of varying herbicide availability. Model validation was done with published and unpublished data for seed bank predictions and mature plants at the end of the growing season. PRIM showed a good performance, with tendency to overvalue at low densities and underestimate at high densities for both variables. A sensitivity analysis was also undertaken for 30 parameters of the model for four scenarios: two with tillage and two with zero tillage. At the top of the list were the weed-free wheat yield and the net sale price for wheat, followed by the weed-free barley yield while the net sale price for barley was in sixth position. The model was also responsive to the cost of diesel fuel and cost of cereal seeds. In the case of fuel price, its sensitivity is correlated to the impact of cultivation costs (fuel consumption) in tillage systems. The most sensitive biological parameters were the *P. rhoeas* annual emergence and the initial seed bank density at 0-5 cm depth, and these should be considered important in further research. Most of the parameters were more sensitive in the tillage scenarios compared to scenarios with non-tillage. The reason is that costs in tillage scenarios are higher because of cultivation operations, resulting in lower incomes, making the annual profit more susceptible to changes in cereal yield, weed densities, etc. In terms of *P. rhoeas* management, preliminary results show that, after 20 years with an average herbicide efficacy of 91% in this period, it is possible to greatly diminish the weed population, but not to eradicate it. PRIM model provides a powerful tool for evaluating the biological, agricultural and economic performance of alternative long-term weed management systems in winter cereals in Spanish dry-land areas. The undertaken validation process demonstrated the potential of PRIM to predict *P. rhoeas* population dynamics. Owing to the model structure, the more detailed the knowledge on the seedbank, the more precise the prediction of seeds and plant densities will be. The sensitivity analyses showed that strategies linked to cost related parameters (i.e. tillage operations depending on fuel cost), and to profit related parameters (i.e. price and weed-free yield of cereals), will drive management decisions. Finally, PRIM may also be used to identify research gaps in *P. rhoeas* management. PRIM shows that economic differences between the scenarios are not due to differences in weed densities but to differences in total weed control costs.

Spatial resolution for site-specific weed control in cereals

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A possible commercial solution for patch spraying against seed-propagated weeds in cereals is a camera mounted in front of the tractor taking images at feasible distances in the direction of travel, on-board image analysis software and spray booms being switched 'on' and 'off' (full or zero herbicide application rate) as the weed damage threshold is passed. The main obstacle for this real-time solution is the lack of feasible image analysis software. As this issue is continually worked on, it is expected that feasible image analysis software will be available in the near future. Due to demands on image quality it is unrealistic to apply images that cover the same size and area as the sprayer's swath, and questions related to image sampling and spraying resolutions will arise when implementing the software: e.g. at what distances in the direction of travel should images be taken? What spray boom widths are feasible? Or, what boom width per camera is recommendable if spraying errors are to be limited to e.g. 10%? To elucidate some on these questions, manual weed counts in 0.25 m^2 quadrats were used to simulate outputs from such tractor-captured images and image analysis software. Quadrats were placed at 192 grid intersection points separated by 1.5 m and 2 m in two perpendicular directions within nineteen spring cereal fields. Each direction was used to simulate both the driving direction and the direction perpendicular to it. Each quadrat was classified into 'spray' and 'no spray' decisions based on a threshold model, and the resulting map defined a 'ground truth' map. Thereafter, 'on'/'off' spraying in control areas whose sizes were given by: simulated boom width ´ simulated image distance, were simulated and mapped. Simulated boom widths and image distances were 2 - 39.5 m and 1.5 - 19.5 m, respectively. Spraying decision per control area was based on the weed status at the single quadrat, simulating the camera's view. These coarser maps were compared with the 'ground truth' map, to estimate mapping error (area above threshold that is missed by the camera), spraying error (area below threshold that is sprayed), total error (sum of mapping and spraying error) and herbicide use. Three different levels of the threshold model were tested: original level, 25% reduced level and 25% increased level. If the density of all broadleaved weed species exceeded 175 plants m^{-2} (threshold for the original threshold level), or the threshold density of *Galeopsis* spp. (25 plants m^{-2}), *Chenopodium album* (45 plants m^{-2}), *Brassica rapa* ssp. *oleifera* (20 plants m^{-2}), *Stellaria media* (45 plants m^{-2}) or *Galium aparine* (1 plants m^{-2}) was passed, the decision was 'spray'. Furthermore, if the sum of two or more of these species exceeded the threshold density of the species having the highest threshold value, the decision was also 'spray'. Simulated mean herbicide reductions were 52%, 42% and 59% for the original, reduced and increased threshold levels, respectively. Only minor differences in mapping and spraying errors were seen due to threshold level. Generally, errors increased by increasing boom width and image distance, and image distance influenced the narrower boom widths most. Non-linear regression models for prediction of mapping, spraying and total errors from boom width, image distance and threshold level were fitted. For the original threshold level and an image distance of 2 m, predicted mean total error for boom widths 2 m, 6 m, 20 m and 40 m were 6 %, 10%, 16% and 17%, respectively. If image distance was set to 5 m, predicted mean total errors were 10%, 12%, 16% and 18%, respectively. The study thus showed that spatial resolution is a key factor for the success of site-specific weed control.

Apera spica-venti population growth and impact under the influence of tillage, crop rotation, location and chemical control level

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Apera spica-venti is a very competitive annual grass weed of which the importance has increased considerably in Denmark in recent years owing to an increased area of winter cereals. Reduced tillage in which the soil is not inverted has received much attention lately, and ploughless tillage for crop establishment is now more commonly observed. However, there is considerable concern that reduced tillage will increase the problems with current populations and promote the spread of *A. spica-venti* to new areas. This could undermine the gradual reduction of pesticide use that has been achieved over the last 20 years in Danish agriculture, since more herbicide use appears to be a likely consequence of adopting reduced tillage. Crop rotation and other preventive and cultural means could play a positive role in this context by counteracting the *A. spica-venti* problems associated with reduced tillage. This study aimed at investigating the proliferation of *A. spica-venti* over 4 years under the influence of crop sequence, primary tillage method and location; and also to study whether a limited herbicide input could suffice for satisfactory control of *A. spica-venti*. The propagation of *A. spica-venti* was followed in a fixed crop rotation and tillage experiment placed at two locations, Foulum and Flakkebjerg; Foulum having a lighter soil texture and cooler and rainier climate than Flakkebjerg. *Apera spica-venti* was introduced at both locations in late September at the beginning of the experiment by broadcasting seeds harvested earlier on in July. In general, the site characteristics at Foulum strongly promoted the growth of *A. spica-venti*, whereas the loamier and drier Flakkebjerg location did not lead to high population densities, irrespective of the experimental factors involved. At Foulum, the density of *A. spica-venti* seedlings counted in spring had increased 11-15 fold after 4 years in the crop sequence, which only comprised autumn sown crops and where non-inverting tine tillage had been applied. In contrast, only minor changes occurred under mouldboard ploughing and direct drilling. Supplementary and detailed studies with seeds of *A. spica-venti* provided an explanation, as they showed a much lower viability of seeds placed on the soil surface as opposed to those incorporated a few cm into the soil. Non-inverting tillage tends to build up a seed bank in the upper soils layers favourable for germination, while with direct drilling weed seeds are mainly placed on the soil surface. Additionally, mouldboard ploughing places a large fraction of the seeds deep in the soil, and thus dilutes the seeds into a much larger soil volume than non-inversion tillage does. Crop rotations with an even mixture of spring and autumn sown crops did not lead to noteworthy changes in the population after 4 years at Foulum, irrespective of tillage method. In general, crop rotation had a much stronger impact on the population than tillage method. Controlling *A. spica-venti* chemically by attaining a 90% target control level did not prevent yield penalties in crop rotations favouring *A. spica-venti* growth. Only when the rotation had half spring-sown crops did *A. spica-venti* become manageable through herbicides. Then even a reduced herbicide input attaining a 70% target control level was a feasible strategy for preserving crop yield. It was concluded that securing herbicide consumption at a reduced level would require non-inversion tillage to be accompanied by a weed management strategy that relies not only on herbicides but also on preventive and cultural methods. In this light, a crop rotation that balances autumn- with spring-sown crops will be a necessary precondition for non-inversion agriculture in many regions.

Habitat fragmentation and weed dispersal: A spatially explicit agricultural landscape model

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As a consequence of human activities, suitable habitat for weed populations has become fragmented. Fragmentation can limit breeding populations and make species more vulnerable to extinction. Habitat fragmentation is often defined as a process where a large expanse of habitat is transformed into a number of smaller patches of smaller total area, isolated from each other by a matrix of habitats unlike the original (e.g. forest areas). Within this context, dispersal is a critical process as it links fragmented populations within heterogeneous landscapes, thus connecting populations that may otherwise be isolated. Despite the practical importance of dispersal at the landscape level, the study of the effect of dispersal for weed management has been a neglected area, perhaps because the focus in weed management is traditionally on the individual field level, thus ignoring the complex and interconnected agricultural landscape of which the field is a part. In this research the consequences of different fractions of habitat fragmentation on the spread and management of long and short-distance dispersed species was studied. In order to simulate an agricultural landscape a two-dimensional lattice map model of R x R spatial cells with four neighbours and absorbing boundaries was developed, meaning that individuals leaving the lattice are lost. Total lattice size was 30 cells x 30 cells, each cell representing a one hectare field. Population dynamics within each cell was modelled using a hyperbolic model, which accounted for intraspecific competition. Short-distance dispersal was considered as an equal division of seed rain over the four neighbouring cells. Long-distance dispersal was considered as a random migration of a proportion of the seed rain beyond the four neighbouring cells. Habitat fragmentation, or the fraction of cells with a suitable habitat, was evaluated with an order parameter (Ω).

$$\Omega = \frac{S_{max}}{\sum_i \sum_j \Theta(i,j)}$$

Where S_{max} is the number of cells constituting the largest patch and Θ (i,j)= 0 if site (i,j) is suitable for weed growth, and Θ (i,j)= 1 otherwise. Lower values of W thus correspond to a more fragmented landscape. The spread of both short and long-distance dispersed species was evaluated under different fractions of habitat fragmentation, varying from 10-90%. Results showed that the spread of weed species whose propagules are dispersed over shorter distances (e. g. *Avena sterilis*) were more reduced by habitat fragmentation than that of long-distance dispersing species (e.g. *Conyza canadensis*). Species specific differences were particularly pronounced when the habitat fragmentation order parameter dropped below 1. This threshold corresponded with a habitat fragmentation of approximately 30% of the total lattice. Habitat fragmentation had no or little effect on the spread of the long-distance dispersal species, but is likely to contribute to the management of short-distance dispersed species. At the farm and regional scale, habitat fragmentation can be obtained by a range of measures, like biological control agents or herbicides, as well as the introduction of weed-competitive varieties and cultural practices, including crop rotation. It is also clear that, specially in more fragmented landscapes, the movement of farm machines (particularly with crop seed and on combines) will play an increasingly important role in "connecting" landscapes, thus facilitating weed spread and undermining the positive effect of habitat fragmentation.

Effect of radiative climate on polarized reflectance by weed seedlings

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Light scattering by seedlings is controlled by structural properties of leaves, incident wavelengths and geometrical aspects of the plant-observer-source of light. Moreover, the part of light which is specularly reflected is largely dependent on leaf roughness, which results from the epicuticular waxes on the external surface. This last component of reflectance is mostly polarized unlike the diffuse part. In a previous experiment, we have checked the fact that different species (dicot *versus* grass) have different type of cuticular waxes that can be detected from polarization degree measurements on young seedlings.

In the experiment we aimed to estimate roughness and refractive index of leaves and test the effect of radiative climate. Our approach is based on the microfacet reflection model. This model assumes that the surface roughness is formed by a collection of small microfacets. Their orientations are distributed symmetrically around the local orientation of the surface of the leaf. Light rays incident on a leaf are reflected by the surface's microfacets that are aligned in the direction and thus verifying Snell-Descartes's law. The spread of the specular component of reflection depends on the standard deviation σ of the statistical distribution of microfacets that is directly connected to the leaf roughness. Small values of σ signify gentle facet slopes and give a distribution that is highly directional around the specular direction (smooth surface). Large values of σ imply steep facet slopes and give distribution that is spread out (rough surface).

By making several polarimetric measurements of the reflected optical light wave, we estimated the refractive index of the leaf (the state of polarization of the specular component depends on this parameter according to Fresnel's equations). Then, this parameter was introduced in the polarimetric reflection model to estimate the roughness parameter σ by inversion of the reflection model.

In order to look at the effect of a possible light regime on these polarimetric features, we conducted a growth cabinet experiment whith 3 weed species (*Datura stramonium*, *Xanthium strumarium*, *Panicum miliaceum*) grown at 3 different light environments (normal, gray filter, green filter) in an incomplete factorial design. Measurements were done on both the distal and proximal part of the leaves, either cotyledons or the first or second true leaves. A few representative results are shown here [estimated refractive index and roughness, ófor the 3 light regimes normal, gray, green] : *Datura* cotyledons : 2.63 & 0.45, 2.36 & 0.42, 2.50 & 0.46 *Xanthium* cotyledons 2.34 & 0.35, not avail, 2.34 & 0.36 *Panicum* 2nd true leave 4.46 & 0.42, 4.50 & 0.41, 4.70 & 0.40. The main conclusions are: 1) refractive index estimates are coherent with bibliographical values for dicot species but not for the grass species (then the initial choice made for specular modeling has to be re-evaluated in case of the grass species) and 2) values of roughness show minor variation with light regime.
These partial results have to be completed with more species, leaves and growth conditions, in order to give a comprehensive picture. Once good estimates of refractive index and roughness become available, it is expected that polarimetric measurements would bring complementary information concerning cover characterization of seedling weeds by remote sensing, still restricted to morphometrical or spectral investigations.

Cuscuta campestris Yuncker: spatial patterns and population dynamics as revealed by semi-random molecular markers

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Weeds are a persistent problem in world agriculture despite intensive efforts to eradicate them or bring their populations under control. Phenotypic and genotypic diversity are commonly cited as central features in the successful survival of weed populations in the face of concerted control operations by farmers. *Cuscuta* (dodder) is a stem and leaf parasite that infects many broadleaf crops, ornamentals and weeds and a few monocot crops. It lives entirely on the host plant, thus reducing the growth and yield of the host. In Northern Italy, *Cuscuta campestris* Yuncker (field dodder) is a widespread common weed in *Beta vulgaris* L. (sugarbeet) fields. Spatial pattern and infestation density are quite unpredictable depending on several factors (tillage, crop rotation, meteorological conditions). There have been few attempts to analyze genetic variability of *C. campestris* populations and the relationships among dodder genotype, parasitic behaviour and field infestation are not known at this time. In the present study, a modified RAPD technique with a system containing additional DNA sequences partly complementary to the semi-conservative sequences of intron-exon junctions, was employed for assessing the variation within and among dodder populations sampled across sugarbeet fields in a three year period. The main objective was to reveal the level of genetic variation of *C. campestris* and assess the degree of spatial genetic differentiation. In 2003 and 2005 dodder samples were collected in the same three sugarbeet fields, located in the near surroundings of Bologna (Italy). In each field three distinct plants were sampled in 4-16 weed spots (for a total of 136 plants). DNA samples from each individual were PCR-amplified using twenty five semi-random primers, and resulting bands were separated by agarose gel electrophoresis. Semi-random profiles were scored for each individual as discrete characters (presence or absence of the amplified products). Components of variance partitioned within and between populations were estimated using analysis of molecular variance (AMOVA). On the basis of the 273 polymorphic fragments, genetic differentiation among populations varied from 4% to 14% in 2003 and from 3% to 19% in 2005. The low among-population variation observed in our study is consistent with a predominantly outcrossing species, where individuals in a population become heterozygous at many different loci, thus maintaining variation from generation to generation. In contrast within each sampled field, in both 2003 and 2005, the majority of total variation was distributed among sampling spots (from 41% to 71%). Spatialization of genetic data highlighted a distribution of diversity correlated with distance between sampling points. The occurrence of genetically similar individuals within a single weed spot was not unexpected considering the relative small distance among sampled individuals. Finally, the genetic features of the 2003 populations were markedly different from those of the 2005 populations sampled in the same fields. The presence of completely different gene pools, one year from the other, may be linked to delayed germination mechanisms of the seed bank in relation to more or less favourable environmental and climatic conditions. Standardized cross-infestation experiments, developing co-dominant marker systems to estimate population-genetic parameters in *C. campestris* populations and subsequent modelling of the evolution of virulence could be possible approaches towards a better understanding and therefore a more effective deployment of control strategy against this noxious weed.

Modeling the emergence pattern of five weed species in maize crops from central Spain

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Understanding the relationship between seedling emergence time and the prevailing environmental conditions is vital to the development of sustainable weed management systems. Obviously, predicting the start and the periodicity of seedling emergence can contribute to take better weed control decisions. In this research, predictive models of the timing of emergence for the main species causing weed problems in maize in central Spain were constructed. Monitoring of seedling emergence was performed during 2005 and 2006 in 42 permanent 0.2 m^2 quadrats regularly spaced along a 200 m straight line located in the maize field. Emergence was sampled weekly throughout the growing season. After each assessment, glyphosate was applied with a backpack sprayer over the sampling points to control emerged weeds. Standard cultural practices were carried out in the maize crop, and included irrigation and herbicide application of atrazine and S-metholachlor, both at 0.96 kg a.i. ha^{-1}. Soil water content and soil temperature at 3 cm depth were continuously recorded during the growing season using four HOBO® U12 data loggers located close to permanent quadrats. The soil water potential was always above the base water potential required for seed germination, as determined in laboratory experiments. Consequently, we considered that soil water was not a limiting factor for weed emergence, and therefore soil temperature (growing degree days, GDD) was used as the only independent variable for predicting cumulative emergence. The data sets of emergence for the different species were fitted to three conventional nonlinear growth curves: logistic, Gompertz and Weibull, using a genetic algorithm. Model validation was based on the sum of the absolute mean square residuals. The five more prevalent weed species were two perennials: *Cyperus rotundus* and *Sorghum halepense*, and three annual broadleaved species: *Abutilon theophrasti*, *Datura ferox* and *Xanthium strumarium*. No significant differences were found in the emergence behaviour for a given species in the two years of study. Emergence of *A. theophrasti* and *S. halepense* were best described by Gompertz functions. The emergence of *D. ferox* and *X. strumarium* were best described by Weibull functions. Although the emergence of *C. rotundus* was best described by the Gompertz function, none of the three functions give a real good fit of the emergence of this species. Evidence of asynchrony in timing of emergence of different weed species was observed. *Xanthium strumarium* and *A. theophrasti* were the earliest emergers, attaining 50% emergence at 47 and 109 GDD, respectively. *Sorghum halepense* and *D. ferox* were intermediate, reaching 50% emergence at 365 and 369 GDD, respectively. *Cyperus rotundus* was the last species to complete 50% emergence (702 GDD). According to these results, it is feasible to control *A. theophrasti* and *X. strumarium* by using post-emergence herbicides or mechanical weeding. The short duration of the emergence period of these two species allows to maximise the efficacy of these post-emergence treatments and to avoid the need for subsequent applications. In contrast, the development of sustainable weed management by avoiding residual herbicide application to control *D. ferox* and the two perennial species (especially *C. rotundus*), would be more difficult.

Simulation of wheat-wild radish (*Raphanus raphanistrum* L.) interference with APSIM

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The interference of wild radish in wheat was simulated using APSIM (**A**gricultural **P**roduction **S**ystems s**IM**ulator) model in 2003 and 2004 at Roseworthy, South Australia. The APSIM wheat model used in this study provided good prediction of vegetative and reproductive growth in the monocultures of wheat and wild radish in 2003 and 2004. As the wild radish module was developed from the canola module, some of the growth parameters were based on canola. The module was modified based on the growth data of wild radish in the field which enabled successful prediction of wild radish growth in monoculture and in mixture in 2003 and 2004. Both wheat and wild radish modules performed well in simulating phenological stages of wheat and wild radish in monoculture and mixtures. In 2003 the observed time to reach maturity by wild radish was earlier than that predicted by the model. However, the maturity time is unlikely to have an impact on competitive interactions between these species. The predictions of soil water was also close to the measured values, however, limited data was an impediment to a more in-depth assessment of this parameter. The output from the model in monoculture had a high correlation to observed data for shoot biomass, LAI and yield of both wheat and wild radish. Although the model was more effective in simulating both wheat and wild radish growth in monoculture than in mixture, the results showed that the weakest regression between observed and predicted data still accounted for more than 60% of the variation. In the mixtures, there were generally higher correlation values between predicted and observed values for wheat than wild radish. The simulation of wheat-wild radish growth in monocultures and mixtures showed that the yields of wheat were reasonably predicted with RMSD (root mean squared deviation) of 1.8 t/ha. The corresponding value of RMSD for wild radish was 0.3 t/ha. Wild radish is a particularly difficult species to model, as its indeterminate growth habit makes it highly responsive to late rainfall events. Wild radish is known for its high plasticity in plant growth under different environmental and competition situations. There was evidence for plasticity in wild radish growth, which was reflected in large increases in wild radish plant height at high plant densities. APSIM, however, is not configured to account for such plastic growth response in wild radish to density and this may have contributed to lower R^2 values for wild radish. The canopy module of APSIM used to simulate competition between mixtures of plant species uses plant height to allocate resources (light) for plant growth. In the model at present, plant height is assumed to have a constant linear relationship with stem weight. However, the competition study in the field clearly showed that the slope of the relationship between stem weight and plant height for both wheat and wild radish changes considerably with wheat and wild radish densities both in monoculture and mixture. The slope tended to be considerably greater at higher plant densities, indicating presence of very thin but extremely tall plants in high competition situations. The statistical analysis showed that the relationship between stem weight and plant height was hyperbolic rather than linear. Therefore, introducing this change to APSIM could further improve the prediction of growth in species mixtures. It is concluded that models such as APSIM can be valuable for studying the competition between field crops and wild radish. However, at present there are some limitations in APSIM competition module that could be addressed with further research.

Spatial dynamics of a *Sorghum halepense* population in a maize monoculture

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Sorghum halepense is a perennial plant very common in most Spanish maize fields. The typical aggregated distribution of this weed and the high cost of the post emergence herbicides required for its control makes it an ideal target for site-specific weed management. The objective of this study was to determine the heterogeneity of sizes and shapes of *S. halepense* patches and the time evolution of these patches under standard agronomic practices.

The study was conducted in Arganda del Rey (Madrid, Spain), in a 2.4 ha maize field that had been cropped annually with the same crop for the last 10 years. The spatial distribution of a *S. halepense* population was monitored during two consecutive years. In 2005, patches of *S. halepense* were located visually at the four leaf stage of maize by walking along parallel transects every 12 m. Geo referencing of patch location was conducted using a backpack DGPS equipment and a pen computer with an appropriate data acquisition program. Patch shape and size were recorded by walking around the perimeter of each patch. In addition, average weed density in each patch was determined by counting *S. halepense* tillers emerging in a series of quadrats spaced 1-m throughout one or two transects of the patch. A few days after sampling, nicosulfuron was sprayed using a coarse site-specific approach: the operator opened or closed the control valve of the 10-m boom sprayer when the tractor entered or left dense patches of *S. halepense.* At harvest time, the location of residual patches was determined by visual scoring from the cabin of a combine with the aid of the same DGPS equipment. The same operations were repeated in 2006. Total weed infested area, patch size and frequency distribution of patch sizes were estimated using ArcView.

In 2005, 12% of the field area was covered by *S. halepense*. Large patches (> 200 m^2) represented 83% of this infested area, whereas medium (30-80 m^2) and small (< 25 m^2) patches represented only 11% and 6%, respectively. Although the positions of the patches generally remained unchanged from one year to the next, the percentage of land covered by *S. halepense* in 2006 increased up to 25%. In general, patch expansion followed the direction of tillage and crop planting. The rate of patch expansion varied for patches of different sizes. Large, medium and small patches increased their area by 56, 185 % and 206% respectively. These results point out the importance of spraying small patches before they expand and invade the whole field. Although the number and the location of most patches detected from the combine did not change compared with those detected before herbicide application, the total area infested was higher at harvest time. This indicates that the coarse site-specific spraying approach used was not satisfactory in eliminating *S. halepense* patches. Furthermore, some areas with low weed density that were not detected in the early stages were detected at the end of the life cycle of the crop. At this time, the green leaves of the weed and its tall panicles contrast clearly with the dry senescent crop.

Analysis of the relationships between emergence processes and life history traits of weed species of North-Western Europe

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In the past, weed control in arable fields mainly relied on herbicide applications. Because of the resulting environmental problems, it is now necessary to take into account all cropping system aspects to optimise weed control strategies. Modelling is an essential tool to evaluate and design integrated cropping systems for weed management because of the large variation in agricultural practices and the complexity of their interactions. Weed emergence is a key stage because it determines both the amount of weeds and the timing of their appearance in the field. Emergence strongly relies on seed ability to develop a shoot which, after germination, grows towards the soil surface. The length of the pre-emergent shoot growth is limited and depends on the species. As a result, the deeper the seeds are buried after tillage, the less chance they have to germinate and emerge. In the present work, this process was studied for various species frequently found in crops in North-Western Europe, in order to build a multi-species emergence model, as an extension of the "cropping system → weed dynamics" model ALOMYSYS. Seeds of three weed species differing in their seed weights were harvested at full maturity: *Matricaria perforata* Mérat, *Veronica hederifolia* L. and *Geranium dissectum* L. Freshly germinated seeds were planted in pots filled with fine sand and nutrient solution. The pots were placed in growth chambers in the dark at 15 °C (20 °C for *V. hederifolia*). Regularly, 5 pots were sampled and the radicle, hypocotyl and cotyledon dimensions and weights measured. A Weibull equation was fitted to hypocotyl and root growth with time. Hypocotyl growth rates were calculated at mid-elongation times. Maximum hypocotyl length was 22 mm (standard-error: 0.2 mm), 142 mm (2.3) and 227 mm (62.25) for *M. perforata*, *G. dissectum* and *V. hederifolia*, respectively. *G. dissectum* hypocotyls grew at a faster rate (20.8 mm/day) than *V. hederifolia* (10.4 mm/day) and *M. perforata* (5.8 mm/day). In contrast, roots remained short for all three species. Maximum length was reached after approximately 120 degree-days, with 6 mm (standard-error: 0.2 mm), 20 mm (0.3) and 20 mm (1.1) for *M. perforata*, *G. dissectum* and *V. hederifolia*, respectively. Pre-emergent growth was mostly devoted to shoot growth to the detriment of root elongation. For all species, the cotyledon weight/area ratio decreased with time. The measured shoot lengths show that deeply buried seeds can emerge but that their emergence will take time. In addition, as their cotyledon weight/area ratio decreases with time and as cotyledons are the first photosynthesizing parts of the seedlings, the deeply emerging seedlings need more time to start up photosynthesis after emergence. They have thus less chance to survive than shallowly-emerging seedlings. The data on shoot lengths can be compared with those on *Alopecurus myosuroides* Huds., *Beta vulgaris L.* "weed beet" and a wild type of *Arabidopsis thaliana* L. found in literature. For these six species, the maximum shoot and root length increased with seed dry weight (maximum hypocotyl length (mm) = 56.4 x seed weight (g) + 6.8; R^2 = 0.89; maximum root length (mm) = 4.9 x seed weight (g) + 6.8; R^2 = 0.86). Shoot elongation in the soil occurs without light and is therefore directly dependent on the seed characteristics such as embryo size or the amount of reserves which are more or less positively correlated to seed weight. These correlations between seed weight and maximum shoot elongation make it possible to add a large number of different weed species to the weed emergence model, as they strongly reduce the measurements necessary to obtain the parameters of the main equations of the emergence model. The present approach needs though to be complemented by the study of the remaining seed bank processes such as seed survival and dormancy or pre-emergent seedling mortality.

The variability in spatial distribution of *Galium aparine* L.

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Weeds are non-uniformly distributed within fields. An aggregated spatial distribution of weed populations provides a potential for savings in weed control. However, the use of the site specific weed management is still limited by the absence of fast and reliable mapping method. Continuous sampling of whole weed flora in large areas is not realistic at present, because of long time demand. The weed map is therefore created mainly on the basis of grid sampling. The resulting weed map is strongly affected by the sampling intensity (i.e. grid spacing and sample areas) and sample arrangement. This problem is important especially at low weed densities and by weeds with low damage threshold. This study is dealing with the impact of weed distribution variability and the arrangement of subsamples on the accuracy of the estimation of the *Galium aparine* population. Detailed mapping was carried out on 2 fields in central Bohemia in order to characterize the spatial structure of *G. aparine* population. Data were collected before the post-emergence herbicide application. Rectangular areas of 400 m^2 and 600 m^2 were defined within a winter wheat field in 2004 and 2006 respectively and the spatial positions of all *G. aparine* seedlings in the plots were recorded using a coordinate system. This sampling method allowed for subsequent simulation of arbitrary type of sampling. Continual sampling with the use of 1 m x 1 m sampling quadrate was simulated and the semivariograms for parallel and perpendicular direction were calculated. On the above two areas, 289 squares at 3 m x 3 m each were created. In each square, sampling with many spatial alignments of four partial samples was simulated. The estimated values of each sampling method were compared with the mean weed density by Pearson`s correlation coefficient. Moreover, an area of 6400 m^2 was sampled on the 5 m x 5 m grid using 2 x 1m^2 sampling quadrates in order to quantify the middle-scale variability in 2004. In order to approximate to normal distribution, the data sets were transformed to $y' = \ln(y + 1)$ before the geostatistical analysis was carried out. Geostatistical analysis shows, that the range of spatial dependence varied strongly with the sampling direction. Semivariograms showed stronger spatial continuity along the wheel tracks in the field in both years. The range of spatial continuity varied from 7.4 m (2006) to 8 m (2004) in the parallel direction and from 4.5 m to 4.6 m in perpendicular direction. A relatively high nugget effect (i.e. residual variance at very small separation distances) which was found mainly in 2004 on both above mentioned mapping scales signalizes a high variability of *G. aparine* distribution. High level of residual variance was found mainly in 2004, when the *nugget-effect* reached 43 % of total variance. In all cases, the sample of 0.25 m^2 better represents the whole area, if it is divided into smaller parts. In 2004 the best correlation with real weed density (r = 0.544) was provided by square-arrangement of subsamples. In 2006 the best correlation (r = 0.716) was found, when the subsamples was arranged perpendicular to crop rows. In both years, poor accuracy of the estimation was reached (r = 0.395 and 0.592), when the subsamples were arranged parallel to crop rows. Overall, higher correlation coefficient calculated in 2006 was caused by the higher weed density in that year. The presented results suggest, that the weed density changed much faster in the perpendicular direction to the wheel tracks. This anisotropic behaviour was also visible in the distribution plots as vertical swaths which were probably caused by the combine harvester. Sampling strategies should always be adapted to the pattern of weed distribution. In this case, it was possible to increase the precision of estimation by optimizing the subsample arrangements without having the sample areas enlarged. This research was supported by the MSM 6046070901 project.

Spatial variability of weeds in the Netherlands and possibilities for site-specific weed control

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Assuming that herbicides are only needed in the weed infested area, the potential savings in herbicide application depend on the weed free fraction of a field. The weed free fraction can be modeled by linking models for the spatial variance and frequency distribution of weed counts, notably Taylor's power law (TPL), and the Negative Binomial Distribution. TPL describes the relation between mean density (m) and its sample variance (s^2): $s^2 = a*m^b$ or $\log s^2 = \log a + b \log m$. Parameter b is an index for aggregation (for $b>1$) and parameter a is a scale factor. In this study, we parameterize those models; using 32 data sets from arable fields in the Netherlands. TPL is fitted to the $\log s^2$ and $\log m$ of the data with regression analysis using number of quadrats as weights. A possible effect of species or dataset on parameter a and b of TPL is investigated by adding them as a factor to the regression analysis.

Dominant weed species throughout the datasets are *C. album*, *P. annua*, *P. persicaria*, *S. media* and *S. nigrum*. For each dataset, most weed species counts have a minimum of zero weeds per quadrat. A general model could be fitted to the data and explained 96.3% of the variance. The species above have an effect on parameter a and b ($P<0.05$). Using the TPL model with addition of either species or dataset as a factor has an equal but small effect on the percentage variance explained. (from 96.3% (the general model) to 97%).

TPL has been fitted to a total of 13 weed species and volunteer potatoes (*S. tuberosum)*. Value of TPL's parameter b lies between 1.24 *(S. vulgaris)* and 1.95 *(E. crus-galli)*, indicating a varying degree of patchiness. For *S. tuberosum* b was lowest (0.78). Regression explains over 91% of the variance, except for *S. tuberosum* (79%).

The results of the regression are subsequently used in combination with the observed mean to calculate the expected weed free fraction $P(0)$ according to the Negative Binomial Distribution. $R^2_{predicted}$ is calculated to compare observed and calculated weed free fraction. Weed free fraction is calculated both with species specific TPL parameters and with those of a general model. Weed free fraction is predicted well with mean and outcomes of the species specific TPL model. Values of $R^2_{predicted}$ for the weed free area is high (>0.87) for the 12 dicot weed species. Grass weed species have lower $R^2_{predicted}$ values (0.74 for E. *crus-galli* and 0.37 for *P. annua*). Using the general model to predict weed fraction gives similar results as the species specific models in the majority of the cases. The outcomes for the remaining species show that the general model is less suitable than the species specific model.

The effect of scale of observation and directionality of the observation quadrat on level of occupancy is determined using a spatially explicit dataset. Orientation of quadrats (elongated in row or across row direction) had no effect on the observed weed free. Clustering quadrats to higher scale levels resulted in quick decrease in weed free area.

This study shows that combining mean weed count with outcomes of TPL predicts the weed free area for all weed species, if species specific models are used. The weed free fraction is variable but can be large enough to consider applying herbicides only to weed infested areas. If thresholds are used for controlling weeds, an even larger area will be considered weed free. The method can serve as a first screening for site specific weed management and it could further serve in ecological studies to determine relations between weed patterns and environmental covariates. More knowledge on the relation between values of the aggregation parameter b of TPL and the actual spatial configuration of weed species will be helpful in understanding weed species ecology and can serve as tools for weed management.

Weed detection in cereal fields using digital image analysis

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Weed populations are known to be aggregated in agricultural fields. Site specific weed control is a procedure to adjust herbicide spraying to spatial weed distribution, and this method can substantially save herbicides. An efficient weed control is only feasible if weed species, their density and spatial distribution are known. Manual methods in weed estimation (e.g. weed counting) are very time consuming and inefficient in practical agriculture. So, technical solutions are required for weed recognition in site specific weed control. Digital image analysis is suitable to identify weed species, groups of species and crops by plant characteristics (e.g. shape and colour). Image recognition and image processing are solutions for automatic weed detection based on computer systems. Digital image analysis makes it possible to analyse images and to make automatic weed mapping. For an automated system to work, it must necessarily be able to identify weed species at a very early growth stage, at which most post-emergence herbicides are effective.

The aim is to assign pixels to background or different objects (e.g. single or overlapping plants). After this step the single objects are examined for individual plant characteristics. For objects, which consist with a certain probability of several overlapping plants, a separation by extrapolation algorithms will be accomplished. All objects should be tested with the differentiation algorithm and classified with sufficient precision. In the context of the research work, a system was developed which consists of a computer and a colour CMOS camera, which were connected by Firewire. Colour images were made at different grid points in spring 2006 within winter wheat fields. The image area covered 350 x 263 mm surface area. The pictures were converted first into RGB colour pictures, because they were transferred from the camera as BAYER or as YUV coded pictures. In a second step the colour pictures will be transformed into another colour space, which uses the colour as an independent component, like for example the HSV- or HSB colour space. Based on the colour shade, the green plants can be distinguished from the different colours of the background. To accelerate image processing it must be checked out if the algorithm could be implemented in hardware and in parallel processing functions. Thus in the future it would be possible to calculate these hardware-based algorithms more rapidly. For such a platform independent development, the test algorithms are implemented in JAVA which is itself platform independent, because of its interpretation technology. So JAVA and the algorithms can, for example, operate on embedded systems.

By use of a digital camera, computer system and recognition software it is possible to discriminate among several weed species in practice. For isolated growing weeds against a well defined background (soil) very good results could be obtained. Overlapping leaves of densely growing weeds need much more calculation time for separating overlapping leaves and completing missing parts. The research includes the finding of objects, the classification of objects, image collection, image transformation and the decision supported site specific weed control. The developed system can differentiate between plants (weed/weed; weed/crop), can make decisions based on threshold values and can be combined with a field sprayer steering herbicide application. First results showed that the recognition system worked with sufficient accuracy for grass and broadleaved weeds (e.g. *Apera spica-venti; Galium aparine*).

Horizontal and vertical distribution of weed seed bank in Saffron (*Crocus sativus* L.) fields

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Geostatistical techniques were used to describe and map the spatial distribution of saffron weed seed bank populations. In three fields located on a private farm near Boshrooyeh (33° North latitude, 57° East longitude), Razavi Khorasan, Iran, weed seeds were identified and counted at 144 points of each saffron field (0.2 ha) based on a 4 m by 4 m grid at two depths of 0-7.5 and 7.5-15 cm in 2005. The seeds of ten weed species were observed across the saffron fields. The semivariogram and cross-semivariogram analysis for common species showed that the range of influence varied with weed species and field. The results indicated that the nugget ratio was 1 to 100 percent depends on weed species (low nugget ratio for species that did not have any seed dispersal mechanism and seeds exhibited an aggregated pattern around the mother plant and conversely, high nugget ratio for species that had a random seed distribution due to various dispersal mechanisms) in three fields. *Carduus pycnocephalus* density data showed nugget ratio of 100 percent, indicated that no spatial dependence was found. *Hordeum spontaneum* and *Polygonum aviculare* seed bank data showed moderate to strong spatial dependence at two depths, which suggests that the seed bank distribution pattern of these weeds was patchy. Spatial dependence of *Cardaria draba* seed bank varied with field (from 43% to 76%). The cross-semivariogram analysis for seed bank data between two depths showed spatial dependence for *Hordeum spontaneum* (21%-98%) and *Polygonum aviculare* (56%-90%) and *Cardaria draba* (60%-75%), while no spatial dependence was found for *Carduus pycnocephalus* seed bank. The maps also showed elongated patches along the field more likely due to direction of irrigation and tillage practices. Patchy weed seeds distribution offers large potential for using site-specific weed control on some fields.

Modeling the effects of cultivation, using plough and other implements, on the re-distribution of weed seeds

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A key component of any comprehensive weed population dynamics simulation model is the prediction of the effects of cultivation on the re-distribution of weed seeds in the soil seedbank. The vertical distribution of weed seeds impacts on both the germination and emergence of weed seedlings, and the survival and persistence of weed seeds. The horizontal distribution of weed seeds affects the spatial competition between crop and weed plants, and knowledge of this spatial distribution impacts on the opportunities for precision weed control. From 1990 onwards, a number of models (primarily empirical statistical models, but also some more mechanistic models) have been developed to separately predict either the horizontal or vertical movement caused by a range of cultivation implements. More recently, we have developed a statistical modelling approach for the joint horizontal and vertical movement. This approach can be further extended to fit a 3D movement model (vertical, horizontal (direction of cultivation), lateral (orthogonal to both)) for implements, such as the plough, which are likely to cause significant movement of weed seeds in all three dimensions. Our modelling approach uses continuous statistical distribution functions to model the movement effects, assuming that the patterns of seed re-distribution can be estimated by such smooth functions. The 3-parameter, shifted gamma distribution provides a sufficiently flexible function to describe the horizontal movement, whilst the beta distribution is used to describe the vertical re-distribution over a bounded range (between the soil surface and the working depth of the implement). Assuming that the smooth beta distribution functions provide a good fit to the observed data, this approach allows the depth profile to be divided into many thinner layers than have been used in data collection, and so provides more precise predictions of the probabilities of seed movement. Most importantly this modelling approach can improve the precision of estimates of the number of seeds in the top few centimetres from where most weed seedlings successfully emerge. Joint models for the horizontal and vertical movement of weed seeds have been fitted to previously collected data from experiments using plastic beads to represent weed seeds, for four common cultivation implements. Whilst providing a reasonably good fit to the observed data, the model fitting revealed the limitations of the sampling approach used in this earlier experiment, and a new sampling approach has been developed for a further series of experiments. These experiments, again using beads to represent weed seeds, considered both the effect of the plough (at different operating depths and on different soil types), and the effects of sequences of implements. Results of the model fitting will be presented together with applications of the fitted models. This modelling approach provides the opportunity to identify whether ideal seed movement distributions can be generated through the use of a sequence of existing cultivation implements, and, if not, may stimulate the development of new implements which can achieve these ideal distributions. Further questions that still need addressing are concerned with the interactions of weed seed movement patterns with other factors such as seed size and seed shape, as well as a wider range of soil types and soil moisture levels.

Weed seedbank changes in site specific weed control

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Weed seedbanks are the primary source of weeds in cultivated soils. This paper reports investigations on site specific weed control and the impact on the weed seedbank. The spatial distribution of weed seeds in the soil and seedling populations were estimated. Based on weed distribution, spatially varied herbicide application was done for grouped and/or single weed species. The decision to spray or not to spray was made according to weed threshold values. Such approaches tend to reduce the level of weed control, resulting in the survival of weeds on untreated areas and that will produce seeds and cause increase in the weed seedbank density. The experiments were carried out on a farm near Braunschweig, Germany (latitude 52°10'48" N; longitude 10°57'36" E) in a long-term field experiment on site specific weed control, which was set up in 1999. Weeds were counted in winter cereals every year in the spring before post-emergence herbicide application. Soil samples (0-30 cm) for seed estimation were taken at the same grid points used for weed seedling counts (2001 and 2004). The seedling emergence method was used to determine seed density in the soil. According to the spatially applied herbicides over a period of two years, the field was divided into 3 parts: areas treated twice (2002 and 2003), areas untreated twice (2002 and 2003), and areas treated variably (untreated once and treated once). To describe changes in weed seedbank density an index value was calculated by dividing seedbank data of each grid point of two years (2001 and 2004). An ANOVA followed by a multiple range test (Tukey`s studentized range (HSD) test) was used to compare the index values of the three area groups. Spearman`s rank correlation coefficients between seedbank and seedling densities were calculated to discover the strength between the spatial distribution of weed seeds and emerged weeds within the field.

Seed counts were compared to weed seedling counts during a period of site specific weed control. Low correlations between seeds and weed occurrence were found. The results indicated a weak link between the spatial distribution of weed seeds and emerged weeds. Concluding the number of seeds in the seedbank is poorly related to the emerged weed population. There were areas in the field with high seedbank populations but low seedling populations and vice versa. However, differences in weed density were observed between herbicide treated and untreated areas. Weed density increased on areas without herbicide treatment (weed density below threshold values) over a two year period. Results indicated that the seedbank density in site specific weed control can be higher on untreated areas compared to conventional weed control and can therefore lead to higher weed infestation in following crops. Such information is essential for the development of weed control strategies and for the acceptance of site specific weed control in agricultural practice.

The results presented indicate that it would be very difficult to make a decision for site specific weed control based on weed seedbank density and a fixed annual emergence rate. In each case, for site specific weed control actual information about weed occurrence seems to be indispensable.

In general, site specific weed control requires more knowledge of weed biology and weed management compared to conventional herbicide application. Further investigations are required to assess the impact of site specific weed control on the weed seedbank and on weed infestations in succeeding crops.

Analysing decision rules for site-specific weed management

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A field experiment was conducted to analyse decision rules for site-specific weed control in consideration of heterogeneous weed distribution and varying soil quality. In 2006, the weed seedling distribution (species and density) in a 3.5 ha winter wheat field was assessed prior to and after post-emergence herbicide application and integrated into a GIS. Threshold based spraying decisions were made separately for three distinct groups of target species, which were each treated with a suitable herbicide: grass weeds *(Isoproturon)*, a combination of *Galium aparine* and *Matricaria chamomilla* (*Florasulam)* and other broadleaf weeds (*Carfentrazon Ethyl* and *Metsulfuron Methyl)*. The herbicide treatments were applied using an automated DGPS-controlled sprayer (Kverneland Group) that varied the three herbicides during the application based on the weed distribution map. Unless the threshold weed density was exceeded no treatment was applied. The experiment consisted of three treatments in which either a low, a medium or a high weed density threshold was used for each of the species. The tested thresholds were: 15/25/50 grasses/m^2 *(Isoproturon)*, 1/5/10 MATCH or GALAP plants/m^2 (*Florasulam)* and 10/30/60 other broadleaf weeds/m^2 (*Carfentrazon Ethyl* and *Metsulfuron Methyl)*. These site-specific treatments were compared to an untreated control (no herbicide) and to plots that had all three herbicides applied regardless of weed density. During harvest, yield was mapped in a 3 x 3 m grid using a DGPS-connected, combine-mounted yield monitor system. An EM 38-sensor was used for the mobile acquisition and mapping of soil apparent electrical conductivity (ECa) after crop harvest (8 x 8 m grid). The EM 38 value is an ordinal measurement of soil quality (texture, clay content and soil organic matter). A polygon grid with 8 x 8 m grid size was created and overlaid with the map layers: soil, weed distribution, plot position, treatment maps and crop yield. A linear mixed model was fitted to the data; the spatial structure was modelled by an anisotropic exponential error structure with additional random row and column effects. The weed seedling distribution in the experimental field was spatial heterogeneous. The average seedling density before herbicide application was 21.6 plants per m^2 but patches with a density up to 365 weeds per m^2 were found. The EM 38 values showed no significant association to weed infestation in the experimental field but had a significant influence on yield (0.185 t/ha less yield per unit, SE 0.08 t/ha). The average crop yield was 9.1 t/ha. Analysis of treated cells revealed a phytotoxic effect of herbicide application of 0.7 t/ha (SE 0.28 t/ha). The grass weeds had a significant influence on grain yield whereas the competition of broadleaf weeds was not significant. The biological weed threshold for grass weeds was 21.6 plants/m^2, meaning that at this weed density the yield in treated and untreated plots was exactly equal. In the untreated control yield losses of about 0.022 t/ha per grass weed/m^2 (SE 0.01 t/ha) were found. Assuming herbicide costs for Isoproturon of 11.50 €/ha and a selling price of 155 €/t for wheat, a yield surplus of 0.074 t/ha has to be generated to warrant herbicide application. Subject to the condition that one ride over with the sprayer is always required; an economical weed control threshold of 25 grasses per m^2 was obtained. Site-specific threshold-based weed management thus allows the avoidance of considerable yield losses, combined with significant reductions in herbicide rates. From the three tested thresholds, the medium (grasses: 25, GALAP/MATCH: 5, and other broadleaf weeds: 30 plants/m^2) was particularly suitable; 77 % herbicides were saved compared to the full load, the herbicide efficacy was 80.5 % and the grain yield 9.78 t/ha. This GIS-based analysing methodology is suitable for on-farm research, provides more information compared to classical experimental designs and thus potentially reduces costs in field trial operations.

A Danish Decision Support System for weed control

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Since 2001, a Danish decision support system (DSS) named Crop Protection Online (CPO) on weed control has been available on the Internet (pvo.planteinfo.dk). A full functional free demo, with a limited, agronomical content, can be accessed, using a Danish, English or German user interface. The development of CPO was initiated in 1986 and was driven by a political action plan aiming for a substantial reduction of the total use of pesticides in Denmark. The principal idea behind this system is to exploit that the composition of weed species differs strongly between fields and that the efficacy of herbicides strongly depends on field-specific conditions. For example, differences in the susceptibility between weed species to a single herbicide can vary with a factor 10 on the dose rate required to produce a specific level of efficacy. CPO estimates the need for weed control in terms of target efficacy levels for specific combinations of crop, undersown crop, weed species, weed density, expected yield and season. Most of this information is gathered and supplied by farmers. The estimation is then done by an expert system that takes into account the following aspects: yield loss, reductions in yield quality, difficulties rising from too much weed biomass in combine harvesters and weed seed production. The present version of CPO is operational for the full assortment of herbicides in 30 different crops. Dose-response functions have been established for about 33,000 combinations of crop, undersown crop, herbicide, season and weed species. These dose-response functions also include 4 different weed growth stages, 9 scenarios of climatic condition and 3 scenarios of water stress, using the concept of 'factor-adjusted' dosages. Tankmixtures are calculated by use of the Additive Dose Model (ADM), which at fixed efficacy levels for different weeds can calculate mixes, which have been optimized for cost or for the Treatment Frequency Index (TFI). The use of one standard herbicide dose is equivalent to a TFI of 1.0, and based on this concept political reduction plans have been set up. Consequently, CPO is operational in most fields in Denmark. The core model drives 4 different applications offering end-users entrances to weed control from a field view, a weed view and a herbicide product view. More than 1,800 field trials have been conducted in Denmark to evaluate the robustness and the potential of various versions of the system. Tests have been made in spring- and winter cereals, field pea, sugar beet and maize. The tests showed that the recommendations produced by CPO are very robust in terms of securing yield potentials and avoiding weed seed production. In cereals, herbicide input was reduced with about 45% as compared to recent sales statistics, whereas in other crops this reduction was less. A recent study indicated, however that Danish farmers are quite reluctant to inspect their fields before selecting herbicide treatments. About 40% of the responding farmers explained that they have difficulties in identifying small weed plants, whereas a lack of motivation also plays a dominant role. Presently, about 1,000 Danish farmers (3%) are paying 90 Euros, and about 300 consultants (100%) are paying about 125 Euros annually in subscription fees. The core concept behind CPO has also been implemented in the Baltic States, Poland and Norway.

Temporal variability of *Equisetum arvense* spatial distribution on gray forest soils

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The weediness of arable lands can be estimated with different level of detail. Detailed weed mapping in which every weed species is considered gives exhaustive information, but is rather time and labor consuming. A pilot study in which the presence or absence of just a single species is indicated may be sufficient for decisions on herbicide use and for describing the changes in spatial distribution of the species. A study was carried out during two years on reclaimed gray forest soils. The study area was 16 ha. In 2005 the field was under oats. The number of weed species as well as species composition was determined in the beginning of June, before herbicide application, in quadrates of 50´50 cm in 115 locations that were disposed as a stratified random sampling scheme. In 2006, after cultivation, the field was divided into three equal parts and either sown by buckwheat, mustard or soybean. Fertilizers and herbicides were only applied on soybean. Scouting was performed in the beginning of June before herbicide application. The presence or absence of some species was determined on spots with a diameter of approximately 2 m. In addition, total soil cover was determined. A total of 149 spots, located on a regular grid, were investigated. To compare the study methods and to examine changes in weed spatial distribution a horsetail (*Equisetum arvense*), one of the prevailing weeds, was chosen as object for further study. Probability kriging and ordinary co-kriging were used for spatial interpolations of this indicator species. Despite herbicide application in 2005, the occurrence of horsetail in 2006 was almost the same as in 2005 (50% of spots and 44% of spots, respectively). Even though the spatial distribution of horsetail changed in the two years, the main core of the zone with high probability of occurrence was constant. In 2006, an additional zone of high probability of horsetail, not connected with the main core, was found. This zone was situated on the soybean area and its occurrence may be a result of fertilizer application at this part of the study area. In 2005 the shape of horsetail spots was roundish, whereas in 2006 the spots became elongated according to the direction of tillage. This caused the relationship between spots of horsetail in 2005 and in 2006 to be weak. No evident relationships between the presence of horsetail and position in relief, level of pH, and contents of mobile phosphorus, potassium and organic matter were found. Co-kriging with these properties did not improve spatial interpolations. The correlation coefficient between total soil cover and presence of horsetail was -0.34. The use of this property slightly improved the spatial interpolations. Areas of horsetail occurrence were compact and may be easily delineated, offering good opportunities for minimization of herbicide use. Quality of interpolation for alternative attributes is weakly depending from sampling. Moreover a reduction in the number of sampling points by one third did not greatly influence the horsetail distribution map. For this reason the rapid and relatively cheap sampling of an indicator species seems to provide the best basis for decisions related to the presence of weeds and the dynamics of the area under weeds.

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Temporal and spatial distribution of weed flora populations in maize fields

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The aim of this study is to characterize the spatial distribution of weed flora and its variation over time, 2003-2004, in a maize field located in Golegã (Tagus Valley). In both years before crop sowing, the field was chisel-ploughed. In 2003 maize was treated with atrazine and nicosulfuron and later in season where *C. album* infestation was higher, due to atrazine resistance, a strip of the field was burned after harvesting. The following year, the field was treated with mesotrione. A grid-based (5x5 m) sampling of 100 scores was taken from the maize field. Samplings were performed on September 2003 (after harvest/before burning), January 2004 (four months after burning) and September 2004 (12 months after burning). Weed seed bank was estimated from April to November 2004/2005 with a greenhouse germination method. The analysis of weed communities' composition was based upon weed density and relative frequency of each species. In 2003 the total weed density decreased from 599,615 plants m^{-2} to 512,701 plants m^{-2} after burning. In 2004 it increased about one and a half fold to 861,911 plants m^{-2}. In spite of weed density increasing, the number of species decreased from 31 species in 2003 to 16 in 2004, belonging to 19 families in 2003 and 14 in 2004 with a prevalence of broadleaved weeds. The number of species found before and after burning ranged from 22 to 23, respectively. *Chenopodium album* was the most abundant weed species before burning, decreasing from 3529±455 to 1525±124 plants m^{-2}. After burning *P. annua* was the second most common, with an increase from 1646±139 to 1898±161 plants m^{-2} followed by *Juncus bufonius* which increased from 766±93 to 1339±131 plants m^{-2}. Twelve species had emerged in both situations; *Chenopodium album, Stellaria media* and U*rtica membranacea* decreased after burning, whilst the high temperatures favoured the germination of monocotyledons such as *Poa annua, Setaria verticillata, Digitaria sanguinalis* (P*oaceae*) and *Juncus bufonius* (*Juncaceae*). Seed density of *Solanum nigrum, Conyza albida, Stachys arvensis* and *Oxalis corniculata* did not differ between the two treatments. In 2004 *J. bufonius* (6405±393 plants m^{-2}) dominated weed composition followed by *C. album* (1687±154 plants m^{-2}) and *P. annua* (318±33 plants m^{-2}). Fourteen species maintained from previous year. *Phalaris brachystachys* and *Trifolium isthmocarpum* were identified in 2004; nine species which did not germinate in 2004, included dicotyledons with low density and two *Poaceae*, namely *Digitaria sanguinalis* and *Setaria verticillata* that had densities above 1000 plants m^{-2} in 2003. Concerning *Juncus bufonius*, which is not a competitive maize weed, the extremely high number of seedling emergence on the seed bank certainly have influenced the differences found among overall seed numbers of the three samples. This fact is probably due to field history (vestiges of communities adapted to flooded conditions) and species biology (annual, short cycle and size). The high density and frequency of *Chenopodium album* could be attributed to the presence of resistant populations selected by more than 10 years of atrazine application. The change in herbicide treatment from atrazine to mesotrione, which was effective on *C. album* atrazine-R populations and also on other species, could be responsible for the reduction of weed seed number from one year to the other. The most representative species were always *Chenopodium album, Juncus bufonius, Poa annua, Solanum nigrum* and *Stellaria media*. Actual maps of the weed seed density distribution did not indicate a patchy distribution for any species, even for *C. album,* the most frequent species. Patchy distribution of weed populations provides an opportunity to develop site specific techniques to manage weeds, which feasibility remains difficult for *C. album* and other small seeded weeds in this situation. In order to get the best picture of the distribution we need to study the spatial distribution of weed flora in other maize crop fields.

Session 5

Herbicide resistance in weeds and crops

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Glyphosate-resistant weeds: a technical review and management recommendations

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Glyphosate has been used extensively for both agricultural and non-agricultural uses for over 30 years. The approval for cultivation of glyphosate tolerant crops has facilitated additional uses of this broad spectrum and non-selective herbicide in crops. Glyphosate-resistant weeds have been found in both conventional and in glyphosate tolerant cropping systems. The cases reported from around the world to-date are *Lolium rigidum* and *L. multiflorum, Eleusine indica, Conyza canadensis* and *C. bonariensis, Plantago lanceolata, Ambrosia artemisiifolia* and *A. trifida, Amaranhus palmeri* and *A. rudis, Sorghum halepense* and *Euphorbia heterophylla* (Heap, 2006, see www.weedscience.org). However the number of species that have developed resistance is low when put in perspective with the substantial areas treated worldwide. Glyphosate has a unique mode of action (competitive inhibition of the EPSPS enzyme) that is less sensitive to resistance development than several other herbicides. The resistance mechanism varies across resistant weeds and seems to be complex. While resistance may result from target site alteration in some cases (*Eleusine indica, Lolium rigidum*), some seem to result from metabolism exclusion (*Lolium rigidum, Conyza canadensis*), and several from a combination of mechanisms. Resistant biotypes are likely to have been present in small quantities in weed populations, and have increased under the selective pressure of glyphosate applications.

Being the leading provider of its proprietary products, namely herbicides and herbicide tolerant crops, Monsanto pursues leadership in stewarding them and providing customer care. Monsanto therefore urges farmers to report any incidence of repeated non-performance on a particular weed and investigates cases of unsatisfactory weed control in order to determine the cause. In general, most cases of failure to control weeds in agricultural applications of Roundup® agricultural herbicides result from management problems or adverse environmental conditions. In the cases where resistance is suspected, Monsanto provides users with recommendations for alternative control methods. Some of the recommendations include:

- glyphosate applications when the plants are more susceptible (e.g. *Eleusine indica, Conyza* sp.),
- cultural practices like tillage and/or mowing (e.g. Lolium *rigidum, Lolium multiflorum, Eleusine indica, Conyza* sp.),
- use of herbicide sequences and tank mixtures, especially in Roundup Ready® systems (e.g. clethodim and sethoxydim for *Lolium* control in orchards or vineyards; pendimethalin, fluometuron, acetanilides, diuron or flumioxazin for *Amaranthus* control in cotton).

In order to optimize the effectiveness of Roundup® agricultural herbicides and to reduce the risk of developing resistance, applications should be made according to recommendations and following established good agronomic practices: know the weed population and dynamics in the fields, use the right herbicide product at the right rate and at the right time as indicated on the product use recommendations (label, etc.), control weeds early, monitor the herbicide's effect to control weed escapes and prevent weeds from setting seeds, add other herbicidal mode(s) of action (e.g. a selective and/or a residual) and cultural practices (e.g. tillage or crop rotation) where appropriate. Experience clearly demonstrates that following these good weed management practices when making glyphosate applications, keeps the risk of developing resistance biotypes low.

Herbicide tolerant crops: 10 years later

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Herbicide tolerant crops (HTC) are a common part of the cropping systems in North America. Their use has grown steadily since they became commercially available less than a decade ago. Currently more than 80% of soybean and 30 % corn grown in the USA annually are cultivars genetically engineered to be tolerant to glyphosate herbicide. The inclusion of several transgenes in a single hybrid, commonly referred as "stacked genes", is also under continuous development. Some corn or cotton hybrids have been genetically engineered to contain two transgenes, one for insect tolerance and one for herbicide tolerance; while others can have three genes, two for herbicide tolerance and one for insect tolerance. Although HTCs may have a number of important advantages in an integrated weed management program, there are also risks and concerns associated with their use and long term management. Therefore, the objective of this presentation is to provide a brief overview of advantages and disadvantages regarding the widespread use of HTCs over the last 8-10 years. Examples of advantages include: (1) broadened spectrum of weeds controlled, (2) increased crop safety, (3) reduced risk of herbicide carryover, (4) price reduction for conventional herbicides, (5) new mode of action for triazine and ALS resistance management, and (6) crop management simplicity. Major disadvantages and concerns from both ecological and practical standpoint include: (1) single selection pressure and herbicide resistance, (2) shifts in weed species, (3) gene flow and gene escape, (4) contamination of organic crops which are becoming popular in developed world and (5) herbicide drift and non-target movement. Current examples of glyphosate resistant weeds in US includes: waterhemp (*Amaranthus rubis* Sauer), lambsquarters (*Chenopodium album*), horseweed (*Conyza canadensis*), giant ragweed (*Ambrosia trifida*), common ragweed (*Ambrosia artemisiifolia*), and palmer amaranth (*Amaranthus palmeri*). There is also a shift in weed species occurring in Nebraska to the problematic weed species such as: wild buckwheat (*Polygonum convolvulus*), Pennsylvania smartweed (*P. pensilvanicum*), lady's thumb (*P. lapathifolium*), ivyleaf morning glory (*Ipomea hederacea*), venice mallow (*Hibiscus trionum*), horseweed (*Conyza canadensis)*, yellow sweet clover (*Melilotus officinalis*), and field bindweed (*Convolvulus arvensis*). An increase in occurence of winter annual weeds was also reported in cropping systems based on glyphosate-tolerant crops in our state. Commonly found winter annuals are: field pennycress (*Thlaspi arvense* L.), shepherds purse (*Capsella bursa-pastoris*), henbit (*Lamium amplexicaule*), and tansy mustard (*Descurainia pinnata* Walt. Britt). Control of the above weed species increases weed control costs, even with the use of HTCs. We believe that HTC, especially the ones based on glyphosate herbicide, can be useful component of the weed management system; however their value can be preserved only by proper management, and reduced overuse. This becomes even more important when other HTC become more readily available (eg. glyphosate-tolerant corn, alfalfa, wheat). It is easy to fall into a trap of overusing, for example, glyphosate when one glyphosate-tolerant crop is grown after another. Therefore, proper use of HTC technology, as a component of integrated weed management program, is the key to preserving the long-term benefits of this technology while avoiding many of the concerns about their use, or misuse.

Herbicide-resistant weeds, a threat to the dryland farming in Israel

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The evolution of herbicide-resistant weeds in dry land farming is continuously increasing and endangering the profitability of non-irrigated arable crops in Israel and other neighboring Mediterranean countries. The region is characterized by long dry summers followed by a short rainfall season (November-March) with low precipitation (150-300 mm per year), and frequent drought years. Chemical weed control in non-irrigated arable crops is crucial due to the strong competition employed by a wide range of broadleaved and grass weeds. Large numbers of herbicide-resistant weeds evolved as a result of limited alternatives for crop rotation, frequent use of herbicides with the same mode of action combined with reduced tillage. Resistance to ALS-inhibiting herbicides was identified in *Chrysanthemum coronarium*, *Conyza canadensis* and *C. bonariensis*, *Capsella bursa-pastoris, Diplotaxis erucoides* and *Erucaria hispanica* in wheat and hay crops. A point mutation in the ALS gene was identified in *C. coronarium* (*Pro197* to either *Thr* or *Ser*) which endows resistance to all ALS inhibitors. A *C. canadensis* population exhibiting a similar pattern of resistance to all ALS inhibitors confers a substitution of *Trp547* to *Leu*. The point mutation found in *C. bursa pastoris* (*Ala122* to *Gln*) however, conferred resistance only to imidazolinone (IMI) herbicides.

Resistance to ACCase inhibiting herbicides due to an altered target site was confirmed in the following grass weeds: *Lolium rigidum*, *Phalaris minor*, *P. paradoxa* and *Avena sterilis*. Several *L. rigidum* and *P. paradoxa* populations were collected from heavily infested fields and their resistance to ACCase confirmed on the whole plant basis. In these populations target site mutations endowing resistance in the carboxyl transferase domain of the chloroplastic isoform of the ACCase were identified and characterized. The mutations responsible for resistance were divided into three different resistance patterns. In the first group *Ile1781* is substituted by *Leu* and plants are resistant to aryloxyphenoxypropanoates (APP) and to most cyclohexanediones (CHD) herbicides. Populations with a substitution of *Ile2041* to *Asn* or *Val* are resistant to APP but not to CHD herbicides and populations where the *Asp2078* has been substituted by *Gln* are highly resistant to both APP and CHD herbicides. Our study clearly indicates that grass weed populations exposed to a high selection pressure by ACCase inhibitors may result in various alterations of the target enzyme endowing different resistance response to these herbicides. In addition, the recent evolution and spread of glyphosate-resistant *C. bonariensis* and *C. canadensis* populations is a most dangerous phenomenon which jeopardizes the adoption of minimum tillage practices and may also pose a threat to irrigated crops due to the easy seed dissemination by wind. In spite of the increased awareness among farmers to the problem, management of herbicide-resistant weeds in arable crops, particularly in arid areas, where crop and herbicides rotations are limited, has become almost 'mission impossible'. We should consider adopting alternative practices such as residual herbicides in the rotation, more frequent, better timed soil tillage and more competitive crop plants.

Characterization of ACCase inhibitors resistant *Phalaris paradoxa*

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Phalaris paradoxa L. (*Poaceae* family) - hood canarygrass - is an annual grass infesting winter cereals in central and southern Italy. This study investigated the resistance status of seven Italian populations of *P. paradoxa* collected from fields where an inadequate level of control was observed following an extensive history of ACCase applications. The aims were also to determine the efficacy of alternative herbicides and investigate the molecular basis of one highly resistant population. Two outdoor pot dose-response experiments were done to collect information on patterns and levels of cross-resistance. Seven-eight herbicide doses (plus an untreated check) were used for each of the following herbicides: clodinafop-propargyl (240 g/L), diclofop-methyl (284 g/L), fenoxaprop (55 g/L), sethoxydim 20% (185 g/L), tralkoxydim 22.5% (250 g/L), pinoxaden (100 g/L), chlorsulfuron (75 g/L), iodosulfuron (50 g/Kg), imazamethabenz (300 g/L) and isoproturon (500 g/L). Each experiment had three replicates with three pots per replicate containing 6 plants each and also included a susceptible population. The experimental design was completely randomised. Biomass and plant survival data were collected 18-21 days after herbicides application. The mean survival and fresh weight for each treatment were expressed as a percentage of the untreated control treatments. The ED_{50}, GR_{50}, for the mean percentage survival and fresh weight respectively, were calculated using non linear regression analysis. Statistical analysis was conducted using an EXCEL®VBA macro based on a log-logistic equation to fit the data. Resistance indexes (R.I.) were calculated from ED_{50} and GR_{50} values ($GR_{50}R/GR_{50}S$, $ED_{50}R/ED_{50}S$). Two populations showed a low level of resistance to diclofop (fresh weight R.I. of 2.5 and 3.4), while only one population displayed a wide pattern of cross-resistance to ACCase herbicides, including sethoxydim (R.I. 40.5) and pinoxaden (R.I. 15.1). This suggested that the resistance mechanism is target site mediated. Genomic PCR amplification and direct sequencing of the carboxyl transferase domain of the ACCase gene pinpointed the presence of an Ile_{1781} to Leu_{1781} substitution in the *P. paradoxa* chloroplastic ACCase of the resistant population. This mutation has already been shown to confer resistance to ACCase inhibitors in other grass weeds, but these results document the first case of an ACCase-resistant population of *P. paradoxa* in Europe. Non-ACCase-inhibiting herbicides with mode of action belonging to the PSII (isoproturon) and ALS inhibitors (iodosulfuron, chlorsulfuron, imazamethabenz) adequately controlled all the tested *P. paradoxa* populations.

Resistance to acetolactate synthase (ALS) inhibiting herbicides in UK populations of *Alopecurus myosuroides* (black-grass)

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The objective of this project was to characterise resistance to sulfonylurea herbicides in UK populations of the grass-weed *Alopecurus myosuroides*. Investigations included field studies, glasshouse bioassays, biochemical and molecular analyses. Responses to the selective sulfonylurea herbicides mesosulfuron-methyl + iodosulfuron-methyl sodium mixture and flupyrsulfuron-methyl were investigated, while extensive use was made of the non-selective sulfonylurea herbicide sulfometuron-methyl as a screen for possible ALS target site resistance in *A. myosuroides*. Initial glasshouse tests identified that resistance to flupyrsulfuron was widespread in UK populations of *A. myosuroides*, while resistance to mesosulfuron-methyl + iodosulfuron-methyl sodium mixture and sulfometuron-methyl was identified in three populations: one from Peldon in Essex, another from Thame in Oxfordshire, and a third from Maidenhead in Berkshire. All three populations contained a proportion of plants which survived treatment with sulfometuron-methyl at the screening dose of 100g a.i. ha^{-1} and mesosulfuron-methyl + iodosulfuron-methyl sodium mixture at the field rate of 12 + 2.4g a.i. ha^{-1}. This was in contrast to eleven typical flupyrsulfuron-methyl resistant UK populations which were controlled by mesosulfuron-methyl + iodosulfuron-methyl sodium mixture and sulfometuron-methyl. DNA sequencing of the ALS gene confirmed that a single point mutation segregated with sulfometuron resistance in the three populations. All highly resistant individuals showed a mutation in the first position of the Pro197 codon of an *A. myosuroides* ALS gene, conferring a predicted proline to threonine target site change compared to susceptible individuals. Enzyme assays confirmed that resistance was due to an altered form of the ALS enzyme less susceptible to inhibition by sulfonylurea herbicides. Comparison of I_{50} values showed a 16-fold difference in enzyme sensitivity between the most resistant sulfometuron selected line and a susceptible standard. This is the first case of ALS target site resistance in a European grass-weed which has been characterised at both molecular and enzyme levels. Results from segregation of sulfonylurea resistant and susceptible phenotypes in crossing experiments indicated that ALS target site resistance in *A. myosuroides* is conferred by a single, dominant nuclear allele but that additional effects are also present. An association was found between parental resistance levels and the degree of resistance in progeny. Field work at one site with ALS target site resistance showed that distribution of resistant plants was uneven. The highest proportions of resistant plants were concentrated in a single area with lower levels present across the whole field. No evidence of the resistant trait was found in neighbouring fields. By 2006, resistance to mesosulfuron-methyl + iodosulfuron-methyl sodium had been confirmed in *A. myosuroides* from 81 farms in the UK, based on glasshouse pot assays of seed samples sent to Rothamsted from sites where reduced control was observed in the field. The precise mechanism of resistance in the majority of these samples is not known. Further work is currently underway investigating the molecular basis of resistance in these populations in order to gain a better understanding of the frequency of ALS target site resistance compared to other mechanisms. ALS target site resistant *A. myosuroides* is predicted to increase with more widespread use of mesosulfuron-methyl + iodosulfuron-methyl sodium in coming years.

Fitness variation associated with herbicide-resistant acetyl-CoA carboxylase alleles in black-grass (*Alopecurus myosuroides* Huds.)

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Pleiotropic effects associated with genes endowing resistance to herbicides are generally predicted to reduce plant fitness. The quantification of these effects is necessary to develop management strategies against herbicide-resistant weeds. We assessed herein the pleiotropic effects associated with three mutant alleles of the herbicide target enzyme acetyl-coenzyme A carboxylase (ACCase) upon plant growth and seed production in black-grass (*Alopecurus myosuroides*). These alleles are widespread among black-grass populations in France.

In each of two field experiments, black-grass populations segregating for Leu-1781 (five populations), Asn-2041 (three populations) or Gly-2078 (two populations) ACCase were produced to obtain several distinct, homogenised genetic backgrounds and permit reliable comparisons among wild-type, heterozygous and homozygous mutant ACCase plants grown in competition with a wheat crop.

No significant differences from wild-type plants in growth and seed production were observed in plants containing Leu-1781 or Asn-2041 ACCase. Plants containing Gly-2078 ACCase displayed a significant reduction in biomass and seed production. This reduction depended upon the plant genetic background, competition and weather conditions. A putative segregation distortion against homozygous Gly-2078 ACCase plants was observed, which also varied with plant genetic background and environmental conditions.

Our work illustrates the variation in fitness cost depending on the resistance gene, the plant genetic background and the environment. This underlines the necessity to identify the resistance gene(s) present in a weed population before designing resistance management strategies. Competitive crops should be effective against Gly-2078 ACCase plants. No pleiotropic effects of Leu-1781 ACCase or Asn-2041 ACCase have been identified upon plant growth and seed production. Such possible effects are now to be investigated in the remaining key points in black-grass life-cycle, to wit, seed dormancy and germination. If Leu-1781 ACCase or Asn-2041 ACCase are associated with modifications of these traits, then cultural practices creating a fitness cost against plants containing these alleles can subsequently be developed.

Resistance of *Apera spica-venti* biotypes to sulfonylurea herbicides and distribution in Poland

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The number of herbicide resistant species is increasing steadily. The risk of herbicide-resistance evolution depends on herbicide use patterns, herbicidal mode of action and the genetic and reproductive characteristics of the weed species. The herbicide resistance is associated with the intensive and repeated use of herbicides with the same or similar mode of action and where reduced tillage is practiced. This review considers examples of herbicide resistant populations of the grass species *Apera spica-venti* (APESV, silky bent grass) in Poland. *Apera spica-venti* is a major weed in winter cereals in Europe. The first report about herbicide resistance in APESV was from Switzerland in 1994 and concerned resistance to isoproturon, followed by a report from Germany and lately in Czech Republic and Poland. We present here the first case of resistance of this species to sulfonylurea herbicides in Poland. The aim of this study was to determine the resistance frequency and level of in APESV populations. Seeds of 223 samples of APESV were collected in 2004-2005 from 88 sites in Poland, where problematic efficacy of herbicides was established. Collected biotypes were compared with a susceptible biotype originated from Switzerland. Seeds of were sown in plastic pots (0,5 L, 9 cm in diameter). Pots were placed in a greenhouse at 18-24 ^{0}C, and at 18h photoperiod. Several herbicides of different chemical groups were tested including chlorsulfuron (ALS inhibitor; group B), isoproturon (PSII inhibitor; group C2) and fenoxaprop-P-ethyl (ACCase inhibitor group A). All herbicides were applied in one or three doses, and tests were conducted twice. Plants were evaluated visually about 2 and 4 weeks after treatment. The results showed that from total samples of APESV tested, 48 samples exhibited poor or very poor control following chlorsulfuron application, 28 samples following isoproturon application and 9 samples following fenoxaprop-P-ethyl application. The final biological evaluation showed that all selected samples of APESV were susceptible to isoproturon and fenoxaprop-P-ethyl applied at all three doses. The resistance to chlorsulfuron was found in 24 location at 32 tested samples of this grass weed. Cross resistance to other sulfonylurea herbicides such as sulfosulfuron, propoxycarbazon and iodosulfuron + mezosulfuron at 4 different doses was examined. The final results confirmed that 24 samples of *Apera spica-venti* biotypes were cross resistance on these herbicides. The resistant biotypes of APESV were found in the north-east, north-west and south-west part of Poland. At this region are big farm and the cereals are mostly cultivated crops.

Resistance study of *Setaria glauca* P.B. to the herbicide acetochlor

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Herbicide resistance is a complex phenomenon linked to the characteristics of the weed populations. Herbicide resistance can results from a number of factors including differences in rates of absorption and subsequent translocation, tissue and subcellular localization of the herbicide, metabolism to products of modified phytotoxicity and differences in target site sensitivity. The long term application of herbicides can result in the selection and spreading of some weed biotypes resistant to these herbicides. Herbicide resistance is generally associated with high selection pressure imposed by a repetitive use a high rates of residual herbicides in monoculture and minimum tillage practices. The aim of the present research is to determine the extent of resistance of *Setaria glauca* to the herbicide acetochlor and to study the main morphological differences between susceptible (S) and resistant (R) biotypes of the weed. *Setaria glauca* seeds from plants that survived the treatment in maize fields (some of them were treated for a long time with acetochlor) and from untreated area were included. Glasshouse pot experiments were conducted during the period of 2003-2004 in the Institute of Plant Protection, Kostinbrod, with R and S biotypes to evaluate their response to the herbicide acetochlor (Relay 900 L^{-1}). Plastic pots containing 250 cm^3 pre-sterilized soil were used. The seeds were placed in growth chamber at 28 ^{0}C for germination and sown about 1 cm depth. The morphological differences between R and S biotypes were determined following soil treatment with progressive doses of acetochlor (0.45; 0.90; 1.35; 1.80 kg a.i/ha^{-1}). The following parameters were recorded: seed germination (%), plant height (cm) and above-ground fresh weight (g). Results show clearly that the survived R plants produced larger seeds in comparison with the S biotype of *Setaria glauca* to acetochlor; the R biotype also produced more above-ground biomass. When acetochlor is applied at 1.80 kg a.i/ha^{-1} the seeds from S biotypes did not emerge. However, the R seeds treated at doses of 0.45 to 1.80 kg a.i/ha^{-1}, 73.5 % to 9.0 % of the seeds, respectively emerged. The results of the implemented ANOVA followed by t-test at $p<0.05$ showed significant differences between the S and R biotypes when treated at low as well as higher doses of acetochlor. These results support the hypothesis that the long term treatments with acetochlor on *Setaria glauca* in the same field resulted in the development of the R biotype. At the lowest concentration of the herbicide the biometrical parameters which characterize the growth and development of the R biotype are similar to the parameters obtained for the untreated control plants. The differences between R and the S plants are highly significant. Based on this study we can conclude that long term applications of acetochlor on *Setaria glauca* favored the evolution of resistance. The morphological differences between the R and S biotypes are proved.

ALS-inhibitor resistant *Apera spica-venti* (L.) Beauv. due to target-site mutation

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Reports on control failure of grass weeds due to herbicide resistance accumulate recently. Black grass (*Alopecurus myosuroides* Huds.) and silky bent-grass (*Apera spica-venti* (L.) Beauv.) are the dominating grass weeds especially in European winter wheat fields. Silky bent-grass is an annual panicle grass mostly occurring on light, fresh soils. It is a strongly tillering plant producing 2000 to 8000 seeds. In Germany, France, Denmark, Belgium and the Czech Republic it belongs to the most troublesome weeds in winter annual grains evolving resistance to ALS-inhibitors. Future research should be focused on clarifying the main resistance mechanisms (e.g. target-site or non-target-site resistance) in order to support and develop strategies of integrated weed management. Furthermore, if the genetic background is clarified genetic markers can be developed for early and fast detection methods. A biotype of silky bent-grass from a winter wheat field in Germany with resistance against ALS-inhibitors was investigated in this study. To exclude other mechanisms of escape from weed control, resistance was proved in single dose assays in the greenhouse before dose-response experiments with propoxycarbazone, sulfosulfuron, and isoproturon were performed with the resistant and a susceptible reference biotype. A statistical significant resistance was observed against sulfosulfuron and propoxycarbazone, while the absence of resistance against isoproturon led to the assumption of target-site resistance as the responsible resistance mechanism. To confirm the role of reduced target enzyme susceptibility, target assays were performed. ALS activity was measured in a crude protein extract obtained from fresh plant material. A statistical significant different ALS susceptibility of the resistant biotype against sulfosulfuron and propoxycarbazone proved target-site resistance, based upon one of five known mutations on the ALS gene. To identify the responsible mutation of the ALS and to manifest the previous results, the relevant parts of ALS gene from resistant and susceptible biotypes were amplified from genomic DNA via PCR and sequenced. Results were aligned and compared with ALS sequences of *A. myosuroides* (EMBL Accession No. AJ437300), *Bromus tectorum* (AF488771) and *Lolium multiflorum* (AF310684). A point mutation of C (cytosine) to A (adenine) on the first position within the triplet of proline at amino acid position 197 is responsible for the change of proline to threonine. This mutation of the ALS protein is well known to cause target-site resistance in different grass weed species. This is the first report of a proline to threonine mutation in silky bent-grass. In order to detect this mutation in future samples a detection assay using the dCAPS technology was developed. This technology is reasonable to support resistance detection in field samples and could be relevant in decision support systems to prevent and reduce resistance development. One benefit of this technology is that herbicide resistance and their mechanisms can be clarified within the field population in short time. Molecular studies of herbicide resistance mechanisms are the basis for further population genetic studies. These results can be used to model population dynamics of herbicide resistant weeds and to define the decisions for a successful weed management.

Herbicide resistance gene flow over long distances by pollination in *Lolium rigidum*

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Lolium rigidum in Australia is the most serious current case of herbicide resistance worldwide because resistant *L. rigidum* is now present across millions of hectares of crop lands. *L. rigidum* is an anemophilous and obligate cross-pollinated weed species often present at high density. Massive amounts of pollen are produced when plants are flowering and substantial pollen movement occurs by wind. As herbicide resistance (R) is widespread herbicide R genes could flow between fields due to the movement of seeds or by pollen drift. There is therefore a high potential for gene flow by cross pollination at distance, however there is no data available for *L. rigidum* on pollen-vectored long distance R gene flow in commercial field conditions. Most data on pollen dispersal has been obtained from small-scale field trials. Before anthesis in the spring of 2005, 84 individual herbicide susceptible (S) *L. rigidum* mother plants were placed into never-disturbed bushland where no ryegrass plants exist near Salmon Gums (Western Australia). Single S plants were arranged at varying distances (0 to 4000 meters) from wheat and pasture fields (pollen donor source), known to be infested with herbicide resistant *L. rigidum*. After anthesis and seed maturation the S plants were harvested and seed collected. Some plants were either eaten by herbivores or died from drought stress. Seeds were obtained from 51 plants suggesting pollen successfully moved with wind and caused cross pollination up to 3000 meters from its source. Herbicide R is a strong marker that can be easily detected. To test whether cross pollination resulted in R gene movement, the seed produced on S mother plants was tested for herbicide R using the ALS herbicide sulfometuron (15 g ha^{-1}). Herbicide R was found in seed produced on S mother plants. Both the amount of seed production and herbicide R followed a leptokurtic distribution according to the distance from the resistant pollen source. Samples of resident plants were also collected throughout the experimental area at 37 different locations (each sample consisted of about 100 bulked plant spikes). The average R frequency (i.e. proportion of plant survival) to sulfometuron in the resident plants was 50%. Seeds produced on herbicide S mother plants must be herbicide S unless they were pollinated by pollen carrying resistant genes from plants in the wheat/pasture fields. In total, 3071 seeds obtained from S mother plants were screened for R to ALS herbicide and R frequency on average was 24%. This represents the average phenotypic frequency of R detected in the progeny of the S population. The expected value of R frequency should be as high as the one obtained for the resident plants (i.e. 50%). However a lower R frequency in the progeny of S mother plants is also expected due to the presence of heterozygous individuals in the donor plants or to the heterozygous status of R endowed by a semi-dominant gene. Also some pollination among S plants cannot be excluded. Our results establish that R gene flow due to effective cross pollination occurred by natural movement of resistant pollen over distances up to 3000 m. The results suggest that long distance herbicide R mobility by pollen drift is a real concern for cross-pollinated species such as *L. rigidum*. This knowledge is critical in understanding the dynamics of R dispersion. This study, complemented by data on pollen competition, will provide an important contribution to understanding and modeling of the evolution of herbicide R and gene flow at the landscape level.

Physiological and molecular mechanisms of glyphosate resistance in *Conyza bonariensis* (L.) Cronq. biotypes from Spain

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Hairy fleabane (*Conyza bonariensis*) is a dicot weed in the Asteraceae family. In Spain this weed infests orchards and first evolved resistance to Group G/9 herbicides in 2004. Group G/9 herbicides are known as Glycines (Inhibition of EPSP synthase). Up to date the mechanism of resistance to glyphosate in these biotypes has not been clearly assessed. The present research examined in details the physiological and molecular basis of glyphosate resistance in 1 susceptible (S) and 4 resistant (R) *Conyza bonariensis* biotypes (sampled in orchards from Andalusia, Spain). Emphasis was given to foliar uptake, metabolism, and translocation of glyphosate, on shikimate accumulation dynamics and on detection of EPSP synthase (EPSPS) mRNA levels. Dose-response tests highlighted that the resistance of R biotypes was dependant on growth stage. At two leaf stage approximately the same LC_{50} (lethal concentration of the herbicide that is required to kill 50 percent of tested plants) values were observed for both S and R biotypes, while at the rosette and bolting stages the R biotypes were from 1.5 to 3 times more resistant than the S biotype. Physiological studies evidenced that glyphosate resistance of hairy fleabane biotypes was not due to an altered absorption or metabolism of the herbicide. The main difference between R and S biotypes was the dissimilar mobility of glyphosate in the whole plant. In the R biotypes the herbicide was less translocated in the downward direction (from leaves to culm and roots): the export of glyphosate out of the treated leaves was from 1.9- to 2.3-fold less than the S biotype. The reduced phloem transport of glyphosate in R biotypes was associated with an increase of herbicide mobility in the upward direction (from culm to leaves): the translocated herbicide, according to the xylem flow, was approximately twice in R biotypes with respect to the susceptible standard. Shikimate accumulated in leaf tissues in greater concentrations than background levels after glyphosate treatment in all hairy fleabane biotypes: on this basis the hypothesis of an insensitive EPSPS was discarded. At the molecular level, two R accessions showed 2- and 2.5-fold higher EPSPS mRNA levels than S plants without prior glyphosate application. A slight, but not significant, increase of EPSPS transcript levels was also observed in the other two R biotypes. In contrast, in R biotypes the synthesis of EPSPS transcripts resulted not to be induced by glyphosate treatments. On the basis of obtained results two physiological features may concur at glyphosate resistance in the investigated R biotypes: impaired translocation of the herbicide and constitutively higher EPSPS transcript levels. The potential for the existence of other components that contribute to resistance in the investigated R biotypes cannot be eliminated at the present time. This partially reflects results of our previous findings about glyphosate resistance mechanisms in horseweed (*C. canadensis* (L.) Cronq.) biotypes from U.S.A. where, along with the two abovementioned factors, an additional survival strategy was identified in R plants: the sprouting of new branches after glyphosate treatments. Studies are in progress in order to investigate the physiological and molecular mechanisms undergoing glyphosate resistance in common ragweed (*Ambrosia artemisiifolia* L.) biotypes from U.S.A. Preliminary molecular results indicated that the induction of EPSPS transcripts synthesis in response to glyphosate-applied doses could be involved in herbicide resistance of investigated biotypes.

Molecular bases for the resistance to ACCase inhibiting herbicides in *Phalaris paradoxa*

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Several chemical classes, aryloxyphenoxypropionates ('FOPs'), cyclohexanediones ('DIMs'), and phenylpyrazoles (DENs e.g., pinoxaden) are effective graminicides in field crops, which inhibit in Gramineae the chloroplastic isoform of ACCase. In recent years, several point mutations in the carboxyl transferase (CT) domain of chloroplastic ACCase of *Lolium rigidum*, *Alopecurus myosuroides* and other grass weeds found to endow high resistance to these herbicides. Field trial conducted in a heavily infested field near Kibbutz Revadim verified the existence of resistant *P. paradoxa* population (RV) to FOPs, most DIMs and pinoxaden applied postemergence at 1.5 the recommended dose. Seeds from RV population and from another resistant population near Kibbutz Shaar Haamakim (SH) were collected and their response to FOPs, DIMs and pinoxaden was examined in pot experiments in comparison to a known sensitive (S) population. RV and SH populations showed resistance to all FOPs, pinoxaden and to most DIMs but not to tepraloxydim and clethodim. The resistance index ranged from 42 to 64 and 6 to 25 in RV and SH, respectively. The mutations responsible for resistance were detected using PCR-RFLP and sequencing. The sequence of the CT domain in RV plants possesses a substitution of *Asp2078* to *Gly.* In SH plants however, an *Ile2041* to *Asn* substitution was detected. No other mutations were detected when the entire CT domain was sequenced and examined. These findings do not agree with previous studies that showed that point mutations in position 2041 confer resistance to FOPs but not to DIMs. Our study demonstrates that exposure to high selection pressure imposed by ACCase inhibitors may result in evolution of different mutations endowing high resistance not only to FOPs and DIMs but also to pinoxaden. This is the first report of population of grass weed possessing a point mutation in position 2041 which shows resistance to DIMs.

A rapid test for ALS herbicide resistance in black-grass (*Alopecurus myosuroides*)

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By 2006, black-grass showing resistance to the ALS inhibiting herbicide 'Atlantis' (mesosulfuron + iodosulfuron), had been detected on 81 farms in 19 counties in the UK. Identification of resistance was based on glasshouse pot assays in which 'Atlantis' (12 g mesosulfuron + 2.4 g iodosulfuron ha^{-1}) was applied at the 3 leaf stage and effects assessed 3-4 weeks later. A quicker and cheaper method for detecting ALS resistance would be useful in order to obtain results by late August for seeds collected in July. Consequently a Petri-dish assay using a single dose of 'Atlantis' (0.1 ppm mesosulfuron+iodosulfuron) and 'Oust' (1ppm sulfometuron) was developed. Good seed quality is vital for the test. Cleaning samples and storing at 30-35 °C for 2-4 weeks increases the germination potential of fresh seed samples. Six 9 cm Petri dishes are needed for each population tested (two replicates for no-herbicide controls; mesosulfuron+iodosulfuron; sulfometuron). Each dish contains three Whatman 9 cm cellulose covered by one 9 cm glassfibre paper plus exactly 50 seeds. It is essential that the larger diameter half of each Petri-dish is used as the lid to minimise drying out. Always include at least one susceptible population and, if possible, an ALS resistant reference population. A triple dilution method makes it easier to measure out the very small amounts of herbicide needed. 0.695g of 'Atlantis WG' (containing 30 g mesosulfuron + 6 g iodosulfuron kg^{-1} product) or 0.333 g of 'Oust' (containing 750 g sulfometuron kg^{-1} product) is added to 250ml of potassium nitrate (2 g L^{-1}) solution. This is then reduced through two dilution cycles (25 ml in 250 ml, then 2.5 ml in 250ml) to produce the best discriminating doses of 0.1ppm mesosulfuron + iodosulfuron and 1 ppm sulfometuron. Seven ml of herbicide or potassium nitrate solution (to enhance germination and growth) is then added to each dish, as appropriate. The dishes are then placed in sealed polythene sleeves in an incubator set at 17 ^{0}C 14 h day (with lights on) and 11^{0}C, 10 h night (lights off). Two methods have been used to assess the dishes after 14 days in the incubator. The most time consuming, but more objective method, is to determine total shoot length per dish by measuring shoot length for each germinated seed (mm). A quicker method is visually assessing the reduction in shoot growth relative to untreated controls for same population. This gives comparable results to shoot lengths, but is much quicker. It is important to recognise that at the dose used (and much higher dose), mesosulfuron + iodosulfuron and sulfometuron will not prevent seedling growth of susceptible blackgrass populations. However, growth will be substantially reduced compared to resistant populations. Example of actual results (August 2006): mesosulfuron + iodosulfuron (0.1ppm) and sulfometuron (1 ppm) reduced total shoot length of a standard susceptible population by 64 - 66 % compared to untreated controls. Only 6 - 9% reduction occurred with an ALS-resistant standard. With three samples, collected in July 2006, only 0 - 10 % reductions were achieved, a fourth sample achieved a 61 – 75% reduction. It was concluded that three were resistant and one susceptible. This was confirmed by subsequent pot assays. Recent research indicates that this Petri-dish test is detecting ALS targets site resistance (Pro 197), as shoot length reductions for an enhanced metabolism standard (Peldon96) were similar to the susceptible. Sulfometuron is included as an indicator of ALS target site resistance and most populations tested so far in the UK give similar results with mesosulfuron+iodosulfuron and sulfometuron. This ALS Petri-dish resistance test appears to be a useful method for the rapid screening of black-grass populations for ALS target site resistance, but it is not as robust as that for ACCase inhibiting herbicides. For a detailed 6 page protocol on the conduct of this test and interpretation of results contact:
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Real Time Quantitative PCR assays for quantification of L1781 ACCase inhibitor resistance allele in leaf and seed pools of Lolium populations

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The I1781L amino acid substitution in the target ACCase enzyme causes broad resistance to ACCase inhibitor herbicides in several monocot weeds of agronomic importance. This mutation results from a substitution of an adenine ('A') residue by either a thymine ('T') or cytosine ('C') at position 5341 in *Alopecurus myosuroides* and at an equivalent position in *Lolium* species, *Avena fatua* and *Setaria viridis*. Two different procedures, the PCR-based Allele Specific Assay (PASA) and the derived Cleaved Amplified Polymorphic Sequence (dCAPS) method, have previously been described for detecting this mutation. The PASA method is a two steps process where PCR is followed by classical horizontal agarose gel electrophoresis to distinguish between sensitive I1781 and resistant L1781 alleles. Because three different nucleotide residues can exist at the 5341 resistance position, two coding for the resistant L1781 allele and one for the wild type I1781 allele, the PASA method does not allow discrimination between homozygous and heterozygous plants in a single PCR reaction. The dCAPS method on the other hand is carried out in three steps, i.e PCR, restriction digestion and gel electrophoresis. Restriction analysis in this particular case is carried out with the enzyme *Nsi* I, that positively identifies the sensitive I1781 allele upon digestion of the original PCR fragment. The dCAPS method was found to be very reliable and able to discriminate unambiguously between homozygous and heterozygous IL1781 and LL1781 plants. Both PASA and dCAPS procedures do, however, have the same drawback in being only applicable to the analysis of individual plants. Therefore it is not amenable to analysis of large number of samples or populations of sufficient size for early warning of emergence of resistance in new geographical locations. Here, we present an alternative high throughput ARMS/Scorpion Real Time quantitative PCR (Q-PCR) method for measuring levels of the I1781L mutation in pools of leaf and seed samples of *Lolium* populations. The limit of detection for 'C' and 'T' mutant alleles in a background of 'A' wild type are 0.02% and 0.0003% respectively. In this study, DNA from batches of 24 half cm leaf segments from different plants or 1000 seeds could be conveniently extracted and accurately analysed. As part of assay validation, the comparative analysis of five geographically distinct *Lolium* populations with dCAPS and Q-PCR procedures demonstrated the accuracy of the latter method, and the three possible II1781, IL1781 and LL1781 ACCase genotypes being distributed as predicted by the Hardy-Weinberg principle. Given the dominance of the L1781 over the I1781 allele at recommended field rates for most ACCase inhibitors, the frequency of herbicide survivors in the field due only to the presence of the I1781L mutation is thus predicted to be $2pq + q^2$, where p and q are the frequencies of the I1781 and L1781 alleles as determined by Q-PCR. The Q-PCR assay established allows detection of very low levels of the L1781 ACCase mutation before resistance would normally be discernible in the field. Therefore it offers the opportunity for tackling resistance at its very onset, potentially avoiding implementation of complicated and often costly weed management practices.

Amaranthus retroflexus L. cross-resistance to ALS inhibitors

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Herbicide application and lack of alternative methods of weed control under intensive agricultural production created convenient ambience for development of herbicide resistant weed species. Continuous use of ALS inhibiting herbicides, especially imidazolinones and sulfonylureas has resulted in the evolution of resistant populations in several weed species. During 2005 and 2006 resistance of weed species *Amaranthus retroflexus* L. to ALS inhibitors (i.e. imazethapyr and nicosulfuron) was studied. Seed of plants that were suspected as resistant to the imazethapyr were collected from various sites in Vojvodina, i.e. Krivaja, Kikinda and Becej. Studies were performed by Petri dish trials and by whole plants studies. Population from ruderal site was included in the trials as a susceptible standard. Herbicides were applied at concentrations of 0.04; 0.08; 0.10; 0.15; 0.20 and 0.40 kg a.i. imazethapyr /l and 40; 50; 80; 120; 160 and 240 g a.i. nicosulfuron /l; as compared to untreated control. Determination of resistance level was performed by resistance index (IR) as compared to the reference susceptible population (IR = ED50 values of resistant population / ED50 values of susceptible population) and they were calculated for the measured morphological parameters (shoots epycotil and hypocotile length, stem height, and fresh foliage weight). Based upon IR of the calculated parameters, the highest resistance to the applied imazethapyr rates was established for the biotype from Krivaja. The IR for epicotyl value was 1.8; for hypocotyl 1.61 and for the fresh foliage weight 2.27, whereas for the stem height IR value was 1.0. Biotype from the Becej had values for epicotyl, hypocotyl and stem height of nearly 1.0, i.e. 0.99 for the fresh foliage weight. The highest susceptibility to the applied imazethapyr rates was established for biotype from Kikinda. Resistance index for hypocotyl was 0.8, stem height 0.9, fresh foliage weight 0.53, and. 1.0 for epicotyl. Based upon IR values of the calculated parameters, the highest resistance to nicosulfuron was established for the biotype from Kikinda. For epicotyl of the IR value was 1.21, for hypocotyl 1.24, and for foliage fresh weight 0.59, whereas for the stem height IR value was 2.95. Biotype from Becej had IR values for epicotyl of 0.89, hypocotyl 0.77, stem height values were 1.80 and 0.43 for the fresh foliage weight. These values were the lowest of all studied samples. For the biotype from Krivaja the, IR values for epicotyl was 2.92, hypocotyl 1.90, stem height 1.53 and for the fresh foliage weight 1.29. By comparative analysis, the beginning of resistance development of *Amaranthus retroflexus* L. from the Krivaja to imazethapyr (IR= 1.0-2.27), as well as toward nicosulfuron (IR= 1.29-2.92) was established. Samples from Becej and Kikinda proved to be extremely susceptible to the herbicide imazethapyr, whereas for the biotype from Kikinda resistance development to nicosulfuron (IR = 0.59-2.95) was established.

Corn poppy (*Papaver rhoeas* L.) populations resistant to photosystem II inhibiting herbicides in Poland

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The evolution of herbicide-resistant weed biotypes is an increasing concern for the growers of today and the future. Selection pressures put on weeds by herbicides have resulted in 314 herbicide-resistant biotypes (Heap 2007). Some factors influencing the development of resistance include continuous use of a herbicide, use of single site-of-action herbicides and genetic diversity of weed species. Herbicides containing active ingredients such as: derivatives of triazine, phenylurea, carbamate acid and diazine block the photosynthetic electron transport chain at the reducing site of photosystem II (PS II). In Poland, the first cases of resistance were recorded in the mid-1980's, in the areas with intensive weed control by triazine herbicides.

The aim of this research was the identification of resistance and cross-resistance of Poppy (*Papaver rhoeas*) biotypes to photosystem II inhibiting herbicides (derivative of triazines, ureas, uracils, pyridazinones, benzothiazoles and phenylcarbamates).

The research was conducted using monitoring tests. During six years (2000-2005) plants (leaves) and seeds of Poppy were collected from 179 fields in South-West Poland. On these fields farmers cultivated through 3-10 years, usually in monoculture, maize, sugar beet and cereals (mainly winter wheat) and intensive chemical weed control by herbicides was used.

Plants and their seeds were collected from all fields and analyzed by two methods: biological tests (evaluation of phytotoxicity, measurement of fresh and dry plant mass and calculating of resistance index - IR) and fluorescence method (measurement of fluorescence changes in leaves of weed). For analysis about 100 plants were collected from each field. Samples were taken from an area of 2500 m^2 (square 50 x 50 m) of each monitored field.

The method allowed identification and confirmation of the occurrence of *Papaver rhoeas* biotypes resistant to photosystem II inhibiting herbicides. The identified biotypes showed, for the majority of cases, high level of resistance (IR>6 – evaluated by biological test). Most of *Papaver rhoeas* biotypes were resistant to herbicides from the triazine and triazinone groups (atrazine, simazine, cyanazine and metamitron) – positive results was determined on about 30% of monitored fields. Moreover, the *Papaver rhoeas* biotypes were resistant to isoproturon and bentazone. Resistant biotypes to derivative of carbamate acid (phenmedipham and desmedipham), lenacil and chloridazone were not detected.

In all monitored fields the percentage of resistant biotypes in *Papaver rhoeas* populations did not exceed 40%.

On monitored fields also three cases of cross-resistance were determined: *Papaver rhoeas* biotypes resistant to atrazine and simazine (samples from 2 fields), atrazine and metamitron (3 fields) and atrazine and bentazone (3 fields).

Similar results of resistance and cross-resistance to triazines and other substances inhibiting the photosystem II occurred in other weeds (e.g. *Amaranthus retroflexus, Chenopodium album, Echinochloa crus-galli*, *Polygonum* spp., *Solanum nigrum* and *Sinapis arvensis*) described by a lot of authors from different Countries.

Resistance to metamitron in selected European populations of *Chenopodium album* from sugar beet

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In several European countries, sugar beet growers are being confronted with unsatisfactory control of fat-hen (*Chenopodium album* L.). In 2004-2005 at Ghent University and IRBAB, resistance to metamitron, a key herbicide in sugar beet, was detected in a limited number of populations from Belgian sugar beet fields. Therefore, the International Institute for Beet Research (IIRB) "Study Group on Weed Control" started a collaborative project to compare the response to metamitron of a geographically wider range of "suspected" *C. album* populations from sugar beet fields with that of reference populations. Seeds collected in the 2005 growing season in Belgium, France, Germany, Sweden and The Netherlands were examined at Ghent University during 2006. In greenhouse bioassays these origins as well as herbicide-sensitive and atrazine-resistant reference populations were subjected to metamitron (2 and 4 mg a.i./kg air dry soil) and, for a more limited number of populations, to atrazine (1.5 mg a.i./kg); each experiment had an untreated control included. Both herbicides were preplant incorporated into a sandy loam soil (pH_{H2O} 6.20 and 2.04 % organic matter content) and 3-4 weeks after seeding foliage fresh weight was determined and compared to that of the respective untreated control. Resistance to metamitron was recorded in the great majority of Belgian (14 out of 16) and French (10 out of 11) populations. With the French origin 'Martainneville' for example, although collected in a field where fat-hen had not been considered to be an acute problem, foliage fresh weight was still 56 % of that of untreated after treatment with 2 mg preplant incorporated metamitron/kg air dry soil, whereas with the sensitive reference population it had dropped to a mere 20 % of untreated. The atrazine-resistant reference *C. album* yielded 66 % of untreated at this metamitron concentration. All Belgian and French metamitron-resistant populations were found to be also (cross)-resistant to atrazine. When subjected to atrazine, 'Martainneville' and the atrazine-resistant reference still produced 87 and 58 % of untreated respectively, whereas the sensitive reference population was completely killed. Although there is a clear relationship between resistances to these herbicides, both acting by inhibition of photosynthesis at Photosystem (PS) II, at present it is impossible to tell (1) which herbicide did select for the resistance: metamitron in sugar beet and/or atrazine in former rotational maize and/or yet an other PS II inhibitor; (2) whether this resistance evolved in the "problem" field itself or had been imported, e.g. with contaminated slurry. The *C. album* sample from Sweden was also found resistant to metamitron, whereas no clear-cut conclusions could be drawn for the samples from Germany and The Netherlands due to poor and/or irregular germination. Yet, the results were indicative that the German and Dutch *C. album* populations were sensitive and resistant respectively to both herbicides. At Broom's Barn, a "suspected" population collected in the United Kingdom was examined. This *C. album* origin was exposed to metamitron pre-emergence and post-emergence (in the 2-6 leaf stage); a sandy loam soil was used and at each application time rates studied were 750, 1500 and 3000 g a.i./ha plus an untreated control. These tests brought evidence for sensitivity of this UK population to metamitron when compared to both an herbicide-sensitive and an atrazine-resistant reference.

Sulfonylurea resistance found in several weed species in Norway

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Sulfonylurea resistant *Stellaria media* was documented in Norway for the first time in 2003. In 2004 and 2005 six populations suspected to be resistant were tested under controlled conditions. Four of the populations maintained more than 50% of biomass even at 4 times normal rate of Express (tribenuron 500 g ai/kg). At double rate of Hussar (iodosulfuron 50 g ai/kg) the biomass was only reduced by 20% compared to unsprayed. In 2006 we collected seed from plants of *Chenopodium album*, *Sonchus asper, Spergula arvénsis* and *Galeópsis tétrahit* which all were claimed to have survived practical treatment with Express and *Tripleurospérmum inodórum* with Hussar. The seed from these populations and normal susceptible populations were sown in trays and transplanted to pots. At 4-leaves stage the plants, six pots per treatment, were sprayed on a spray bench with spray volume 250 L per ha, after the following protocol: Express; N (normal rate= 14 g product per ha), 2N and 4N. Hussar; N (normal rate=150 g product per ha), and 2N. Atlantis (iodosulfuron +mesosulfuron); N (normal rate= 200 g product per ha) and 3N. Ariane S (MCPA+ clopyralid + fluroxypyr) was used as a non sulfonylurea control treatment. After treatment the plants were kept in greenhouse at 20 °C day and 16 °C night. Day length was 16 hour. The plants were harvested 3 weeks after treatment and weighed.

T. inodórum completely survived all Express and Atlantis treatments and normal rate of Hussar. At double Hussar rate the weight was reduced to 85% compared to unsprayed plants. The weight of the normal susceptible plants was reduced to between 17 to 6%. The *G. tetrahit* population was very tolerant to all three sulfonylurea herbicide. Plant weight after normal rate of Express was 99% compared to unsprayed plants. 2N and 4N rate reduced weight to 87 and 79% respectively. The dose rates of Hussar reduced plant weight to 77 and 74%. Unfortunately our control population did not germinate but normal rate of both herbicides has more than 90% effect in susceptible G.tetrahit. The *S. asper* population completely survived normal rate of both Express and Hussar. 2N and 4N rates of Express reduced the weights to 73 and 28%. However, double rate of Hussar reduced the weight to 12% of untreated plants. Atlantis at N and 3N dose rates reduced the weights to 75 and 64% respectively. The weight of the treated susceptible plants varied between 1-3 % of the untreated independent of herbicide and dose. *S. arvensis* was only tested against Express. The test plants survived normal rate without weight reduction. 2N and 4N reduced the weight to 84 and 64% respectively. The *C. album* population was completely susceptible. It can be concluded that sulfonylurea field resistance in *S. media* is common in Norway. Examples of resistance or high tolerance have been proved in *S. asper, G. tétrahit, T. inodórum and S. arvénsis*. In addition cross resistance between different sulfonylurea herbicide has been shown. Atlantis was used in Norway for the first time in 2005. There are some obvious reasons for the build up of sulfonylurea resistance in Norwegian cereal cropping. Since the first sulfonylurea herbicide was introduced in 1984, there has been a steady growth in use. The increase was stimulated when Norway introduced tax rates on pesticides according to their environmental and toxicological properties and the price on this group of herbicide has become very low compared to phenoxy acids and other non sulfonylureas. In the period 2003-05, sulfonylurea was applied on 74% of the area. Besides the crop rotation consist mainly of cereals and the fields are treated with sulfonylureas year after year.

Testing resistance of *Abutilon theophrasti* Med. to atrazine

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In Serbia due to high efficacy and low cost, atrazine has been used for decades as major herbicide for weed control. The use of herbicides for the first few years provided excellent control but small number of naturally-resistant plants were not controlled and propagated during the selection period imposed by the herbicide. Research projects in the past have established reliable physiological and morphological parameters for detection of these resistant weeds. For photosynthesis-inhibiting herbicides, the most reliable parameters were changes in fresh and dry biomass, and chlorophyll fluorescence. The goal of this research was to evaluate the resistance of different populations of *Abutilon theophrasti* Med. to atrazine and verify the eficacy of different methods for resistance determination. Resistance of suspected populations (R_1- Veliki crljeni; R_2- Glogonjski rit) were tested using chlorophyll fluorescence, total amount of chlorophyll (using *Spad* meter), chlorophyll extraction by dimethylphormamide and measuring morphological and physiological parameters of intact plants. Seeds from known atrazine susceptible populations were collected from areas that had not been previously treated with any herbicide (S - from Padinska Skela). The results show that measuring chlorophyll fluorescence and the total amount of chlorophyll were the most reliable methods for this weed species. Chlorophyll fluorescence showed differences in sensitivity/resistance during the first 24 hour after treatment. The index of resistance was 1 (ratio R_1/S). The amount of chlorophyll measured showed differences 5 days after treatment, with index of resistance of 3. The most reliable morfological parameters for distinguishing between susceptible and resistant populations were: shoot fresh and dry weight. The estimated index of resistance showed high susceptibility of the S population and small differences between the suspected populations: R_1/R_2=4, R_1/S=15.9, R_2/S=3.9 for fresh weight; R_1/R_2=4, R_1/S=14.7, R_2/S=3.6 for dry weight. Based on the physiological parameters obtained (resistance to diffusion and intensity of transpiration) the reliability in the second assessment was low there were no differences between the treated and non-treated plants in all the populations tested. The differences between the populations tested with regard to the amount of the extracted chlorophyll using dimethylphormamide were the least reliable parameter. This research show small differences in sensitivity to atrazine of suspected resistant populations R_1 and R_2 and confirmed susceptibility of S population.

Response of *Cyperus difformis*, *Shoenoplectus mucronatus* and *Alisma plantago-aquatica* to penoxsulam

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Chemical weed control in paddy rice often involves by the continuous use of the same active ingredients, which strongly contributes towards the risk of selecting herbicide resistant biotypes. Determining the variability of response, and possibly the baseline, of key weed species to a given herbicide is important for monitoring shifts in the sensitivity of weed populations. Penoxsulam is a new ALS inhibitor triazolopyrimidine sulphonamide for post-emergence application in rice. This study describes the responses of 12 populations of *Cyperus difformis* and *Alisma plantago-aquatica* and 11 populations of *Shoenoplectus mucronatus* to penoxsulam and proposes a method to obtain baseline sensitivity information from a limited number of susceptible populations. The populations were collected throughout Southern Europe from 2002 to 2004, but mainly in Italy, from sites with widely differing herbicide history, including some where ALS inhibitors had never been used. Some known resistant biotypes were also considered. Dose-response experiments were performed in the greenhouse using an experimental set-up simulating paddy rice field conditions. Eight doses of penoxsulam were applied to each biotype at growth stage BBCH 12-14. Log-logistic dose-response curves were fitted to the plant survival and fresh weight data and the $ED_{50,80,90}$ and $GR_{50,80,90}$ plus their standard error were estimated. Population sensitivity/resistance status to two sulfonylureas widely used in rice crops was also determined by screenings performed at the recommended field doses. Plant survival and fresh weight gave similar results, although the latter provided a clearer distinction between completely susceptible populations and the others.

In *Cyperus difformis* the ED_{50} and ED_{90} ranged from 3.71 to 9.44 and from 5.59 to 10.69 g a.i. ha^{-1}, respectively, for the 7 susceptible biotypes; from 17.05 to 27.94 and from 22.48 to 60.50 g a.i. ha^{-1}, respectively, for 4 intermediate biotypes and were higher than 320 g a.i. ha^{-1} for the highly resistant biotype. In *Shoenoplectus mucronatus* the ED_{50} and ED_{90} ranged from 1.89 to 11.37 and from 2.75 to 15.08 g a.i. ha^{-1}, respectively, for the 8 susceptible biotypes; from 11.12 to 21.15 and from 17.69 to 33.65 g a.i. ha^{-1}, respectively, for 2 intermediate biotypes and were higher than 640 g a.i. ha^{-1} for the highly resistant biotype. In *Alisma plantago-aquatica* the ED_{50} and ED_{90} ranged from 2.17 to 10.22 and from 4.34 to 16.12 g a.i. ha^{-1}, respectively, for 6 susceptible biotypes; from 17.29 to 32.87 and from 27.18 to 46.91 g a.i. ha^{-1}, respectively, for 4 intermediate biotypes and from 132.90 to >320 and >320 g a.i. ha^{-1}, respectively, for 2 highly resistant biotypes. Populations susceptible to the two tested sulfonylureas were also susceptible to penoxsulam and several populations resistant to some sulfonylureas were controlled by penoxsulam at recommended field rate. However most of these showed a shift in tolerance to the triazolopyrimidine. One population per species proved to be totally cross-resistant to penoxsulam and sulfonylureas. The results show that variability among susceptible biotypes is relatively low and have confirmed the inherent activity of penoxsulam against the 3 weed species, but also show that previously evolved resistance can sometimes influence its performance, so resistance risk management strategies should be developed.

Inheritance of glyphosate resistance in *Conyza bonariensis* Spanish biotypes

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Conyza spp is becoming a major weed problem in Spain, mainly in no-till permanent crops. Glyphosate resistance has recently been reported to occur in some Spanish biotypes of *Conyza bonariensis*. Crosses have been made between two R (resistant) and one S (susceptible) individuals, and response to glyphosate has been studied in F1 and F2 progenies. F1 plants (37 individuals) were grown in a greenhouse until seed production, then were pruned and sprayed with 2.14 kg glyphosate ha^{-1}. F2 plants (179 individuals) were grown under controlled conditions (27ºC/21ºC; 16h/8h; day/night) and sprayed with 1.44 kg $ha^{-1}$of glyphosate at the rosette stage (18-20 leaves). Mortality and chlorophyll content were measured in F1 and F2 until 28 DAT (days after treatment) and compared with plants obtained by self-pollination of parents (F0). Fitness penalty was also studied analyzing seed germination of crosses and biomass production of R and S individuals. Results show that the glyphosate resistance is probably polygenic because a wide segregation was found both in the F1 and F2. F1 segregation means that parents probably were not homozygous for resistance, and this was confirmed by the response of the parent's first self-pollination. The high segregation in the F1 and F2 is evidenced by individuals more resistant than the resistant parents. This result suggests that no individual possesses all the alleles for resistance or susceptibility. As a consequence, an increase in the resistance factor is expected if glyphosate selection pressure continues on the resistant populations. Mean values (biomass and chlorophyll content) of F1 and F2 are very similar to results obtained with the resistant parents which would mean that resistance is dominant. Resistance is probably nuclear because crosses were made in both ways and no mother effect was observed. A germination test revealed that resistant biotypes have lower germination than susceptible. A fitness penalty in the pollen production of the resistant biotypes was hypothesized on the basis of F1 seed germination. An additional experiment was done with plants of two R and one S biotypes (38 plants per biotype) and results indicate that, in absence of glyphosate, R biotypes accumulate shoot dry biomass faster than the S biotype. The obtained results indicate that a correct rotation of herbicides may reduce the proportion of resistant individuals in short term.

Session 6

Invasive plants and biological weed control

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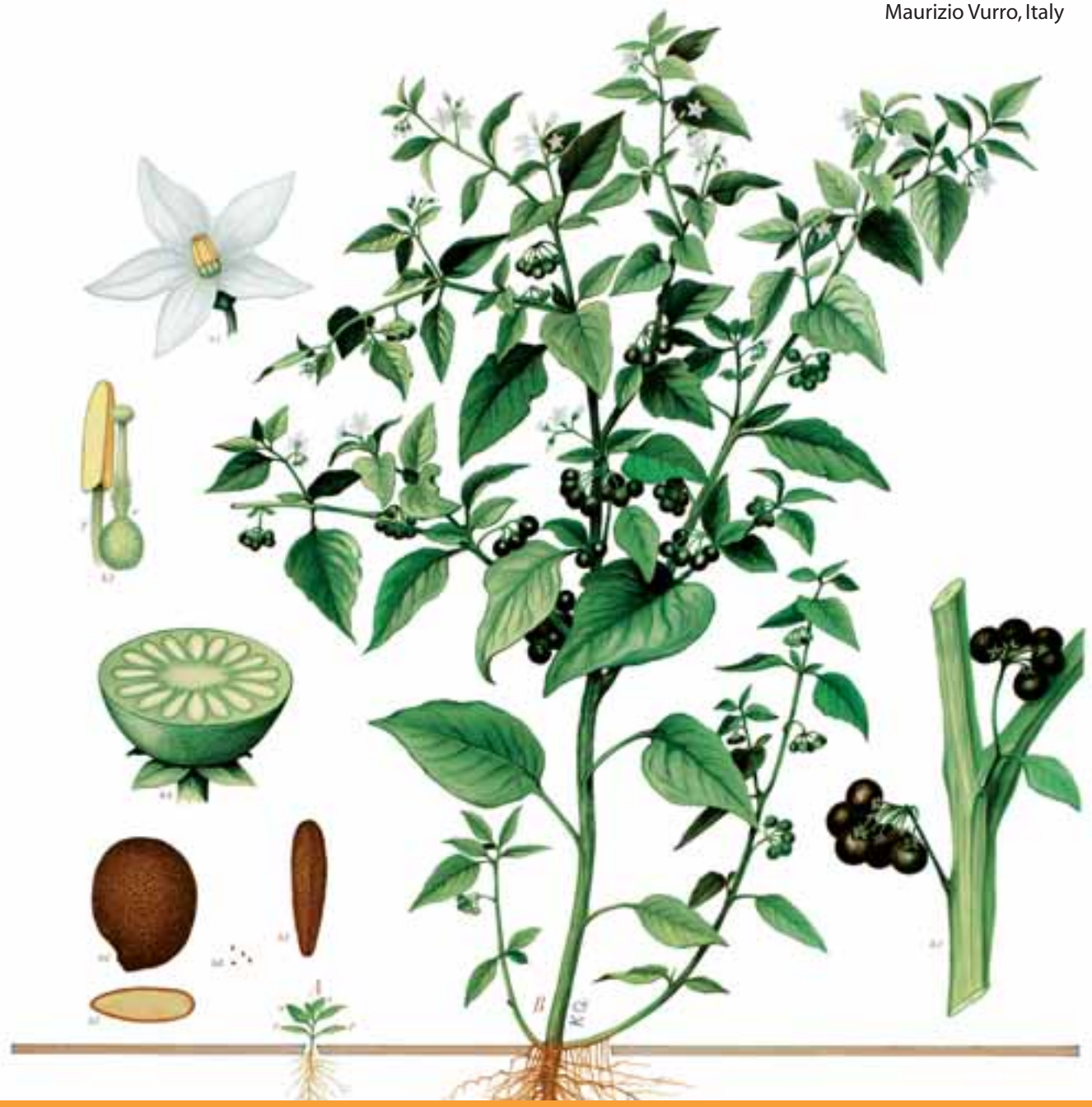

Weed biology serves practical weed management

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The pursuits of weed scientists cover a remarkable breadth of scientific disciplines, but the common base for weed science is that ultimately, it is a practical applied science which serves society in ensuring the effective and responsible management of weed species (Jordan et al. 2002). Often the diversity in the approach of weed scientists veils the practical goal. This may especially be true for weed biology studies. Plant biology (weed biology) includes the science of all forms and phenomena of plants (weeds). It is a broad field and taken out of context and in discrete portions, studies of weed biology may appear esoteric and far from application. However, as an accumulated body of work, the study of weed biology has traditionally and will continue to serve practical weed management.

An understanding of weed biology has always facilitated weed management. In traditional farming systems, prior to the use of herbicides, effective weed management relied on farmers' knowledge of the nature of given species and management techniques that would exploit species weaknesses. For example, in 18th century England, Jethro Tull advocated the use of diverse rotations for weed management because he knew of the diversity of weed species on arable lands and the diverse biology among these species. In the era of weed management after the introduction of synthetic chemical herbicides there was a great interest among weed scientists in exploring herbicide efficacy. At the beginning of this era there was some speculation that weed eradication may be possible, but as problems arose with herbicide intensive weed management, including herbicide resistant weeds and population shifts to difficult to control weeds, weed scientists returned to the study of weed biology.

In broad-acre low input and reduced tillage cropping popular in the majority of field crop production areas, weed problems continue to evolve and weed biology studies continue to serve practical weed management. For example, in western Canada dandelion (*Taraxacum officinale* Weber in Wiggers), traditionally a problem species only in perennial forages and lawns, has become a problematic species in field crops. Efficacy studies have shown that most in-crop herbicides are not particularly effective on established populations. A field biology-based study of this simple perennial revealed that true seedlings generally did not emerge until after in-crop herbicides had typically been applied. As such, in the absence of fall management dandelion populations were growing unchecked. Recommendations for a switch to fall instead of spring management of this species lead to much better management efficacy.

New weed problems will still rely on understanding weed biology. For example, the engineering of plant species to produce novel traits will create a need for trait confinement (for some traits). Volunteer and feral populations can facilitate novel trait escape and movement and managing these species is a new challenge for weed scientists. Understanding the biology of crop species is fundamental not only to devising management strategies for these populations but also for assessing the trait escape and movement risk for targeted novel trait platform species. For example, the persistence of canola (*Brassica napus* L.) makes it a poor candidate for the production of novel traits requiring confinement.

As weed problems continue to evolve, it will remain true for weed scientists that understanding weed biology is essential for practical weed management.

Current perspectives in *Orobanche* biological control

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Broomrapes (*Orobanche* spp.) are parasitic weeds that have a devastating effect on many important crops such as tobacco, tomato, faba beans, sunflower and legumes. Such root parasites exert the greatest damage prior to their emergence and the majority of field loss may occur before diagnosis of infection. The control of this parasitic plant is exceedingly difficult. A wide variety of approaches (physical, cultural, chemical and biological) have been explored against root parasites showing partial success. However, a considerable number of research activities have been directed towards the introduction of natural or synthetic chemical stimulants into the soil in order to induce germination in absence of the host. This control strategy is known as the "suicidal germination" approach and has been extensively stated as a promising method for the control of the holoparasite.

Based on this approach the efficacy of a natural product Algit Super® was evaluated in Petri dishes for its stimulatory effect towards broomrape seeds, suggesting its potential use as stimulant for *Orobanche* control. Algit Super® consists of an *Ascophyllum nodosum* extraction, a well-known alga for its beneficial influence on plant growth. Two experiments were conducted. The first one's goal was to find the most effective concentration of Algit Super® on *Orobanche ramosa* seeds germination and the second one was to examine the response of *Orobanche* spp. seeds at the effective concentration of the product and at different temperature regimes.

Firstly, aqueous solutions of Algit Super® were evaluated for *Orobanche ramosa* seeds at the following concentrations: 2.5, 1.25, 0.313, 0.078, 0.019, 0.0048 and 0.0012 % v/v. Germination showed a concentration dependant course, in a bell-shaped form, with a maximal germinability at 0.019 % v/v, while higher and lower concentrations failed to trigger *Orobanche* seeds. The populations examined responded to Algit Super® in a similar way compared to the reference stimulant GR24. The next step was to assess the efficacy of Algit Super® on *O. ramosa*, *O. aegyptiaca* and *O. crenata* seeds at the active dose of 0.019 % v/v and at three incubation temperatures (18, 20 and 23 C). In particular, 20 populations of *O. ramosa,* 18 populations of *O. aegyptiaca* and 10 populations of *O. crenata* seeds were evaluated. Population diversity was studied according to the temperature level each time. GR24 was used as stimulant-control. The highest germinability was observed at 20 C for all *Orobanche* species after Algit Super® treatment. *O. ramosa* seeds demonstrated the highest response (94.3 %) whereas *O. crenata* the lowest (3.1 %). *O. aegyptiaca* reached a maximum of 71.7 %. *Orobanche* seeds exhibited the same behaviour at 18 and 23 C temperature regimes but with lower response. The decrease in germination values ranged from 20-33% for *O. aegyptiaca* and 8-13% for *O. ramosa*. *O. crenata* exhibited extremely low germination values. The seeds of all *Orobanche* species exhibited analogous response after being treated with the reference stimulant (GR24) at all temperatures. Radicle lengths were also affected after Algit Super® treatments and in most cases the values for radicle elongation were higher (2.457 mm) than those obtained from GR24 treatment (1.510 mm).

Despite the fact that each *Orobanche* species demonstrated a specific behaviour at both stimulants and at all temperatures, variation was observed in germination rates between and within populations even when originating from the same region. This observation arouses the scientific interest and broadens the spectrum of our research leading us to conduct further experiments concerning the diversity on *Orobanche* seeds germination, a key factor for the efficacy of *Orobanche*'s control.

Effect of previous environment on regrowth of *Elytrigia repens*, *Cirsium arvense* and *Sonchus arvensis* in autumn

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The global temperature and concentration of CO_2 are increasing and future prospects indicate that they will continue to increase and that there will be greater climatic variability. During autumn and winter, increased climate variability is expected to result in more precipitation and clouds and hence reduced levels of irradiance. The aim of this study was to reveal if a change in climate and plant size can alter the capacity for regrowth or dormancy status of roots or rhizome pieces during autumn for two ecotypes (59°N and 63°N) of *Elytrigia repens*, *Cirsium arvense* and *Sonchus arvensis*. Different plant sizes were obtained by planting pieces of rhizome (*E. repens*) or root (*C. arvense* and *S. arvensis*) at two times; 1 June and 30 June 2005. The pieces were planted in 5 cm pots and placed under greenhouse conditions, and after 2-4 weeks transplanted to 10 L plastic bags and placed outdoors at Særheim (58°47'N, 5°41'E)). The effect of climate change in autumn from 1 September 2005 was simulated by placing plants from the last planting time in field chambers. Treatments in the chambers included an increase in temperature of 2-2.5 °C, an increase in CO_2–concentration (550 ppm vs. 370 ppm), or an increase in both factors. A control in field chambers was also included, along with a control in outdoor conditions with and without 30% shading. The plants from the first planting time were placed outdoors without any change in environment; thus the control outdoors included two planting times. To test the regrowth capacity/dormancy status, the plants were taken out of these environments 3-4 October and 31 October-1 November 2005. The roots or the rhizomes were separated from the plants, cut into pieces of 5 cm or 2 nodes, respectively, and planted in 12 cm pots at 2 cm soil depth. These pots were subjected to constant temperatures of 5, 8, 11 and 14 °C and with a photosynthetic photon flux density of 150-180 µmol m^{-2} s^{-1} 12 h per day in growth chambers for six weeks. After three and six weeks, the number of above-ground shoots and cumulative length of all shoots were assessed. At the end of the experiment fresh weight and dry weight of above-ground plant parts were determined. Preliminary results indicate that only *E. repens* and *C. arvense* had regrowth. More growth was seen in the test started in early October than in October/November. *E. repens* regrew from 5 °C. *Cirsium arvense* required a higher temperature than *E. repens,* and regrew from 11-14 °C depending on test time. When tested in early October, a previous temperature increase in the field chambers resulted in more regrowth capacity in *C. arvense*, especially when growing at 11 °C. There was a negative effect on regrowth capacity of an increase in CO_2 in *C. arvense*. The reduction in irradiance level prior to the test did not have any effect on the regrowth capacity. In *E. repens* the Northern ecotype produced a higher biomass at 14 °C than the southern ecotype. At the other temperatures no difference between ecotypes were detected. The effect of plant size prior to establishment of the temperature test interacted with ecotype and/or test time only in *E. repens.* The plant size did not influence regrowth in *C. arvense*. *Sonchus arvensis* did not produce any above-ground shoots at both test times. We think this is because the roots of this species may be dormant in autumn. It was unexpected compared to previous studies that *S. arvensis* was dormant in late autumn. This study confirms that *E. repens* can grow later in autumn and is easier to control by e.g. stubble cultivation than *C. arvense*. However, with a global warming, the growth of both species may increase, and make it more possible to control also *C. arvense* in autumn. The dormancy of *S. arvensis* hampers the possibilities for mechanical control in autumn.

The agro-ecology of Italian rye-grass (*Lolium multiflorum*) as a weed of arable crops

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Italian rye-grass (*Lolium multiflorum*) is a serious weed of cereal crops and is becoming an increasing problem in the UK. The first case of herbicide resistance in UK populations of *Lolium multiflorum* was detected in 1990. By 2004, a total of 324 farms in 28 counties in England had been shown to possess herbicide-resistant populations. Understanding the agro-ecology of the weed can help us to better understand the threat posed by this weed and to develop improved control strategies. Consequently, as part of these studies, the seed production potential of five field populations was determined in 2006. In June 2006 plants with intact inflorescences ('heads') were collected from untreated areas of winter wheat crops in Lincolnshire (Louth), Essex (Peldon and Wickford) and Cambridgeshire (Chatteris 1 & 2). Sampling was carried out using 18-24 random quadrats per site (size varied depending on the weed density) and all plants within each quadrat were collected. The numbers of plants m^{-2}, tillers and heads $plant^{-1}$, head length, spikelets $head^{-1}$ and seeds $spikelet^{-1}$ were determined. The mean number of seeds per spikelet (8.6 – 12.5), spikelets per head (21.9 – 27.2) and head length (22.1 – 32.2 cm) varied relatively little between sites, despite the large differences in population density (12.8 – 200 plants m^{-2}). In contrast, the number of tillers $plant^{-1}$ and heads $plant^{-1}$ differed greatly between sites depending on the density of the weed. The populations with a high density of rye-grass plants (200 and 95 plants m^{-2}) had fewer heads per plant (2.9 - 3.9) than those with a lower plant density (12.8, 25.0 and 27.3 plants m^{-2}), where there were 16.7, 21.5 and 16.4 heads $plant^{-1}$ respectively. Consequently, the main determinant of seed production was head numbers per unit area. There was less than a two-fold difference in seed production m^{-2} between the five sites (70,379 - 134,832) despite a 15.6 fold difference in rye-grass plant densities. This demonstrates that rye-grass plants are very adaptable to different weed densities, and that very high seed production is possible from low density populations. At the three lowest densities studied here seed production per plant varied from 4598 to 7196 seeds $plant^{-1}$. This is at least five times the amount that is typically produced by black-grass (*Alopecurus myosuroides*) plants at equivalent weed densities and explains why uncontrolled rye-grass infestations can increase so rapidly in winter wheat crops. Therefore, the success of Italian rye-grass as a weed of winter cereals appears to be linked to its ability to produce a high number of heads per plant, and consequently a large number of seeds per unit area, even at low plant densities.

Seed germination and dormancy of seedlots of *Chenopodium album* in different countries of Europe and North America

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Twelve seed lots of *Chenopodium album agg.* from Canada, Czech Republic, Denmark, Finland, Italy, Norway, Portugal, Spain, Sweden, United Kingdom and the USA were characterised for responses to chilling, light, potassium nitrate and temperature. The research is part of a multi-location experiment performed by the EWRS Germination and Early Growth Working Group. The associated field experiment is designed to determine how the magnitude and distribution of emergence of *C. album* varies with the timing of superficial soil disturbance around the time when emergence occurs in undisturbed soil. The seed characterization reported here is intended to help explain differences observed in the field. Three experiments are reported. The first concerned germination at a wide range of sub- and supra-optimal constant temperatures on a temperature gradient plate. The second explored the responses of imbibed seeds to chilling. The third was a factorial experiment in which effects of light and dark and of water and nitrate were investigated. Viability of all seedlots exceeded 68% (median 89%) based on germination in the optimal treatment of the third experiment, i.e. at 10 °/20 °C (12 h/12 h) with fluorescent light (12 hours per day) on top of Whatman 181 seed testing paper moistened with 0.01 Molar potassium nitrate. The lowest apparent viability (68%) arose in the Norwegian seedlot, but as this was also the most dormant, its viability was probably underestimated due to a failure to relieve residual dormancy in some seeds. The seedlots varied widely in dormancy. Using maximum germination on the temperature gradient plate (Expt 1) to estimate *non*-dormancy, the least dormant seeds originated from Finland (85% germination) and Denmark (52%) while the most dormant were from Illinois (17.5%) in the USA, the Czech Republic (12.5%) and Norway (10%). Interestingly and quite unexpectedly, optimal constant temperatures for germination (13, 18.3, 19.7, 21 and 26.3 °C, respectively) were more obviously associated with dormancy than with provenance. [The gradient operated between 2.4 and 34.2 °C and the seeds were imbibed on moist paper and exposed to diffuse laboratory light during intermediate germination counts.] In Expt 2 and again contrary to expectations, no seed lot responded positively to imbibed chilling for up to 49 days at 3.1 °C or for 28 days at -2.8 °C. Instead, there was some evidence of an induction of secondary dormancy with prolonged chilling at 3.1°C. In the third experiment, responses to the dormancy-relieving factors, light and potassium nitrate (0.01 M), were clear in all seedlots at an alternating temperature of 10 °/20 °C (12 h/12 h). Maximum germination always occurred when seeds were exposed to both of these factors. However, in some seedlots (Canadian, Italian, British, Danish and Finnish) responses were roughly additive to light and potassium nitrate, while others (Illinoian, Spanish, Polish and Czech) showed a highly synergistic response, such that over 40% of individual seeds in the germination tests would only germinate if both dormancy-relieving factors were present concurrently.
Further analysis of the results may evaluate thermal times for germination from Expt 1 and link the results of all three experiments with seedling emergence following disturbance in the field.

Soil degradation of parthenin – does it contradict a role in allelopathy of the invasive weed *Parthenium hysterophorus* L.?

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Parthenium hysterophorus L. is a noxious weed that spread from its endemic habitat in tropical America and naturalized in moderate and warm climates in many parts of the world. Invaded areas frequently turn into dense monocultures of the weed and the invasive success is thought to be in part attributable to the release of phytotoxins from plant material. The sesquiterpene lactone parthenin has been described as major phytotoxin biosynthesized by various invasive *P. hysterophorus* populations and a role in allelopathy is presumed. Leaching from intact leaves and decomposition of plant leaf residues are considered the most important modes of parthenin release into soil and especially contents found in residues seem to ascribe parthenin an ecological role. However, allelopathic effects in a soil environment not only depend on total amounts of phytotoxins released, but also the bioavailability and persistence of phytotoxins in soil are important factors determining plant chemical interference. Therefore, understanding bioavailability and soil persistence is essential to predict allelopathic effects. To allow a better estimation of the ecological significance of parthenin for the interference potential of *P. hysterophorus*, the soil persistence of the compound was studied in laboratory tests by HPLC-DAD analyses as affected by several influencing factors [concentration, preconditioning (*i.e.* soil pretreated with parthenin), level of *P. hysterophorus* infestation, soil moisture, soil type, sterilization, temperature]. Tests were conducted following a standard protocol (10 µg parthenin/g soil, 40 % WHC, 20 °C, darkness) with respective variations in experimental factors. Each test comprised 16 soil samplings taken over a period of 0-50 d in order to model degradation curves and estimate DT_{50}-values. Furthermore, dose-response bioassays evaluated the phytotoxicity of soil applied parthenin on growth of *Lactuca sativa* L. Bioassays were conducted as germination assays using nine parthenin concentrations (0-1.6 mg parthenin/g soil). Results show parthenin to be rapidly degraded with average DT_{50} values of 59 h under standard protocol conditions. The process of degradation showed a characteristic initial time lag before a reduction of parthenin was detectable. In comparison to standard conditions, degradation rates varied depending on experimental factors. Sterilization of test soils significantly delayed the disappearance time and, thus, microbial degradation is strongly indicated. Degradation was also delayed at lower soil moisture levels (DT_{50} = 98 h at 20 % WHC) and higher parthenin concentrations (DT_{50} = 251 h at 820 µg parthenin/g soil). Degradation was faster at higher temperatures (DT_{50} = 33 h at 30 °C), in soils with high CEC_{pot}, in soils preconditioned with parthenin, and in soils previously infested with *P. hysterophorus.* Despite its relatively low persistence, parthenin proved to be phytotoxic in soil bioassays with ED_{50} values for growth inhibition ranging from 140-600 µg parthenin/g soil depending on the soil type used. Formation of metabolites more active than parthenin was not indicated. If the observed phytotoxicity in soil is compared with estimated amounts of parthenin present in the soil under field conditions at naturally occurring *P. hysterophorus* densities, parthenin concentrations would substantiate allelopathic effects. However, the observed high biodegradability of parthenin in soil suggests that for parthenin to have allelopathic effects, it may require rather high *P. hysterophorus* densities resulting in high levels of parthenin in the soil, soils with a low capacity to degrade parthenin, and/or soil conditions that favor the persistence of parthenin. Hence, soil factors may notably govern the role of parthenin in the interference potential of *P. hysterophorus.*

Effect of temperature on phenology of *Solanum nigrum*

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Solanum nigrum L. is a well-known weed in southern Sweden, especially in crops like carrots and celery with poor competitive effect, large row distances and lack of effective herbicides. It constitutes a special problem in cultivation of garden peas, since the fully-grown berries are difficult to separate from peas in the food processing industry. The seeds remain non-dormant until July, and consequently seedlings are emerging and need to be controlled during a long period by repeated mechanical or chemical treatments. Thus, it is of great interest to develop a model, which could predict at what date weeding could be terminated without the risk of harvested peas being infected by berries. Two experiments were conducted to test the hypothesis that temperature sum could be used to predict the phenology of *S. nigrum.* In experiment 1, seeds were germinated in petri dishes and subsequently sown in 1.5 L pots filled with soil consisting of 6 % clay, 11 % silt and 83 % sand. Fifteen pots, with one plant per pot, were placed in each of three climate chambers. The conditions in the chambers simulated changing temperature and photoperiod in southern Sweden during the period 15 April–15 July, 15 May–15 August and 15 June–15 September, respectively. Development stage of plants, according to a modified BBCH-scale, was registered every 2nd or 3rd day. Results showed that the phenological development from emergence to mature berries could be well described by a thermal time model. The first visible bud (stage 51) appeared at 343 day degrees (base temperature 3 °C) from sowing in petri dish. The first berries were visible (stage 71) at ca. 660 day degrees and reached full size (stage 89) at ca. 1100 day degrees. The differing climates did not affect the temperature sum required to reach a given development stage. In experiment 2, the development of plants was followed at four sites in the region of Skåne, southern Sweden. Individual plants, emerging at different dates from 15 May to 10 July, were marked and the development stage was registered weekly. Data was analysed using the temperature sum from development stage 11-12 (1-2 true leaves) to stage 51 (first buds) and stage 71 (first berries visible), respectively, in a regression versus time (Julian days) to stage 11-12). The number of day degrees to development stage 51 increased with time, but only at one site when analysing thermal time to stage 71. Thus, the thermal model overestimated the effect of high temperatures in mid-summer on the rate of development, especially from the two-leaves stage to the bud stage. For plants studied in the field the mean temperature sum from stage 11-12 to stage 71 was 576 day degrees, based on 109 observations and regional temperature registrations (base temperature 3 °C). This is to be compared with 520 day degrees for plants grown in the climate chambers when temperature sum was calculated from stage 11. In conclusion, the results from the climate chamber experiment imply that it might be possible to develop a thermal model, which could predict the phenology of *S. nigrum*. This would greatly benefit the cultivation of garden peas, by making it possible to reduce the number of herbicide applications. Also, in other crops it might be possible to predict the time for viable seeds to develop, and thus the need for weed control to avoid build-up of the soil seed bank. However, as indicated by results in experiment 2, further work with the model must take into account the overestimation of the effect of high mean temperatures on the phenology.

Morpho-anatomical plasticity of *Ranunculus acris* and *Ranunculus repens* in response to environmental variability at Vlasina wetlands (SE Serbia)

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Wet habitats of Vlasina highland, once the largest Balkan's peatbog habitat, are overgrown by numerous types of *Ranunculus* species, among which very expansive species such as *R. acris* and *R. repens*. Both species are hygromesophytes. *R. acris* inhabits the borders of wet meadows and pastures, whereas *R. repens* settles continually flooded, as well as occasionally dried localities. This latter species is characterized by a great phenotypic variability and re-differentiates from terrestrial to aquatic forms whenever the environmental conditions change. The aim of this study was to investigate the differences in morpho- anatomic adaptations of leaves, stems and roots of *R. acris* and *R. repens* collected from different localities, i.e. dry and wet meadows around the Vlasina. Measurements (30) of plant organs were carried out using a light microscope (Leica) with a special image analyzer (Leica Q-Win). *R. acris* could be found only in the terrestrial form. *R. acris* plants are characterised by lower leaves much longer and wider (53.7 and 23.8 mm, respectively), than the upper (32.9 and 19.7mm, respectively) leaves. The whole leaf thickness of *R. acris* as well as the thickness of the palisade and the spongy tissues is higher in lower leaves (38.2 μ and 59.2 μ, respectively) than in upper leaves (19.4 μ and 30.8 μ, respectively). The stems are made of compact layers of primary cortex and rhexigenuous pith cavity in ratio 1:1. The root is also compact and the ratio of primary cortex - vascular cylinder is 2:1. Terrestrial forms of *R. repens* from moderately wet habitats are characterised by leaves long at least 32.3 mm, much longer than the aquatic (18.1 mm) leaves, while they are approximately of the same width (58.6 mm). The whole leaf thickness of *R. repens* as well as the thickness of the palisade and the spongy tissues is higher in terrestrial (55 μ and 79 μ, respectively) than in aquatic form (38 μ and 60 μ, respectively). The stems of *R. repens* from the aquatic environment are three times longer (0.124 m) compared to stems of plants from flooded meadows around the lake (0.04 m). Aquatic stems usually consist of 4-5 internodes, while the terrestrial ones have 2-3 internodes. The terrestrial stem cortex is more developed and twice thicker (1311μ and 568 μ, respectively) than the aquatic stem. There are 5-6 vascular bundles in the vascular cylinder of the aquatic form of *R. repens*, while in terrestrial stem their number vary from 13 to 20. The rhexigenuous pith cavity of the terrestrial stems is approximately two times larger than in aquatic stems (896 μ and 478 μ, respectively). The root of aquatic form of this specie is characterised by wider cortex diameter. Besides, the ecophysiological properties of these species correspond to their structural adaptations. Therefore, the short living hygromesophyte *R. acris* is characterised by RWC (between 40-68%) and the water potential of an average of (-1MPa). Conversely, the transitional hygromesophyte, *R. repens* markedly varied in RWC, varying between 30-73% for the terrestrial form and 40-88% in the aquatic form. However, the water potential is characterized by a greater variability in the aquatic form, from (-0.4 MPa) to (-2.4 MPa) then in the terrestrial from (-1MPa) to (-2 MPa).The structural and the ecological/physiological differences exhibited in all plant organs of these species imply, in one hand their adaptability to the specific conditions of their ecologically different habitats, and in the other hand, the possibility of a rapid adaptation to the spatial changes in the environment, which has been observed in *R. repens*. The expansibility of this latter species is further shown by the ability in forming large number of stolons on very wet, peat bog habitats.

Assessment of seed dispersal in *Conyza bonariensis*, an invasive wind-dispersed weed

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Over two years we studied seed dispersal in *Conyza bonariensis*, in SW Spain. Sticky traps, 0.4 x 0.225 m in size, were arranged at different distances, ranging from 1 up to 100 m, from a small, seed source population consisting of 85 plants (first year) or 55 plants (second year) evenly spaced 0.25 m, established from transplanted seedlings in the centre of a 3-ha open, flat field. For distances greater than 5 m, traps were placed at two heights, 0.25 and 1.5 m, whereas traps distant 5 m or less were placed only at 0.25 m height. In the first year, traps were arranged in all compass directions but more traps were placed in the a priori most favourable N-E and the most unfavourable S-W quadrants for dispersal, according to the prevalent wind direction at the study site. In the second year, in order to increase sampling effort, traps distant more than 5 m from the source were concentrated in two 22.5º sectors, oriented to NE, downwind the source population, and NW. A meteorological station was placed in the study field to record wind speed and direction. Seed counts on traps were carried out generally every 5 days throughout the dry season, from the onset of dispersal in early summer to early autumn, when most of the seed production and dispersal had already accomplished in source populations. Numbers of seeds dispersed in each interval were estimated by determining the number of newly dispersed capitula in ten plants and multiplying the resulting mean number per plant by the number of plants and by mean number of seeds per capitulum. In both study years, the observed dispersal curves were markedly leptokurtic, with the vast majority of seeds (>90% based on the mean number of seeds per trap at each distance) found in the nearest traps to the source. Nevertheless, some seeds were regularly found at the greatest distance, indicating that seeds can travel at least 100 m, and thus indicating long distance dispersal ability. Wind speed and direction showed a strong daily pattern in most of the dispersal intervals and in both cumulative periods, with higher speeds in the central hours of the daytime. During these daily windows, the wind pattern was strongly directional (Rayleigh test for uniformity of directions, $p<0.001$ in all study intervals), with mean angles for the cumulative period of 32.8º and 26.3º (i.e. within the N-E quadrant) in the first and second year, respectively. The pattern of seed dispersal was also strongly directional and, in most of the dispersal periods, it was explained by the wind pattern, as shown by trigonometric polynomial models ($p<0.05$). Source populations produced 3.7 and 5.8 million seeds in the first and second study years, respectively. According to distribution of seeds trapped up to 5 m from the source, an estimated fraction of 51.0% and 49.7% of the seeds was dispersed into the most favourable N-E quadrant during the first and second year, respectively, whereas the most unfavourable S-W quadrant received only 23.2% and 8.9% of dispersed seeds. In the second year, the NE-oriented sector, downwind the source, received 2.5-fold seeds compared to the NW-oriented sector. In both study years, more seeds were found in the upper than in the lower traps in the most favourable directions for dispersal, whereas the opposite was true in unfavourable directions, indicating different vertical distribution of dispersed seeds. A combined effect of differential horizontal wind speeds and convective updrafts, expected during the daytime in the hot summer days, could probably explain this contrasting vertical pattern. Results suggest that, in *C. bonariensis,* long-distance dispersal ability and strong directional patterns of seed dispersal must be accounted for in order to design management of the weed both at the within-field and landscape frame.

Effect of environmental conditions on the seasonal dormancy pattern expression of *Centaurea cyanus* seeds

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Centaurea cyanus is a common weed in Poland with a persistent soil seedbank. However, regarding the ecophysiology of their dormancy and germination, there is no detailed knowledge available for the development of biological or integrated weed control systems. The objective of the study was to determine the impact of soil temperature, concentration of nitrates, desiccation and light conditions on the seasonal dormancy pattern of *Centaurea cyanus* achenes.

Seed lots were collected in summer and dry stored at 4 °C. Their germination was tested in Petri dishes, on filter paper soaked in 0.25 mM KNO_3, following 0.5 h exposure to red light, in the dark, at 12 °C, for 10 days. The germination tests were carried out after 5 months pre-incubation period in wet sandy loam at various constant temperatures (2, 6, 12 and 19 °C) and at temperatures rising stepwise from 2 to 26 °C. Additionally, the germination of dry stored seeds was tested at three constant (5, 12 and 19 °C) and fluctuating temperatures (12/12 h at 5/19 °C). The achenes were also buried in the field in autumn. Once a month for a period of one year, a sample of the buried achenes was exhumed to test germination after red light irradiation or in darkness, with or without nitrate and with or without desiccation.

The dormancy of imbibed seeds of *C. cyanus* was induced by rising stepwise temperatures from 2 to 12 °C. The temperature increase above 12 °C resulted in dormancy relief. Both low and high constant temperatures led to dormancy breaking. *Centaurea cyanus* achenes demonstrated 100% viability after one year of dry storage at a low temperature and 95 % viability after one year of storage in a natural soil seedbank. *Centaurea cyanus* seeds did not show any apparent endogenous seasonal dormancy pattern and, dry stored at 4 °C, they had a high germination level over a year (80-100%). Environmental conditions in the soil seedbank resulted in a decrease in germination and the development of seed dormancy (germination of 29-52%). The laboratory experiments suggested that the decrease of seed germination was caused by daily temperature fluctuations. The dormancy was apparently relieved only in October in desiccated seeds. Nitrate and light affected seed germination to a lesser extent, and their effects were season-related.

Ecophysiological studies enabled a better understanding of the considerable variation of life cycle strategies in this species, which can be a summer and winter annual as well as biennial plant. *Centaurea cyanus* appeared to be very plastic in terms of ecophysiology and expression of the seasonal dormancy pattern allows the species to germinate and survive in different seasons and very varied environments.

Actual water consumption by the chosen weeds of *Asteraceae* family on the mature stage of development depending on environmental conditions

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The species composition of the phytocoenosis is one of the factors influencing the water balance of the ecosystems and subsequently that of the agroecosystems. Both crops and weeds participate in the water balance in agrophytocenosis. Knowledge of crop and weed transpiration is important not only for estimating the whole agrophytocenosis transpiration but for evaluating water competition between the arable crops and the weeds. Field water demands of the weed species selected from the *Asteraceae* family were observed during the year 2006. The plants observed were *Artemisia vulgaris* L., *Conyza canadensis* (L.) Cronq and *Lactuca serriola* L. The goal of the experiment was to estimate the average daily water consumption of the weed species mentioned above on the basis of sap flow measurements. The experiments were carried out in the trial field of the Czech Agriculture University in Prague – Suchdol from 3 August to 27 August, 2006. The transpiration measurements were realized by the sap-flow meter T 4.2 (EMS, Brno, CZ). The actual values were measured continually within a ten-minute interval on seven plants of *C. canadensis* and *L. serriola* and seven stems of three plants of *A. vulgaris* accordingly. In the experimental site other meteorological phenomena such as global solar radiation, air temperature and humidity and precipitation were observed. The plants were in flowering and maturing stage of the seeds during the evaluation process. The average weight of plants or stems (*A. vulgaris*), their height and the base diameter of plants (stems) were estimated at the end of our measurements. The average daily sap flow values (an average of the plants evaluated) were 0.045 kg for *C. canadensis* (a standard deviation "s" equals to 0.036) and 0.072 kg for *L. serriola* (s = 0.066). The average sap flow through one stem of *A. vulgaris* was 0.076 kg (s = 0.050). The average weight and height figures of the evaluated plants (stems) were 68.7 g and 1584 mm for *A. vulgaris*, 18.2 g and 1166 mm for *C. canadensis* and 46.9 g and 1518 mm for *L. serriola*. Following our actual results we have found the amount of sap flow correlates well with the global solar radiation if sufficient amount of soil water is provided. In case of weed plants suppressed by crop plants, the sap flow is significantly influenced by the vapor pressure deficit. The considerable fluctuation of the sap flow values during the day as well as daily fluctuation within the period evaluated (see "s") was caused by the solar radiation dependency. In addition to it, the sap flow was influenced by the air temperature and humidity. If we compare e.g. the daily water consumption of the weeds mentioned above with the sap flow through *Brassica napus* (variety Navajo), which varied from 0.012 to 0.119 kg day^{-1} within the flowering and maturing stage during our measurements in the year 2005, we can conclude the water demands of *B. napus* are similar to those of *C. canadensis* and *L. serriola*. The occurrence of one *L. serriola* plant m^{-2} in the *B. napus* crop concerning its water demands is of the same effect as the increase of *B. napus* number by one plant m^{-2}. Concerning *A. vulgaris* the whole water consumption is conditioned by the number of stems per plant. If the number of stems longer than 1 m $plant^{-1}$ is between 2 and 10, then the daily water consumption is between 0.152 and 0.760 kg $plant^{-1}$ which is more than we measured in case of *Zea mays* (0.350 kg $day^{-1}plant^{-1}$). Our results showed that the transpiration demands of the evaluated weeds reached the same or higher values in comparison with some cultural plants.

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Allelopathic activity of *Cyperus esculentus* L.

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Since its first appearance in 1993, yellow nutsedge (*Cyperus esculentus* L.) has been considered as a serious invasive plant in Hungary. Beside its intensive vegetative reproduction, allelopathy may also play important role in its rapid distribution (Drost *et al*. 1980). Pot experiments under glasshouse conditions were carried out to study the effect of *C. esculentus* shoot and root residues on the germination and development of some test species. The roots and shoot of *C. esculentus* and *Juglans regia* L. leaves were cut into small pieces and dried in the glasshouse for a week. *Juglan regia* is a well known species for its allelopathic characteristics, therefore it can be used as a standard for allelopathic studies (Szabó 1999). Dried shoots and roots of *C. esculentus* and *J. regia* leaves (800 g) were mixed into three lots of 10 kg of a soil mixture, composed of sand + peat in a ratio of 1:2. Another lot with the same soil mixture was also prepared for use as a control. Each of the four soil lots (*C. esculentus* root and shoot residues, *J. regia* leaf residues and control) were kept moist for three months and after that (in the middle of September) the soil lots were used to fill plastic plots (16 cm in diameter) that were sown with 50 seeds of one of the selected test species, of which there were six replicates. Maize (*Zea mais* L.), sunflower (*Helianthus annuus* L.), white mustard (*Sinapis alba* L.), sugarbeeet (*Beta vulgaris* L.) and common ragweed (*Ambrosia artemisiifolia* L.) were chosen as test species. Germination rate was recorded daily for seven days after sowing (DAS) until no further emergence occurred. Germinated seeds were removed, except for four seedlings in each pot. The plant height, fresh and dry weight of the plants were recorded 35 DAS.

Shoot residues of *C. esculentus* did not significantly influence the germination of the test species. The plant height of maize and sunflower was enhanced by 35% and 12%, respectively compared to control. The fresh weight of common ragweed was 1.5 times greater, while that of maize, sunflower and white mustard were twice that of the control. The dry weight of common ragweed and sunflower were 1.5 times greater, while that of maize was twice that of the control plants.

Root residues of *C. esculentus* did not significantly influence the germination of the test species. Root residues significantly reduced the plant height of sunflower and white mustard by 17% and 61%, respectively. Fresh and dry weights of maize, sunflower and white mustard were reduced by 37-38, 33-35 and 67-68%, respectively, due to the root residues.

Leaf residues of *J. regia* significantly enhanced white mustard germination by 17%. A significant, 49% and 28% reduction was observed in plant height of common ragweed and sunflower, respectively. A significant 67-75% and 14-17% reduction in the biomass production of the above-ground parts was observed with common ragweed and sunflower, respectively. On the contrary, the fresh weight of white mustard was increased by 47% due to the leaf residues of *J. regia*.
It is concluded, that allelopathic activity greatly depended on the plant parts of the donor plant (*C. esculentus*), the test (recipient) species and the physiological processes studied. Shoot residues of *C. esculentus* increased, while *J. regia* leaf residues and *C. esculentus* root residues decreased biomass production of some test species.

On the basis of our results, allelopathic characteristics of *C. esculentus* roots were demonstrated in pot experiments, but future examinations are also necessary under field conditions.

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Genetic diversity of ragweed *Ambrosia artemisiifolia* L. a comparison of the maternally inherited cpDNA and mtDNA

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Common ragweed (*Ambrosia artemisiifolia* L.) native in North-America, became in a few decades a successful invasive species in Europe. Since 1920 it is present in Hungary, and since the middle of the 1990's ragweed is the most widespread weed in the Carpathian basin. This region is the most heavily infected area in the old continent. Beside that, ragweed is also the main cause of pollen allergy. How serious this problem is can be illustrated by the fact, that to date about 20% of the Hungarian inhabitants suffer from pollen allergy, mainly caused by the ragweed pollen. At the Georgikon Faculty we started a program for getting molecular genetic information about ragweed, for a better understanding of the plant, and for contributing to future development of more sophisticated weed protection techniques. At first we analyzed the molecular genetic control of triazine resistance, which is a maternally inherited characteristic. Than we studied the genetic variability of the chloroplast and mitochondrion genome. We chose these approaches, because both the chloroplasts and the mitochondrions are maternally inherited, and they can be spread only with the seed. We compared the chloroplast (cp) and mitochondrion (mt) DNA of East,- and West-Hungarian as well of Canadian (Montreal) and USA (Wisconsin) collected ragweed samples. Four randomly chosen individual plants of each ragweed population as well a sunflower hybrid and a sunflower variety have been used in the analysis. From 13 cpDNA and 12 mtDNA sequences, which have been detected with universal primer pairs 5 (cp) as well 4 (mt) gave useful products for further analyses. PCR products have been digested with 9 and 8 different restriction enzymes, respectively, and after electrophoresis the resulted patterns were evaluated. The results were compared to the sunflower (*Helianthus annuus*) organelle genome.

For the highly conserved cp genome in average 8% polymorphism was detected between the different ragweed samples, and when sunflower was also included than the level of polymorphism was 39.6%. In the case of the mitochondrion genome, where recombination is common, in average 17.88% polymorphism was detected between the different ragweed samples, and when sunflower was also included than the level of polymorphism was 27.81% - less than expected from the cpDNA results. From the data dendrograms were constructed using both the UPGMA and the Neighbor-Joining methods, and a bootstrap analysis was performed, too. Both methods gave similar results: the USA samples were homogenously grouped, while the Hungarian samples proved to be closely related with the Canadian ones. The sunflower samples showed to be characteristically distant from all ragweed samples. When all organelle DNA data were synthesized, the obtained single dendogram showed that while the USA samples were homogenously grouped, all Hungarian and Canadian samples were mixed in the UPGMA analysis. In the case of the Neighbor-Joining method beside the USA group the West-Hungarian samples grouped also homogenously.

Each evaluation method revealed a tight relationship between two East-Hungarian and two Canadian samples. These results are also historically supported, because the former East-Block countries bought grain from Canada rather than the USA. Our data show that the chloroplast and mitochondrion genome can be effectively analyzed by the PCR-RFLP technique in the phylogenetic comparison of ragweed populations. Using the same methodology we are now analyzing ragweed samples from different places of North-America and from different European countries.

Seed dormancy heteroblasty as blueprint for *Setaria faberii* seedling emergence

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How do agricultural communities assemble? Community assembly is predicated on seedling recruitment timing, which in turn is the single most important determinate of competition and interactions with neighbors. Upon what does seedling emergence timing depend? This paper is a report of several studies conducted to test the hypothesis the *Setaria faberii* plants shed heteroblastic seeds that determine subsequent seed dormancy cycling in the soil and seedling emergence patterns. In other words, seed dormancy heterogeneity at abscission and dispersal time is the 'blueprint' for seedling emergence timing and pattern. *Setaria faberii* parental plants induce differing levels of dormancy capacity in individual seeds produced on their synflorescences during embryogenesis: seed dormancy heteroblasty. This dormancy quality is maintained by seed for their entire life. Field soil-seed pool studies were conducted in 1997-2000 in Iowa agricultural fields with 44 different *S. faberii* seed populations to determine their subsequent behavior. Seed heteroblasty for each population was characterized shortly after abscission and shortly before burial in the soil in bare, marked, cores. Seed heteroblasty was determined by seed germination assays in 'ideal' controlled environmental conditions after incrementally increasing durations of after-ripening (4° C, moist, dark). The earliest seed produced by parent plants (e.g. August) was the most dormant, while relative dormancy decreased in seed produced later in the season as the photoperiod declined into the autumn. Seed were buried in 10 cm depth soil cores in 4 different years at two different Iowa, USA, common nursery locations. Weekly emergence was observed for all populations for up to two years post-burial. Mixture models consisting of four normal distributions during the first half of the growing season revealed consistent, oscillating, patterns of seedling emergence, each unique to an individual population and nursery. Spearman rank correlations revealed a strong relationship (P<0.014 for all periods) between population germinability rank and cumulative emergence rank by Julian week. These observations reveal a fine scale adaptation of seed dormancy variability by *S. faberii* to local field conditions. Heteroblasty is strongly correlated with subsequent seedling emergence timing, as modulated by local environmental conditions. Is recruitment pattern influenced by Nature or Nuture? Our evidence indicates that seed dormancy heteroblasty accounted for 50-70% of the observed variability. These studies provide evidence that seed dormancy variability is the blueprint for seedling emergence, the single most important trait determining subsequent plant community structure. Heteroblastic structure also reveals the hedge-bet structure of a *S. faberii* population for maximizing fitness when confronted with agroecosystem disturbances.

Phytotoxic and allelopathic properties of species used as cover cropping in vineyards, orchards and berry fields

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Cover cropping improves soil protection and weed management with a reduction in herbicide applications. Nevertheless, in numerous situations, farmers hesitate to install such ground cover because of its competition with the crop and its potentially negative effects on the quantity and quality of the harvest. In order to keep the advantages of cover cropping, while limiting its negative impacts, it is proposed to introduce species, which despite their low competitive ability still limit weed development. Cover cropping, using plants with strong phytotoxic properties, was tested in field conditions, especially in vineyards, orchards and berry fields.

More than 30 plant species were screened through laboratory and glasshouse bioassays, in order to assess their phytotoxic properties and allelopathic potential. In these assays, common weed species (*Amaranthus retroflexus*, *Apera spica-venti*, *Chenopodium album*, *Rumex obtusifolius*, *Senecio vulgaris*) were used as receptor plants. Aqueous extracts and/or dry residues from several species, such as *Agrostis sp*., *Bromus tectorum*, *Hordeum murinum*, *Hieracium pilosella*, strongly inhibited the development of the receptor plants. Moreover, aqueous extracts of *H. pilosella* also displayed a very potent inhibitory effect on their germination.

By comparing different accessions, collected at several periods, we observed genetic as well as seasonal variations in the phytotoxic properties of some species. Comparisons between these variations and the phytochemical profiles of plants and extracts allowed the determination of some of the molecules involved in the phytotoxic effects; especially phenolics, such as umbelliferone in *H. pilosella* or chlorogenic acid and luteolin-7-0-glucoside in *B. tectorum*. The genetic and seasonal variations also contributed to the choice of the accession to be tested in the field.

Agrostis stolonifera, *B. tectorum* and *H. murinum* were tested as cover cropping in vineyards, orchards and raspberry fields between 2001 and 2006. Trials also started in orchards and vineyards in 2005 with *H. pilosella*.

In the raspberry trial, *A. stolonifera* offered a complete, permanent and weakly competitive covering of the ground during four consecutive years: spontaneous weeds were perfectly controlled without any application of herbicides and yields were not affected, compared to the weed-free plots used as control. In vineyards, good results were obtained with *B. tectorum* and *H. murinum*. These winter annual grasses germinate in autumn, offered good ground cover during the winter and completed their life cycle in spring, when the crop initiated its development. After flowering and seed setting, they formed a dry mulch, highly phytotoxic, which certainly contributed to maintaining the ground clear of weeds throughout the summer. These species germinated again the following autumn to initiate a new cycle. In one of the trials in vineyards, *H. murinum* still covered 65 % of the inter-rows in the fourth winter after the initial sowing.

Field studies are now being carried out to confirm the presence and effect of the phytotoxic compounds isolated from these plants used as cover cropping.

The use of such a weakly competitive cover could certainly be improved by choosing the most appropriate species for the given soil and climatic conditions, by using highly allelopathic genotypes and by optimising management techniques, such as mowing and tillage.

Suppressive effects of extracted barley root exudates on weed species

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There is an ongoing shift in the paradigm concerning weed control – from the traditional method of attacking weeds by artificial means, to increasing the competitive ability of the crop and thereby reducing yield losses caused by weeds. The ability of a crop to inhibit the development and growth of weeds is one of the most important factors in a weed control strategy. With current research providing new knowledge concerning plant defence mechanisms, for example allelopathy, we can now anticipate a whole new field of research regarding weed control in agriculture. It may be possible to utilise weed-suppressing factors secreted by crop species as a weed control strategy that is beneficial to the environment. Increased knowledge in this area may also lead to production of more effective bioherbicides, suitable for use in both conventional and organic cultivation. Barley cultivars and landraces have been shown in biotests to have different allelopathic effects on test species, with correlations to weed suppression in field studies.

In the Swedish research project 'Isolation and Identification of Weed Suppressing Factors Secreted by Barley', the aim is to isolate, identify and characterise the allelochemical compounds released in root exudates of barley landraces and cultivars with allelopathic effects. Identification of individual active substances provides the potential to develop DNA-markers, map the genes responsible for the allelopathic effect, make plant production of allelochemicals resource-efficient and perhaps also lead to production of bioherbicides.

In one of the studies, the aim was to investigate whether barley plant density in pure stands influenced the production of allelochemicals in root exudates from the barley. To collect the root exudates, the direct resin adsorption method was used. Three-day-old barley (cv. Lina) seedlings were transplanted into a previously autoclaved pot (diameter 13 cm) containing XAD-4 resin and a Mes-Tris buffer. The pots were then placed in a growth chamber. After 14 days the seedlings were separated from the resin. The root exudate was then extracted from the resin. The density of the barley plants in the experiment varied between 1 and 32 plants per pot.

To examine the active compounds collected in the root exudate, a bioassay was performed with three test species, *Stellaria media*, *Viola arvensis* and *Lolium perenne,* using multidishes where each test plant could be tested separately. The root exudate extracts were diluted with distilled water and distilled water was used as a control. The test species were pre-germinated for 7, 9 and 3 days, respectively, before being placed in the multidishes with diluted root exudate extract. The multidishes were kept in a growth chamber for one week and the root lengths of the test plants were measured before and after the test period. The experiment was repeated.

The results showed that the allelochemicals extracted from the barley root exudates at all plant densities inhibited the root growth of the test species compared with the control. Preliminary results indicated also that the density of barley plants affected the production of allelochemicals from individual plants.

The occurrence of annual life forms in different weed beet populations in the Czech Republic

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Weed beet (*Beta vulgaris* subsp. *maritima* x subsp. *vulgaris*) is a serious problem in beet production areas of the Czech Republic. It was introduced into our agroecosystems as a seed impurity when the beet seed started to be imported from southern European countries inside the native range of wild sea beet (*B. vulgaris* subsp. *maritima*, syn. *B. maritima*). It has spread rapidly through sugar beet fields and is a limiting factor of sugar beet production. Beet as a crop is a typical biennial plant with some individuals bolting in the first year of vegetation. Bolting occurs usually as a reaction to environmental conditions – mostly low temperature during critical phase of ontogenesis. Wild sea beet is the second of weed beet progenitors and appears as annual, biennial or perennial herb. The weed beet is widely reported to be annual. This is one of the most significant biological properties to make it a serious weed. In field crop stands, biennial or perennial forms are not able to reproduce so their portion should be very low. They do not produce flowers in crop stands so they can not enrich the soil seed bank, but they act as crop competitors and they can also decrease crop quality when harvested together with the crop tubers. In crop stands, biennial or perennial forms can only be managed mechanically in the inter-row space. Treatment with non-selective herbicides that is widely applied to control annual weeds and bolters can not be effective because these weed beets and the crop plants are the same size.

We tested offspring of plants from 11 different populations of weed beet collected in sugar beet stands in different regions of the Czech Republic to obtain the occurrence of annuals in each of them. Mother plants were collected in following locations: Caslav, Libochovicky, Loucka, Okor, Ostrovacice, Suchdol u Caslavi, Svrkyne, Satov, Trnene Pole, Tursko, and Zvoleceves. Collected seed clusters were sown on the experimental field of the Czech University of Agriculture in Prague – Suchdol. From each location, the offspring of 10 (8-11) plants counting approx. 100 seed clusters were sown in May. During the vegetation period, plants in generative phase were counted and taken off the plots. At the end of vegetation, remaining plants in vegetative phase were counted. Comparing numbers of flowering plants with those that remain in the phase of leaf rosette, the rate of annuality was calculated.

At the end of vegetation, we obtained the following data on the portion of annual individuals among populations (in alphabetical order): Caslav 63.1%, Libochovicky 91.4%, Loucka 79.3%, Okor 59.6%, Ostrovacice 70.7%, Suchdol u Caslavi 90.%, Svrkyne 54.3%, Satov 77.2%, Trnene Pole 59.3%, Tursko 91.5%, and Zvoleceves 70.5%. Results showed that the percentage of annual plants varied from 54 to 91% with the average of 73%. The lowest numbers of annuals were found among the offspring of the plants from Svrkyne (54.3%), the highest numbers from Libochovicky (91.4%) and Tursko (91.5%).

Our results show that weed beet population differ in the percentage of annual individuals and the differences are statistically significant (statistical analysis – see poster). The reason could be the different origin (populations with lower rate could originate from founder plants with higher tendency to be biennial or perennial) or in recent cross-breeding with crop plants that can increase the portion of biennial plants among the weed beet population.

Comparative germination ecology of 22 annual tropical weeds

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Seed dormancy pattern is an important species attribute to understand to be able to predict seedling emergence. Dormancy level may change over time and/or in response to environmental events, greatly affecting the temporal pattern of germination. We investigated 22 annual weedy species common on arable land in eastern Ethiopia. Most of them were non-native, 10 belonged to Asteraceae, 2 each to *Boraginaceae* and *Solanaceae*, and the remaining eight were single representatives of other familes (*Primulaceae, Papaveraceae, Acanthaceae, Chenopodiaceae, Brassicaceae, Malvaceae, Lamiaceae, Polygonaceae*). The seeds were subjected to three different pre-treatments: cold (5 °C) or warm (23 °C) incubation, or dry storage at 23 °C, 30% RH, all in darkness, for up to 30 weeks. Germination were then tested at four temperature regimes either in continued darkness, or supplied with light during daytime.

We use the term "dormancy pattern" while referring to what environmental events that reduce and, if applicable, induce, dormancy. Following this, also species/seed batches with considerable germination when fresh can show a dormancy pattern by responding to pre-treatment with increased (decreased) germination and/or a widening (tightening) range of germination environments acceptable for germination. To focus on possible changes, not on germination per se, the differences between germination of fresh seeds and germination after pre-treatment, were used in principal component analysis. This enabled us to group species with similar responses to the pre-treatments, and to identify under which conditions dormancy changed most.

The most important differentiating factor among species in PCA was germination preferences: weather they expressed a response to pre-treatments when tested in both light and darkness or only when tested in light. Most species responded only/mostly in light (e.g. *Anagallis arvensis* and *Galinsoga parviflora*), which in practice means that soil disturbance has to occur to make buried seeds germinate. Some species, e.g. *Datura stramonium*, germinated nearly as well in darkness as in light. It was also important whether cold or warm pre-treatment reduced dormancy. A number of species responded with increased germination after all three (e.g. *Acanthospermum hispidum*) or to both warm and cold pre-treatments (e.g. *Parthenium hysterophorus*), but some showed a clear response after only cold (e.g. *Verbesina encelioides*) or warm (e.g. *Trichodesma zeylanicum*) pre-treatment. We conclude that in this weed flora, time *per se* is as important as specific environmental events reducing the degree of dormancy in seeds.

Considering the relatively small seasonal temperature differences in the study area, and the geographical distribution of the species covering areas without a pronounced cold period, it is noteworthy that so many species responded clearly to a cold pre-treatment. This suggests that this dormancy reduction pattern is an evolutionary conservative character. The response could remain from before development of the actual species, from hypothetical ancestral populations for which dormancy reduction during cold periods was favourable. The response could also be a result of evolution of a seed dormancy pattern with distribution of germination of each cohort over time regardless of current environment, thus, dormancy reduction during a cold period may have been a response not useful, neither harmful, during the evolution of the present species.

Morphological differences of *Echinochloa crus-galli* (L .) P. Beauv. Populations in Turkey

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Echinochloa crus-galli is an annual weed that is native to Asia and found throughout the world. The broad ecological tolerance and competitive ability of *E. crus-galli* makes it particularly successful weed in over 60 countries in rice fields. Phenotypic and genetic variability among *E. crus-galli* ecotypes would be influenced by agricultural practices, crop characteristic, geographic location and herbicide pressure. Differences between weed populations may affect response of chemical or biological control. Thus, the objective of this study was to evaluate the ecotypic variability of *E. crus-galli* collected from different locations in Turkey by means of morphological characteristics.

Echinochloa crus-galli seeds were collected from 34 locations in Turkey. At each location, seeds were randomly collected from five different sites in rice growing areas. The distance between sampling sites within each location was 5-10 km to prevent natural seed dispersal. *Echinochloa crus-galli* seeds were grown under glasshouse conditions and the seeds were grown in pots containing 5 kg of paddy field soil. Pots were arranged in a complete randomize design with five replications. Water levels were maintained at 5 cm above soil surface from thinning to maturity. The pots were watered and fertilized according to the regional standard. The harvested plants were collected in paper bags, dried for 3 d at 70 ^{o}C and weighed for biomass. Morphological characteristics such as germination speed (Day After Sowing), seedling growth rate, tillering number, leaf area index (cm^2), plant height (cm), spikelet length (cm), above-ground biomass (g), root dry weight (g), number of seeds and 1,000 seed weight (g) were measured. Morphological characteristic assessments were subjected to SPSS hierarchical cluster analysis (a statistical method used in the construction of a dendrogram). The diversity was presented using a created dendrogram. Morphological characteristic data were transformed (square root) before the SPSS analysis. Six groups were classified at a taxonomic distance of 13.5 in the dendrogram using average linkage. The first group consisted of 13 ecotypes. These ecotype are respectively P16-P29-P6-P26-P27-P9-P23-P25-P22-P30-P24-P5-P8. The second and fourth groups consisted of 6 ecotypes. Ecotypes of group two were P7-P32-P21-P28-P33-P15 and ecotypes of group four were P12-P13-P4-P20-P11-P34. Groups three, five and six each consisted of three ecotypes. These were P2-P3-P1, P17-P19-P18 and P10-P31-P14 respectively.

Morphological characteristics, such as germination speed, were lowest (1.5 DAS) for group one. Germination speed of group one and group six varied between 1.5 and 25.35 DAS respectively. Plant heights were the highest (113.95 cm) for group six and lowest (118.90 cm) for group two. Leaf areas were the lowest (15.92 cm ^{2}) for group three and highest (37.28 cm ^{2}) for group five. One thousand seed weights (g) were the lowest (2.30 g) for group three and lowest (0.10 g) for groups two and four. Plant height (124.47 cm), above-ground biomass (59.21 g) and seedling growth rate (53.20 DAS) were the hıghest for group three and group four had the highest spikelet length (18.16 cm). There was no seedling growth rate or tillering number for group five.

High morphological variability was found among individual *E. crus-galli* ecotypes and varied with geographic locations. For example, characteristics such as seedling growth rate and tillering number of group five were found to be different from other groups. The results showed that variability in morphological characteritics had been observed even from the same location. The variability of *E. crus-galli* ecotypes might be due to adaptability to the geographic locacitons and weed management practices.

The effect of gap size on seedling establishment, growth and fruit production of *Tribulus terrestris*

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The changes introduced in agricultural practices in some areas of Catalonia (NE Spain) could contribute to increase the spread of the summer annual *Tribulus terrestris* L. (Zygophyllaceae), traditionally considered a ruderal species in the region, and allow it to colonise crop fields. For this reason, we started a programme in 1999 to study the potential of the *T. terrestris* population to expand its range by analysing its capacity to colonise gaps of four different sizes (A=0.01, B=0.04, C=0.09, and D=0.16 m^2) created by removing vegetation without disturbing the soil (canopy gaps). A gap can be defined as a type of release from resource competition. Compared to intact vegetation, it presents a reduction in competition for one or more resources (light, water, etc.) and changes in other environmental factors (soil temperature). The different stages of seedling establishment may be affected by gap conditions. The experiment started in May 2003 on an unsown plot located in a corner of a field with a forage pea crop at Caldes de Montbui, Barcelona (46°12'N and 4°33'E). *T. terrestris* emergence and mortality were monitored in the gaps from May to October. Four blocks (with 4 replicates randomly assigned within each block) were considered because a gradient in the seedbank density could be expected due to the proximity of an unsurfaced road (edge effect). At the end of the season, surviving plants were collected and oven dried at 80ºC for 48 hours, and fruit and total aboveground dry weights were measured. Analyses of variance and mean separation (Student-Newman-Keuls) considering block and gap sizes as mean sources of variance were performed on seedling emergence and plant dry weights. Over the season there were two short periods or flushes of germination (after rainfall episodes of 14.6 mm and 43.4 mm, respectively). A total of 253 seedlings emerged during the season in the total surface area of 4.76 m^2 without vegetation. The number of seedlings m^{-2} (mean values) corresponding to the four gap sizes were: 12.5 in A, 51.2 in D, 56.3 in C, and 65.0 in B. The level of emergence observed in the smallest gaps (0.01 m^2) was significantly lower ($P<0.05$) than in the other gaps. None of the seedlings that emerged in the first period survived the drought recorded from June to mid August. There were no significant differences in total aboveground (TA) and fruit (FR) biomass of plants harvested at the end of their annual cycle in gaps of the sizes B, C and D. The proportion FR/TA was quite close to 50%. Likewise, mean aboveground biomass per plant and mean fruit biomass per plant observed in gaps B, C and D did not exhibit significant differences. In contrast, block was a significant effect for all the variables analysed. Thus, the emergence of seedlings and the development of plants (including the reproductive fraction) were clearly influenced by the distance from the field edge. In conclusion, considering gap sizes of 0.01, 0.04, 0.09, and 0.16 m^2, the establishment of *T. terrestris* was affected by gap size, because the smallest gaps registered levels of emergence about four times lower than the larger ones. Therefore, reducing the surface area of bare soil, particularly during May and June, when the occurrence of effective rains may facilitate the emergence of seedlings, would contribute to prevent weed spread.

Variation in *Beta*-complex revealed by RAPD markers

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Most domesticated plants are part of crop-weed-wild complex within which genetic exchange occurs regularly. The *Beta*-complex provides a scientific model for studies of gene introgression and local evolution, but also raises practical issues in crop protection through the presence of weed beet and in biological conservation of the wild forms. With the advent of transgenic sugar beet varieties research is focused on the potential gene flow from GM sugar beet cultivars to weed beet and other wild beet relatives. Numerous studies have been devoted to assess the genetic diversity among sugar beet lines and in germplasm collections, but so far there have been no published studies on the genetic diversity and distance between the weed and crop beet varieties over a local scale. A total of 136 accessions – consisting in 40 sugar beet varieties (commonly grown in the Czech Republic), 86 weed beets (Czech populations) and 10 sea beets *B. vulgaris* ssp. *maritima* (French or Italian origin) were analyzed using 30 randomly amplified polymorphic DNA markers. A 61.1% polymorphic bands and a genetic similarity matrix based on Nei and Dice's index ranging from 95.7% to 81.4%, were obtained, showing a high level of divergence among populations. The distances ranged between 0.043 and 0.206, with the closest genetic similarity being found for the individuals of the weed beet from Trněný Újezd and Únětice. Differentiation among the weed, wild and variety groups was reflected in medium significant among-population variation (2.83%, $P<0.065$). It was found 29.37% of RAPD variation among all populations within groups ($P<0.0001$), and 37.80 within populations ($P<0.0001$, AMOVA). Outcrossing plants have generally higher allozyme diversity within populations and lower genetic divergence among populations. In most species genetic diversity is greater among wild populations than among crop populations in terms of numbers of alleles. In this case, the number of alleles among sugar beet varieties was higher than in weed and wild populations, although differences were not statistically significant. The additional measure for partitioning genetic variation was obtained by the Shannon-Wiener index (SW) because it is relatively insensitive to the inability of RAPD to detect heterozygous loci. The genetic diversity as estimated by SW showed the highest level in sugar beet varieties (1.54±0.49). The dendrogram separated the individuals according to their geographical and taxonomic designations. *B. vulgaris* ssp. *maritima* was clearly distinct from weed beet and sugar beet. The sugar beet genotypes clustered in one group due to the fact that they were developed from the same ascendants used in breeding programmes. The study demonstrated the intermediate position of weed beet between cultivated and wild beets. The weed beet – hybrid between sea and sugar beet - clustered in two different groups according to the frequency of growing in crop rotation. In the crop rotations with higher sugar beet growing offset the similarity between sea beet and weed beet was lower.

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Effects of interactions between germination environment, seed provenance and soil disturbance on emergence of *Chenopodium album*

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Soil disturbance may influence weed emergence. Positive influences could occur by exposing seeds to light or increasing oxygen in the soil, by reducing water logging, or by breaking soil crusts. Negative effects include killing or burying seeds that have already started to germinate. Our hypothesis was that the later the soil was disturbed, the fewer seedlings would occur because of the preponderance of the latter negative effects. In the field, a disturbance event could be affected through preparation of seedbeds or mechanical weed control. Added knowledge about the effects of such disturbance events on any modification of emergence patterns or depletion of the seedbank will be beneficial. An experiment commenced in autumn 2005 aimed to assess the influence of the treatments on the magnitude and distribution of emergence of *Chenopodium album* agg., variability of the common seedlot among locations, and differences between the common seedlot and the local seedlot within a location. A common seedlot of *C. album* from Denmark was used at 11 locations: Canada, Czech Republic, Denmark, Finland, Italy, Norway, Portugal, Spain, Sweden, United Kingdom and USA (Illinois). A local seedlot of *C. album* was also included at each site. 1000 seeds of either seedlot were mixed into a standard soil mixture in 24 plots of app. 0.035 m^2 to 5 cm depth in autumn 2005. The treatments were disturbance, simulating tillage, at 5 different times before, at and after emergence in spring 2006 in undisturbed soil. In no cases did the treatments result in the expected decrease in number of emerged seedlings over time from the first to the last treatment for the common seedlot. However, except for two locations, a decrease was seen for at least some of the later treatments, indicating that our hypothesis could be true for these treatments. The reason for less emergence after early disturbance could be that this disturbance was often performed in very moist soil, possibly resulting in dense soil with less aeration and a crust that was difficult to penetrate. Almost all treatments resulted in more emergence than the no disturbance treatment. However, the effect differed greatly among locations. At one location, emergence was increased to 7 times that in untreated soil, while at another the largest increase was only about 1.3 times greater than the untreated soil. Most locations reached between 2 and 6 times the number of emerged seedlings in disturbed compared to untreated soil. The actual numbers also differed greatly among locations: the lowest emergence varied between 10 and 150 seedlings, the highest between 90 and 380 seedlings. Noticeable time lags between disturbance events and emergence flushes were not consistent among sites and are most likely explained by environmental variability at the time of disturbance. Generally, disturbance in a dry soil resulted in a much longer lag phase than a disturbance in a moist soil, or in a dry soil shortly before a precipitation event. Initial results showed significant differences in emergence patterns between common and local seedlots. At half of the locations the emergence from local seedlots was lower – in some cases much lower – than the common seedlot from Denmark, while at the remaining locations they were approximately the same. Also the reaction to timing of treatments differed between seedlots within some of the locations. All of these results warrant further analysis and exploration, and a new series of experiments is being planned. Despite variation amongst locations, the results overwhelmingly demonstrate that seedling emergence of *C. album* reacts positively to superficial soil disturbance. Further and more detailed information can be found at http://www.ewrs.org/GEGWG.

An investigation on weed seed viability in different depths of compost piles

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Adding fresh manure to cropland results in an increased weed population from seeds present in the manure. The composting process can destroy weed seed viability. In an experiment seed viability of sixteen important weed species in forage fields were investigated after a composting process.

Viability of all of the seeds were tested by Tetrazolium chloride at the start of the experiment and prior to exposure to the composting process . This percentage viability was used as a base to compare seed viability after the composting process. Seeds were enclosed within nylon mesh bags and buried in two compost piles. One of the piles was covered by plastic sheets the other was left uncovered. The moisture content of the manure was approximately 70% and was made from cow manure. The mesh bags containing the seeds were buried at depths of 0.5 m, 1 m and 1.5 m from the surface for a period of 4 months during summer. The seed packets were removed on a monthly basis to test for seed viability. The experiment was carried out using a factorial design on randomized complete design with four replications, factor A (putting packets in at three different depths) and factor B (removing packets after 1, 2, 3 and 4 months). The seed viability of covered and uncovered piles for each species were compared using a t- test.

The results showed a linear correlation regression dependence of weed seed viability lost in compost on composting temperature. The compost piles tended to be hotter temperatures at 0.5 m (60-70 °C) than at 1 and 1.5 m. This was probably because the pile was better aerated at 0.5 m. Weed seeds lost their viability at the 0.5 m depth where they had been exposed to the greatest temperatures. In the covered compost pile, seed viability loss and temperature were lower than the uncovered compost pile. Almost all of the sixteen weed species were killed following 2 months exposure at 0.5 m in the uncovered compost piles. Exceptions inlcuded *Cuscuta monogyna, Goldbachia laevigata, Chenopodium album* and *Amaranthus retroflexus* which were killed after 3 months burial.

The experiment revealed that the composting process with adequate oxygen and water that generate high temperature (above 60 C) can destroy weed seed viability after 3 months.

The effect of the site on the germination of prickly lettuce achenes (*Lactuca serriola* L.)

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Prickly lettuce (*Lactuca serriola* L.) is an adventive annual or biennial species of the *Asteraceae* family. The plants are excessively spread on uncultivated non-agricultural land throughout the Czech Republic and are spreading to arable land as well. The purpose of this research was to determine the level of germination of achenes growing on non-agricultural land; and based on this level, to estimate the impact which prickly lettuce populations growing on non-agricultural land have on the weed infestation of arable land. For our research in 2002 and 2003, three different sites were chosen: a field (arable land), a balk (adjacent to arable land) and a rubble heap (distant from arable land). At each site, 50 plants were selected, and their mature achenes were collected. Eight different variants of germination conditions were used. For every variant, 8 repetitions with 15 achenes each were carried out. Before germination, the achenes were exposed to different environmental conditions. Half of the achenes was exposed to -20 °C in a freezer for a period of 30 days, while the other half was stored at room temperature and was not exposed to sub-zero temperatures. Then, the whole process of germination itself took place at a temperature of 18 °C and on two different substrata: either on three layers of damp filter paper in Petri dishes, or on a 30-mm layer of siliceous sand. Half of the achenes on both substrata germinated in daylight for 12 hours. A quarter of the achenes in Petri dishes germinated in the dark, while a quarter of the achenes on the siliceous sand was covered in a 5-mm layer of sand. The obtained data were analysed by the analysis of variance (ANOVA) using the UNISTAT software, with a subsequent test of differences in average values using the method of the least significant difference (LSD).
The total average germination of all variants prickly lettuce achenes was 84 %. The differences in the germination of frozen (82.4 %) and non-frozen (82.2 %) achenes were statistically insignificant. Germination in the Petri dishes (83.7 %) and on the siliceous sand (80.1 %) also showed statistically insignificant differences. The germination of achenes which matured in 2003 (79.8 %) was considerably lower than that of the achenes which matured in 2002 (84.8 %). The achenes germinated significantly more (90.9 %) in 12 hours of daylight compared with germination in the dark (73.8 %). The germination of the achenes which had matured in the balk (78.6 %) was significantly lower in comparison with the germination of the achenes from the rubble heap (86.0 %). The results of the germination of the achenes that matured in the field (82.3 %) did not significantly differ from the germination in the balk or the rubble heap. The achenes collected in the non-agricultural land (i.e. balk and rubble heap) showed a very high level of germination (approximately 80 %). A high level of germination of achenes and their very easy spreading by wind to long distances are the most important factors which make *Lactuca serriola* a dangerous infesting weed in uncultivated agricultural land. These sites act as sources of renewal and complementation for the populations of prickly lettuce on arable land. The qualities of reproduction of the prickly lettuce make it a weed species which is able to spread relatively quickly. Uncultivated sites (i.e. balks and rubble heaps) then work as supplies of new achenes, which achieve a higher level of germination than the achenes that have matured in fields.

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Influence of diurnally alternating temperatures on fat-hen (*Chenopodium album* L.) seed germination

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Chenopodium album L. (fat-hen, common lambsquarters, goosefoot) is a common annual species regarded among the most widely distributed weeds in the world and mainly troublesome to potatoes, vegetables and other spring-sown crops. The aim of this study was to investigate the responses of several temperatures (constant or alternating) on seed germination of this invasive species. Therefore, *C. album* seeds were randomly collected from a potato crop in Greece, in the summer of 2001 and placed in germination Petri dishes. These dishes were placed in incubators set to a 12/12 h day/night and at four temperature regimes (10/20, 20/30, 30/40 and 40/50 °C) and rated daily for germination over a three-week period. It was found that the germinability of the seeds was the highest for the 20/30 °C treatment and lowest for the 40/50 °C treatment (88 and 32 %, respectively), while the 10/20 and 30/40 °C regimes resulted to intermediate values. The low germination percentage of the seeds at 40/50 °C was possibly due to the usually adverse effects of high temperatures on seed germinability of several plant species. The second laboratory experiment was designed to determine the effect of the magnitude of the temperature amplitude on seed germination and to compare germination rate and percentage. In that case, the incubators were set to the temperature regimes of 25/25, 22.5/27.5, 20/30 and 17.5/32.5 °C. Our results indicated that the seed germination rate of *C. album* was significantly increased after a shift of daily temperature amplitude from 0 to 15 °C. The final germination percentage and rate for the constant temperature treatment (25 °C) were significantly lower (by 27 to 66 % and by 5 to 28 %, respectively) than the corresponding values for all the alternating temperatures. It is also noticeable that *C. album* seed germination was stimulated, despite that the daily mean temperature was the same as the temperature difference increased from 0 to 15 °C. Additionally, in order to investigate the potential utility of our results in agricultural practice and to examine some of the effects of soil solarization on soil temperatures, a preliminary field experiment was also conducted in 2001 for four weeks. The experiment included two treatments, solarized and nonsolarized, arranged in a totally randomized design with four replications. Transparent polyethylene (PE) sheets, 0.05 mm thick, were used to cover the plots (plot size was 2 m long by 2 m wide), while soil temperatures at 5 cm were monitored every 20 min with thermistor sensors for both solarized and control plots and averages were recorder hourly by a data logger. Our results indicated that the soil temperature at 5 cm for the uncovered plots fluctuated between 28.4 and 38.6 °C with a daily mean at 33.1 °C (the mean temperature difference for the control was 9.2 °C), whereas soil solarization (covered plots) increased the mean temperature to 41.5 °C and the mean temperature difference to 14.8 °C. Consequently, it seems that a possibly uniform and massive germination of *C. album* seeds could be enhanced by means of solarization, as long as -judging from our second laboratory experiment- the achieved temperature alternation is crucial for their germination. Conclusively, this study is a preliminary attempt towards investigating the effects of alternating temperatures on the depletion of seed bank by promoting massive seed germination of *C. album*. Furthermore, our results indicate the potential role of solarization as a management tool for the effective control of fat-hen, by means of the increase of the daily temperature range. Indeed, solarization could be taken into account and combined with other practices, in order to contribute to a long-term population reduction of this weed.

Effect of plant size and hardening conditions on frost tolerance of *Elytrigia repens*, *Cirsium arvense* and *Sonchus arvensis*

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Due to climate change, the global temperature and the concentration of CO_2 are expected to increase within the next 100 years. In addition, more variable climate during the autumn and winter is expected in Norway, with more precipitation and clouds, i.e. reduced irradiance level. The aim of this study was to reveal if this expected climate change in autumn will alter the hardening and thus the frost tolerance in rhizomes or propagating roots from plants of various sizes (planting time) and ecotypes (59°N and 63°N) of *Elytrigia repens*, *Cirsium arvense* and *Sonchus arvensis*. One piece of rhizome (*E. repens*) or root (*C. arvense* and *S. arvensis*) was planted 1 June, 30 June and 1 August 2005 in 5 cm pots, and placed under greenhouse conditions at Særheim (58°47'N, 5°41'E)). After 2-4 weeks the plants were transplanted to 10 L plastic bags and placed outdoors. Plants from the two last planting times were placed in six different environments on the 1 September 2005. These included an increase in temperature of 2-2.5 °C, an increase in CO_2–concentration (550 ppm vs. 370 ppm), or an increase in both factors, compared to a control in field chambers, and with 30% shading outdoors compared to a control outdoors. The plants from the first planting time were placed outdoors without any change in environment. On the 15 November 2005 and 24 January 2006 the plants were taken out of the environments. The roots or rhizomes of the plants were cut into pieces of 5 cm or 2 nodes, respectively, and planted in 12 cm pots at 2 cm soil depth. These pots were subjected to a control at 2 °C and 5 different freezing temperatures of -3 to -18 °C depending on species. The freezing procedure started at 2 °C, and the freezing rate was 1 °C h^{-1} down to the minimum temperature, interrupted by 12 h at -2 °C to remove free water on/in plant parts. The minimum temperature was kept for 24 h and followed by thawing of 1 °C h^{-1} up to 2 °C interrupted by 1 h at 0 °C. Then, the pots with roots/rhizomes were placed for four weeks under greenhouse conditions. Dry weight of above-ground plant parts and the root/rhizome viability (0=dead, and 5=no visual damage) were assessed at the end of this period. Some preliminary results from this study are presented here. As expected, roots or rhizomes from larger plants (early planting time) had a higher frost tolerance than when coming from smaller plants (late planting time). Assessed as root/rhizome viability for the medium planting time, the Northern ecotype of *E. repens* had the highest frost tolerance (LT_{50} (temperature that killed 50% of the roots/rhizomes) ≈ -18 °C), followed by the Southern ecotype of *E. repens* (LT_{50} ≈ -15 °C), *S. arvensis* (LT_{50} ≈ -14 °C in November, and -18 °C in January) and *C. arvense* (LT_{50} ≈ -8 °C) at both test times, unless otherwise stated. For *S. arvensis* in November, a warmer climate prior to freezing reduced the frost tolerance, while for all other species in November and all species tested in January the previous environment did not have any effect on the frost tolerance. The above-ground dry weights showed the same pattern in the results as root/rhizome viability concerning frost tolerance, except for *S. arvensis* tested in November, which had a maximum growth at -12 °C, and almost no growth at 2 °C. For *S. arvensis* at -12 °C the dormancy was probably broken while higher temperatures did not break dormancy. For the freezing test in January, the above-ground dry weight was the same from 2 to -12 °C in *S. arvensis* because dormancy was broken at this time.

Dormancy cycle in *Solanum nigrum* seeds

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Solanum nigrum L. is considered as a weed of many crops in different countries. Increased knowledge regarding the seed dormancy characteristics would facilitate development of effective weed management programs. The objective of this experiment was to characterize the seasonal dormancy cycle in this species. The experiment was carried out 2004 to 2006 in a randomized complete block design with four replicates. Portions of 100 seeds were buried in pots outdoors in November and exposed to natural temperatures. At monthly intervals, samples of the seeds were randomly exhumed and germination was tested in incubators at three different germination conditions including i) high temperature and light (HL) at 25/15 °C, with 16/8 hours light/darkness, ii) the same temperature regime in complete darkness (HD), and iii) low temperature and light at 18/8 °C, 16/8 hours light/darkness (LL). The initial level of dormancy was investigated in a germination test of fresh seeds. Germinability was 28.5, 0.5 and 0% in HL, HD and LL, respectively. The results of the burial experiment showed that seeds of *S. nigrum* have an annual dormancy cycle indicating that cold and warm temperatures basically cause relief and induction of dormancy, respectively. Thus, the species principally behave as a summer annual. After one month of burial, germination was complete or almost complete from December to July when exhumed seeds were tested in HL. High percentages of germination (>90%) were achieved in LL, and HD, after 4 and 5 months of burial, respectively. Surprisingly, germination was reduced with 44 and 57% in May in HD and LL, respectively, in the first year of burial. This was followed by an increase in germination during June and a peak in July. This short-lasting induction of dormancy was repeated in June the second year, but was only observed in HD where germination was reduced by 33.5%. The main dormancy induction started in July and lasted until September, when almost all seeds were dormant. In the first year, dormancy breaking started in October and in December germination was 97, 75.6, and 71% in HL, HD, and LL, respectively. The second year a reduction in germination was observed when exhumed seed were tested in HD and LL in January and February, respectively. From July to termination of the experiment in November 2006, decrease and increase in germinability of the seeds resembled the pattern of the first year. The present study showed that requirements for germination the first winter decreased as time of burial increased. Under prolonged winter conditions, seeds seem to gain the ability to germinate in both light and darkness. There was a reduced germinability of buried seeds after December 2005 until May 2006 when tested in HD as compared to those tested in HL. This shows that light plays an important role in triggering seed germination during certain periods. Thus, germination in this species is to some extent phytochrome regulated, whereas soil temperature is a key factor regulating the seed dormancy cycle. In conclusion, seasonal changes in the breakage and induction of dormancy were similar throughout the whole period of the experiment, suggesting consistency in the seed dormancy pattern of *S. nigrum*. Thus, induction of seed dormancy during summer inhibits late germination and subsequent plant death in autumn.

Seed propagation characteristics of red rice (*Oryza sativa*) as a weed

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Red rice (*Oryza sativa* L.) often becomes one of the most troublesome paddy field weeds in rice-producing countries. Weedy red rice has unique seed propagation characteristics that are different from those of cultivated rice, including strong seed dormancy and a shattering habit. These characteristics are important for the survival of red rice as a weed in paddy fields. In this study, we examined the seed propagation characteristics of red rice from different parts of the world in the climate of Tsukuba, Japan (lat 36° 0′29″ N, long 140° 1′18″ E, 50 m ASL, annual mean temperature 14.3 °C, monthly mean temperature max. 25.7 °C and min. 3.6 °C, annual rainfall 1400 mm, monthly rainfall max. 184 mm and min. 51 mm). The Institute of Genetic Resources, Kyushu University (Japan) and National Small Grains Research Facility, USDA-ARS provided 80 and 59 red rice accessions, respectively. These red rice accessions collected from North and South America (United States and Brazil), Europe (Italy, Hungary, and Russia), South and Southeast Asia (Pakistan, India, Nepal, Sri Lanka, Indonesia, and the Philippines), and East Asia (China, Korea, and Japan) were studied. The numbers of shattered seeds (spikelets) at harvesting time (September 2005) and the numbers of germinated and dormant seeds the next spring (May 2006) were determined. The characteristics of each accession were also examined to classify it as closer to wild or domestic using Morishima's discriminant analysis. We found that red rice accessions from most of the countries where accessions were collected had a strong shattering habit. In particular, more than 500 seeds per plant of red rice accessions collected from the United States, Brazil, India, and Japan shattered before harvest. The shattered seeds of red rice from the United States and Brazil were able to overwinter in the Tsukuba climate; about 20% of the shattered seeds germinated the next spring, and the rest of the shattered seeds survived as dormant seeds, forming a seed bank in the soil. Red rice from India and Pakistan showed strong dormancy, with about 50% of the shattered seeds surviving as dormant seeds, but few of the shattered seeds germinated the next spring. In contrast, Japanese red rice, particularly a accession collected recently from Nagano prefecture, had a strong shattering habit, and most of the shattered seeds germinated the next spring but did not survive as dormant seeds. Some of the Korean red rice accessions had characteristics similar to the Nagano red rice. Discriminant analysis on the wild and domestic characteristics of the accessions indicated that red rice from North and South America, Europe, and South Asia (Pakistan, India, Nepal, and Sri Lanka) had characteristics closer to those of wild rice, in contrast to most of the red rice accessions from Southeast Asia (Indonesia and the Philippines) which showed more domestic characteristics. Red rice from East Asia, except that from Nagano, showed a wide variation between wild and domestic tendencies, although the red rice from Nagano clearly showed more wild characteristics. The differences in the characteristics of the red rice accessions of different regions might reflect the utilization or ferality of red rice in these areas. Red rice collected from Nagano has become a serious weed problem in Japanese direct-seeded paddy fields since the 1970s. Other red rice accessions with strong shattering and dormancy habits might also be able to survive as weeds in Japanese paddy fields, even if they have not been considered weedy accessions in the countries from which they were collected. In conclusion, the seed propagation characteristics of red rice vary from region to region, and they may reflect the cultivation systems (for example rotation or continuous cropping) and weeding systems (such as the practice of hand weeding) used in these regions. We should take great care when cultivating new accessions of red rice, especially when using the direct-seeding system, because these accessions could easily become weedy if they have characteristics that allow them to survive in the field, such as shattering.

Seed dormancy in *Digitaria sanguinalis*: the role of the spikelet bracts

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Many weed species exhibit seed dormancy. In particular, several studies have presented experimental evidence that most propagules of hairy finger-grass (*Digitaria sanguinalis* (L.) Scop.) cannot germinate after shedding. The objective of this contribution is to elucidate the role of caryopsis covering structures in seed quiescence. Germination trials were performed with one lot of one-year-old seeds and two lots of fresh seeds tested immediately after harvest. The seeds were gathered from two fields located near Barcelona (north-east Spain). The one-year-old seeds were collected in September 2004 and dry stored at room temperature until tested. The first lot of freshly harvested seeds was obtained at the beginning of November 2005, and the second lot was collected from the same plant population 10 days later. Both lots were harvested by gently rubbing the mature inflorescences. For all three lots, spikelets (caryopsis enclosed within the lemma and palea, one bracteole from a sterile floret and glumes) and caryopses (hand dehulled spikelets) were tested. In addition, an intermediate level of dehulling (removing only the bracteole and the glumes) was tested with the first freshly harvested lot. All germination trials (250 seeds distributed in 5 Petri dishes) were carried out at 20 ºC (12h darkness)/30 ºC (12h light). Seeds were considered to be germinated with the emergence of the radicle. Tetrazolium tests were performed on non-germinated seeds after an incubation period of 30 days. The final percentages of germination were compared using an analysis of variance followed by Tukey's honestly significant difference (HSD) test after arcsine transformation of data (P=0.05).

The results indicate that the one-year-old seeds were non-dormant. No significant differences were found in the cumulative germination percentages between hulled and dehulled caryopses (> 90% in both cases). However, it is worth noting that the germination rate of dehulled caryopses was higher than that of the hulled ones. In particular, in just three days the germination percentage of dehulled caryopses reached 95%, but only 60% in hulled caryopses. In this case, the percentage exceeds 90% after 17 days from the beginning of the germination trial.

The mean germination percentage of the seeds from freshly collected spikelets was 16% (0-36%, 2 lots). In contrast, when the spikelets were dehulled the mean germination percentage reached 90% (72-100%, 2 lots), whereas when only the glumes were removed it decreased to 19% (4-27%, 1 lot). These results suggest that lemma and palea have a key role in delaying germination after shedding. Previous studies on other species showed that this externally imposed dormancy can be a consequence of these covering structures: (i) restricting gas exchange and/or water uptake, (ii) containing germination inhibitors, (iii) modifying the light requirements of the embryo, (iv) constituting a mechanical barrier for the emergence of the radicle, or (v) being involved in more than one of these mechanisms. Furthermore, significant differences were detected between germination percentages of freshly harvested seed lots. Germination percentages of both hulled and dehulled caryopses were significantly higher in the second lot (96% and 28% respectively) than in the first lot (83% and 3% respectively). These differences suggest the occurrence of embryo dormancy in freshly shed seeds.

In conclusion, the results show that seed dormancy in hairy finger-grass is mainly caused by caryopsis covering structures, but some embryo dormancy mechanisms could also be involved.

Allelopathic potential of *Helianthus tuberosus* L. dried leaf tissues

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Helianthus tuberosus L., the common Jerusalem artichoke, is a member of the Asteraceae family and is native to North America. During the last years, researchers increased their interest in the Jerusalem artichoke because of the high content of inulin in the tubers that has a number of current human consumption and industrial applications, including the potential production of bioethanol. Detrimental economic relevance of this species is associated to its invasive behaviour, which is enhanced by the presence of tubers and rhizomes and by its allelopathic potential. Allelopathy may be favourable to *H. tuberosus* cultivation, but could potentially affect successive crops.

Experiments were conducted in the greenhouse to evaluate the effects of *H. tuberosus* on germination and seedling growth of 7 crops and 6 weed species. The crops included were *Phaseolus vulgaris* L. (green bean), *Triticum aestivum* L. (wheat), *Zea mays* L.(maize, cultivar Marano), *Pisum sativum* L. (pea), *Lycopersicon esculentum* Mill.(tomato), *Oryza sativa* L. (rice) and *Cucurbita pepo* L. (zucchini). The weeds considered were *Amaranthus retloflexus* L., *Chenopodiun album* L., *Digitaria sanguinalis* (L.) Scop., *Echinichloa crus-galli* (L.) Beauv., *Portulaca oleracea* L. and *Solanum nigrum* L. The study was carried out in pots (8x8 cm^2, 8cm height) filled with a mixture of sand and powdered *H. tuberosus* dry leaves (1.28 g per pot, corresponding to 2 t ha^{-1}). A control treatment with pots filled with sand only was also included. The number of plants per pot varied from 4 to 20, according to the species. Allelopathic potential was measured as reduction of germination, shoot height, shoot and root weight in comparison to control. Strong inhibitory effect was observed on germination of leguminous crops (70.8% on pea and 68.4% on green bean), and on several weeds such as *A. retloflexus*, *P. oleracea* and *D. sanguinalis* (46.7%, 42.2% and 32.4%, respectively). The highest inhibition of shoot height was recorded in pea (72.2%) and *E. crus-galli* (72.1%). *A. retloflexus* and *D. sanguinalis* showed the highest percentage inhibition of aboveground fresh weight (75.9% and 49%, respectively). The greater inhibition of root fresh weight was observed in pea (63.1%). Pea and *A. retloflexus* were, on average, the most sensitive species. No effect was observed on winter wheat, maize, tomato, rice and zucchini, among the crops, and on *C. album* and *S. nigrum*, among the weeds. Generally, shoot and root growth inhibition was observed in concurrency with reduction of germination. A significant stimulatory effect was recorded in root fresh weight of tomato. *H. tuberosus* confirmed to be allelopathic toward some weeds (e.g. *E. crus-galli*), and also against other species never reported to be sensitive (e.g. *A. retroflexus*, *D. sanguinalis*). The lack of effects on maize and wheat suggests that the introduction of *H. tuberosus* as a rotational crop could not interfere with germination and early growth of these crops. Furthermore, *H. tuberosus* residues may release allelopathic compounds into the soil, that could interfere with weeds infesting successive crops, theoretically contributing to weed control.

Bioecological traits of *Ambrosia artemisiifolia* L. in North-West Italy

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Common ragweed, *Ambrosia artemisiifolia* L. is an annual plant of the Asteraceae family originating from southern North America. In Europe this species has begun to spread since the early 1940's and nowadays it is present in several European countries, where it has become one of the major causes of summer pollinosis. In Italy, common ragweed is mainly distributed in northern regions, where, since the mid-'90s, it started to infest annual summer crops. The fast-growing importance of the common ragweed, both in agriculture and in public health stresses the need to improve the knowledge of the bioecological traits of this species in the North-Italy environment. Two experiments were carried out with the aim to evaluate: (1) the influence of storage conditions on seed dormancy, and (2) the effect of plant density on plant growth dynamics. In the first study, seeds of the common ragweed were collected during autumn 2005, in wheat stubble from a field in which the first infestations were reported in 2001. The seeds were cleaned and then stored in field conditions at room temperature, and at +25 °C, +5 °C, and –20 °C. Germination tests were performed starting from 80 days of storage (mid-February) every 15 days up to 28 weeks (end-June), in order to cover the main period of germination in a natural environment. At the first assessment, the germinability ranked in the following order: field (60%) > +25 °C (17%) > room and +5 °C (10%) > -20 °C (0%). Afterwards, germinability of the seeds stored in the field peaked to about 82% from 110 to 140 days (20 March – 20 April), and then gradually fell to no germination at 193 days (20 - June). Seeds stored at +25 °C did not show a definite trend and germination ranged from 18% to 37%. Germinability of seeds stored at room temperature and at +5 °C increased up to about 40% at 123 days (beginning of April) and remained constant till 193 days. Seeds stored at –20 °C started to germinate from the second assessment (95 days) and germinability grew following a quasi-linear pattern till 193 days, increasing about 1% every two days.

In the second experiment, carried out in field conditions, a natural infestation of ragweed was thinned to obtain densities of 4, 12.5 and 25 plants/m^2. Plant height, biomass, and leaf area were assessed starting from the 2-leaf stage until seed production. Final plant height averaged about 90 cm, without differences between densities. Final total biomass (dry weight) per square meter was directly correlated to density, as averaged 916, 936 and 1180 g at 4, 12.5 and 25 plants m^2, respectively. Final total biomass per plant was more affected by spacing, as it averaged 687, 224 and 140 g, at the same three densities. Concurrently, more biomass was allocated in the leaves at the higher densities, as the ratio leaf biomass/total biomass averaged 16.2%, 20.6%, and 21.4% at the three densities, respectively. A compensation of differences between density and biomass per plant was observed in particular between medium and lowest densities, where a small difference in terms of total biomass per square meter was recorded. The final number of leaves per square meter averaged 5900, 6600, and 9600 at the highest, medium and lowest density, respectively. At the same densities, the number of leaves per plant averaged 1160, 1590, and 4400, respectively, the maximum leaf area surface per plant averaged 210, 240, and 450 cm^2, and the corresponding LAI values were 5.4, 2.9, and 1.8.

The reproductive strategy of common dandelion (*Taraxacum officinale* Web.)

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The common dandelion (*Taraxacum officinale)* is a troublesome and widespread weed in disturbed habitats, gardens, pastures, meadows, vineyards and plantations. Damage can be significant in fabaceous crops such as alfalfa and artificial grasses. The aim of this study was to obtain information about the annual germination cycle, primary dormancy and the effect of light and dark on the germination of the seeds of *T. officinale*, as well as the regenerative capacity of different root segments. Experiments were set up under laboratory conditions and the effect of soil depth on the germination of *T. officinale* seeds was investigated under greenhouse conditions in two different soil types (a brown forest soil and a Sapric Histosol loam soil).

Under favorable conditions, seeds were able to germinate uniformly and at a high percentage two months after collection and very little seasonality could be observed. Germination ranged from 3% to 82% and the average germination, from tests run for a period of 105 weeks, was 46.60%. Seeds did not show primary dormancy and germinated immediately after collection (91%). Maximum germination was 91%, and minimum was 60%. The average germination achieved after 16 weeks was 77.81%. This could be the basis for its rapid spread and establishment Longyear (1918) and Martinková-Honek (1997) obtained similar results. Germination was increased in light (10 hours natural lighting), achieving 90.75% germination and seed germination was significantly (P <0.01) reduced (31%) under dark conditions. Seeds germinated more rapidly from the surface soil layers, than from deeper soil layers. The fact that the seeds need light to germinate, partly explains this observation and similar results have been reported in the case of *Chenopodium album* and *Ambrosia artemisiifolia* (Béres, 1994).

Greater percentage germination was observed from the soil surface and in the case of the two soil types, germination from the surface was similar (76-75.5%). However, from burial at 1 cm, 49% germination was observed in the brown forest soil, whereas 60% germination was observed in the Sapric Histosol (loam soil). This resulted in a 36% and 21% reduction in germination respectively, as compared to the surface. At a burial depth of 2 cm, germination was 37% and 41.5% for the brown forest soil and loam soil respectively and from 3 cm the germination rate was 26% and 31.5% for the brown forest soil and loam soil respectively. Minimum germination was obtained from 5 cm depth in the case of the brown forest soil, but at this depth in the loam soil the seeds of *T. officinale* did not germinate. No emergence was observed from depths > 5cm in either soil type. A close negative correlation coefficient and a significant difference (P <0.01; $SZD_{5\%}$=4.13 and 3.84) was achieved between the burial depth and germination of the seeds. With good cultivation, mature seeds shed on the soil surface could be incorporated into the deeper soil layers, decreasing their chance to germinate and successfully emerge.

The results also clearly showed an intensive and less intensive regenerative period of the root segments. Intensive shoot development was in the late autumn - winter months, whilst the less intensive period was in late spring-summer. An average correlation coefficient was obtained between the number and length of shoot. In the case of root segment "A" (root segment situated closest to the collar) was 0.4890 and in the case of root segment "B" (root segment situated furthest from the collar) was 0.5949. Depending on the nutrient supply, cutting several times could be an effective weed control by reducing the frequency and intensity of shoot development.

Session 7

Biodiversity and weed communities

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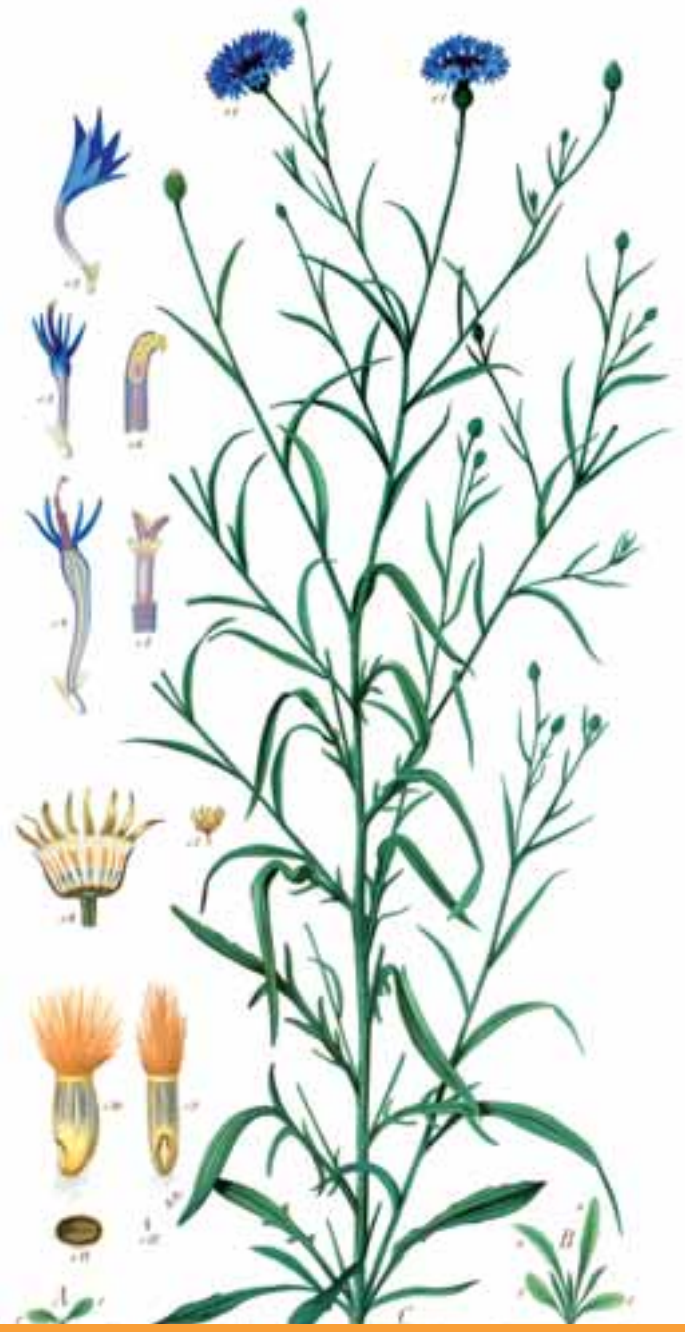

The case for conserving weeds

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The post war intensification of agricultural production in Europe has been associated with population declines of a number of taxa that are reliant on farmland habitats, including weeds. The decline in the abundance and diversity of the arable flora is of concern to policy makers for two reasons. Firstly, a number of arable plants have become rare on a national scale and require conservation measures. Secondly, as well as having an intrinsic value, weeds also provide an important ecosystem service as a source of food for higher trophic groups. The increased use and efficacy of herbicides has been identified as a major causal factor in the decline of a number of species of farmland birds on a continental scale, particularly those that forage in field centres for weed seed or phytophagous invertebrates. The UK Farm Scale Evaluations (FSEs) of the environmental impact of genetically modified herbicide tolerant crops recently provided further compelling evidence of the role of arable weeds in supporting farmland biodiversity.

In response to the loss of biodiversity and ecosystem function in European farmland, a number of conservation measures have been introduced as part of subsidised agri-environment schemes. These schemes include options targeted at the conservation of the annual weed flora including reducing herbicide and fertiliser inputs. While policy makers increasingly view arable plants as an ecological resource, however, farmers are naturally predisposed to view them negatively as an impediment to profitable crop production. They are, therefore, fundamentally opposed to managing weeds in crops for biodiversity. As a result, in the UK, uptake of options targeted at the cropped field centres has been low. Therefore, while the introduction of agri-environment schemes have delivered measurable environmental benefits (particularly when targeted at individual species with local action plans), there is a growing concern that they are not adequately addressing the decline in the annual ruderal vegetation and the ecosystem function it provides. As the effectiveness of weed control measures increase, this important component of the fabric of countryside may continue to decline and, ultimately, be lost.

If the conservation of biodiversity in field centres is to reconcile with crop production, ways need to be found of quantifying, and managing these two opposing functions of weeds. One promising approach is to assess weed communities in terms of their plant functional traits. This approach has been used to identify two beneficial functional groups of weeds that have a relatively low competitive ability with the crop but are also valuable as a resource for invertebrates and birds. Models of crop – weed competition and weed population dynamics are important research tools for identifying acceptable levels of these beneficial plant types to conserve in the context of economic weed thresholds. However, robust, practical methodologies need to be developed to apply these tools on-farm. The trait based approach has also been used to study the contrasting response to agricultural intensification of populations of weeds that have become rare and those that have remained common. Deleterious combinations of the plant traits that determine competitive ability and fecundity were identified using a combined model of crop – weed competition and weed population dynamics. The further development of these approaches would be a powerful tool for predicting the response of weed communities to future agricultural change or conservation measures.

Biology of pre-dispersal seed predators of two knapweed species, *Centaurea stoebe* and *C. scabiosa* (Asteraceae)

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Little is known on pre-dispersal seed predation on herbaceous weeds. Pre-dispersal predation of seeds was studied in *Centaurea stoebe* L. and *C. scabiosa* L. (Asteraceae), which became troublesome weeds in the USA. The principal question addressed here was how the presence of seed-head feeding insects influences quantity and quality of seeds produced per flower-head. Moreover, we were interested in selection of the predators for flower-heads of different locations within a plant (central or marginal flower-heads) or between different sizes of plants (small and big).

Complete and ripe flower-heads of 15 small and 15 big plants of *C. stoebe* were collected at the end of July 2005 at a rocky hill in Motol (central Bohemia, Prague, 50°03'N, 14°19'E, altitude 330m a.s.l.) and in the same time flower-heads of 15 small and 15 big plants of *C. scabiosa* were collected at a meadow in Prokopské údolí (central Bohemia, Prague, 50°02'N, 14°23'E, altitude 220–326m a.s.l.). Flower-head position, its volume, number, weight and germination of seeds with regard to size of the plant were recorded. For each flower-head of *C. stoebe* and *C. scabiosa* examined, presence or absence of pre-dispersal predators was recorded.

The following pre-dispersal predators were presented: Tephritidae (Diptera), Cecidomyiidae (Diptera) and Anobiidae (Coleoptera). The fruit flies (Diptera: Tephritidae) were the dominant predators, including both gall-forming (*Urophora* spp.) and cocoon-forming (*Terellia* spp.) species. In our experiments *Urophora affinis*, *U. quadrifasciata* and *Terellia virens* in flower-heads of *C. stoebe* were determined and *U. cuspidata* and *T. colon* were observed in *C. scabiosa* flower-heads.

On average, 72% of all *C. stoebe* flower-heads and 88% of all *C. scabiosa* flower-heads examined were affected by tephritids. Tephritids preferred flower-heads on big *C. stoebe* plants (LME, $F_{1,119}$=16,5, P<0,0001), but not on *C. scabiosa* plants (LME, $F_{1,28}$=1,31, P=0,26). Volume of *C. stoebe* and *C. scabiosa* flower-heads was correlated with total number of seeds in flower-head. Number of damaged seeds in *C. scabiosa* flower-heads increased with the number of *Terellia colon* larvae.

Weight of undamaged seeds from small and big *C. stoebe* plants didn't differ (LME, $F_{1,108}$=0,24, P=0,62), but the weight of the seeds were different in central and lateral flower-heads (LME, $F_{1,14}$=8,0, P=0,013). Destructive predation by gall forming species (*U. affinis* + *U. quadrifasciata*) increased the weight of undamaged seeds in *C. stoebe* flower-heads (LME, $F_{1,109}$=5,4, P=0,02, y = 0,001 + 0,00015 log[x+1]), suggesting an adaptive change in allocation of the plant resources as a response to predation. *Urophora* sp. does not create metabolic sinks, new flower buds may develop without the lack of nutrients.

Weight of undamaged seeds from small and big *C. scabiosa* plants didn't differ (LME, $F_{1,28}$=0,34, P=0,56), as well as in central and lateral flower-heads (LME, $F_{1,27}$=0,18, P=0,67). Damage on seeds of *C. scabiosa* caused by tephritids was lethal to these seeds as they were unable to germinate. This could be a reason, why are tephritids able to control knapweed populations in America. However, germinability of undamaged seeds from the attacked flower-heads was not reduced compared to non-attacked flower-heads.

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Post-dispersal weed seed predation by vertebrates and invertebrates in organic and conventional cereal fields

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Weed seed predation represents a significant process in the reduction of the yearly input of seeds into the soil seedbank, regulating in this way the density of seeds and the population dynamics of the weeds in agricultural systems. Researchers have investigated how weed seed predation could be a valuable component of integrated weed management programs, increasing reliance on ecological processes and reducing dependence on mechanical and chemical control practices. The species of seed predator involved in the process, responding differently to farming practices, may be an important source of variation because of the differences in mobility, food preferences, habitat preferences. The aim of this study was to assess the effects of two different farming systems (organic, ORG and conventional, CONV) on post-dispersal seed predation of *Avena ludoviciana* Dur., *Lolium multiflorum* Lam. and *Sinapis arvensis* L. in winter wheat (*Triticum aestivum* L.). Four field experiments were conducted in 2005 and 2006 in two sites of central Italy (Casalina 42°57'N - 12°22'E, 165 m a.s.l. and S. Apollinare 43°00'N - 12°18'E, 260 m a.s.l.) where vertebrate and invertebrate post-dispersal weed seed predation was assessed during the crop cycle, from the end of May to crop harvest, and on stubble, from the end of July to early September, for a total of 6-8 samplings in both years. Weed seed predation was measured using seedcards following the methodology developed by Westerman *et al.* (2003). Fifty seeds both *L. multiflorum* and *S. arvensis* and twenty seeds of *A. ludoviciana* were lightly glued to rectangular sandpaper cards (4.5 x 9 cm) dusted successively with a fine layer of sieved soil and then placed in accordance with a completely randomized experimental design, with 3 replicates and plots of about 3000 m^2. For the study of seed predation three measurements were carried out: 1) weed seed predation by vertebrates; 2) weed seed predation by invertebrates ; 3) "no predation" check. To asses weed seed predation rates for each weed species and sampling period Abbott's formula (1945) was used. The data obtained were transformed to log+1 to satisfy the assumption for homogeneity of variance and submitted to analysis of variance.

Results showed that: 1) the average rate (over species and periods) of seed predation was not significantly different between the two cropping farming systems in both years: 30% in ORG and 29% in CONV in 2005; 31% in ORG and 34% in CONV in 2006; 2) temporal variability of predation rates during the complete sampling period was similar in the two farming systems and characterized by high rates in end of May-beginning of June and after the harvest on the stubble; while low rates were assessed just before the harvest in the end of June-beginning of July; 3) *A. ludoviciana* seed predation rate was lower than *L. multiflorum* and *S. arvensis* in 2005 in both farming systems and in 2006 in ORG (17% vs 30% and 40%, respectively on average) while no statistical difference was assessed in CONV in 2006 (37%, on average); 4) invertebrate post-dispersal weed seed predation was higher than vertebrate seed predation in summer and lower in spring and early autumn; however, over the whole sampling period, no statistical difference was assessed between vertebrates and invertebrates predations.

Effect of rotational fallows on weed communities of subsequent crops

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The detected decline in farmland biodiversity is often attributed to agricultural intensification and changes in crop production. Rotational fallow is one of the recommended options to promote biodiversity by diversifying the current dominance of cereal cropping in Finland. The main objective of our field experiment was to compare grass-dominated fallows of different competitive abilities in relation to the diversity of weed flora. The hypothesis was that the flora would be more diverse during the fallow years, but the weed infestation in subsequent cereal crops should not represent any insurmountable disincentive for economical crop production. Six different green fallow types with four replicates were included, comprising the following factors: 1) duration of the fallow (1 or 2 years), 2) establishment method (undersown or not undersown) and 3) seed mixture (*Trifolium pratense-Festuca pratensis* or *Agrostis capillaris-Festuca ovina* with *Phleum pratense* in both mixtures). Spring barley and barley stubble were included as a reference in combinations of four-year crop sequences. After the fallow years in 2003-2004, all experimental plots were ploughed to a depth of 15-20 cm before sowing of cereals. The weed infestation was studied in winter rye in 2005 and spring barley in 2006. At the early tillering stage of crop, four small plots (2 x 10 m) within each large experimental plot (44 x 66 m) were treated with herbicide (metsulfuron-methyl in rye, MCPA/clopyralid/fluroxypyr in spring barley). The abundance of weeds was assessed from untreated and treated quadrates in August before harvesting the crop. The inclusion of fallows into crop rotation increased the weed diversity in cereals only by a couple of species from the average of 14-15 species in continuous cereal rotation. The two-year *Agrostis-Festuca* fallow favoured the subsequent species diversity most (ANOVA: $P<0.05$, both in herbicide-treated and untreated plots). The biomass of weeds in cereal rotation was significantly higher ($P<0.001$) in winter rye than in spring barley, partly due to extremely dry growing season in 2006. The biomass of weeds in rye was either lower (in two fallow treatments with $P<0.05$) or non-differing after fallows compared to cereal rotation. In contrast, one year later the weed biomass in spring barley was higher (in two fallow treatments with $P<0.01$) or non-differing in the fallowed plots compared to cereal rotation. The weed infestation was relatively low after the competitive *Trifolium-Festuca* fallow which was, however, not the most favourable option in terms of plant diversity during the fallow years. *Polygonum aviculare*, *Tripleurospermum inodorum* and *Phleum pratense* were the most abundant species in rye whereas *Chenopodium album, Cirsium arvense* and *Stellaria media* were predominant in spring barley. Herbicide treatment decreased effectively both the number of species and the biomass of broad-leaved weeds in both cereal crops. The most severe weed management problem resulting from fallowing was an increased infestation of grass species, both naturally regenerated and sown ones, particularly *P. pratense*. *Elymus repens* was dominant both after fallows and in cereal rotation. Grass weeds pose an actual threat as there are no selective grass herbicides for rye and barley on the Finnish market. Nevertheless, the cereal yields were even higher after fallows than in continuous cereal rotation indicating a positive effect of fallows on soil structure and nutrient supply, particularly after *Trifolium*. Rotational fallows are currently implemented as a subsidized measure in our national agri-environmental support scheme. In order to gain significant benefit to biodiversity from fallowing, the botanical composition, weed management and duration of fallows are of importance in order to cope with weeds in subsequent crops.

Weeds in oilseed rape in Germany – status and assessment of changes

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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. They are subject to steady changes due to varying cropping sequences, herbicide use programs, tillage regimes, etc. In the present study the occurrence of 'new' weeds in winter oilseed rape (OSR) in Germany and changes in the composition of weed species especially in areas of high OSR cropping intensity are examined, quantified and spatially allocated. Data on weed species currently found in winter oilseed rape, the extent of their occurrence, regional distinctions and changes over several years are collected. Hence, the contribution of OSR cropping to biodiversity in arable systems can be assessed on the one hand, as well as the potentials for changes in susceptibility to herbicides of present weed species on the other hand. In order to create distribution maps and species lists, an extensive monitoring of weeds in winter oilseed rape was carried out. Two independent subsamples were taken in autumn 2005 and summer 2006 both involving plots throughout Germany but applying different experimental methods. Autumn investigations took place on untreated sites and aimed at providing a quantitative overview of general weed intensity and the share of each species while summer investigations were carried out on herbicide-treated sites to examine the spatial distribution of such problematic weeds explicitly occurring after herbicide treatment. In autumn, weed frequencies and densities were determined at the four to six leaf stage of rape by randomly placing a 0.1 m² quadrate frame ten times in each plot, and identifying and counting all plants within the frame. Summer scouting was conducted between the end of rape flowering and harvest, using a one to four rating scale based on weed cover across the field. Summer investigations also included details on weed spatial patterns indicating whether weed species predominantly occurred near crop edges or in the middle of the field as well as their degree of patchiness and weed cover in patches. In first investigations of rape fields in autumn 2005 (n = 466) and summer 2006 (n = 140) a total of 128 weed species from 29 plant families has been recorded with dicots dominating strongly. As expected, species richness was higher in the untreated autumn samplings. There, 114 species were identified, compared to 66 in summer, which is not only due to herbicide treatment but also to weed ecology and the height of crop canopy. Weed species composition and frequency were also different between autumn and summer investigations. Volunteer cereals, mainly winter barley, were the most frequent weeds in autumn investigations, infesting 90% of the fields. Other predominating weed species in autumn were *Matricaria* spp. (79%), *Stellaria media*, *Viola arvensis* (71% each), *Capsella bursa-pastoris* and *Thlaspi arvense* (70% each). On treated sites in summer *Matricaria inodora* was the most frequent dicotyledonous species, still infesting two thirds of all investigated fields, followed by *Cirsium arvense* (50%), *Galium aparine* (39%) and *Sisymbrium officinale* (30%). Predominant grasses in autumn investigations were *Poa annua* and *Apera spica-venti*, whereas in summer *Agropyron repens* and *Bromus sterilis* were the most present ones. The frequency of perennials was much higher on treated sites in summer. Regional differences in occurrence were observed e.g. for *Sisymbrium* spp., *Anchusa* spp. and *Geranium* spp. Referring to dispersal indices, the weed species most explicitly preferring the field centre were *Viola arvensis*, *Cirsium arvense* and *Galium aparine*. In contrast, *Bromus sterilis*, *Anthemis vulgaris* and *Rumex obtusifolius* were mainly found near the crop edges. *Sonchus arvensis, Cirsium arvense* and *Polygonum convolvulus* showed the highest degree of patchiness, whereas *Viola arvensis* most frequently followed a random pattern.

Flora changes in Danish arable fields

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Several political initiatives have been taken to meet the growing concerns about negative side-effects of the intensification of land use practices during the last decades. Declining species' diversity and abundance, and pollution of the environment have been reported worldwide. In order to assess the overall effect on the wild flora of changing management of the arable land, country-wide surveys are needed. Surveys of the weed flora in Danish arable fields were conducted in 1987-89 and 2001-04 using the same botanical method (Raunkiær technique). Frequencies of 68 common weed species in spring barley, spring rape, winter rye, winter wheat, and grass leys were compared. Weed frequencies in general increased during the period. On average, the frequencies of the 67 species found in single Raunkiær analyses increased 45-75% in the annual crops, but remained the same in grass ley. Species which are particularly important as food sources for invertebrates and birds have increased considerably in some of the crops. The frequency of grass species such as *Apera spica-venti* and *Poa annua* has increased remarkably possibly due to larger areas with winter crops. Some perennial weeds such as *Cirsium arvense* and *Artemisia vulgaris* have also become more frequent probably because of less use of mechanical weed control and a reduction in the use of appropriate herbicides. The dominating weed species in 2001-04 were largely the same as in 1987-89, namely *Capsella bursa-pastoris*, *Chenopodium album*, *Elymus repens*, *Myosotis arvensis, Poa annua*, *Polygonum aviculare*, *P. convolvulus*, *P. persicaria*, *Stellaria media*, *Taraxacum* sp., *Veronica arvensis*, *V. persica* and *Viola arvensis*, with frequency larger than 10%, but *Apera spica-venti*, *Chamomilla suaveolens* and *Matricaria perforata* were added to the list in 2001-04. Only few species occurred less frequently in 2001-04 than in 1987-89 and only in some crops. The frequency of the noxious weed species *Elymus repens* has significantly declined in wheat fields. The agricultural policy has a tremendous influence on the market prices of agricultural products and a change in policy immediately affects farmers' choice of crops and management strategies. This can result in dramatically flora and fauna changes in a country within a relatively short period. As the common weed species make up an important food reservoir for wildlife the new trends in management of the arable land seems to enable more biodiversity in the landscape.

Some observations on flower visitors of Mediterranean weeds

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In spite of the frequent self and wind-pollination systems of the common weeds, it is not clear if plant-insect interactions could be important for the weed persistence dynamics. The study initially focused some wildflowers. Due to the experience that even in not-attractively evolved flowers (i.e. color, shape, scent, etc.) insect interactions with the reproductive structures happened, it was quickly extended to the other common weeds. A three years study (2004-2006) with diurnal field observations in several Mediterranean agro-ecosystems was carried out in order to investigate flower visitors dynamics in both common weeds and wildflowers weeds. Observations were conducted in conventional and organic agricultural systems in the North of Tuscany. The most abundant weed species were labeled and their flower visitors were recorded and captured for their identification during the spring-summer period. Wildflowers were highly visited by several specialized and unspecialized insects. The most frequent were Hymenoptera (overall Apidae, Halictidae and Andrenidae), Diptera (overall Syrphydae, Bombyliidae and Tachinidae), Lepidoptera (overall Lycaenidae, Pieridae and Sphingidae) and Coleoptera. Zygomorphic flowers, such as in the cases of *Consolida regalis*, *Echium vulgaris*, *Gladiolus italicus*, *Lamium amplexicaule* and *Kickxia spuria* were visited mainly by specialized long-tongued bees (Melittidae, Megachilidae, Anthrophoridae and Apidae) virtually as a consequence of the particular position of the nectaries. On the contrary actinomorphic flowers were visited by a higher number of visitor species. For example, almost all of the Asteraceae species (i.e. *Centaurea cyanus*, *Chrysanthemum myconis* and *Cirsium arvense*) showed a higher degree of unspecialized visitors, such as short-tongued bees (Colletidae, Andrenidae and Halictidae) and even Coleoptera, probably due to the inflorescence morphology that allows an easy availability of both nectar and pollen. However, even several actinomorphic flowers showed specialized visitors as a consequence of the length of their corolla tube. In these cases, three different potential pollinators, capable to reach the nectaries, appear to be important: long-tongued bees, Lepidoptera and Diptera Bombilidae. This was observed in *Centaurium erithrea*, *Knautia arvensis*, *Jasione montana* and *Agrostemma githago*. This specificity in the plant-insect interaction could represent a potential risk in their dynamics in conventional agro-ecosystems were pesticides appear to restrict the pollinators quantity and quality. However, the tested hypothesis that only the wildflower weeds were visited by potential pollinators was turned out mistaken. Indeed, in spite of the prevalent autogamy and/or anemophily of the common weeds, several unexpected species were insect-visited. Several observations (overall of bees) were carried out in Solanaceae (*Datura stramonium* and *Solanum nigrum*), Convolvulaceae (*Calystegia saepium* and *Cuscuta campestris*), Cariophyllaceae (*Stellaria media*), Portulacaceae (*Portulaca oleracea*) and Asteraceae (*Conyza canadensis* and *Aster squamatus*). In this last botanic family bees were noted even in *Xanthium strumarium*, a monoecious species with male and female flowers. In Brassicaceae (*Raphanus raphanistrum* and *Sinapis arvensis*) it was evident the unspecialized plant-visitors interaction overall by bees, Lepidoptera and Diptera. However, while the several wildflowers were visited during all of the flowering time, the common weed species (characterized by less evident flowers) were pollinated only at the end of the summer. It is described in literature that during this period a strong lack of wildflowers can occur and consequently even the not specialized weeds could represent a food source (pollen and/or nectar). This late-summer flower-visiting could have an ecological role increasing the genetic variability by cross-pollination (mutualistic or accidental) and thus in the weed persistence dynamics in the agro-ecosystems.

Weed seedbank biodiversity in Emmer wheat (*Triticum dicoccum* (Schrank) Schübler) in a mountainous agro-ecological oasis (Garfagnana, Tuscany)

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The aim of this work was to check the hypothesis that a low agronomic pressure is linked to a high biodiversity level. Indeed, in the selected cropping systems pesticides are traditionally not used for ecological reasons as well as for food quality requirements. Investigations were undertaken in eight agroecosystems (of this mountainous environment of north Tuscany), selected regarding their uniformity in the agronomic management. The cropping systems are characterized by Emmer wheat (local germplasm) in rotation with forage crop, no herbicides, only organic manure, soil harrowing, little crop extensions of roughly 3,000-5,000 square meters. In the autumn 2005 soil cores (4 cm diameter) were collected from two different depths (0-15 and 15-30 cm). Seeds were extracted and determined in laboratory by using an "floating" method. The quantitative seed bank (0-30 cm) ranged between 16,000 and 47,000 seeds m^{-2}, distributed in two soil layers (0-15 cm and 15-30 cm). In these seed banks more than 80 botanical species were identified, without predominance of any species. Seeds of several wildflowers species such as *Anthemis cotula*, *Legousia speculum veneris*, *Consolida regalis*, *Echium vulgare*, *Silene* spp. and *Viola tricolor* were found. The relative density of each species was not more than 5%. The high biodiversity level probably is enriched by the presence of the forage in the crop rotation for two reasons: i) diversification of the agronomic disturbance dynamics (cutting the forage crops) ii) presence of ungerminated seeds as a consequence of the frequent physical dormancy of the sown forage species. Indeed several *Fabacee* species were found in the seed bank such as *Trifolium* spp., *Melilotus* spp. *Medicago* spp., *Lathyrus* spp, *Lotus corniculatus* and *Onobrychis viciaefolia*. While the presence of forage crops in the rotation seems to have a crucial role in the timing of agronomic management, the scattered cropping in mosaic geometry appears to be important to diversify the flora in the space. Indeed only a scattered land use implies the nest and food availability for the survival of wildflower pollinators. Also interesting is that the seed bank was formed even by rare species such as *Agrostemma githago* and *Centaurea cyanus*. The size of the seed banks of these two species (both less than 1 seed m^{-2}), was less than the following field emergence (approx. 2 and 3 plants m^{-2} respectively). More competitive weeds (for example *Raphanus raphanistrum*, *Galium aparine*, *Avena fatua*, *Lolium multiflorum*) were only present in low numbers, too (approx. 1-2% of the relative density). Their interference with the Emmer and the forage crops was agronomical sustainable – probably as a function of the complexity of the interference in the phytocoenosis.

The two rare species *Agrostemma githago* and *Centaurea cyanus* have almost completely disappeared from the conventional agricultural landscape since several years. The almost total application of the high developed seed cleaning techniques in the conventional agro-ecosystems very much affects these species. Thus, within the investigated area, the traditional way of cleaning the Emmer-seeds promotes the presence of these rare species in Emmer wheat fields.

In conclusion, this high biodiversity level confirms the hypothesis, that the low agronomic pressure avoids the botanic simplicity and prevents the floristic co-evolution from troublesome weed phytocoenosis.

Effect of continuous and rotational use of herbicides on weed flora of rice (*Oryza sativa* L.) under long-term rice-wheat cropping system

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Since the start of the green revolution, rice-wheat rotation is the most predominant cropping system in north Indian Plains, which are known as the 'food basket' of India. Application of pre- and/or post emergence herbicides is the most prevalent method of weed control, currently being used on more than 75% of the cropped area in this region. Intensive use of a particular herbicide, or a group thereof, continuously year after year may lead to problems like herbicide residue accumulation, evolution of herbicide resistance and shift in weed flora. Isoproturon-resistant *Phalaris minor* in wheat is the well established evidence in this region. In view of this, a long-term field experiment to study the effect of continuous and rotational use of herbicides in rice-wheat cropping system was initiated during 1993 at research farm of the department of Agronomy and Agrometeorology, Punjab Agricultural University, Ludhiana. Under the same experimental setup, the present investigation was conducted during *Kharif* (summer) 2003 with the objective to study the effect of continuous and rotational use of herbicides on shift in weed flora, nutrient uptake and productivity of rice. Two new weed species, *Leptochloa chinensis* and *Ammania baccifera* were recorded infesting the experimental field, for the first time during the eleventh year of study. Continuous application of anilofos resulted a shift in weed flora towards the dominance of *Caesulia axillaris* and *Cyperus iria* by decreasing the intensity of *Ischaemum rugosum* from 1.3 plants m^{-2} (26.6%) during 2001 to 0.1 plants m^{-2} (0.2%) during 2003. In contrast, the continuous use of butachlor and pretilachlor shifted the weed flora towards the dominance of *I. rugosum,* but gave a good control of *C. iria* and *C. axillaris*. Continuous and rotational use of herbicides had no significant effect on productivity of rice. However, all the herbicide treatments were significantly better than unweeded control, which recorded lowest grain and straw yield of 1.3 and 4.5 t ha^{-1}, respectively. The "Two hand-weedings" treatment recorded the highest grain and straw yield of rice (5.2 and 13.0 t ha^{-1}, respectively) and all herbicide treatments were statistically at par with it. No herbicide residue in soil or rice grain was detected after eleven years of continuous application of butachlor and anilofos. All the herbicide treatments were statistically at par with respect to nutrient uptake by crop and weeds and were significantly better than unweeded control. The build up of selection pressure due to continuous use of a particular (group of) herbicide(s) shifted the weed flora towards the species which were not at all or less effectively controlled by it. Rotational use of different herbicides and groups thereof is suggested as a good alternative to keep the weed population in crops (particularly rice) under control. This will also help in keeping these particular herbicides effectively useful for weed control in same crop over longer periods of time

Crop sequence effects on weed populations in potato crop

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A three-year experiment with potato (*Solanum tuberosum* 'Monalisa') included in an intensive crop rotation was conducted in 2002-2004 at the Experimental Station of Loreto (39º05' N; 08º43' W) in Beira Litoral, Portugal. The experiment was a RCB design with four treatments (rotation *vs* monocropping) with 4 replicates: treatment A – potato monocropping, and three treatments of a four year rotation where potato was included in the first year of rotation (B), on the second (C) and on the third (D). Crop rotations included maize/fababean – pepper/forage-beans/cauliflower – potato/broccoli. Each plot was 180 m^2. The experiment was designed to study the effects the preceding crop on weed density and composition in potato crop. Weed control was based upon pre-emergence herbicide application (EPTC in potato and maize, alachlor in beans and oxyfluorfen in cauliflower and broccoli) and cultivation (hand-hoeing in pepper). Weed abundance and composition were assessed every year in 5 quadrates 0.5 m (1.25 m^2) before and after cultivation or herbicide application. Crop production ranged from 36.6 t ha^{-1} to 11.3 t ha^{-1} and from 40.6 t ha^{-1} to 11.5 t ha^{-1} for potato grown under monocropping or rotation respectively. The decrease over the years showed no significant differences between both systems. During the whole period 39 species were identified. Weed composition was dominated by annual dicotyledons but *Cyperus esculentus* was also abundant. Analysis of variance and canonical discriminate analysis showed that in general the year influenced weed density to a greater extent than crop sequence; however, weed composition was affected by the interaction between crop sequence and year. Weed density in monocropped potato increased from 479 plants m^{-2} in 2002 to 2260 plants m^{-2} in 2004. Weed density was 3114 plants m^{-2} and 1738 plants m^{-2} in potato crop, cultivated on the second and on the third year of rotation, respectively. In 2003 there was an increase in weed density in all crops which could be attributed to increased rainfall. The prevailing weed species (> 10% relative density) in monocropping were *Galinsoga parviflora* (increasing in time); *Datura stramonium* (relevant in 2002/2003, but with no occurrences in 2004); *Amaranthus retroflexus* (relevant in 2002/2003, but with significant reduction in 2004); *Cyperus esculentus* (with significant reduction in time). In crop rotation, the most prevalent weed species varied depending on the preceding crop: *G. parviflora* and *Portulaca oleracea* dominated after two years of rotation (with beans and cauliflower as preceding crops), whereas *G. parviflora, P. oleracea, Solanum nigrum* and *Cyperus esculentus* were the most abundant species after the three-year rotation which included pepper/forage (2002) and beans/cauliflower (2003). Results suggest that crop rotation would not result in increased weed problems whereas continuous monocropping might increase weed infestations. Crop yields varied with year and were related to rainfall and weed control effectiveness.

Dependence of weed infestation in crop rotation on soil pH and nutrient content

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The weed infestation of a crop rotation: spring oil seedrape–spring barley–red clover–winter wheat–spring barley in the period was investigated 2000 –2005 in order to evaluate the effect of different soil pH and nutrient content levels. Different soil pH levels (pH_{KCl} 4.1; 5.1; 5.4; 5.9; 6.2 and 6.6) were formed by the initial liming in 1976 and periodic liming after each crop rotation. After systematic crop fertilization with single, double and triple rates of mineral fertilizers (N, P, K) the content of mobile phosphorus/potassium in the soil was: 70 / 130 (unfertilized), 120 / 210, 190 / 280 and 280 / 310 mg kg^{-1} respectively. With the decreasing soil acidity from pH 4.1 to 6.6, the weed infestation consistently declined in all crops. Weed infestation in spring oil seedrape plots with soil pH from 4.1 to 6.6 declined by 47% ($r = -0.87$, $P \leq 0.01$). Significant decrease of *Scleranthus annuus* and *Spergula arvensis* (by 77%, $P \leq 0.01$), *Viola arvensis* (by 53, $P \leq 0.01$), *Elymus repens* (by 51%, $P \leq 0.01$) was determined. In the same plots the number of *Chenopodium album* increased by 55% ($P \leq 0.01$). A significant dependence ($P \leq 0.01$) of weed numbers in spring barley crops on different levels of soil pH appeared ($r = -0.71$ in 2002 and $r = -0.96$ in 2005). The decrease of total weed numbers in spring barley crop depended on significant decrease number of *Scleranthus annuus*, *Spergula arvensis* ($P \leq 0.01$), *Viola arvensis* ($P \leq 0.01$) and *Elymus repens* ($P \leq 0.01$ in 2002). However, with reduced soil acidity from pH 4.1 to 6.6 the number of *Chenopodium album* and *Tripleurospermum inodorum* in spring barley stands increased by 48 and 133% respectively. The largest reduction in weed numbers under the effect of soil liming occurred in barley crop because of improved agrochemical soil properties. More competitive crops resulted differently to acidofilic and nitrofilic weeds. Weed infestation of red clover crops which were grown in the plots with soil pH ≥5.4 declined by 26% compared to those plots with soil pH 4.1. This effect changed the density of prevailed weeds: *Tripleurospermum inodorum*, *Elymus repens* decreased and *Sonchus arvensis* increased. Significant dependence ($r = -0.90$, $P \leq 0.05$) of the weed infestation of the winter wheat crops on increasing soil pH from 4.1 to 6.6 was determined. Significant ($P \geq 0.01$), decrease of *Scleranthus annuus*, *Spergula arvensis* and significant increase of *Sonchus arvensis* ($P^{3} 0.01$) took place in this crop. Different content of mobile phosphorus/potassium in the soil had a certain effect on total weed infestation in the crops and on the composition of weed species in crop rotation as well. *Chenopodium album* and *Tripleurospermum inodorum* responded to the increase of nutrient content in soil positively and their number increased in all crops. Species of *Scleranthus annuus* and *Spergula arvensis* were sensitive to the competition power of cultivated plants and their density decreased in plots with higher nutrient content in the soil. With increasing phosphorus/potassium content in the soil from 70 / 130 to 280 / 310 mg kg^{-1} weed infestation of spring oil seedrape crop decreased by 25%. The density of prevailing weeds species of *Scleranthus annuus, Spergula arvensis*, *Viola arvensis*, *Elynus repens* decreased and the density of *Chenopodium album* increased in these spring oil seedrape crops. Total weed infestation of red clover crop increased because the increased density of *Tripleurospermum inodorum, Sonchus arvensis, Elymus repens.* Different content of phosphorus / potassium in the soil did not have significant effect on the weed infestation of winter wheat and spring barley crops. Here a decreasing number of the acidofilic weeds was accompanied by an increasing number of the nitrofilic weeds.

Is weed community dynamics in cover crop-based arable systems related to species ability to host Arbuscular Mycorrhyzal Fungi?

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Cover crops have long been used in agriculture to improve soil quality, reduce soil erosion and suppress weeds. They can also promote the development of Arbuscular Mycorrhizal Fungi (AMF) networks in soil. The importance of AMF goes beyond the plants exchange of assimilates for nutrients especially phosphorus from the fungi. Recent studies show that AMF could influence plant productivity and community dynamics. However, it is uncertain whether or not weed-AMF interactions, up to now largely unexplored, can influence weed community dynamics in cover crop-based rotations and whether this type of knowledge could be used to design more sustainable cropping systems. This study aims to assess the effects of different combinations between cover crop species and management options (differing in tillage system and nitrogen fertilisation rate) on weed community dynamics and suppression analysed in terms of AMF host *vs* non-host species. The study was carried out in a long-term field experiment based on a maize-durum wheat-cover crop 2-yr rotation started in 1993 at CIRAA 'E. Avanzi' of the University of Pisa, Italy. The experiment was arranged as split-split-plot design with four replications. The factors were: main plot factor = tillage systems: (1) Low Input System (LIS) or (2) Conventional System (CS); sub-plot factor = nitrogen fertilization rates: 0, 100, 200 or 300 kg ha^{-1} N (in the maize crop); sub-sub-plot factor = cover types: (1) *Vicia villosa* (AMF host), (2) *Trifolium squarrosum* (AMF host), (3) *Brassica juncea* (AMF non-host) and (4) control (without cover crop). This paper focuses on the 2005-2006 period of the study (cover crop and maize phases of the rotation). During the cover crop phase (full vegetative stage), weed density and composition significantly varied between cover crop treatments. Weed density (both AMF host and total) was lowest in *V. villosa* and total number of species was lowest both in *V. villosa* and *B. juncea*. AMF host cover crops like *V. villosa* enhanced relative percentage of AMF-host weed species while *B. juncea* suppressed it. Relative density of two of the most abundant AMF host weed species were generally enhanced with *V. villosa. Lolium* spp. for example, in both CS and LIS was significantly higher in *V. villosa* compared to control and *B. juncea*. *Sonchus* spp. was almost absent in LIS but under CS it was significantly higher in *V. villosa* compared to control, *B. juncea* and *T. squarrosum*. Relative density of *Veronica* spp., an AMF non-host, was significantly lower in *V. villosa* under CS. In the following maize crop (four-leaf stage), CS had lower weed density (total and AMF host) than LIS for all cover crop types. There were no differences between cover crop types in CS whereas in LIS both total and AMF-host weed densities were higher in the control plots than in the plots with winter cover crops. Total species richness in CS was lower in the control than after *B. juncea* whereas in LIS it was higher in the control and after *B. juncea* than after *V. villosa*. Relative density of *Polygonum aviculare,* an AMF non-host, in CS was significantly lower after *B. juncea* than after *V. villosa* and *T. squarrosum.* Nitrogen fertilization significantly decreased weed density (total and AMF host); total number of species and relative density of *Veronica* spp. but it significantly increased the relative density of *P. aviculare.* These results indicate that AMF may influence weed community dynamics by stimulating the presence of AMF host weed species especially during the cover crop phase of the rotation. Cropping system-weed-AMF interactions are complex, thus further studies are needed to clarify them.

Biology of fragmented and depleted populations of cornflower (*Centaurea cyanus*)

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Cultural techniques used since the 1950 years lead to the reduced abundance and frequency of weed populations. Especially, fragmentation of the agricultural environment resulted in the decrease of the area and connectivity of the habitat. It is especially true for rare weed species, which can have dramatic impact in terms of genetic structure of plant populations and biodiversity conservation. We investigate the consequences of such an evolution of the agriculture for *Centaurea cyanus*, the cornflower. It is an ubiquist species that was very widespread and dense in European fields up to the middle of the 20th century. Seed sieving and anti-dicotyledonous herbicides in cereals led it to a dynamics of rarefaction. Although it is a noxious weed, it is still considered as emblematic of the flora associated with cereal cultures, together with poppies. At the society level, it represents a patrimonial species that deserves to be protected. For Weed Science, it offers the opportunity to study the processes leading to species extinction, the exchanges among populations within a metapopulation, and the re-colonization processes. In a preliminary approach, we studied the level and the structure of the genetic variability of five cornflower populations in each of two regions of France. In Burgundy, near Dijon, cornflower is frequent, although not abundant. In the western Poitou-Charentes, nears Poitiers, cornflower is observed in a few locations only. Leaf isozyme variability was analysed on adult plants collected in the fields at the end of the winter. Nine loci were interpreted for five enzymes: diaphorases, esterases, glutamate oxalate transaminases, lactacte dehydrogenases, and leucine amino-peptidases. The mean numbers of polymorphic loci (P=86%) and of alleles per locus (A=2.6) were higher than those recorded in the literature for other annual and allogamous species. However, most of the populations showed a lack of heterozygotes, which could be explained either by a non-panmictic mating system, or a selection against heterozygous seedlings during the winter. For the first hypothesis, we showed that self-pollination was 200 times less efficient than cross-pollination to produce seeds, which could be due to a self-incompatibility system, but we cannot rule out the occurrence of a few self-pollinating individuals. The second hypothesis is under study on seed samples, i.e. genotype identification among the direct result of the reproduction, in order to check any flaw in the isozyme analysis and inheritance. Finally, although the level of variation was high, significant but weak between-regions and between-populations differentiations were observed (Fst=0.04 and 0.06, respectively). These low values, with respect to other insect-pollinated species, could indicate an important homogenising gene flow among populations. Alternately, the pattern of variability observed could reflect the ancient abundance and the wide connected distribution of the species before the fragmentation of its habitat begins. Works are developed to gain more insight in this debate, especially to examine the role of the soil seed bank to buffer and delay the decrease of the genetic variability caused by modern agriculture versus the capability of cornflower to maintain a high variability through long distance, insect–mediated pollen dispersal. This kind of study could open the way to a landscape comprehensive approach of species diversity, maintenance and adaptation to changing environment.

Effect of tillage on soil weed seed bank and weeds in a corn-wheat rotation in southern Iran

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In order to evaluate the effect of six tillage treatments on soil weed seed bank and weeds in a corn-wheat rotation, a study was conducted in Kooshkak Agricultural Research Center of the College of Agriculture of Shiraz University in spring, summer and fall of 2003 (corn) and in the 2003-2004 cropping year (wheat). The tillage treatments were mouldboard plow +4 disk-harrow passes, mouldboard plow +3 disk-harrow passes, mouldboard plow +2 disk-harrow passes, chisel +3 disk-harrow passes, chisel +2 disk-harrow passes, and chisel +1 disk-harrow pass. Since one disk harrowing normally would not be sufficient to provide uniform seedbed in the region, therefore additional disk harrow treatments were considered to improve final seedbed, thereby various influences on weed seed bank were expected. A weed-free and a weedy treatment were also included as additional treatments. The experiment was conducted using a split-plot design with four replications in which tillage treatments were the main factors and weedy and weed free treatments were the sub factors. Means were compared using the Duncan's multiple range test ($P \leq 0.05$). Results indicated that weed seed bank decreased in weed free plots and increased in weedy treatments. Tillage treatments affected soil weed seed bank. In chisel plowed plots, soil weed seed bank was 19% larger than in moldboard plowed plots. Chisel +1 disk-harrow pass with weeds had the highest weed seed bank. Maximum dry weights of weeds in corn and wheat fields were in the chisel +1 disk-harrow plots. Dry matter of weeds in chisel treatments was higher than in moldboard plow. Height, grain yield and aboveground biomass of corn and wheat in weedy plots were less than in weed-free ones. Height of corn and wheat was highest in weed free plots that were tilled with chisel +3 disk-harrows and mouldboard +2 disk-harrows, respectively. Height of wild oat in all treatments was slightly higher than wheat. Maximum biological and grain yields of corn were in moldboard +4 disk-harrows with and without weeds. Corn grain yield in this tillage treatment was 36% (weedy) and 43% (weed-free) higher than chisel +1 disk-harrow. Wheat field plots without weeds that were tilled with chisel +2 disk-harrows had highest biological yield and were not different from those of moldboard +2 disk-harrows. Wheat biological yield in weed-free chisel +2 disk-harrows was 18% higher than moldboard +4 disk-harrows and 27% higher than chisel +1 disk-harrow.

Size and composition of seedbank in organic and conventional cropping systems

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The growing interest in the environmental and safety aspects of the conventional agricultural systems has promoted the spreading towards different management systems based upon the reduction of external inputs (e.g. low fertilizers and herbicides rates, soil conservation tillage) or the use of organic practices (e.g. cultural and physical weed control instead of chemical ones). In this context the knowledge about the weed seedbank could be crucial for assessing the effects of different practices on the weed flora dynamics. The aim of this study was to evaluate the weed seedbank of an organic (ORG) and a conventional-low input (CONV) cropping system carried out in central Italy (Perugia, 42°57'N - 12°22'E, 165 m a.s.l.) since 1998.

In both cropping systems a 3-year crop rotation was used: intercropping green manure (only in organic system), summer cereal or vegetable crop and winter cereal or grain legume. Each crop rotation was repeated three times on an area of about 2500 m^2. Weed control in the organic system was performed by mechanical methods (i.e. tine-harrowing in winter cereals; hoeing, hoeing-ridging, and/or finger-weeding in wide-row spring and summer crops. In the low input system weed control was realized by pre and/or post-emergence herbicide application integrated with mechanical control. In both systems seedbed preparation was performed by shallow ploughing (0.30 m depth) and harrowing. Weed seedbank was determined in December 2005 that is at the end of the third year of the second cycle of crop rotation, at the beginning of winter wheat crop cycle. Ten soil samples were taken in each replication of both systems in an area of 70 m^2 (3.5 x 20 m) by a 40 mm diameter manual soil corer at three different depths (i.e. 0-0.1, 0.1-0.2, 0.2-0.3 m). The soil samples were identified separately and oven dried at 15°C. The seed extraction was carried out using an original filter-system and low-pressure water. Then the seeds were identified by a backlit magnifying glass (8x) and an optical microscope (45x) and counted afterwards.
Results showed that: 1) no significant differences were found between crop systems in terms of weed species number (23 in ORG and 20 in CONV) due to the same crop rotations applied; 2) no significant differences were found in relation to soil depths, due to the same soil tillages; 3) the 0-0.3 m total weed seedbank in ORG (78'244 seed m^{-2}) was significantly greater than in CONV (15'744 seed m^{-2}) because of a lower efficacy of weed management; 4) in both systems the dominant species were summer species like *Portulaca oleracea* (56% of total seedbank in ORG, 40% in CONV), *Amaranthus retroflexus* (32% ORG, 23% CONV) and *Chenopodium album* (4% ORG, 5% CONV) due to higher nitrogen and water supplies in spring and summer than in winter crops, that improves weed growth and seed production.

How will global change affect weeds of cotton in western Turkey?

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With a sown area of 204,000 ha (2003), the Aegean region is a prime cotton producing area of Turkey. The associated weed flora is diverse and dynamic. Introduced species like *Xanthium strumarium* and *Amaranthus retroflexus* play a major role. Changed crop husbandry has been another determinant of floral shifts. For instance, irrigation repressed *Prosopis* spp. and fostered *Portulaca oleracea*; *X. strumarium* and *Solanum nigrum* benefited from being tolerant to trifluralin. Global change encompasses, *inter alia*, changing climate and land use, and can be expected to foster shifts in weed flora and crop-weed relations, e.g. via differential species responses to higher atmospheric [CO_2]. This study attempts to assess the risk of future problem weed introductions to the region and discuss possible effects of climate change on cotton-weed competition. To locate likely source areas of invasive weeds, the CLIMEX software was employed. Areas with courses of temperature and rainfall similar to those in the Aegean during the cotton season (May - November), with and without irrigation and climate change (+3 °C in winter, +5 °C in summer, -10% annual rainfall) were identified, and regional weed florae compared to that of Aegean Turkey. Effects of climate change on crop-weed competition were assessed using phenological models of cotton, *X. strumarium* and *S. halepense* run with regional climate data and calibrated to reflect observed phenology. Responses to temperature increases by 2 °C to 4.5 °C (depending on season) were simulated. Regions climatically similar to the Aegean are (a) current climate/rainfed: south Mediterranean, South Africa, South Australia; (b) current climate/irrigated: southeast U.S., Uruguay, northeast Argentina; (c) climate change/rainfed: dry areas of North Africa, southwest North America, Australia; (d) climate change/irrigated: south U.S. (Texas/Georgia). Cotton weeds of these regions not present in Turkey include *Sida spinosa* (Americas), *Anoda cristata* (Australia), *Malvastrum* spp. (South America, Australia), *Polymeria longifolia* (Australia), *Solanum elaeagnifolium* (Americas). The latter has spread to Greece and Syria, where it harms irrigated cotton production. It may pose the most imminent threat to cotton-producing areas of Turkey. The genera *Ipomoea* and *Commelina* exist in Turkey, but are no major weeds in the Aegean. These predominantly tropical genera may get more competitive and problematic in a warmer climate. Also, a spread of weeds that recently emerged in other regions of Turkey, e.g. *Dinebra retroflexa* and *Physalis philadelphica* cannot be ruled out. Cotton is commonly sown in mid-April, emerges in May, starts flowering in June and matures in late September. The critical period for weed competition roughly ranges from late May to early August. Due to herbicide application and seedbed preparation in April, *X. strumarium* starts to emerge in late May, bloom in late June and mature in early September. Accordant dates for *S. halepense* are mid-May, mid-June and early August. In a warmer climate, the minimum temperature for sowing cotton (17°C) would be reached three to four weeks earlier. Emergence and flowering were predicted to start three weeks earlier and maturity six weeks earlier. Emergence, flowering and maturity of *X. strumarium* were predicted two, three and four weeks earlier, respectively. Findings for *S. halepense* were analogous. Weed growth and crop critical period would still coincide according to the simulations. Competition would likely be more intense due to more rapid potential growth of crop and weeds. Further factors that may affect crop-weed competition relate to differential effects of temperature, water supply and [CO_2] on C_3 and C_4, or on rhizomatous and non-rhizomatous, species. C_3 plants like cotton and *X. strumarium* may benefit more from higher [CO_2] under irrigation; increased evapotranspiration due to higher temperature can favour C_4 plants like *S. halepense* under rainfed conditions.

Weed communities in hemp plantations in Poland

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The results of studies on weed communities in hemp plantations in Poland are presented, with respect to the changes in the level of infestation during the past 40 years (1967-2006). The observations were made in three intervals in the years 1967-1970, 1989-92 and in 2006. Weed density and biomass and weed species composition were studied in hemp plantations located in four Experimental Farms of the Institute of Natural Fibres (Poznan). In hemp cultivation in Poland the greatest threat is posed by weeds typical for cereal and root crops: *Chenopodium album* L., *Lamium amplexicaule* L., *Viola arvensis* Murr., *Fallopia convolvulus* (L.) [Löve],, *Stellaria media* Vill., *Thlaspi arvense* L., *Polygonum nodosum* [Pers.], *Galinsoga parviflora* Cav. and *Elytrigia repens* (L.) [Nevski]. In the last four decades the mean number of species occurring in hemp has slightly grown (from 21 to 28 species m^{-2}), however no weeds that can be described as specific for hemp cultivation have been observed. Total weed density and biomass in the years 1967-2006 have been relatively constant, only in the years of economic crisis (1987-1989) these indicators reached the highest values. A relatively stable composition of weed species is nevertheless accompanied by disappearing of certain species (*Polygonum nodosum* Pers., *Vicia hirsuta* (L.) S. F. Gray, *Spergula arvensis* L.) and an increasing occurrence of others (*Capsella bursa-pastoris* (L.) Med., *Polygonum aviculare* L.).

Were endangered weed species common in the past?

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In the last decades, a decreasing abundance of many weed species was observed. Nowadays, around one hundred plant species spontaneously occurring on arable land are mentioned in Black list (extinct) or Red list of endangered vascular plants of the Czech Republic (published in 2001). We compared present occurrence of these species (information taken from the Key to the Flora of the Czech Republic, 2002) with the situation at the beginning of 20th century. Based on F. Polívka's Flora (1900-1904) we can say that 14 % of today endangered weed species were rare already one hundred years ago, opposite to 27 % of today endangered weed species that were common in that time. The rest of evaluated weed species were scattered in their occurrence, neither common nor rare. The group of species that were rare already at the beginning of the 20th century includes *Adonis flamea, Asperula arvensis, Bifora radians, Glaucium corniculatum, Melampyrum barbatum, Polycnemum majus, Sagina apetala, Silene conica, Silene dichotoma, Silene gallica, Stachys arvensis, Turgenia latifolia, Valerianella carinata, Vicia pannonica*. Much more interesting is the second group of species – those that were relatively common in the past. This group includes: *Adonis aestivalis, Agrostemma githago, Ajuga chamaepitys, Anchusa officinalis, Bromus arvensis, Bromus secalinus, Caucalis platycarpos, Centaurea cyanus, Coronopus squamatus, Cuscuta epilinum, Cynoglossum officinale, Filago arvensis, Galeopsis angustifolia, Hyoscyamus niger, Lappula squarrosa, Melampyrum arvense, Misopates orontium, Myosurus minimus, Odontites vernus, Papaver argemone, Papaver dubium, Ranunculus arvensis, Stachys annua, Teesdalia nudicaulis, Valerianella rimosa, Verbena officinalis*. Comparing these two groups, we can say that there are twice more species now endangered that were frequent members of the agrophytocoenoses in the beginning of the 20th century. This group should be more intensively studied, to find biological properties of the species and/or differences in agricultural systems that caused their rarity. Both must have a strong influence on the presence of the species and can possibly be generalized.

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Rotational fallows increase seed-food availability for farmland birds

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Intensification of cropping measures has declined the availability of food for seed-eating farmland birds. Diversification of crop rotations with rotational fallows could reverse this trend. In the present work, a four-year (2003-2006) field experiment was established in southern Finland to study the effects of different types of rotational fallows on the seed-food availability for farmland birds. The main objective of the field experiment was to compare grass-dominated fallows of different competitive abilities in relation to the diversity of weed species. The hypothesis was that the seed-food availability would be higher in fallows with less competitive grass mixture. Six different green fallow types were included in the experiment, comprising the following factors: 1) duration of the fallow (1 or 2 years), 2) establishment method (undersown or not undersown) and 3) seed mixture (*Trifolium pratense* - *Festuca pratensis* or *Agrostis capillaris* - *Festuca ovina* with *Phleum pratense* in both mixtures). In addition, spring barley and barley stubble were included as a reference in combinations of 4-year crop sequences. Winter rye was sown in autumn 2004 and spring barley in the spring 2006 after fallowing years. The experiment was conducted on clay soil as a randomized complete block design with four replications for each of the eight treatments. The size of each experimental plot was 0.3 hectares (44 m x 66 m). Seed samples (20 x 100 cm^2) were collected from topsoil (1-2 cm) each year after growing season. Seed numbers and species richness were compared between fallow treatments by ANOVA. Altogether 25 weed species were encountered during the experiment. The most abundant species were *Chenopodium album*, *Fallopia convolvulus*, *Galium spurium* and *Myosotis arvensis*. The number of weed species was higher ($P<0.05$) only in two fallow types (2-year *Agrostis-Festuca* and stubble) compared to continuous cereal rotation. However, the seed number was higher ($P<0.05$) in five fallow types compared to cereal rotation. The fallows which did not differ from cereal rotation were both sown with competitive *Trifolium*-seed mixture. In the comparison between similar seed mixtures second year fallows had higher ($P<0.05$) seed numbers. Establishment by undersowning decreased the seed number in competitive *Trifolium*-seed mixture ($P<0.001$). As expected, sowing of less competitive seed mixture resulted in higher seed food availability for farmland birds. Rotational fallows are implemented as a measure in the Finnish Agri-Environmental Support Scheme (2007-2013). In order to gain significant benefit to seed-eating farmland birds from fallowing, the botanical composition and duration of fallows are of importance.

Biodiversity of *Chenopodium* sp. in the segethal communities on Silesia lowland (South-West Poland)

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In the segethal communities of SW Poland some representatives of *Chenopodium* genus occur, distinguished with a morphological convergence to *Ch. album* L. They belong to the following species: *Ch. acerifolium* Andrz., *Ch. glaucum* L., *Ch. ficifolium* Sm., *Ch. opulifolium* Schrad., *Ch. suecicum* J.Murr. and *Ch. strictum* Roth.

These species often are mistakenly identified as *Ch. album s.l.* For this reason they are practically undistinguished in the polish bibliography and no data are available about the distribution of these species.

Investigations were carried out in the years 2001-2005, in the region Silesia Lowland, in the south east of Wroclaw. Distribution of *Ch. spec.* were mapped in cereals and in root crops (beets and potatoes) on 20 localities. The localities were selected by means of "golden points" method. The localities differed with regard to the fertility of the habitat (pseudopodsolic, brown and black earth soils). The occurrence frequency of investigated species was classified in three groups (+++ - frequent species, appeared on 100-61% localities, ++ - medium-frequent species, appeared on 60-31% localities, + - rare species appeared on 0-30% localities). The observations reveal, that in the investigated area *Ch. acerifolium* is the most frequently occurring taxon (+++). This species appears with the high frequency on all types of soils and in almost all plant communities. However *Ch. album,* although associated with a similar soils, occurs much rarely on the segethal habitats (++). The observations of this species in SW Poland show, that *Ch. album* appears more often on ruderal, than on segethal localities.

The other species occur in the segethal communities occasionally (+), but they are good bioindicators of the soil fertility. *Ch. ficifolium*, *Ch. glaucum* and *Ch. opulifolium* are associated with rich soils. In investigated area they appear on wroclaw black earths in the associations *Lathyro-Melandrietum* and *Lamio-Veronicetum.*

Ch. strictum and *Ch. suecicum* are associated with a mean loamy soils in *Aphano-Matricarietum* and *Echinochloo-Setarietum*.

Expanding segetal weed species in central-east Poland

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Analysis of segetal flora in central-eastern Poland made in the last 40 years indicates two main changes directions: decrease of genetic resources in extreme habitats and increase of population of taxa that positively reacted towards anthropic pressure, namely those resistant to herbicides. The aim of this study was to indicate the qualitative changes of expanding segetal flora within that region. The study material consisted of 1450 phytosociological records taken by means of Braun-Blanquet method in crop canopies in 1967-2006. The largest number of records were taken from brown soils developed from loess (over 45%), then pseudopodsolic soils developed from sands (34%), and the smallest from rendzinas (8%), chernozems (6%) and alluvial soils (2%). Plant communities were mainly studied in cereals and potato. The increase of a species habitat density (increase of phytosociological constancy) and/or elevated quantitative proportion expressed as coverage coefficient D was accepted as a symptom of its expansion. Moreover, species migrating from other habitats were taken into account. This paper includes a full list of species considered as expanding in 1990-2006 and some in 1967-1985. One particular category of expansion consisted of 12 common occurrence species, including *Amaranthus retroflexus* L., *Apera spica-venti* (L.) P. Beauv., *Avena fatua* L., *Capsella bursa-pastoris* (L.) Medik., *Chenopodium album* L., *Echinochloa crus-galli* L. P. Beauv., *Galium aparine* L., *Galinsoga parviflora* Cav., *Galinsoga ciliata* (Raf.) S.F. Blake., *Stellaria media* (L.) Vill., *Veronica arvensis* Poir. and *Viola arvensis* Murray. Most of the above species increased their proportion due to changes in cropping practices and increase in weed herbicide resistance similarly to the *Matricaria maritima* L. ssp. *inodora* (L.) Dostal., *Centaurea cyanus* L. and *Galium aparine* spread in 1967-1985 as a result of long-term 2,4-D and MCPA groups herbicide application. At present, locally expansive species (II expansion category) are: *Anthoxanthum aristatum* Boiss. and *Bromus secalinus* L. The former spreads onto podsolic soils developed from sands in the protective zone of Polesie National Park, Solska Forests and Janów Forests; the latter on rendzinas and brown soils developed from loess near Zamość, Chełm and Krzczonów Landscape Park. Species migrating from other habitats (III expansion category) are: *Descurainia sophia* (L.) Webb ex Prantl, *Artemisia vulgaris* L. and *Lactuca serriola* L. These taxa penetrate to crop cultivations from ruderal habitats and possess the ability of vegetative reproduction, thus permanently widening their previous range of occurrence.

Weed phytocenosis in winter rye canopy developed after six years of ploughing or conservation tillage

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Winter rye is a crop exhibiting strong competitive ability towards weeds as a result of the fast spring growth of its canopy. In rye cultivation, herbicides are not frequently used because weeds are expected to be suppressed by rye plants setting up a dense canopy. Field research was carried out in 1998–2003 at the Experimental Farm Bezek (Agricultural University of Lublin). An experiment was set up in a randomized block design with four replications on a loamy sand. Soil reaction was slightly acidic (pH 6.0) and humus content was 12 g kg^{-1}. The purpose of this work was to determine the influence of conventional (stubble cultivation 8-10 cm + pre-plant ploughing 18-20 cm depth) and conservation tillage (rigid-tine cultivation 18 cm depth) on weed density, weed species composition and biomass in a winter rye crop. Winter rye was cultivated in the following crop rotation: potato–spring barley–winter rye. Phosphate (17.5 kg ha^{-1}) and potassium (41.5 kg ha^{-1}) were applied at seedbed preparation. A first dose of nitrogen (30 kg ha^{-1}) was applied in early spring before vegetation re-growth and a second (30 kg ha^{-1}) at the shooting stage. Winter rye seeds dressed with tebuconazol were sown at a rate of 400 grains m^{-2} with a row spacing of 11 cm. No plant protection measures were subsequently applied. Assessment of the canopy weed infestation was done prior to winter rye harvest. Weed density and the air–dried above-ground biomass m^{-2} were estimated from two randomly located sampling areas of 1 × 0.5 m size in each plot. Both weed density and biomass data were statistically analysed by means of ANOVA and means were compared by the Tukey test. Total weed species number and composition were also analysed. On average, weed density and biomass amounted to 55.7 plants m^{-2} and 46.2 g respectively after ploughing and to 113.4 plants m^{-2} and 106.4 g after conservation tillage. Dicotyledonous weed density did not significantly differ between tillage systems. However monocotyledonous weed density, total weed density and total weed biomass were significantly reduced by conventional tillage compared to conservation tillage (by 72.7%, 50.9% and 56.6% respectively) in the winter rye canopy. Prior to winter rye harvest, 27 weed species (21 dicots and 6 monocots) were detected in the ploughing treatment while 30 weed species (24 dicots and 6 monocots) were detected in the conservation tillage system. Compared to conservation tillage, conventional tillage reduced density of *Agropyron repens* (by 88.2%), *Apera spica-venti* (by 78.9%), *Stellaria media* (by 50.0%) while increased density of *Plantago major* (by 84.2%), *Chenopodium album* (by 64.9%) and *Fallopia convolvulus* (by 53.8%). Ploughing suppressed species such as *Stachys palustris, Cerastium holosteoides, Centaurea cyanus, Lapsana communis, Lamium amplexicaule, Veronica persica* and *Lolium multiflorum* while conservation tillage suppressed *Chamomilla suaveolens, Gnaphalium uliginosum, Vicia cracca* and *Setaria pumila*. *Apera spica-venti* was the most abundant species in winter rye, especially under conservation tillage. The present results indicate that an increase in weed infestation can occur after introduction of reduced tillage. The reason of this heavy infestation is the higher number of weed diaspores, so there is an immediate need of reducing the soil seed bank.

Seed availability and weed cover for birds on different crop stubbles during winter

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Food availability in winter, in the form of weeds and seeds, is an important factor affecting the survival of many farmland bird species. The provision of over-winter stubbles is supported in some European agri-environment schemes, but with little scientific rationale. A randomised spilt-split plot design experiment was established to evaluate weeds and seeds in different stubbles. Main plots (24x40m) sown with winter wheat, winter linseed, spring barley, spring oilseed rape and maize, were divided into subplots subject to conventional or restricted herbicide use and sub-sub plots (12x20m) with and without stubble cultivation. Assessments were made before harvest and in the stubble phase and crop yields were derived from a small-plot combine harvester and, for maize, silage weights. Weed populations in crops were assessed in terms of ground cover using 10x0.25m^2 quadrats per sub-sub plot. In the stubble phase, above-ground weed cover was assessed in 10x0.25m^2 quadrats on two occasions and on four occasions using seven smaller 0.09m^2 quadrats per sub-sub plot. The latter quadrats were located where seeds on the soil surface were sampled using a Vortis suction sampler. Seeds on the soil surface were counted from a subset of samples taken immediately after harvest and in mid-winter. In the case of sub-sub plots that were cultivated with a Dynadrive, sampling began immediately after the stubble cultivation.

During the crop and stubble phases, there were significant differences in weed cover between crops, herbicide treatment and date. Before harvest, conventional herbicide programmes in wheat and maize kept weed cover low. Weed cover in rape was generally high, but lower on conventional plots. Similarly, in linseed and barley, weeds were significantly reduced on conventional subplots, though significant weed cover was present. There were significantly lower crop yields under reduced herbicide programmes for wheat and maize, but not the other three crops. In the case of oilseed rape, yields were particularly low, reflecting both a late harvest with seed shedding and a poor crop. During the stubble phase, weed cover was generally higher in uncultivated stubbles that followed a reduced herbicide crop. Weed cover was lowest in maize stubble, and consistently lower in winter wheat than spring barley stubbles. Oilseed rape stubbles had highest weed cover in winter, though barley and linseed stubbles in autumn also had high weed cover, particularly with reduced herbicide programmes. Weed cover on conventional wheat plots were generally low. Total plant cover in stubbles, including crop volunteers, was greatest on reduced herbicide, uncultivated stubble plots, particularly for the first two sample periods.

Weed seeds were more abundant at harvest under reduced herbicide treatments. Weed seed densities at harvest were highest in linseed and rape stubbles. However, reduced herbicide regimes of all crops provided seed densities of about 5000m^{-2} through the winter and, of the conventional crops, spring barley provided the best seed resources in mid-winter. Spilt crop grain had largely disappeared by mid-winter. Spring crops, reduced herbicide programmes and lack of stubble cultivation provided more weeds and seed in the stubble phase. Maize is not likely to be a useful stubble crop, whereas oilseed rape, linseed and barley stubbles, especially following reduced herbicide programmes, may provide significant resources for birds in winter.

Weed survey in central north Bulgaria

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During 2004-2006, a national survey of weed communities in winter wheat, barley, maize and sunflower was done in 14 different regions of Bulgaria. The objective was to improve knowledge of the weed communities of cultivated areas in order to develop effective weed control. The software "Kadis" was created for data base development, analysis and mapping of weed flora in Bulgaria. The survey in Central North Bulgaria (V. Turnovo region) was part of the national weed investigation. A total of 103 representative fields of winter wheat crop (6,600 ha), 31 of winter barley (1,650 ha), 73 of sunflower (4,230 ha), and 37 of maize (2,300 ha) were assessed by visually scoring weeds in the whole field and margin. The estimation of weed density was taken according to density cover index (d.c.i.): 0 = none present; 1 = weak degree of infestation (evaluated cover <5%); 2 = average degree (5-25%); 3 = high degree (25-50%); 4 = very high degree (50-100%). In winter wheat, a total of 39 species was found. The dominant weed species in the fields were: *Cirsium arvense* (L.) Scop. (71% of the fields with d.c.i. 2-3), *Galium aparine* L. (54% with d.c.i up to 3), *Anthemis arvensis* L. (47% with d.c.i. 2-3), *Sinapis arvensis* L. (47% with d.c.i up to 3). The most problematic grass weeds were: *Avena fatua* L., *A. sterilis* ssp. *ludoviciana* (Dirieu) Gillrt&Magne, and *Alopecurus myosuroides* Hudson. It was found that *Cephalaria transsilvanica* (L.), *Conium maculatum* L., *Daucus carota* L., *Cichoria intybus* L., and *Rumex crispus* L. spread from margin to the field. The increasing expansion of *Cirsium arvense* was evident in the last decade. In winter barley the most frequent perennial weeds were *Cirsium arvense* and *Sorghum halepense* (L.) Pers., while the most frequent annual were *Galium aparine, Anthemis arvensis*, *Sinapis arvensis*, and *Avena* sp. In sunflower, since the last national survey in 1980, an increasing tendency for the dominance of some perennial weeds likes *Sorghum halepense* (L.) Pers. (82% of the fields with d.c.i up to 3), *Cirsium arvense* (73% with d.c.i up to 3), *Convolvulus arvensis* L. (48% with d.c.i of 2) was found. Among annual weeds the most frequent were *Xanthium strumarium* L. (53% of the fields), *Abutilon theophrastii* Medicus (56%), *and Sinapis arvensis* (51%, with high degree of infestation). New species which were previously almost unknown have appeared, e.g. *Conyza canadensis* (L.) Cronq. and *Lactuca serriola* L. The most problematic weeds in maize were *Sorghum halepense* (94% of the fields with d.c.i up to 3-4), *Cirsium arvense* (70% with d.c.i 2-3)*, Convolvulus arvensis* (62% with d.c.i 2-3), *Abutilon theophrasti* (43% with d.c.i 2-3), *Xanthium strumarium* (62% with d.c.i 3), *Solanum nigrum*, *Setaria* sp.*,* and *Echinochloa crus-galli* (L.) Beauv. An aggressive spread of *Sorghum halepense* in both uncultivated and cultivated fields was evident. It can be concluded that, due to climate and economic changes occurred in the past years, weed species abundance is increasing becoming a serious problem. Tillage practices and herbicide weed control technologies used have not been sufficient. The increasing size of area infested with *Cirsium arvense, Sorghum halepense*, *Rumex crispus*, as well as density cover index, associated above all with use of disc harrowing. The choice of crops in rotations, chemical and mechanical weed control, fertilization, soil management, sowing technique, purification of seeds and agricultural land separation are the main reasons for these negative processes.

Species diversity of arable plant communities in contrasting landscapes of the Rolling Pampa (Argentina)

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Diversity of plant communities, as accounted by the number of species, is determined by factors operating at different scales. Effects of competition and disturbance on the richness of plant communities are well understood, while determinants acting at the landscape and regional scales are less known. Therefore, our aim was to explore the relationships between: (1) species diversity and landscape heterogeneity; and (2) local (a), turnover (b), and landscape (g) diversities in weed communities. Plant species richness was sampled in field habitats cropped with cool- (wheat and pea) and warm-season crops (maize and soybean). Landscapes, fields, and field habitats (fence-row, field edge, and field centre) were hierarchically nested to compare a-, b-, and g-diversity. Percent of cropland in the landscapes was chosen as a straightforward indicator of heterogeneity, because it was negatively correlated with the Simpson diversity index (Gini coefficient, 1 - Y) of the land uses in a landscape. Species diversity was additively partitioned into its a-, b-, and g-diversity components, calculating b-diversity as the difference between g-diversity and mean a-diversity. Total species richness was 222. Regardless of the cropping season, g-diversity decreased as the proportion of cropland in a landscape increased. Within each landscape, fence-row habitats had the highest g-diversity values, which increased with landscape complexity level. Since a-diversity did not significantly differ between crops and landscapes in each field habitat, b-diversity reflects the variation of community composition among the fields in a landscape, as a result of the landscape complexity. Fence-rows b-diversity had the highest relative contribution of total species richness, being ca. 40% in cool- and ca. 36% in warm-season crops. Field edges b-diversity was significantly higher in pea than in wheat and in maize than in soybean. b-diversity of field centres was higher in pea than in wheat crops, whereas there were not significant differences between the warm-season crops. Variation of the inner field b-diversity in pea and maize indicates that mass effects from field margins are involved in maintaining the species richness of weed communities. Plant diversity of agricultural landscape could be enhanced not only by maintaining highly diverse non-cropped areas, but also by increasing the richness of crop species (i.e. growing crops differing in growing cycle and ground-cover dynamics).

Seasonal changes in the emergence of arable species of *Galium* as related to their origin

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Galium aparine and *Galium spurium* are two weed species that highly affect cereal crops. In this work the emergence pattern of seeds from three *G. aparine* populations with different origin (Spain, UK and Germany) and from two *G. spurium* populations (Spain and UK) was analysed. Seeds were sown in Lleida (Spain) in a dryland area with a Mediterranean climate. The experimental design was a randomised block with three replicates, each block containing 15 plots of 2 x 1 m^2. The species were sown in each plot at a density of 400 seeds m^{-2} at three different dates (cohorts). The first cohort was sown on 23rd November 2005, the second one on 13th January 2006 and the third one on 10th March 2006. For each plot the number of new emergences occurred in three 0.33 x 0.33 m^2 quadrates was followed weekly. The results obtained were fitted with cumulated degree days. All populations showed more emergences in the first cohort than in the second or the third ones. However, the second cohort showed a lower mean time of emergence; as a result, the first and the second cohorts overlapped in time. The emergence of seeds sown in March was very low and extended in time. These results permitted the separation of two groups of populations: the Spanish ones and the Central Europeans. The Spanish *G. aparine* and *G. spurium* had higher percentages and, in general, lower mean time of emergence (8.9% and 31.4% and 260 and 254 degree days for each species respectively; 1st cohort) than the ones from UK (3.7% and 3.3% and 310 and 254 degree days; 1st cohort) or from Germany (1% and 310 degree days; 1st cohort). Among the Spanish populations, *G. spurium* resulted the species with more emerged seedlings (31.4%, 15.3% and 6.2% for the 1st, 2nd and 3rd cohort respectively), whereas *G. aparine* emergence was significantly lower (8.9%, 7.9% and 4.5%). These differences disappeared regarding to degree days needed to start emergence (254, 147 and 213 in *G. spurium* and 260, 140 and 288 in *G. aparine* for the 1st, 2nd and 3rd cohorts respectively). Similarly, there were no differences between the British species in percentage of emergence: both *G. aparine* and *G. spurium* presented similar rates (3.7%, 2% and 0.2% for the first cohort and 3.3%, 3% and 1.5% for the second one). Finally, *G. aparine* from Germany, which was a spring population, was the one that showed the lowest emergence percentage (1%, 1% and 0.3%). This work demonstrates the different emergence behaviour between native populations of both *Galium* species and their different potential weediness in our agricultural systems. Furthermore, differences among Spanish and Central European populations within each species, as in other weed species, seem to rely on their origin and intrinsically on the effect of ecological environment where the parent plants grew, which will ultimately determine the success of germination and emergence.

Minimum tillage effects to control *Convolvulus arvensis* L. in a fluvisol

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Due to its biological features and difficulties in control, *Convolvulus arvensis* L. has a greater proportion in weeding process of winter and spring cereals and generally, in all agricultural crops in Romania. The integrated control of *Convolvulus arvensis* L. is difficult because of its perennality and great ecological plasticity, which decrease the effect of control measures, compelling to adequate crop rotation and use of agro technical methods and specific herbicides. By applying the minimum tillage systems on fluvisol type of soil, several important changes are observed both for participation of this species in weeding and in the seed reserve in soil. The rotation crops were: soyabean (glyphosate-resistant), wheat and maize, tested in 5 experimental treatments: conventional tillage: V_1 – classic plough (20-25 cm) + disc –2x (8 cm) (control); minimum tillage: V_2 – disc harrow (6-8 cm) + rotary harrow (10 cm); V_3 - rotary harrow (10-12 cm); V_4 – paraplow (18-22 cm) + rotary harrow (8 cm); V_5 – chisel plough (18-22 cm) + rotary harrow (8 cm). The experimental design used in this study was a randomized complete block design with three replications. The area of a plot was 300 m^2. Except for the soil tillage system, the entire technology applied was similar in all variants, including the herbicide used: glyphosate for soyabean, dicamba for wheat and acetochlor for maize. Results were analysed by ANOVA test. In the pedo-climatic conditions of Cluj Napoca, one *Convolvulus arvensis* plant produces 500-600 seeds. The seeds germinate from 2-8 cm soil depth, and can germinate immediately after shedding, at soil temperatures over 2 °C. The root system is very deep (up to 3-5 m). The main root has lateral ramifications, all having root buds that might generate suckers, especially from the first 50-60 cm of length. Root buds density is very high, a 5 cm root fragment being able to produce up to 25 aerial suckers that coming out to the soil surface. The aerial stems can reach up to 1.5 m height but they die at first frost without killing the dormant buds. The vegetative multiplication is stimulated by the roots fragmentation found at the soil surface and, for this reason, *Convolvulus arvensis* control through soil tillage is more difficult compared to other perennial weeds such as *Cirsium arvense* and *Agropyron repens.* By applying minimum tillage a stimulation of multiplication by seeds and vegetative organs of *Convolvulus arvensis* was observed. The highest percentage of this species in the weed community was found in the treatment with disk + rotary harrow (39.1% in soyabean, 4.2% in wheat and 24.2% in corn). In ploughing, *Convolvulus arvensis* percentage decreased to 19.2% in soyabean, 0.9% in wheat and 3.8% in corn. Soyabean was the crop with lowest weed presence, respectively 2.3-2.9 weeds m^{-2} of which *Convolvulus arvensis* represented 10.3 to 39.1%. In soyabean, by sowing genetically modified varieties resistant to glyphosate, it was ensured an efficient control of *Convolvulus arvensis* only in a dose higher than 1,620 g a.i. ha^{-1}, applied in 2 successive steps. After 3 years of applying the minimum tillage soil system of disk + rotary harrow we observed an 11% increase of weed seeds reserve in the 0-30 cm soil layer compared with the ploughing system. In the first 10 cm soil depth, in the treatment disk + rotary harrow, we found 91% of the total weed seeds and in the ploughing treatment 71%. *Convolvulus arvensis* seed number increased in the minimum tillage treatments by 16%. Of the total seeds in the soil seed bank, 77% were localised in the first 10 cm of depth.

Does composition of weed community determine the assemblage of granivorous carabids?

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Recent data indicate that besides having negative impact on crops, particular weed species may increase animal biodiversity, including vertebrates and invertebrates. Considering insects, both beneficial and pest species seem to profit from weediness in arable land. However, there is evidence that positive impact on species richness and diversity vary markedly between weed species. Although much data on phytophages is available, how granivorous species benefit from increased weed abundance is unknown.

The objective of this study is to determine how composition of weed assemblages within crops affects the assemblages of granivorous carabid beetles. It was hypothesized that the latter would differ between patches of particular weeds, depending on the degree of specialization and preference for seeds by carabids. This hypothesis was tested using metal enclosures ($0.16m^2$) that were placed within patches of weeds naturally established within crops. Each enclosure (sample) ran for two weeks during which arthropods enclosed in the sampled area were collected by means of pitfall trap. The character of vegetation within each enclosure was described as an estimated relative abundance of particular weed species. In total 43 samples were taken in Praha – Ruzyně at four occasions between 9.5.-23.8.2006. The data (abundance of particular granivorous carabid [dependent variables] vs. relative abundance of particular plant species [environment variables]) were analysed for each sampling occasion separately, using Redundant Analysis (RDA) followed by Monte-Carlo permutation test using CANOCO 4.5 for Windows.

In spring, *Stellaria media* and *Capsella bursa-pastoris* were the dominant weeds. In summer, *Cirsium arvense*, *Tripleurospermum inodorum*, *Polygonum aviculare* and *Tussilago farfara* dominated in the study plots.

In total, 501 carabid individuals were recorded, including both adults and larvae. Of that amount 399 were adults of granivorous (known to consume seeds) species. RDA revealed that structure of weed community as described by the relative abundance of particular plant species affected composition of carabid assemblage. However, this effect was significant only in 2 out of 4 sampling occasions. In the first sampling occasion (9/5/2006), only *S. media* explained significant amount of variation in carabid distribution (Monte-Carlo permutation test: F=5.47, p=0.002), the effects of other two "environments" were not significant. In the last sampling occasion (9/8/2006), only effect of *T. inodorum* on carabid distribution was significant (Monte-Carlo permutation test: F=4.31, p=0.006), while the effect of the other 4 weeds was not significant. Nevertheless, when the results of ordination were visualized on the biplots, consistent associations of particular carabids and weeds could be found across sampling occasions: *Amara familiaris* and *Harpalus luteicornis* are associated with *S. media*, *Acupalpus meridianus* with *C. bursa-pastoris* in spring, with *T. inodorum* in late summer etc.

The preliminary results thus indicate that composition of weed populations in crops translates to the diversity and composition of granivorous carabids.

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The long-term impact of crop management practices on weed seedbank changes

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The soil weed seedbank is an important source for establishment of actual weed infestation (occurrence of annual and perennial weeds). The seed density and species composition of the seedbank is determined by locality, especially by soil and climatic conditions, but also by different crop management practices. They include tillage system, crop rotation and weed control management. The size of weed seedbank was assessed in long-term field trials in two different locations (Pernolec and Hnevceves) in the Czech Republic. These trials which were established in 1975 include treatments with two different crop rotations (the first one with 70% of cereals and the second one with 50% of cereals) and intensity of chemical weed control (herbicides applied or not). The conventional tillage including ploughing to the depth of 0.25 m was used by all crops in both crop rotations. The two herbicide applications differed in type of applied herbicides. The first treatment includes only synthetic auxins (2,4-D and MCPA), the second treatment was based on changing of different types of herbicides (a broad spectrum of active ingredients, e. g. 2,4-D, MCPA, clopyralid, chlorsulfuron, chlortoluron, bentazone and others). A soil core sampler with a circle base of 2.0 cm in diameter was used to 0.3 m of depth. Dried samples were mixed by hand in a bag. From the mixed sample, two 200 g samples were taken for analyses. The elutriation method using a device Analysette 3 (vibratory sieve shaker, Fritsch firm) was applied for seedbank assessment. The principle of this method is elutriation of wet soil samples on a metal sieve with mesh size of 0.25 mm with a mild flow of running water. The remaining parts on the sieve (non-elutriated proportion of mineral and organic particles larger than 0.25 mm and weed seeds) were rinsed into a beaker and filtered. The proportion which remained on filter paper was dried at a room temperature and weed seeds were collected using tweezers and a preparation needle, identified and counted. Due to small dimensions of seeds, it was necessary to use a magnifying lens or stereoscopic microscope (magnification 5–10x). Only the entire seeds were counted. Results showed that the highest number of entire weed seeds was in the no-herbicides treatments at both localities. In the crop rotation with 70% of cereals weed seedbank was higher on the treatment where synthetic auxins were used as compared to that where a broad spectrum of active ingredients was used. The size of weed seedbank could be classified as high, since the average of entire seeds in total was 30,240 m^{-2} at locality Pernolec and 56,381 m^{-2} at locality Hnevceves. This difference can be explained through better soil and climatic conditions in Hnevceves that can play an important role in reproduction of weeds. The number of weed species decreased especially from treatments without herbicides (11 or 12 of weed species) to those with herbicides (5 or 6 of weed species). The weed composition was also influenced by locality. The main weed species at Pernolec were: *Chenopodium album, Fallopia convolvulus, Lamium purpureum, Veronica persica, Stellaria media, Thlaspi arvense, Viola arvensis, Polygonum aviculare, Galeopsis tetrahit, Myosotis arvensis, Tripleurospermum inodorum* and *Papaver rhoeas.* The main weeds at Hnevceves were: *Chenopodium album, Amaranthus retroflexus, Fallopia convolvulus, Sinapis arvensis, Lamium purpureum, Veronica persica, Stellaria media, Polygonum lapathifolium, Thlaspi arvense, Galium aparine, Tripleurospermum inodorum* and *Euphorbia helioscopia.* This work was supported within the project 1B53045 funded by National Agency for Agricultural Research, Ministry of Agriculture, Czech Republic.

Insect injury and mortality of weed seedlings on early abandoned field

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Herbivory on alien plant species has been frequently studied in order to find phytophagous insect species that could be used in biological control. Less attention has been paid to quantify the role of phytophagous insects in reducing the spread of native weed species. Some studies suggest, that insect herbivory may be important aspect during early old-field succession, but data are relatively scarse.

The recruitment of plants and their mortality due to insect injury was investigated for annual *Thlaspi arvense* L. (field penny-cress) and *Chenopodium album* L. (pigweed) during a secondary succession on early abandoned field. The experiment was performed in experimental fallow field established in 1996 at Prague-Ruzyně (50°06´ N, 14°15´E, altitude 350 m, annual mean temperature 8.2 °C, precipitation 477.4 mm). Monitoring proceeded in spring periods in 1997-1999. Seedling emergence, insect injury and mortality of weed seedlings were monitored between 6-30 May 1997, 21 April-4 June 1998, and 19 April to 31 May 1999. Cumulative numbers of field penny-cress and pigweed seedlings were recorded in 3-7 d intervals. The damaged plants were counted and evaluated in 3–7 d intervals too. Cumulative numbers of dead plants were recorded in the same intervals. Observations started after emergence of *T. arvense* and *Ch. album* seedlings. The date of recruitment, recruitment rate and seedling abundance of the weed populations studied showed substantial differences between years. The highest average abundance of field *T. arvense* and *Ch. album* seedlings were recorded in 1999 (102 individuals/m^2 and 83 individuals/m^2, resp.), the lowest in 1998 (27 individuals/m^2 and 11 individuals/m^2, resp.). The numbers of seedlings correlated with rainfall, which was also highest in 1999 (53.6 mm) and lowest in 1998 (7.5 mm). The most important herbivores in this experiment were the flea beetles (*Phyllotreta* spp.), especially in *T. arvense* seedlings. The plants were attacked from emergence on. Consequently the whole populations of *T. arvense* (100% in 1997 and 1998, 94% in 1999) were injured by flea beetles to some extent. The injury was greatest in younger seedlings. The proportion of dead plants increased steeply at the beginning of the vegetation period when the plants were in the stage of cotyledons and the first leaves. The mortality of *T. arvense* and *Ch. album* varied between years and was low in 1997 (17.1% and 5.3%, resp.) and 1999 (15.8% and 4.0%, resp.). The highest mortality of *T. arvense* and *Ch. album* plants (94% and 23%, resp.) was recorded in 1998 due to drought in early spring period and low abundance of weed seedlings.

The results of this study indicate that early herbivory may be an important mortality factor of weed plants and together with environmental stress may shape the secondary succession on early abandoned field.

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Broomrape (*Orobanche* spp.) occurance in agricultural areas in Turkey

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Broomrape species (*Orobanche* spp) are obligate root parasites from *Orobancheaceae* family. Their main origin is the Mediterranean area. They infested areas with similar climatic conditions worldwide. Total losses of crop due to broomrape infestation have been observed up to 100 % when farmers plow the field and remove crop before maturing because of heavy broomrape infestations. The flora of Turkey, which is the main source of plants in Turkey recorded 36 broomrape species. However, only a few of them have been considered important weeds in agricultural areas depending on importance of crop and occurrence and intensity of broomrape. These are *Orobanche aegyptiaca*, *Orobanche crenata*, *Orobanche cumana*, and *Orobanche ramosa*. *O. aegyptiaca* and *O. ramosa* are very similar species, which cause distinction problems and occur together on tomato, lentil, tobacco, potato and faba beans. *O. crenata* is a problem in lentil and faba bean fields as sole populations or mixed populations with *O. aegyptiaca/O. ramosa*. *O. cumana* causes identification problem with *Orobanche cernua*, which infests sunflower. Although it is recorded as *O. cernua* in the Flora of Turkey, weed scientists and breeders use the term *O. cumana*. There is no very clear data about extent and level of broomrape infestation in crops in Turkey. Here, estimations were compiled using data, papers, surveys with stakeholders and the experience of authors. Turkey produces 950 000 t sunflower seeds on 440 000 ha area. More than half of the sunflower fields in Turkey are infested by broomrape. *O. cumana* has races and the most virulent race, race H, has been determined in Turkey only. Evolving new more virulent broomrape races requires new broomrape-resistant sunflower varieties being developed. Imidazoline herbicide resistant (IMI resistant) varieties, bred by using conventional methods, broomrape resistant varieties, and non-resistant conventional varieties cover approx. 33 % of the total sunflower area each. Imazapic is also registered for use in tobacco, which is grown on 190 000 ha, and conventional sunflower fields, but it is not used in tobacco fields due to several sequential applications required. Half of the tobacco fields have been already infested with broomrape. Pulses are important crops in Turkey, which are sown on 1 544 800 ha. No record was found for broomrape infestation on chickpea in Turkey although it is recorded on lentil, faba bean and pea. Imazapic and imazethapyr herbicides, both are from the imidazoline family, are used in red lentil fields. From this crop around 66 % of the fields are infested by broomrape. Broomrape infestation occurs on 58 % of fields with faba beans. Broomrape infestation in tomato fields in the Marmara Region, an area of Turkey where mainly processed tomato are grown, is estimated with over 75 % of fields, while it changes 5-80 % in some locations in other regions. There are no registered herbicides for use in tomato for broomrape control. Rotation and organic amendments are applied to reduce the level of infestation. It is also recorded in potato, pepper, and eggplant fields. Solarisation controls broomrape and is applied in greenhouses.

Study of weed seed bank after 24 years of different tillage systems

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Soil erosion is nowadays an environmental and farming problem. Conservation farming tries to reduce this problem with techniques that keep residues from previous crop covering and protecting the soil from erosion. No-tillage and minimum tillage are two of the best known conservation techniques. Tillage reduction causes changes in weed communities. These changes can only be foreseen with long term experiment and are difficult to extrapolate to different places and conditions. In Sevilla (Southern Spain) there is an experiment that was established in 1982 in a farm that is representative of dryland annual crops in the area. Our objective was to study the influence of tillage system on the weed seed bank and emerged flora. The experimental design was a completely randomised layout with three treatments (conventional tillage, minimum tillage, i.e. chisel and no-tillage) and three replicates. Plot size was 180 x 15 m and in each plot 21 soil samples were taken, at the beginning of 2006, within a fixed quadrate of 10 x 5 m. Soil samples were cylinders of 5 cm diameter and 8 cm depth. Samples were sieved with 1.0, 0.5 and 0.25 mm mesh. Weed seeds were identified and counted. The field experiment was visited two times more to count weed emergences. Seed bank and field emergence results indicate that total weed density increased when tillage was reduced as it has been reported in similar studies. In our experiment, seed bank increases were of 16% for minimum tillage and 91% for no tillage practice. Seed bank increase was particularly evident for *Amaranthus blitoides, Kickxia spuria* and also *Anagallis arvensis*. Conversely, *Chrozophora tinctoria* seems not to be adapted to conservation farming because its density decreased with tillage reduction. *Polygonum aviculare* showed the highest seed bank in minimum tillage plots which is consistent with some previous studies. *Malva parviflora* and *Picris echioides* are known to cause problems in conservation farming and this is confirmed by our results on actual vegetation, although an increase in their weed seed bank was not detected. Finally, spores of mycorrhizal fungi were detected in reduced tillage treatments.

Weed flora in poplar nurseries

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Due to the wide inter-row spacing and open canopy in the early stages of plant development, poplar nurseries are an ideal place for the development of weeds. Despite the use of agrotechnical measures, weeds still represent a problem in the nurseries. For this reason, the Institute of Lowland Forestry and Environment has focused great attention to the study and application of herbicides in poplar nurseries. However, for the successful application of herbicides, along with the cultivated plants, it is very important to know the composition and structure of the weed flora because only in this way adequate suppression measures can be applied. Although geographical distribution of vegetation mainly depends on climatic factors, vegetation diversity also depends on edaphic factors. With this aim, the composition and abundance of weed flora was studied on sample plots of the Institute during 2002 and 2003. Research included three localities (Lugarnica, Fister and Petrovaradinsko) which differed by soil physical-chemical characteristics. The sample plot at the locality Lugarnica was loamy form of fluvisol, Fister - sandy form of fluvisol, and Petrovaradinsko - humofluvisol. During the two-year research, the species and the average density of weeds were recorded per unit area. The data were based on three samples per elementary plot which were not chemically treated or mechanically cultivated. Results showed that the differences in soil physical-chemical characteristics affected the composition and abundance of weed flora at the study localities. The greatest number of weed species was recorded at Fister. Seventeen species were recorded in the first study year, and sixteen in the second year. At Lugarnica, eleven species were recorded in the first year and thirteen in the second year, while at Petrovaradinsko nine species were recorded in both study years. At all localities, the percentage of dicotyledonous weeds was far greater compared to monocotyledons, plants belonging to the group *Magnoliophyta.* In 2003, *Equisetum arvense,* a species belonging to the group *Equisetophyta* was identified at Petrovaradinsko. The analysis of the biological spectrum at all three localities showed the prevalence of plants belonging to the group therophytes, but with a significant percentage of geophytes and hemicriptophytes. The great percentage of therophytes indicates that the most represented species at the study localities were annual herbaceous plants, which perish completely in unfavourable conditions and only the seeds remains for the reproduction and spreading Intensive application of agrotechnical measures in poplar nurseries decreased presence of geophytes and hemicriptophytes while abundance of therophytes was favoured.

The influence of field border plant communities on the occurrence of *Conium maculatum* (L.) in agrophytocoenoses

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Conium maculatum (L.) is one of the expanding weed species in the Czech Republic. Its occurrence is significant especially in the field border plant communities, on the borders of drive-ways and on waste places. The influence of field border plant communities on the occurrence of *C. maculatum* in agrophytocoenoses was observed in fields in central Bohemia between 2003 and 2006. 13 localities south of Moravia have been chosen because of their infestation with *C. maculatum* for the observations. *C. maculatum* was observed in agrophytocoenoses on trial plots with a size of 312 m^2 (12 x 23 m) and also on the field border within an area of 1 x 12 m oriented from the border into the field core. Subsequently we determinated the number of *C. maculatum* plants per m^2. We did this observation from June till August each year and moreover in 2006 we determined the average plant height and measured the stem base diameter. Therefore plants of *C. maculatum* from agrophytocoenoses (70 plants) and plants from field border communities (90 plants) were assessed separately. The plants of *C. maculatum* were in phase of flowering till ripening of the seeds in the time of observation. Statistical analysis was done by applying Tukey method (a = 0.05) using Statgraphics®Plus, ver. 5.1. ANOVA. *C. maculatum* was determinated in winter wheat, spring barley, winter rape, sugar beet, white mustard and pea during observations. *C. maculatum* was mostly observed in stand of winter oil seed rape (six localities). We found a statistically significant effect of field border plant communities on the occurrence of *C. maculatum* in the arable crop. The highest number of *C. maculatum* plants per square meter (1.4 plants) within the field was found on the arable land one meter from the field border. This effect was statistically significant. The number of *C. maculatum* plants ranged between 0.2 and 4.2 plants per m^2 in the field border plant communities. Overall, the highest concentration of *C. maculatum* was determined outside the field in a distance of one meter from the field border towards the field border plant communities. There the average number of *C. maculatum* plants was 1.7 per m^2. The height of plant in the field border communities was 1913 mm and 1788 mm in the crop stands. There were no statistically significant differences in the height of plants from agrophytocoenoses and from field borders. The average of plant stem base diameter was 15 mm in field border and also in the crop stands. The results showed that the main reason for the occurrence of *C. maculatum* in fields is because of its existence in the field border plant communities. The same problem has been observed with *Arctium tomentrosum*. Invasion of this species along drive-ways is supported by non-existing land management in the respective areas. The chance of expansion of *C. maculatum* in arable crops depends on the cultivation and chemical protection of field borders. Even though *C. maculatum* has been observed only sporadically on arable land this time, its potential as an arable weed must not be underestimated. It may be supposed that the occurrence of *C. maculatum* in the landscape will increase which will also promote its diffusion to agrophytocoenoses.

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Grasses distribution in Italian wheat fields

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According to our investigation carried out during the spring 2005 in 104 untreated fields (4 randomized 150 m^2 areas in each field) in all regions of Italy, assessed by Braun-Blanquet phytosociological method, grass weeds represent approximately a quarter of all weeds. *Avena sterilis* L. is the most common weed in the wheat fields: it represents 28% of all grasses in Italy and is mainly widespread in the southern regions (Apulia, Basilicata, Sicily and Sardinia), where it represents about 38% of all grasses. *A. fatua* L. is less widespread and is mainly distributed in the northern regions (Emilia Romagna and Veneto); noting also the occasional presence of *A. magna* Murphy et Terrel in the North (Veneto and Friuli Venezia Giulia) and of *A. barbata* Potter in the South of Italy. It is important to note the presence of sulfonylurea-resistant phenotypes of *A. sterilis* in Apulia and Basilicata, where the continuous wheat cropping, often for more than 10 years, is common.

The second most diffused species is *Lolium multiflorum* Lam., which represents 20% of all grasses. The species distribution mainly concerns the central Italy, from the Adriatic sea to the Tyrrhenian sea, involving the Marche, Umbria, Tuscany, Lazio and Sardinia regions and where it represents 26% of all grass weeds. *L. perenne* L. is fairly widespread in northern Italy, whereas in southern Italy (mainly Apulia and Basilicata) *L. rigidum* Gaudin is more diffuse. During the investigation, *L. temulentum* L. has not been noticed, but it has been indicated in some small areas in Tuscany and in Sicily. Sulfonylurea-resistant phenotypes have been recorded also for *Lolium* spp.: *L. rigidum* in Apulia (province of Foggia) and *L. multiflorum* in Lazio (province of Rome).

The genus *Phalaris* spp., with the species *Ph. paradoxa* L., *Ph. brachystachys* Link. and *Ph. minor* Retz, represents 17% of all grass weeds in Italy. The highest spreading of these species is in southern regions, where they represent 34% of grass weeds. They are largely diffuse also in central Italy, where they represent about 20% of grasses. Their northern border of distribution is situated in the province of Bologna (Emilia Romagna) and they are not present in the other northern regions. *Ph. paradoxa* is the most widespread species, prevailing over the other species particularly in the central regions. *Ph. brachystachys* is almost as widespread as *Ph. paradoxa* in Sardinia and Sicily isles and in southern Italy, whereas *Ph. minor* is present in more arid areas.

Alopecurus myosuroides is the most diffuse grass weed in northern Italy (32% of all grasses), also with *tectarista* form (Viggiani), already cited in the 2004 EWRS Symposium. Its presence is less frequent (11%) in central Italy (particularly in the tyrrhenian areas and in Umbria) and much less frequent (4%) in southern Italy.

Poa spp. are present with three species: *P. trivialis* L. (the most diffused), *P. pratensis* L. and *P. annua* L. On the whole, these species represent 23%, 8% and 0.5% of grass weeds in the northern, central and southern regions, respectively.

Bromus spp. are widespread in all sites, but especially in the central and northern regions with the species *B. sterilis* L., which represents 7% of grasses in these regions. Other occasional species are *B. hordeaceus* L., *B. tectorum* L., *B. diandrus* Roth, *B. arvensis* L. and *B. commutatus* Schrader. Actually these weeds do not represent a big problem, but their spread is increasing each year, also because they show a low sensivity to most graminicides.

On the contrary, *Apera spica-venti* is a problem in wheat crops but only in Piedmont (northern Italy), where it represents about 50% of grasses. Fortunately, this species is not present in the rest of Italy. The occasional presence of *Hordeum murinum* in all sites, of *Polypogon monspeliensis* in central and southern areas, of *Vulpia ciliata* in central Italy and of *Dasypyrum villosum*, *Hordelymus europaeus* and *Cynosurus echinatus* in the Sardinia isle was notable, too.

Floristic impoverishment of arable weed communities in the Silesian Upland (southern Poland) as a result of intensification of agriculture

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The interest in the problem of changes in segetal flora and vegetation has being growing in recent years and attract interest of many authors. The list of threatened segetal plant species in Poland was prepared. Moreover, some weed species were included into the Polish Red Data Book of Plants.

Researched area was the Silesian Upland (ca 4000 km^2) – region located in southern Poland. Despite of strong urbanisation and industrialisation of the Silesian Upland, significant part of the investigated area has still agricultural character. The studies on segetal vegetation and flora were conducted in years 1995-2006. On the basis of 500 phytosociological reléves taken by the classical method of Braun-Blanquet nine weed associations as well as numerous rump communities (more then 53% of analysed patches in cereal crops and about 8% in root plant crops) were distinguished. Comparison of the results of the performed studies with literature data (19th century – 80th of 20th century) shows far-reaching qualitative and quantitative changes in the composition of segetal communities in the researched area. In the investigated segetal plant communities the list of characteristic association species was in the recent investigation very often not complete. The majority of rare and endangered weeds is characterised by very narrow ecological amplitude. These species are considered to be very sensitive to modern agriculture methods, e.g. chemisation, introduction of new cultivars, efficient cleaning of seed materials, drainage etc. The share of numerous speirochoric species, dicotyledonous therophytes (especially sensitive to herbicides), weeds connected with wet habitats and species occurring on stubble fields, shows a decreasing tendency. Some expansive species, e.g. *Apera spica-venti, Elymus repens, Avena fatua, Cirsium arvense, Galium aparine, Echinochloa crus-galli, Galinsoga parviflora, Galinsoga ciliata* played an important part in the structure of the studied communities. They are frequent and abundant elements of the analysed agro-phytocoenoses. The species mentioned above often have a strong mass production and become the dominant species, higly competitive with cultivated plants as well as with other weeds.

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