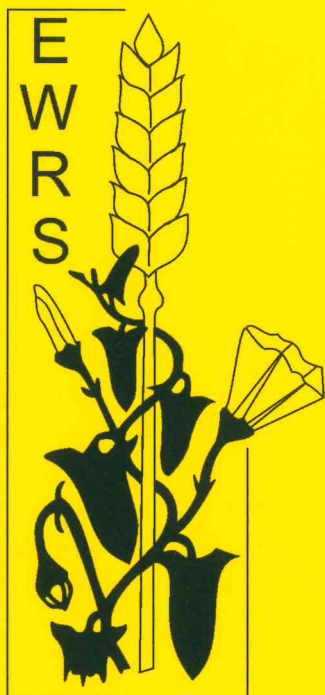


15th SYMPOSIUM

Kaposvár 2010

12 – 15 July, 2010



E W R S

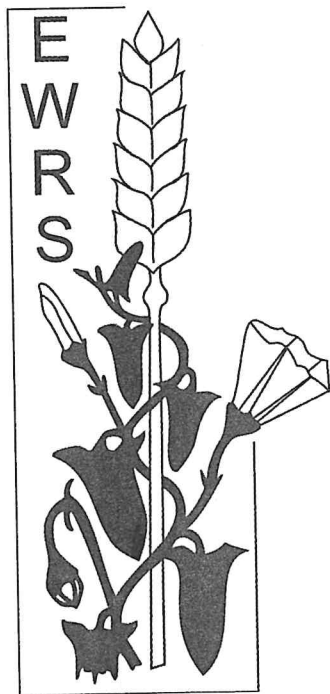
*European Weed
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PROCEEDINGS

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EWRS

European Weed Research Society
Europäische Gesellschaft für Herbologie
Société Européenne de Malherbologie

EWRS 15th SYMPOSIUM, Kaposvár 2010

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Copies of the Proceeding may be obtained from:

EWRS Bookstore
P.O. Box 28
NL-6865 ZG Doorwerth
The Netherlands

These Proceedings were edited / complied by

Asszisztencia Congress Bureau Ltd.
Szent István krt. 7.
H-1055 Budapest
Hungary

and edited by the Session Organizers:

L. Bastiaans, C. Bohren, S. Christensen, B. Gerowitt, P. Hatcher,
H. Krähmer, P. Kudsk, B. Melander, E. Pannacci, B. Rubin, J.
Streibig, F. Tei, A. Thompson, K. Torresen, M. Vurro

Printing:

Pannónia-Print Ltd., Budapest

ISBN: 978-963-9821-24-8

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CONTENTS

Opening Session	7
Session 1: Herbicide Resistance – Oral presentations	11
Session 1: Herbicide Resistance – Poster presentations	19
Session 2: Weed Biology - Oral presentations	55
Session 2: Weed Biology - Poster presentations	63
Session 3: Weed Diversity in Time and Space - Oral presentations.....	103
Session 3: Weed Diversity in Time and Space - Poster presentations.....	111
Session 4: Weed Ecology - Oral presentations	151
Session 4: Weed Ecology - Poster presentations	159
Session 5: Invasive Plants and Biocontrol - Oral presentations	195
Session 5: Invasive Plants and Biocontrol - Poster presentations	203
Session 6: Non chemical tactics and strategies - Oral presentations.....	243
Session 6: Non chemical tactics and strategies - Poster presentations.....	253
Session 7: Chemical weed management - Oral presentations.....	281
Session 7: Chemical weed management – Poster presentations	291
Author's Index	330

OPENING SESSION

Invited paper

Session organizer:

Hansjörg Krähmer

ARABLE weeds of Hungary. The fifth national weed survey (2007-2008)

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The change of weed flora has been continuously followed in Hungary for more than 60 years. Former national weed surveys were carried out in four times in 1947-53, 1969-71, 1987-88 and 1996-97 years. During the last two decades Hungarian agriculture has undergone an immense transformation which made necessary new national weed surveys. The purposes of weed surveys are to determine the most important weeds and to examine the spreading of weeds.

The fifth national weed survey in the fields was carried out in 2007-2008 years in the vicinities of 195 settlements of Hungary using the Balázs-Ujvárosi quadrat method. The surveyed settlements were selected out of the most typical soil types on the basis of the genetic soil map of Hungary. Winter wheat and maize, which are the most important cereals in Hungary, were surveyed. At all selected vicinities 10-10 sample quadrates (each of 4 x 4 m) were indicated in winter wheat and maize, respectively.

Based on the data of weed surveys the following results were obtained: *Tripleurospermum inodorum* (L.) Schultz-Bip. kept its first place in the dominance order of weeds in winter wheat as compared to previous years. The importance of *Ambrosia artemisiifolia* L. increased, it is believed to be the second most important weed in winter wheat. Intensive spreading of *Apera spica-venti* (L.) P. B. could be observed, its cover percent almost doubled in the last 20 years. At the same time the cover percent of *Galium aparine* L. considerably reduced due to the effective weed control technologies. Although its average cover is very high and it is the fifth most important weed species of winter wheat. The dominance of the main perennial weeds is high. Cover percent of *Cirsium arvense* (L.) Scop. decreased, while that of *Convolvulus arvensis* L. and *Elymus repens* (L.) Gould increased in the last 10 years.

Echinochloa crus-galli (L.) P. B., *Ambrosia artemisiifolia* L. and *Chenopodium album* L. are the three most important weeds in maize fields. *E. crus-galli* was the first weed in early summer, while *A. artemisiifolia* had the greatest value of cover in maize at the end of summer. The rapid spreading of more annual grasses – *Setaria pumila* (Poir.) R. et Sch., *S. viridis* (L.) P. B., *Panicum miliaceum* L. and *Digitaria sanguinalis* (L.) Scop. could be observed. Among perennials the cover percent of *Elymus repens*, *Cirsium arvense* and *Cynodon dactylon* (L.)

Pers. increased, while the reduction in cover percent of *Convolvulus arvensis* continued. In the last 20 years the intensive spreading of *Abutilon theophrasti* Medic. and *Helianthus annuus* L. could be observed on maize fields in Hungary. *Cyperus esculentus* L. var. *leptostachyus* Boeck. and *Asclepias syriaca* L. are spreading in the country, which are hardly controlled weeds.

SESSION 1
HERBICIDE RESISTANCE

Oral presentations

Session organizers:

Baruch Rubin & Anne Thompson

A novel in-season method for detecting resistance to post-emergence ACCase and ALS herbicides in grass weeds

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Inhibitors of acetolactase synthase (ALS) and acetyl CoA carboxylase (ACCase) are very important herbicides for post-emergence grass weed control in small grain cereal crops. As with most single site herbicides, however, they are prone to resistance evolution especially when used extensively, often as the sole method of weed control and with limited crop rotations. To date 39 and 38 grass weeds species have evolved resistance to ALS and ACCase herbicides respectively. In the absence of new graminicide modes of action and the phasing out of some active ingredients due to environmental concerns, it is of the upmost importance to detect and manage resistance in the field as early as possible. Several methods based on whole plants, seeds, seedlings, DNA and enzyme analyses have been developed. However, the laborious and time consuming whole plant pot test is still the most commonly employed method for confirming resistance following herbicide application. In this study we describe a novel in-season method for detecting resistance to ACCase and ALS inhibitors in grass weeds. It consists of a simple bioassay with reference sensitive and suspected resistant seedlings plated on agar containing discriminating rates of herbicides. The test has been primarily validated in the glasshouse, growth cabinet and phytotron on *Lolium* seedlings at the 1-3 leaf stage, germinated in the glasshouse or outside to mimic field conditions. Survivors to discriminating rates of herbicides are recorded at around 10 days after plating. Provided the test is carried out in sufficient light and correctly chosen discriminating doses are used, the levels of false positives and negatives of resistance are very low demonstrating the robustness of the method. Based on several pre-determined target site and non target site resistant *Lolium* populations and three commonly used ACCase and ALS inhibitor herbicides, namely clodinafop-propargyl, pinoxaden and iodo-mesosulfuron, we demonstrate that the results from the agar based seedling assay correlate very well with the classical whole plant pot test carried out under controlled conditions in the glasshouse. The method has proved very transferable to other grass weeds with minimal efforts and has been successfully applied to *Lolium* seedlings collected from two UK fields in 2009. As it can be applied very early in the season, it provides an opportunity for predicting herbicide efficacy prior to field application and thus allows for an informed choice of herbicide for effective weed control. To distinguish this cost effective, simple and early season bioassay from the many existing ones we propose to refer to the method as the Syngenta's "Resistance In-Season Quick (RISQ) test".

Non-target site multi-herbicide resistance mechanisms: *Echinochloa phyllopogon* as a case study

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Echinochloa phyllopogon (Stapf) Koss [syn. *E. oryzicola* (Vasing.) Vasing.] is a major weed of rice. After repeated herbicide use, populations of this species have evolved resistance to multiple herbicides from different chemical groups and with different modes of action: molinate and thiobencarb very long-chain fatty acid inhibitors, the acetyl CoA carboxylase (ACCase) inhibitors fenoxaprop-ethyl and cyhalofop-butyl, the acetolactate synthase (ALS) inhibitors bispyribac-sodium, bensulfuron-methyl, and penoxsulam, and the carotenoid biosynthesis inhibitor clomazone. All resistant (R) biotypes showed similar morphological and amplified fragment length polymorphism (AFLP) traits as the susceptible biotypes. The water-seeded and continuously-flooded rice system of California favored the proliferation of the aquatic and highly competitive *E. phyllopogon* that is well adapted to the submergence stress imposed by this environment. Weed-suppressive flooding of rice fails to control *E. phyllopogon* and farmers have to rely heavily on herbicides. Studies conducted during the last ten years have shown variable herbicide resistance levels, from low to high (R/S ratios 2 to 18). Although resistance due to target site alterations has been well documented for some of these herbicide groups (ACCase and ALS inhibitors), such resistance mechanism has not been found in California's *E. phyllopogon*. The use of specific enzyme inhibitors, induction by substrate experiments and use of liquid chromatography and mass spectrometry methods suggested initially resistance to different herbicides was due to enhanced herbicide metabolism involving inducible cytochrome P450 monooxygenases, as well as glutathione S-transferases and conjugation with cysteine in the case of resistance to fenoxaprop-ethyl. Although herbicide monooxygenation is the main biotransformation mechanism found in R plants, these plants have also shown versatile herbicide detoxification capabilities. More recent studies indicate R *E. phyllopogon* is also resistant to the auxin-like herbicide quinclorac and to the PSI inhibitor paraquat, which suggests R plants have also mechanisms to avoid stimulation of ethylene production by quinclorac, to overcome the toxic effect of cyanide associated with natural ethylene over production in R plant tissues, and to mitigate photooxidative stress caused by both herbicides. In the case of quinclorac, R plants showed greater inducible β -cyanoalanine synthase activity, which is the major cyanide detoxifying enzyme in plants. The existence of more than one mechanism mitigating herbicide toxicity will complicate herbicide resistance management in rice. In addition, enhanced tolerance toward oxidative damage and ethylene-related toxicity, as well as the high activity and content of inducible cytochrome P450 monooxygenases, suggest R *E. phyllopogon* biotypes could be more tolerant to certain abiotic-stresses, leading to higher adaptive ability for growing under sub-optimal environmental conditions; it would also suggest that growth in such environments may, in turn, pre-select for herbicide resistance evolution in weed populations.

Presence and distribution of wild oat (*Avena* spp.) and herbicide-resistant populations across a typical cereal producing region of Greece

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In the years 2006-2009 a random survey was conducted across a typical wheat producing region in the central part of Greece. The objective of this study was to examine wild oat variability (presence and distribution of the main species) and establish the presence and distribution of potentially herbicide-resistant populations in this specific area. A total of 234 wheat, barley and oat fields were visited, with wild oat populations collected from 150 fields (in 84 fields, 0 to 9 plants were found in the sample path, which was considered insufficient to constitute a representative sample). The surveys were conducted during a two week period at the beginning of maturity, from May 2006 until June 2009. Each surveyed field was walked through by the two diagonals and records were kept of the wild oat species present and of their density. Furthermore, a representative sample of panicle and seeds were collected and transferred to the laboratory of Weed Science (Benaki Phytopathological Institute). The collected wild oat panicles and seeds were further examined to verify species identification; the seeds were separated, air-dried and stored in paper bags at room temperature until used. Greenhouse experiments were conducted to compare seedlings grown from wild oat accessions of this region under the same conditions and for an initial screening with some of the most commonly used ACCase-inhibiting herbicides in Greece (clodinafop, diclofop and fenoxaprop). Our 4-year field survey indicated that, despite the widely adopted practice of using herbicides, wild oats were found at the time of maturation to be present in most of the cereal fields (more than 80%). The species present in most cases was *Avena sterilis* while *A. fatua* was found to coexist in small patches and at lower densities only in 11-18% of the surveyed fields, with a clear ongoing tendency. Furthermore, for the safe *in situ* recognition of the species, a set of selected characters based on the mature spikelets is also proposed, while a high degree of variability in the dominant *A. sterilis* was also revealed. It is also noticeable that some of the wild oat accessions were found to contain individuals resistant or potentially resistant to one or more ACCase-inhibiting herbicides, requiring for their control 4-10 higher than the recommended rates. Additionally, at least five populations resistant to diclofop where also cross-resistant to clodinafop, fenoxaprop or both. Therefore, good stewardship and integrated weed management practices, such as diversity in herbicide use and cultural management, are strongly encouraged in order to mitigate wild oat populations and minimize the ongoing herbicide resistance evolution.

Two different resistance mechanisms in two *Chrysanthemum* species

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Chrysanthemum coronarium L. (crown daisy) and *C. segetum* L. (corn marigold) are annual winter weeds (Asteraceae, Compositae), native to the Mediterranean, highly spread in arable and irrigated fields. Over the years, these species have become major weeds in Israel infesting rain fed cereals, especially wheat and other winter crops. The common way to control broad leaf weeds is the use of various acetolactate synthase (ALS) inhibitors applied post-emergence. Our observations as well as frequent farmers complaints have indicated that the ALS inhibitor, tribenuron-methyl failed to control *C. coronarium* in the Negev and *C. segetum* in the Lower Galilee in wheat fields. The aims of this study were to investigate the molecular, physiological or agronomical mechanisms involved in the resistance of *C. coronarium* and *C. segetum* populations to ALS inhibitors. Dose-response experiments at the whole-plant level and *In vitro* studies revealed that the *C. coronarium* R biotypes were highly resistant (>200 folds) relative to the S biotype to tribenuron-methyl with cross-resistance to other sulfonylurea herbicides. Three amino acid substitutions were found in region 1 of R *C. coronarium*: Pro197 either to Thr, Ser or Arg. All have been shown to endow resistance to ALS inhibitors in other weeds. Dose-response experiments with various sulfonylurea (SU) herbicides on *C. segetum* revealed no significant difference between the putative S populations to the putative R populations. Both populations survived high rates of tribenuron-methyl. *In vitro* ALS studies have shown that *C. segetum* populations examined are susceptible to tribenuron-methyl and DNA sequence analysis of the ALS gene demonstrated that the nucleotide sequences of the tested biotypes was not modified, indicating non target site resistance. Spray retention on the leaves of *C. segetum* was compared with the spray retention on *C. coronarium* leaves. The number of drops per cm² and % of leaf coverage were significantly greater in *C. coronarium* than in *C. segetum* (p>0.05). Removal of the epicuticular wax followed by application of a fluorescent tracer resulted in a significant increase in leaf area covered with spray solution in *C. segetum* but there was no effect on leaf coverage of *C. coronarium*. The addition of a nonionic surfactant to the spray solution enhanced the herbicidal activity due to an increase in spray retention on the leaf surface and improvement of leaf coverage with the spray drops. The properties of the *C. segetum* non-wettable leaf surface caused the plant to deter the herbicide spray solution. We postulate that the long term use of SU herbicides without a surfactant has selected individual *C. segetum* plants with a less wettable leaf surface that reduces the retention of the herbicide spray solution resulting in a poor weed control.

Transcriptomics-based identification of genes involved in non-target-site based resistance to acetyl-coenzyme A carboxylase (ACCase) inhibitors in *Alopecurus myosuroides*

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The repeated use of herbicides has led to the selection of resistant weed individuals. In *A. myosuroides*, non-target-site based resistance (NTSR) plays the major role in resistance to acetyl coenzyme-A carboxylase (ACCase) inhibitors. NTSR is a major threat to herbicide efficacy because it can confer cross-resistance to herbicides with different modes of action, and because the cross-resistance patterns associated to NTSR mechanisms are currently unpredictable. To better understand NTSR and to develop molecular diagnosis tools, it is necessary to identify genes underlying NTSR. Very little data is currently available regarding the molecular basis of NTSR. NTSR is generally considered a quantitative trait endowed by the differential expression of many genes that are also involved in the general plant response to stresses. Mostly, it is considered that the expression of genes involved in NTSR is mainly up-regulated in resistant plants compared to sensitive plants. Transcriptomics tools are now available that enable to screen the whole transcriptome of an individual plant, and to identify genes differentially expressed among individuals with contrasted phenotypes (e.g., resistant and sensitive). These tools offer an appealing way of identification of genes governing NTSR.

Our aim was to identify genes differentially expressed between *A. myosuroides* plants sensitive to ACCase inhibitors and plants resistant due to NTSR mechanisms. For this purpose, we used two complementary transcriptomics techniques that each enabled to investigate the expression of thousands of genes in a single experiment. We used heterologous hybridisation of *A. myosuroides* transcriptome on wheat DNA microarrays to identify genes with a moderate level of differential expression. Another transcriptomics technique, Suppression Subtractive Hybridization (SSH), was used to identify genes that were highly up-regulated in the resistant plants compared to the sensitive plants. The function of the genes putatively involved in NTSR was identified after their homologies with known genes in the international databases. A total of 9 genes were identified as good candidates to the role of genes involved in NTSR. Eight of these genes encoded proteins homologous to enzymes potentially capable of degrading herbicides or potentially involved in response to the oxidative stress induced by ACCase inhibitors application, and could thus be directly involved in NTSR. The last gene encoded a protein highly similar to a protein involved in signal transduction. This gene is potentially involved in the general plant response to stresses. It could serve as marker for the occurrence of NTSR in a plant. All the genes identified are interesting potential targets to develop molecular tools for NTSR detection that will aid in designing strategies helping sustaining herbicide efficacy.

Modern tools to diagnose herbicide resistance

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Herbicide resistance has become a major threat to modern agriculture due to the intensive reliance on chemical control, especially those herbicides belonging to ACCase and ALS chemistries. Bayer CropScience (BCS) has developed accurate and sophisticated methods to assess which mechanisms of resistance are present in problematic weeds. A modern and dedicated lab is mandatory in order to satisfy the increasing demand to analyze samples originating from infested fields and provide the best information on the resistance status in a particular field. Therefore, a proper resistance lab must be equipped with cutting-edge technologies that are capable of measuring changes in absorption, translocation, metabolism and target site alterations in plants that render a population resistant.

ABSORPTION AND TRANSLOCATION: In agriculture, plant cuticles often represent the major barrier for penetration into plants when herbicides are sprayed on leaf surfaces. Additionally, the outer surface of the cuticle is covered by crystalline waxes which have a strong effect on spray retention. Recent studies have demonstrated the ability of plant cuticles to reduce the concentration of herbicides that penetrate into the leaves, this being considered as a selective resistance mechanism that allows weeds to survive at field doses. Reduced translocation is not a common mechanism for herbicide resistance.

METABOLISM: The majority of herbicides can be detoxified to some extent by weeds through metabolic processes, but not at a rate sufficient to prevent herbicidal action. However, resistant weeds can metabolize a herbicide at a rate sufficiently rapid that they are not controlled. The biochemical mechanisms used by plants to detoxify herbicides can be grouped into two major categories: primary metabolism (oxidation, hydrolysis and reduction) and secondary metabolism (conjugation, secondary conjugation and transport into the vacuole). BCS has developed innovative methods to determine whether a weed is metabolically resistant or not. They are based on reverse phase liquid chromatography (RPLC) of plant extracts to separate the herbicide from the corresponding metabolites formed during the incubation time. Cutting-edge technologies such as HPLC, XLC and LC/MS are routinely used for the detection of metabolic resistance in weeds.

TARGET-SITE RESISTANCE: The most important sites of action and reported mutations include ALS (mutations at positions A122T, P197A,H,I,K,L,M,Q,R,S,T,W, A205V, D376E, W574L,R and S653N,T), ACCase (I1781L, W1999C, W2027C, I2041N,V, D2078G, C2088R and G2096A), EPSPS (P106A,S,T) and PSII (V219I, A251V, S264G,T and N266T). Classical methods to define resistance include Sanger sequencing, PASA (PCR amplification of specific alleles), and CAPS/dCAPS (derived cleaved amplified polymorphic sequences). BCS is performing the analysis of TSR by using pyrosequencing technology which is capable of detecting all known mutations present in weeds, and of discovering new ones. Overall, pyrosequencing is a practical alternative method that can be used in a high-throughput format for molecular surveillance of target-site resistance. BCS is providing an in-depth weed resistance analysis and is using this information to generate scientifically sound recommendations for individual fields to help delay or reduce the spread of herbicide resistance or manage an existing resistance problem.

SESSION 1
HERBICIDE RESISTANCE

Poster presentations

Session organizers:

Baruch Rubin & Anne Thompson

Resistance to ALS inhibiting herbicides in *Apera spica-venti*

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Loose silky-bent (*Apera spica-venti*) has become one of the most troublesome weed in recent years in the Czech Republic. Control failures are especially caused by reduced efficiency of sulfonylureas inhibiting acetolactate synthase (ALS). Taking into account that sulfonylureas have been used to control of *Apera spica-venti* for 20 years, the probability of resistance occurrence was high.

The monitoring of occurrence and detection of biotypes with suspected resistance in *Apera spica-venti* have been done in the Czech Republic since 2000. Since that time several resistant biotypes were detected using dose-response assays and field experiments. First, various ALS inhibitors were tested, and in order to examine the occurrence of multiple resistance the efficiency of acetyl CoA carboxylase (ACCase) and photosystem II inhibitors was determined. The objective of other methods was to explain the bases and mechanisms of resistance. *In vitro* ALS assays were conducted using the methods described by Singh et al. 1988 and Ray 1984. Specific regions of the *als* gene were amplified using PCR, sequenced and compared between the resistant (R) and sensitive biotypes (S).

Statistically significant differences in resistance factors between R and S biotypes were found in pot and field experiments. The resistance factors in R biotypes ranged from 6.7 to 1446. Cross resistance was detected for chlorsulfuron, sulfosulfuron and iodosulfuron. The resistance was also verified to the active ingredients that have never been used on the concrete plot (e.g. sulfometuron). To date *Apera spica-venti* has not developed resistance to ACCase inhibitors. One tolerant biotype resistant to PS II inhibitors was found by testing in pot experiments. The significance of the differences in the ALS activity between resistant and susceptible biotypes indicated a modification of the herbicide binding site in the ALS enzyme. This modification was confirmed in *Apera spica-venti* plants from two locations in the Czech Republic using the molecular-genetic methods. Two point mutations were detected at amino acid position 197 in domain A of *als* gene in the nucleotide sequences of resistant biotypes. Susceptible plants from the same locality do not show these changes, thus confirming target site resistance. There might be other resistance mechanisms involved such as changes in uptake, translocation and increased metabolism of herbicide with respect to high differences in sensitivity to sulfonylureas.

This work was financially supported by MSM 6046070901 and QH71218 projects.

***Alopecurus myosuroides* resistant to ALS-inhibiting herbicides found in the Czech Republic**

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Although black-grass (*Alopecurus myosuroides*) is the grass weed with low importance in the Czech Republic, several highly infested fields with plants surviving herbicide treatment with ALS-inhibiting herbicides were found. To date, *A. myosuroides* has developed resistance to a total of five classes of herbicide, with resistant populations found in ten countries. Although enhanced metabolism plays an important role in herbicide resistance in black-grass, it could not account for resistance in all of the populations. The selection of herbicide resistance in black-grass is an increasing problem and is continuously spreading in different regions in Europe. In this study, the physiological and molecular basis of resistance in *A. myosuroides* was investigated. Biotypes with suspected resistance were collected from fields in the south Bohemia where ALS-inhibitor had failed to give adequate control in the field. The susceptible population (S) was provided by Herbiseed company. Responses to the selective sulfonylurea herbicides mesosulfuron-methyl + iodosulfuron-methyl sodium mixture, ACCase-inhibitors (fenoxaprop-P-ethyl, tralkoxydim, pinoxaden) and PSII inhibitors (isoproturon, chlorotoluron) were investigated in pot experiment. Plants were treated at the 3rd leaf stage and effects assessed 4 weeks later. ALS enzyme assay was performed to reveal the mechanism of resistance. ALS inhibition was quantified against formulated products of different herbicides. A conserved region of *als* gene, in which mutations are known to confer resistance, was amplified from samples of (S) individuals and plants with suspected resistance (R) and sequenced. The R population exhibited resistant pattern to herbicides with active ingredient mesosulfuron + iodosulfuron (efficacy 15-40% at recommended dose) and IPU (efficacy 30-80%) on the whole plant level. Susceptible and resistant individuals were successfully controlled with ACCase based compounds (efficacy >98%). The shift against susceptible standard proved the resistance status also in ALS enzyme assay. Although statistically significant, relative resistant ratios were only about 1 times higher for the R biotype. No changes in the encoded amino acid sequences A₁₂₂, P₁₉₇, A₂₀₅, W₅₇₄ and S₆₅₃ were found. There was high similarity (>95%) between sequences from R and S biotype and several synonymous and nonsynonymous SNPs were revealed. The identified positions A₁₄₇, A₁₉₁, N₅₆₅ and P₆₅₂ are not known to be involved in herbicide resistance and obviously not crucial for proper functioning of the *als* gene. This would suggest that the resistance in *R. A. myosuroides* is very probably not target site mediated and results indicate that another mechanism is responsible for resistance.

This work was financially supported by MSM 6046070901 and QH71218 projects.

Variability in reaction and resistance toward PS II inhibitors within *Chenopodium album*

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In higher plants, resistance to triazine herbicides was first observed in 1970. First evidence for herbicide resistance within biotypes of *Chenopodium album* in Germany was provided in 1980. Research indicated that these particular biotypes were resistant to the Photosystem (PS) II-inhibitor simazine. Frequent use of triazine did select for plants having a Ser-264-Gly mutation on the *psbA* gene resulting in triazine-resistance. This *psbA* gene encodes the D1 protein of PS II which is the target site of PS II-inhibitors. Following these observations, cross-resistance to other PS II-inhibitors was also observed. In this study, we aimed to test different biotypes of *Ch. album* regarding their variability in reaction, resistance and cross-resistance pattern to different active ingredients. Three dose rates of terbuthylazine, metamiltron and metsulfuron + thifensulfuron were respectively tested in climate chamber bioassays. *Ch. album* biotypes from experimental field sites where triazines have intensively been applied until the year 1989 followed by application of various active ingredients in different intensities since 1994 were particularly investigated. The experiments indicated that the majority of the tested *Ch. album* populations was not controlled by terbuthylazine applied at the 2-4 leave stage at rates of 375, 750 and 1125 g ha⁻¹. On the contrary, susceptible biotypes were completely controlled by 375 g ha⁻¹ terbuthylazine. Although observed ED₉₀ level of suspected resistant biotypes were lower than those typically observed for biotypes with target-site resistance, target-site resistance was assumed for resistant *Ch. album* populations. No relation between intensity of previous herbicide treatment on the experimental field site and resistance level of the investigated biotypes could be observed. Moreover, the extensive use of atrazine and simazine on the experimental field sites before the year 1989 can be regarded as the main reason for the observed pattern of resistance. Resistant populations also exhibited the expected cross-resistance to metamiltron likely to be caused by the shared target sites of both terbuthylazine and metamiltron. However, suspected resistant biotypes showed no resistance towards ALS-inhibitors.

PCR analyses using Randomly Amplified Polymorphic DNA (RAPD) and Inter Simple Sequence Repeats (ISSR) markers were conducted. In RAPD-PCR, primers with an arbitrary sequence are employed whereas in ISSR –PCR analyses, complementary sequences to two neighbouring microsatellites are used as primers. However, no clear correspondence between molecular markers and the characteristic of herbicide resistance was detected. This result is likely to be caused by the high intraspecific variability that is characteristic of *Ch. album*. Our results show that herbicide strategies based on a frequent use of active ingredients from the HRAC C1 group such as terbuthylazine in corn-based crop rotations or metamiltron in sugar-beet can select for resistance and cross resistance in *Ch. album*.

Identification and integrated management of glyphosate resistant biotypes of *Conyza* spp. in Greece

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The repeated use of glyphosate in minimum- and no-tillage systems can greatly increase the risks of glyphosate reduced efficacy and weed resistance. Greek farmers rely heavily on glyphosate use especially in perennial crops. The present study was conducted because of many recent reports of *Conyza* becoming increasingly difficult to control. Therefore, the main objectives of our study were to evaluate the presence and distribution of glyphosate-resistant populations of *Conyza* spp. in several target-regions of southern Greece, where a relatively low effectiveness of glyphosate is already reported and to highlight alternative solutions. Sixty Greek populations of *Conyza* species, sampled from several prefectures, were studied under controlled conditions to confirm glyphosate resistance. Some of these sites were already known to have histories of weed-control failures because of farmer complaints registered at local cooperatives. When seedlings were at the rosette stage (7 to 9 cm in diameter, 10 to 15 leaves), they were sprayed with 360 g ae/ha of glyphosate using a custom-built, compressed-air, flat-fan nozzle experimental sprayer. Additionally, ten populations were selected, and dose-response experiments were also carried out. The pot experiments were conducted twice, while fresh weight of aboveground plant part of each pot was recorded 28 d after treatment (DAT) and presented as a percentage of the untreated control for each accession. Furthermore, a field trial was conducted twice, using four of the most resistant and most susceptible populations of *Conyza*, with the objective of confirming resistance to glyphosate under field conditions and testing several alternative herbicide solutions (glyphosate, glufosinate, oxyfluorfen, diquat and triasulfuron). In the initial screening, under controlled conditions, significant differences in glyphosate response between populations were revealed. Glyphosate resistance was confirmed in three populations in southern Greece as confirmed under controlled conditions and field trials. It is remarkable that, glyphosate rate of 0.72 kg ae/ha provided 100% and 10% control for the most susceptible and resistant populations, respectively. In some cases, glyphosate rates required to control resistant populations were 5 to 12 times higher than those required to control the most susceptible populations. Field trials testing alternative herbicides (residual and no-residual) resulted in a high efficacy of some of them (diquat, glufosinate, oxyfluorfen) on *Conyza* spp. and along with various integrated management strategies (e.g. soil tillage, stem cutting) could mitigate the spreading of glyphosate resistance.

The quantification of the target-site resistance to mesosulfuron/iodosulfuron in a black-grass (*Alopecurus myosuroides* Huds.) biotype with a Pro197-to-His mutation from a winter wheat field in Poland using pot test and petri dish assay

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Black-grass (*Alopecurus myosuroides*) is becoming a more important weed in winter wheat growing areas of Poland. The resistance to herbicides may follow and has to be monitored. In this investigation seeds of black-grass were collected from a winter wheat field in Bieganów near Krosno Odrzanskie (middle west of Poland) in 2007. The farmer complained about herbicide performance failure. Seedlings were analysed for target-site resistance (TSR) to ACCase and ALS inhibiting herbicides via Pyrosequencing of PCR generated DNA-fragments. No TSR to ACCase inhibitors was detected. A Pro197-to-His mutation was identified in almost all plants confirming TSR to ALS inhibitors as the underlying resistance mechanism. Several Pro197 mutations are recently described in *A. myosuroides*. A Pro197-to-His mutation is described in several weed species worldwide and is responsible for TSR to sulfonylureas and triazolopyrimidines. In order to quantify the reaction of the biotype of *A. myosuroides* to the ALS inhibitors mesosulfuron/iodosulfuron and herbicides of alternative mode of action, dose-response assays in greenhouse with whole plants in pots and Petri-dish assays with seeds were performed. The obtained resistance factors for mesosulfuron/iodosulfuron were 4.26 in the whole plants test and 5.46 in the seedling bioassay, respectively. Herbicides of other mode of action than ALS that were tested showed no resistance. The results indicate that TSR to ALS inhibitors is the only resistance mechanism in this biotype. The resistance factors reflect the present resistance status in the field population. The results and the different methods to detect and quantify TSR are compared and discussed.

Efficient control of common ragweed in herbicide-resistant sunflowers halts allergenic pollen production

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Control of common ragweed (*Ambrosia artemisiifolia*) was studied in 2006-2008 in fields of new sunflower hybrids (Rimisol and PR63E82) resistant to the herbicides imazamox and tribenuron methyl, respectively. The experiments were conducted in a commercial farm in Győr-Kismegyer, Hungary. In the project area during the herbicidal treatments ten 2x2 m sampling areas, identified by GPS coordinates, were covered and assigned as untreated control. Weeds at the sampling sites were surveyed regularly. A portable Hirst-type air sampler was used to register the concentration of airborne pollen grains. Statistical analyses were conducted using the Statistica 6.1 software. Both herbicides were highly efficient in controlling weeds in sunflower (*Helianthus annuus*): fields of herbicide-tolerant sunflower remained free of common ragweed until the end of June. Weed surveys at the end of August (when ragweed pollen production is at its maximum) showed that the few common ragweed plants emerging in July and August can not efficiently compete for light, water, and nutrients in established sunflower stands. Diminished common ragweed density (<1% weed cover), reduced plant height (27.6% of the untreated controls) and reduced number of pollen-producing flowers (6.3% of the untreated controls) practically halted escape of common ragweed pollens from stands of herbicide-resistant sunflowers. Our study clearly indicates that the new technology based on the use of sunflower hybrids resistant to acetolactate synthase-inhibiting herbicides is a highly efficient tool to control common ragweed in sunflower fields and, as a result, to reduce concentrations of its allergenic pollen in the air.

First investigations on metabolism of the herbicide sulfosulfuron in resistant populations of *Apera spica-venti* (L.) Beauv. using High Performance Liquid Chromatography (HPLC) and combined Liquid Chromatography/Mass Spectrometry (LC/MS)

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Apera spica-venti (APESV) is considered one of the most relevant grass weeds occurring in European winter annual cereal production. During the last decades, repetitive application of ALS-inhibitors combined with high percentage of winter cereal crops in the rotation and reduced tillage practices led to the development of resistant APESV populations in several European countries including Czech Republic, Poland, Germany, Denmark and Switzerland. Although target-site mechanisms are well-known factors being involved in the resistance phenomenon, herbicide-specific metabolic pathways may also play a decisive role in conferring resistance. In this work, metabolic investigations were conducted with the herbicide sulfosulfuron on different APESV populations which exhibited resistance to sulfonylurea herbicides (SU) in whole-plant bioassays. In these populations, no mutation was found in most of the known positions involved in resistance within the ALS gene. Main goals of the study were: 1) to investigate the degradation rate of the herbicide; 2) to detect and quantify the presence of specific sulfosulfuron metabolites of known structure (isolated from winter wheat plants) in the studied APESV populations. Plants were grown in the greenhouse under controlled conditions of temperature, illumination and humidity and harvested 3 hours and 2, 4, 6, 8, 11, 14, 17 and 21 days after herbicide treatment (DAT), respectively. Sample extracts were then analyzed in the chemical laboratory using HPLC/DAD (High Performance Liquid Chromatography/Diode Array Detection) and combined HPLC/MS (HPLC/Mass Spectrometry) in order to increase the sensitivity of the measurements. The preliminary results of this first experiment revealed a high degradation rate of the herbicide sulfosulfuron in all tested populations starting already from the second day after treatment until the end of the observation period (21 DAT) as compared to the first sample harvesting (3 hours after treatment). More specifically, the primary metabolite desmethyl sulfosulfuron was detected in all populations but differed in its proportion over time. The presence of this metabolite suggests that a direct demethylation through the action of the enzymatic complex Cytochrome P450 Monooxygenase is the first degradation step of the herbicide sulfosulfuron in APESV. The metabolites sulfonamide and aminopyrimidine were detected in two populations as well, but only in close proximity of the detection limit (0,01 µg/g). In order to be able to assess the toxicity of the metabolite desmethyl sulfosulfuron, phytotoxicity assays were conducted on seedlings in Petri dishes under controlled conditions of temperature and humidity. The obtained results, statistically determined by paired *T*-test ($p < 0,05$), revealed a significant lower inhibition of root growth by desmethyl sulfosulfuron as compared to sulfosulfuron and a non significant difference in terms

of inhibition of shoot growth. However, both compounds showed a significant difference in terms of inhibition of both root and shoot growth as compared to untreated seedlings. Further experiments are being conducted as well in order to 1) verify whether the used irrigation system (sprinkler irrigation) may have had an influence on the course of herbicide degradation over time due to wash-off effects and 2) identify the metabolic pathway of sulfosulfuron in APESV after the primary degradation step with the use of LC/TOFMS (time-of-flight mass spectrometry technology).

Comparison of resistance levels in Danish and British black-grass populations using different diagnostic methods

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The objective of this study was to compare different methods for detecting herbicide resistance in black-grass: the Rothamsted Rapid Resistance test in Petri dishes, an indoor pot experiment and an outdoor container experiment. The experiments were carried out with 16 different populations of black-grass (10 Danish and 6 British) of which 13 were rated as resistant to one or more herbicides in previous tests. The Petri dish test and the pot experiment each included one dose (except two doses of fenoxaprop-P in Petri dishes) of five different herbicides. Doses are shown in ppm for the Petri dishes and in g/ha for the pot experiment: fenoxaprop-P (3.33 and 10 ppm/69 g/ha), clodinafop (10 ppm/30 g/ha), cycloxydim (5 ppm/150 g/ha), pendimethalin (5 ppm/2000 g/ha) and sulfometuron (1 ppm) or mesosulfuron + iodosulfuron (14.4 g/ha), while the container experiment only included pendimethalin (2000 g/ha). The Petri dish tests were carried out with 50 seeds in each dish and two replicate dishes. Visual assessments were made after 2 weeks. The pot experiment was carried out in 0.3 L pots with 6 plants per pot and 5 replicates. Pendimethalin (900 g/ha) was applied at the 1- to 2-leaf stage, and a second application (1100 g/ha) was made at the 3- to 4-leaf stage. The other herbicides were applied at the 3-leaf stage. Fresh weight was recorded 4 weeks later. The container experiment was performed in 7 L boxes with 0.5 g seeds mixed in the upper 3 cm soil. Pendimethalin (900 g/ha) was applied one week after sowing. The number of healthy seedlings was counted 2 months later. The 'R' system¹ was used for interpreting the results of all experiments. The results of the Petri dish test revealed that the dose can be critical for the number of populations rated as resistant. Thirteen populations were rated resistant at 3.33 ppm fenoxaprop-P versus 8 populations at 10 ppm. Only one population was resistant to cycloxydim, while 2 populations were resistant to pendimethalin and sulfometuron, respectively. The results of the pot experiment confirmed resistance to fenoxaprop-P and clodinafop in 9 and 8 populations, respectively. None of the Danish populations were resistant to cycloxydim and mesosulfuron + iodosulfuron, while one and two British biotypes, respectively, were resistant to these herbicides in the pot test. The post-emergence efficacy of pendimethalin was too low, and the results were not reliable. The container results showed that four out of nine populations were resistant to pendimethalin indicating enhanced metabolism. Consistency in rating during all screenings was obtained for five Danish populations and six British populations. The overall conclusions were that the resistance levels of the Danish populations were lower than the British populations and that the results from the pot experiment were more reliable than the results from the Petri dish experiments.

¹ Moss SR, Clarke JH, Blair AM, Culley TN, Read MA, Ryan PJ, Turner M (1999): The occurrence of herbicide-resistant grass-weeds in the United Kingdom and a new system for designating resistance in screening systems. The 1999 BCPC conference, Weeds, 179-184

Factors affecting control of herbicide resistant *Alopecurus myosuroides* (black-grass) with mesosulfuron+iodosulfuron ('Atlantis')

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Controlling *Alopecurus myosuroides* is becoming increasingly difficult due to the loss of active ingredients as a consequence of EU legislation and lack of new modes of action. Maintaining efficacy of remaining products, such as mesosulfuron+iodosulfuron ('Atlantis') is critical for effective weed control in winter wheat. Two outdoor pot experiments were conducted during the spring of 2009 to study two factors which could reduce the efficacy of 'Atlantis'. Firstly, how rainfast is 'Atlantis' and, secondly, is there antagonism between 'Atlantis' and the fungicide chlorothalonil ('Bravo'), a commonly used mixing partner?

Three populations were used; a standard susceptible (ROTH05), an enhanced metabolism resistant (HERB06) and an ALS target site resistant (PELD03) population. Two-litre pots were filled with growing medium, 20 seeds sown and emerging plants thinned to six plants per pot prior to spraying. Herbicides were applied using a laboratory sprayer equipped with two Hardi ISO-F-02-110 nozzles operating at 300 kPa and 5.6 km h⁻¹ delivering a spray volume of 161 L ha⁻¹. Six or seven doses of mesosulfuron+iodosulfuron (1.5+0.3 to 96+19.2 g a.i. ha⁻¹, 12.5% – 800% field rate) were applied in both experiments. Simulated rain treatments (5 mm over 20 minutes) were applied using a raintower 1, 3 and 6 hours after herbicide application, plus untreated. Herbicide was applied alone, or in combination with two doses of chlorothalonil (500 and 1000 g a.i. ha⁻¹), in the antagonism experiment. Both experiments were randomized block designs with three replicates and foliage fresh weight was recorded 4 weeks after treatment. Percent reductions in foliage weights, meaned over three herbicide rates, (25%-100% field rate), with rain 1, 3, 6 h and no rain after herbicide treatment were respectively: 30%, 42%, 56%, 86% for PELD03; 58%, 67%, 83%, 99% for HERB06; 97%, 96%, 99%, 99% for ROTH05 (S.E. ± 4.2). Thus, simulated rainfall reduced herbicide efficacy up to 6 hours after herbicide application, especially on the resistant populations. Percentage reductions, meaned over the same three herbicide rates, with 1000, 500 and no chlorothalonil, were respectively: 45%, 51%, 65% for PELD03; 64%, 87%, 95% for HERB06; 93%, 99%, 99% for ROTH05 (S.E. ± 2.9). Thus, chlorothalonil reduced activity of mesosulfuron+iodosulfuron by up to 20 – 31%, especially on the resistant populations. The experiment showed that both rain soon after spraying and antagonism can reduce the control of black-grass by mesosulfuron+iodosulfuron. It is imperative that these adverse effects are minimized in order to maximize weed control, especially on resistant populations.

Combined target site resistance to ALS and ACCase inhibiting herbicides in the grass weed *Alopecurus myosuroides* (black-grass)

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The objective of this work was to investigate resistance to ALS and ACCase inhibiting herbicides in several UK populations of the grass weed *Alopecurus myosuroides*, and to identify the particular mutant isoforms of ALS and ACCase associated with resistance in each case. A specific aim was to confirm the presence of ‘combined’ target site resistance, in which separate mutations conferring resistance to ACCase and ALS inhibiting herbicides are present in the same individual plant. Six populations collected from sites where resistance was reported in the field were screened initially in a whole plant glasshouse assay. Each individual plant (20-30 plants per population) was split into three parts and individual clones treated with mesosulfuron+iodosulfuron (ALS) and cycloxydim (ACCase) at the field rates of 12 + 2.4 g a.i. ha⁻¹ and 200 g a.i. ha⁻¹, with a single clone being left untreated from each plant as a reference. Levels of resistance to both herbicides were high, with four populations showing combined ALS and ACCase resistance. All populations showing combined resistance contained a proportion (23 - 95 %) of plants which survived treatment with both herbicides. DNA sequencing of the ALS and ACCase genes from dead and surviving plants confirmed that all plants containing the mutant ALS isoforms T197 and L574 survived treatment with mesosulfuron + iodosulfuron resistance while those with the L1781 mutant ACCase isoform were resistant to cycloxydim. Plants containing the wild type ALS and ACCase isoforms P197 and I1781 were fully susceptible to mesosulfuron+iodosulfuron and cycloxydim applications, respectively. A multiplexed genotyping assay covering all of the single nucleotide changes currently known to confer resistance to ALS (7 different SNPs over 6 different positions of the ALS gene) and ACCase inhibiting herbicides (8 SNPs over 7 positions of the ACCase gene) was designed using a SNaPshot multiplex kit supplied by Applied Biosystems. The assay was optimized for automatic detection as far as possible using resistant and susceptible plants where the entire ALS and ACCase gene sequences were known. Proportions of plants with mutations conferring altered isoforms of ALS and ACCase were high overall, with T197 and L1781 being the most common resistant ALS and ACCase isoforms, respectively. Further work is currently underway to investigate the frequency of combined ALS and ACCase target site resistance in UK populations of *A. myosuroides*. Resistant *A. myosuroides* with combined ALS and ACCase mechanisms is predicted to increase as options for post-emergence control decrease and existing ALS and ACCase herbicides are relied upon to a greater extent.

Response of *Conyza* spp. to glyphosate is dependent on environmental conditions

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Conyza bonariensis and *C. canadensis* are major weeds in roadsides, orchards and cultivated fields, mainly when reduced tillage is practiced. We found that several populations of *C. bonariensis*, *C. albida* and *C. canadensis* can tolerate higher than the recommended rates of glyphosate with increasing the temperature from 16°C to 34°C and with plant age from 15 to 100 days after planting (DAP). Shading of plants for 3 d before glyphosate application significantly increased their sensitivity to the herbicide. In addition we identified several populations which exhibit clear resistance to glyphosate (GR) independently of environmental conditions. Comparative studies conducted with GR and glyphosate sensitive (GS) *C. bonariensis* have shown that the level of resistance ($RI = ED50R/ED50S$) vary from 3.6 to 36 depends on the selection parameter. No differences between GR and GS were detected in shikimate accumulation when leaf discs were exposed to glyphosate for 18 h in light. However, when GR and GS plants were treated post emergence with glyphosate (0.18 kg ae/ha), the GS plants accumulated 1.6 to 3.7 folds more shikimate then the GR plants within 24 h. Using ^{14}C -glyphosate we found that GS and GR plants absorbed similar amounts of ^{14}C in source leaves, but GS plants translocated more glyphosate to untreated leaves, apex and roots as compared to GR plants. These results indicate that the GR and GS biotypes of *C. bonariensis* differ in glyphosate translocation from site of uptake to the site of action in the chloroplasts.

Study on the *in vitro* regeneration of rhizome fragments of *Elymus repens* (L.) Gould originated from cycloxydim tolerant maize

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Elymus repens (L.) Gould is one of the most important perennial grass weeds in Hungary. Its effective control is difficult because of its vegetative reproduction and spread. Despite the wide range of available herbicides, its control is rather ineffective in maize. In order to solve this problem, the introduction of DUO-SYSTEM® (registered trademark of BASF Agro) programme can be an important leap forward. It opens the door to the extensive application of cycloxydim (Focus Ultra, 100 g a.i. l⁻¹, BASF Agro) graminicide in the cycloxydim tolerant maize (CTM) hybrids. Thus the aim of our study was to examine to what extent the Focus Ultra treatments applied in different doses and times in field experiments can influence the re-growth of the rhizomes of *E. repens*. In the laboratory experiment we examined the effect of the different treatments with Focus Ultra on the bud activity of the rhizomes of *E. repens*. Samples were collected in a cycloxydim tolerant maize field near Keléd (47°5'N; 17°7'E), where the cultivar ES Ultrastar was sown on 7th July 2009. After cleaning, one hundred rhizomes from each treatment were cut into one-node segments. They were placed in growth chambers under 20±2 C°. For the study of bud activity, sprouted shoots were measured every third day for 15 days. On the basis of the *in vitro* regeneration study, we established that cycloxydim translocated well in each treatment and significantly decreased the bud activity of the rhizome segments. The largest decrease (83.3 %) was shown by the treatment with the dose of 400 g a.i. ha⁻¹ cycloxydim. Almost similar decrease (78.8%; 71.2%) was observed in the case of the dose of 250 g a.i. ha⁻¹ cycloxydim with 0.1 l/ha adjuvant hepta metil-trisiloxane (Spur, 210 g a.i. kg⁻¹, Interagro), and 400 g a.i. ha⁻¹ cycloxydim (2 x 200 g a.i. ha⁻¹) in split application. Besides, the cycloxydim strongly inhibited the re-growth of the non-dormant buds. By the 15th day of the Focus Ultra treatment with the dose of 400 g a.i. ha⁻¹ cycloxydim showed little re-growth (6.69 mm) compared to the untreated rhizomes (37.47 mm). On the segments from the other two treatments, the dose of 2 x 200 g a.i. ha⁻¹ cycloxydim in split application produced shoots of only 13.13 mm on average, and the dose of 250 g a.i. ha⁻¹ cycloxydim with 0.1 l/ha adjuvant Spur produced shoots of 19.19 mm on average. These results indicate that DUO-SYSTEM® programme introduced recently can be more suitable and effective against *E. repens* in maize than the conventional post emergent herbicides, and it can prevent further spread of this dangerous perennial weed species.

Local evolution of the global resistance to ACCase inhibitors in *Alopecurus myosuroides*

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Herbicide spraying programs vary in time and in space. In time, because during a cropping season, herbicides sprayed in a field depend on the crop rotation, on current regulations and on herbicide efficacy. In space, because herbicide spraying programs, like all cultural practices, vary with the field, the region and the country. As a consequence, from the point of view of the evolution, weed species occurring across several countries are expected to be divided into small 'adaptive units'. These units are all the individuals of the species occurring within a given field. Neighbouring units are connected to form a global population (metapopulation) by seed- and/or pollen-mediated gene flows, which ranges and intensities are generally poorly known.

Alopecurus myosuroides is a noxious grass weed of winter crops that evolved resistance to ACCase inhibitors. We used nested samplings of *A. myosuroides* populations from the whole area of maximum occurrence of the species in NW Europe down to a region a few square kilometres in size to determine 1) at which geographical scale the evolution and propagation of resistance occurred, and 2) whether national differences in agricultural practices, and especially particularities in herbicide use, had an impact on the frequency and on the kind of resistance mechanisms selected for in *A. myosuroides* populations. We observed that 1) resistance arose and spread in regions a few kilometres in size, and 2) while resistance in *A. myosuroides* was essentially endowed by non-ACCase-based mechanisms, the national particularities of agriculture left their mark upon the geographical structure of resistance in this weed, which is an unprecedented observation.

Herbicide resistance in grass weeds in the arid and semi-arid climate

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Evolution of herbicide-resistant grass weeds endangers the profitability of arable crops in the arid and semi-arid climate. The relatively small number of crops available often obliges the farmers to grow cereals as monoculture interrupted with fallow, minimize soil tillage and the repeated use of the same mode of action herbicides. This selection pressure imposed by the continuous use of ACCase inhibitors and ALS inhibitors resulted in the evolution of a large numbers of ACCase-resistant as well as ALS-resistant grass weed populations. ACCase-resistant populations of *Lolium rigidum*, *Phalaris minor*, *P. paradoxa* and *Avena sterilis* are widely spread in arable crops causing a significant yield reduction. Seven different target site alterations at the CT domain of the ACCase leading to target site resistance (TSR) were discovered so far, endowing different cross-resistance response to these herbicides. The most dangerous point mutations detected in *L. rigidum* and *P. paradoxa* are Ile1781>Leu and Asp2078>Gly that confer resistance to all types of ACCase inhibiting herbicides -Fops, Dims and Dens. ALS-resistant with and without resistance to ACCase were detected in *L. rigidum* populations that withstand high rates of ALS inhibitors were detected in cereals monoculture. We recently discovered a multiple-resistant *L. rigidum* population that confers resistance to ALS, ACCase and glyphosate, emphasizing the threat to the agro-ecosystem. The tendency of farmers to apply lower doses of herbicides facilitates the evolution of non-target site resistance (NTR). The situation where in the same population one may find different resistance mechanisms (NTR and TSR) as well as different site mutations that lead to different response of the weed to herbicides, make planning a rational weed management very difficult. The need for integrated weed management is now crucial.

Survey on metamiltron-resistant *Chenopodium album* L. in Belgian sugar beet

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Chenopodium album L. (Fat-hen) with a serine-264-glycine mutation is resistant to Photosystem II-inhibiting herbicides like the triazinone metamiltron, a key herbicide in sugar beet. In recent years, this resistant biotype may have caused unsatisfactory weed control in Belgian sugar beet. However, the dimension of the problem was yet unknown. Therefore, in 2008 a survey covering the whole Belgian sugar beet area was conducted. In 308 randomly selected fields, *C. album* plants surviving weed control were counted followed by sampling their leaves. First, the number of surviving plants was used to estimate the prevalence of fields with unsatisfactory control and to classify the surveyed fields. Twenty percent of the fields had more than 500 surviving plants per hectare and were thus classified as fields with unsatisfactory *C. album* control. Then, the share of the resistant biotype in a field was determined through DNA-analysis on ten or two sampled plants from fields with unsatisfactory or good *C. album* control, respectively. Using the restriction-enzyme *FspBI* in a cleaved amplified polymorphic sequence-analysis (CAPS-analysis), 794 plants were screened for the serine-264-glycine mutation. The resistant biotype was present in 95% of the fields with unsatisfactory *C. album* control indicating that metamiltron-resistance is an important but not the only cause of poor weed control in sugar beet. Very interesting was the occurrence of the resistant biotype in 74% of the sampled fields with good *C. album* control. Unfortunately, this only demonstrates that the serine-264-glycine biotype has spread over the entire sugar beet area. Indeed, without information on the original amount of resistant plants in these fields (i.e. before weed control), it would be rash to conclude that metamiltron may also effectively control the resistant biotype. Finally, all results were visualised on the map of Belgium but no pattern was found during this mapping. In conclusion, the results indicate that though the metamiltron-resistant biotype has spread over the whole sugar beet area, it is not (yet) causing severe problems in every field. To get a more accurate estimation of the portion of resistant plants in the field and the effect of herbicide treatments on this biotype, an elaborate survey will be conducted in 2010 on fields that have both untreated and differently treated plots installed.

Chlorophyll fluorescence protocol for quick detection of triazinone resistant *Chenopodium album* L.

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Sugar beet growers in Europe are more often confronted with an unsatisfactory control of *Chenopodium album* L. (Fat-hen), possibly due to the presence of a triazinone resistant biotype. So far, two mutations on the *psbA*-gene of *C. album*, i.e. serine-264-glycine and alanine-251-valine, are known to cause resistance to the Photosystem II-inhibiting triazinones metamitron, a key herbicide in sugar beet, and metribuzin. The serine-264-glycine biotype is most common and cross-resistant to many other Photosystem II-inhibitors like the s-triazines atrazine and terbuthylazine. The second resistant *C. album* biotype, recorded in Sweden, is highly resistant to triazinones but only slightly cross-resistant to terbuthylazine. Since farmers should adapt their weed control strategy in the presence of a resistant biotype, a quick and cheap detection method is needed. Therefore, through trial and error, a protocol for detection of triazinone resistant *C. album* with chlorophyll fluorescence measurements was developed and put to the test. The final protocol consists of four steps, namely incubation, dark adaptation, chlorophyll fluorescence measurement and interpretation of the results. Each experiment held a sensitive and one or two resistant *C. album* reference populations and three replications. First, *C. album* leaves were incubated for three hours under natural light in one of the following herbicide solutions: 0 μM (i.e. untreated control), 25 μM metribuzin (as SENCOR), 200 μM metamitron (as GOLTIX) and 25 μM terbuthylazine (as TYLLANEX) respectively. To ensure absorption, 0.025% rapeseed ester oil (as TIPO 842 g/l) was added to all solutions. Second, the Petri dishes with leaves and herbicide solution were transferred to a dark room for 30 minutes of dark adaptation and preparation of the leaves for the next step by patting them dry. Photosynthesis yield (F_v/F_m), i.e. the fraction of absorbed light used for photosynthesis, was measured with the Pocket PEA Chlorophyll Fluorimeter (Hansatech Instruments, UK). In leaves from sensitive *C. album*, herbicide treatment reduces photosynthesis yield due to inhibition of photosynthesis at Photosystem II. This results in a difference of photosynthesis yield, i.e. the yield gradient, between the untreated control and herbicide treatment. Finally, comparison of the yield gradient of a tested plant with that of the reference populations allowed its classification. A plant was classified as sensitive to the examined herbicide when the yield gradient was comparable to that of the sensitive reference, whereas a lower yield gradient resulted in a classification as resistant. While metribuzin and, to a lesser extend, metamitron treatment allowed a quick detection of triazinone resistant *C. album*, terbuthylazine treatment was able to distinguish the serine-264-glycine from the alanine-251-valine biotype. As a final test, 265 plants that could carry the serine-264-glycine mutation were classified with the protocol. Simultaneously, a cleaved amplified polymorphic sequence (CAPS)-analysis was conducted on DNA from leaf tissue of the same plants to verify the presence of this mutation. Only one mismatch was found when results of both detection methods were compared. The testing results illustrate that this protocol provides a reliable, quick and cheap alternative for DNA-analysis and bio-assays to detect the triazinone resistant *C. album* biotypes.

ACCase-inhibitor resistance in *Sorghum halepense*: evaluation of nucleotide variability at the acetyl coenzyme A carboxylase gene

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Sorghum halepense (L.) Pers. is a rhizomatous grass weed infesting summer crops and recently a few populations in Italy have evolved resistance to ACCase-inhibiting herbicides. Understanding the spread of *S. halepense* genotypes in the field is important for herbicide resistance management. We investigated the resistance mechanism involved in two field-selected *S. halepense* populations (05-2 and 05-4), highly resistant to aryloxyphenoxypropionates (FOPs) and weakly resistant to cyclohexanediones (DIMs) and analysed the nucleotide variability in the ACCase gene target of the herbicides. The individuation of a region of the ACCase gene with an appropriate degree of variability will permit further studies on the evolution of the herbicide resistance gene within and between populations. Johnsongrass susceptible populations (06-10), as well as plants of *S. bicolor*, were also considered. DNA samples from each plant were PCR-amplified to obtain a 2,132 bp ACCase sequence that included the ACCase herbicide-binding domain and two introns. The amplified fragments were purified and directly cloned in a vector. The sequence analyses highlighted that an Ile₂₀₄₁ to Asp substitution occurred in the CT domain of the ACCase gene in most plants of populations 05-2 and 05-4. These findings are in agreement with previous studies which showed that point mutation in position 2041 confers resistance to FOPs but not to DIMs. However, no mutation was found in a few resistant plants of both populations and these plants appeared less damaged than the mutated ones, so indicating that another resistance mechanism may be present. The alignment of 63 ACCase sequences of 2,132 bp revealed the presence of 68 polymorphisms, forming 33 haplotypes. Besides the nucleotide substitutions, two indels and a deletion of 6 bp were found in the intron no. 31 (number referred to the blackgrass ACCase sequence). The analysed sequences revealed a higher nucleotide variability in the intron no. 30 (nucleotide diversity value (μ) was 0.00665). A sliding-window analysis showed that along the CT domain the nucleotide diversity was lower than in its 3' flanking region. A higher proportion of singleton polymorphic sites were found in the coding region of the CT domain and most of them were synonymous substitutions. This indicates that the non synonymous mutations may not occur anywhere in the CT domain and that most of them are maintained by positive selection exerted by the ACCase inhibiting herbicides. Among the informative polymorphic sites found in *S. bicolor*, most were also present in the ACCase sequences of *S. halepense* that did not have the mutation endowing resistance in position 2041. This indicates that these SNPs are ancestral variants of the gene. The nucleotide variability observed in the ACCase DNA fragment makes it suitable for studying the gene evolution within and between populations, as well as for phylogenetic purposes.

First Occurrence of glyphosate resistance *Lolium rigidum* in Italian vineyards and olive groves

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Greenhouse screenings and outdoor dose-response experiments were conducted to investigate two *Lolium rigidum* populations from a northern Italian vineyard (population “R-332”) and a southern Italian olive grove (population “R-336”). The two populations were not adequately controlled in the field by the registered rates of glyphosate. Both samples evolved under intensive chemical weed control based on glyphosate. Population R-332 had been treated at least for 15 years with glyphosate, with 2 applications per year up to 1800 g a.e. ha⁻¹ and R-336 for 30 years, with about 2 applications per year up to 2700 g a.e. ha⁻¹. Compared with the northern vineyards, the weed management adopted in the southern olive groves was characterised by inadequate treatment equipment. Shikimate accumulation was measured spectrophotometrically at 24, 48, 72, 96 and 216 hours after treatment with two glyphosate doses. A dose-response experiment allowed the calculation of a resistance index (R.I.) of about 4 for the northern R-332 population and about 19 for the southern R-336 based on survival data. The R.I. based on fresh weight was about 2 for the R-332 population and about 15 for the R-336. Population R-336 treated with 10,800 g a.e. ha⁻¹, which is more than 10 times the recommended dose (1x) normally used in field conditions, had a 30% (S.E. 9.5%) survival. A mutation Pro-106-Ser was detected in this population. This mutation does not usually endow a high resistance index so further investigations are underway to reveal other possible resistance mechanism(s). The shikimate accumulation clearly discriminated the R populations from the susceptible standard population (S) collected in central Italy (never treated with glyphosate and susceptible to all herbicides) at the lower dose, while R and S had comparable accumulation at the highest dose. However, R plants fully recovered within 21 days. Multiple-resistance to ACCase inhibitors was also investigated to establish whether chemicals from different herbicide groups could be applied to manage glyphosate resistant populations. A few surviving individuals were recorded of R-332 treated at field dose of fluzifop (156 ga.i. ha⁻¹), while R-336 was completely controlled. Integrated weed management must be implemented to effectively control and limit the dissemination of R populations. Different resistance management strategies have to be considered according to the different resistance profiles observed for the two populations and the different landscape features (precipitations, temperatures, soil) characterising northern vineyards and southern olive groves.

Glyphosate resistance in Europe

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Glyphosate is the world's most widely used herbicide, with many registrations for agricultural, urban and semi-natural environments. Glyphosate is an important tool, especially for broad-spectrum weed control and inter-row vegetation management in perennial crops like olive and citrus groves, orchards and vineyards. Despite the frequent use in these crops, there are only a few confirmed cases of glyphosate resistant weed populations in Europe. The first reported case dates back to 2004 and involved four populations of *Conyza bonariensis* found in southern Spanish olive groves. The glyphosate rates required to control resistant populations were 7 to 10 times higher than those needed to control the susceptible populations. In 2006 a resistant population of *Conyza canadensis* was reported in southern Spain, while another was claimed in the Czech Republic in 2007. This latter case is still under investigation. Glyphosate-resistant *Lolium rigidum* was recently found in French vineyards (2005 and 2007) and in Spanish citrus groves (2006), while resistant *Lolium multiflorum* was identified in Spanish olive groves (2006). New cases of resistant *Lolium* spp. are reported from Italian vineyards and olive groves. In all these cases *Lolium* plants were not controlled at recommended glyphosate field rates. Although there are only a few glyphosate resistant weed populations in Europe, the sole reliance on glyphosate for weed control especially in perennial crops carries the risk of selecting for more resistance. Glyphosate being the key herbicide for weed control in the agriculture and urban landscape, its loss would constitute a huge threat and would increase weed control costs.

A wise and sustainable glyphosate usage should be adopted. Resistance management should be based on principles of Good Agricultural Practices and Integrated Weed Management:

- using the right rate at the right time;
- applying glyphosate when the plants are more susceptible and environmental conditions are favourable for its uptake;
- integrating herbicides with different modes of action (e.g. a selective or residual herbicide) and mechanical control in the weed control programme.

The new EU legislation on the sustainable use of plant protection products is likely to reduce the number of active ingredients and herbicide modes of action available for weed control and therefore introduces new challenges for managing weed resistance.

The gas chromatography and isothermal calorimetry as the methods to estimating resistance of *Centaurea cyanus* to chlorsulfuron

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Of all biotypes resistant to herbicides, 107 species do not respond to ALS – inhibiting herbicides. Currently the number of biotypes resistant to these herbicides is higher than weed species resistant to the other groups. The mechanism of sulfonylurea herbicides affecting consists in disturbance of biosynthesis of free amino acids. The first step in biosynthesis of a branched chain amino acids (valine, leucine, isoleucine) is catalysed by the enzyme ALS (acetolactate synthase enzyme). In Poland, the first reported case of the species resistant to chlorsulfuron (ALS inhibitor) was recorded in 2001 on wheat plantation. The objective of the research was defining the changes in the free amino acids content and rate of heat flow from the leaves of *Centaurea cyanus* resistant to chlorsulfuron. Resistance tests of the biotypes were conducted in the greenhouse. The seed samples were collected from fields with winter wheat in South – West Poland, where the efficacy of chlorsulfuron was unsatisfactory. The rates of herbicides corresponded to 1 and 8 multiplication of recommend dose applied in field. In confirmation of resistance to chlorsulfuron as identified in biological tests, the chemical analyses were performed. The analyses investigated the influence of different chlorsulfuron doses on branched chain amino acids content in the leaves of resistant *C. cyanus*. The analyses were carried out applying the gas chromatography method. In the resistant biotype followed the significant increase of valine, leucine and isoleucine concentration in comparison with untreated plants. Analyses of rate flow from the leaves of *C. cyanus* were conducted in an isothermal calorimeter at 20°C. A leaf fragment was put into ampoule, equilibrated for 25 min and then the rate of heat flow was recorded. Comparisons were made between the same biotype treated with chlorsulfuron or untreated plant (control). Two days after treating plants with chlorsulfuron, a significant increase of heat production in resistant biotype of *C. cyanus*, in comparison to control, was observed. Defining the changes in the free amino acids content and rate of heat flow from leaves can be useful methods for the detection of resistance to chlorsulfuron in *C. cyanus* biotypes.

The researches were supported by the State Committee for Scientific Research, Poland in the frame of Grant No. N N310 300134.

Growth analysis and fitness costs associated with mutation 2041 in ACCase-inhibitors resistant *Sorghum halepense*

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Sorghum halepense is a polyploid, rhizomatous spring-summer weed of Mediterranean environments that has recently evolved resistance to acetyl-coenzyme A carboxylase (ACCase) inhibiting herbicides used in Italian dicot crops. Four resistant populations were sampled in Northern Italy from 2005 to 2007. Molecular analysis confirmed that in all of them a single amino acid substitution Ile-2041-Asn had occurred in the ACCase gene (Pignata *et al.*, 2008, Scarabel and Sattin, 2010). There is no information in the literature about possible fitness costs related to this mutation in *Sorghum*. Possible fitness costs associated with the mutation 2041 were evaluated through a growth analysis experiment in 2009. Rhizomes were obtained in 2008 from herbicide selected plants (with fluazifop at 125 g a.i./L) of the four above-mentioned resistant (R) and two susceptible (S) populations grown outdoors. At the end of the season, the shoots were removed and the pots containing the substrate with roots and rhizomes were left outside. In spring 2009, the rhizomes were washed, cut and transplanted into pots containing silty-loam soil. The pots were placed outdoors in a semi-controlled environment. Four plants were considered for each population. For each plant, three clones (i.e. three rhizome nodes/buds) were planted in 30-litre pots (one clone per plot). cDNA from each plant was analyzed through a 2041-CAPS (Cleaved Amplified Polymorphic Sequence) method and the presence of the mutation 2041 was confirmed in all samples. Five samplings were performed at temperature sums (°C d) 58, 263, 555, 955 and 1530 (temperature sum 0 was set when 50% emergence was recorded). In each of them, the shoot material was cut and divided into main and secondary stems, panicles and seeds. The belowground material was accurately washed and divided into rhizomes and roots. All these parts were placed in an oven at 105 °C for 36 h and then weighed. Several other characteristics were recorded: maximum height, no. of tillers and panicles. Rhizomes were also photographed and image analysis was performed to detect length, area and average diameter. Classical growth analysis and ANOVA were performed for the main features. No statistically significant differences were detected among populations in the trend and final total weight per plant, while R populations showed a slightly lower belowground biomass accumulation. Furthermore, on average R populations seem to accumulate more biomass in roots rather than rhizomes. Significant differences between R and S populations were recorded for the rhizome/panicle weight ratio (mainly due to the significant lower panicle production of the R populations), with the R populations showing values about 50% higher than the S populations. This is the first report of a possible fitness cost associated with the mutation 2041. Of course, the results need further confirmation so the experiment will be repeated next year.

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Herbicide resistance in *Apera spica-venti* - a survey of arable field populations in Northern Germany

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Apera spica-venti (L.) P.Beauv. is a winter annual grass weed with increasing populations in autumn-sown crops. The use of reduced herbicide doses has been widely adopted by farmers in Germany. Complaints about reduced efficacy of graminicides against *Apera spica-venti* are increasing throughout different regions of Germany. A random survey of cropping fields throughout Northern Germany was conducted to determine the extent and frequency of resistance in populations of *Apera spica-venti* to commonly used herbicides. Seed samples were collected from a total of 25 cropping fields, with a previously known management history, and subsequently tested for resistance. Collected populations were screened with herbicides of four different modes of action that are commonly used in Germany: aryloxyphenoxypropionate, sulfonylurea, two phenylureas and dinitroaniline. Whole-plant bioassays were performed in glasshouse-experiments. Seedlings were sprayed in the two-leaf-stage with five different commercial formulations. Resistance status was assigned using the MOSS four-category R system. Half of the tested populations were susceptible to all herbicides. For both isoproturon and clodinafop resistance may be developing in two accessions each. In two further origins iodosulfuron performance was reduced to a very low level and we confirmed resistance.

Effect of weed control technologies on herbicide-tolerant sunflower hybrids

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Herbicide tolerant sunflower hybrids play an increasing role in the sunflower production. Weed management in sunflower production is getting more and more difficult in case of annual and perennial dicotyledonous weeds, especially in hard, dry spring. Two actives, imazamox and tribenuron-methyl could be a solution for farmers on those weeds. Most of the farmers chose the Clearfield technology and the use of tribenuron-methyl herbicides. Small plot experiments were carried out to investigate the phytotoxicity of herbicides on imazamox (IMI) and tribenuron-methyl (SU) tolerant sunflower hybrids under field conditions. At harvest wet content and crop yield was determined. Oil content of the achenes was measured under laboratory conditions. In 2007 we studied the phytotoxicity of imazamox and tribenuron-methyl herbicides in six different dosages on sunflower hybrids and weeds. The dose rates were sprayed as 0.5, 1, 1.5, 2, 2.5 and 3 time rates of label recommendations, respectively. In 2008 the experiment was repeated involving some pre-emergence treatments also. Normal and double rates were applied, combined with split and full applications. Higher doses decreased crop yield in both IMI and SU sunflower hybrids, although oil content was not influenced significantly. In 2008 our experiments proved that higher dosages of imazamox cause the fall of oil content of IMI hybrids. In case of SU hybrid the double dose resulted in the lowest oil content. The different pre-emergence technologies did not cause significant changes in oil content within the same post-emergence treatments. Imazamox and tribenuron-methyl did not cause permanent damage of the examined herbicide-tolerant sunflower hybrids. A critical point in weed control is the growth stage of the weeds. At the same time sunflower would limit application time, too. Weed control efficacy dramatically reduced after growth stage B-14-16, due to the crop could cover a significant part of the emerging weeds. Thus, technology should avoid late applications. Generally post-emergence treatments are done at 4-6 leaf stage of sunflower. By this time the weeds are well-developed and can cover each other, which can greatly decrease the efficacy of herbicides. It was started that post-emergence treatments alone are not sufficient for the good weed control effect. Benefit of these technologies is definitely to control effectively large-seeded weed species (e.g. *Ambrosia artemisiifolia*, *Datura stramonium*, *Abutilon theophrasti*), which are able to emerge from deeper soil layers, where pre-emergence herbicides can not penetrate. We concluded that for an acceptable weed control an additional pre-emergence treatment is needed. Pre-emergence treatments controlled those weeds, which the post-emergence treatments were not able to eradicate. These experiments confirmed that the new weed control technologies (normal dosages for IMI and SU hybrids) could be used safely in sunflower production without impact on oil content. Experiments confirm there is a need for pre-emergence (conventional) weed control. Yield data showed different results across the years, thus this parameter remains unsettled.

Roundup Ready Corn 2 positioning in Europe

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Roundup Ready Corn 2 is the brand name for MON-ØØ6Ø3-6 (OECD unique identifier), genetically modified maize tolerant to glyphosate. This product, cultivated first in 2001 in the US, currently available in many world areas, is awaiting approval for cultivation by farmers in Europe. In the Roundup Ready Corn 2 system, yield potential is maximized by delivering consistent weed control and excellent crop safety. Improved crop safety as compared to currently used traditional maize weed control systems is achieved because the Roundup Ready trait delivers complete tolerance to glyphosate on Roundup Ready Corn 2 hybrids.

To date, European farmers utilize three principal weed management regimes in maize: a pre-plant treatment based on residual herbicides, or two pass programs, based on a pre-emergence treatment followed by post emergence herbicides, or a total post-emergence program. In Roundup Ready Corn 2, glyphosate has numerous benefits in replacing the currently used post-emergence herbicides. Combined with residual herbicides, the wider window of application of glyphosate increases the flexibility to manage weeds when spray conditions are most favorable, thus respecting best herbicide use practices. The non persistence of glyphosate reduces crop rotation and crop replacement constraints. Moreover, the Roundup Ready Corn 2 system facilitates options such as minimum tillage practices, which are known to favor reduction of fossil energy consumption, CO₂ emission and soil erosion, among other environmental and economic benefits. Introduction of glyphosate as a weed management tool in combination with reduced rates of sequence or tank mix partners contributes to proactive and sustainable weed resistance management programs in maize and within the farm crop rotation. To minimize the risk of any shift in efficacy and potential development of weed resistance, Monsanto recommends that growers start with a clean field, apply Roundup at recommended label rates, at the right time (esp. regarding the weed development stages), under favorable application conditions, and include other weed management control measures where appropriate. Glyphosate has no residual herbicidal activity and has limited mobility because it binds tightly to soil. The compound presents very low mammalian toxicity, minimal risk to terrestrial and aquatic species including fish, birds, mammals and invertebrates and does not bio-accumulate. Roundup Ready Corn 2 is a technology that provides effective and economical weed control in maize with unsurpassed crop safety helping farmers maximize its yield potential. In Europe this new alternative in-crop weed management system can help reduce the risk of further herbicide resistance to develop in maize, addressing sustainable environmental, economical, and social requirements.

Susceptibility of volunteers of some herbicide-resistant sunflower hybrid against different ALS-inhibitors

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Volunteers of sunflower have become increasingly frequent in Hungary. Production of herbicide-resistant hybrids can cause cross-resistance against ALS-inhibitors in the subsequent years. Susceptibility of volunteers from five resistant and one conventional sunflower hybrid has been investigated. These hybrids were: CLHA-PLUS/IMISUN (IMI), CLHA-PLUS (IMI), NK Brio, (conventional) NK Neoma (IMI), LG 56.58 (IMI), PR63E82 (SU). Tested herbicides were: methsulfuron-methyl (Ally 20 DF) 45 g/ha, rimsulfuron+thifensulfuron-methyl (Basis 75 DF) 20 g/ha, tritosulphuron (Biathlon) 50 g/ha, tritosulphuron 50 g/ha + fluroxypyr 0,3 l/ha (Biathlon Star), tribenuron-methyl (Express 45 SX) 45 g/ha, aminopyralid+pyroxsulam+florasulam+cloquintocet-mexyl (Genius WG) 0,2 kg/ha, triasulfuron (Logran 75 WG) 43 g/ha, foramsulfuron+isoxadifen-ethyl (Monsoon) 2 l/ha, imazamox (Pulsar 40 SL) 1,2 l/ha, thifensulfuron-methyl (Refine 75 DF) 10 g/ha, amidosulfuron+iodosulfuron-methyl-Na+mefenpyr-diethyl (Sekator) 0,3 kg/ha, rimsulfuron (Titus 25 DF) 45 g/ha. Field experiment was carried out in five randomized plots. Datas were statistically analyzed with ARM-software (LSD P=5%). Sunflower hybrids with the new IMI gene (CLHA-PLUS/IMISUN, CLHA-PLUS) were significantly more susceptible against herbicides (they are better controlled), with exception of Titus. Against NK Neoma and LG 56.58 volunteers Logran, Genius, Sekator, Biathlon, Biathlon Star, Titus herbicides were effective. Control effect of Express, Refine and Monsoon herbicides was very poor. The SU-resistant hybrid showed larger tolerance than IMI-resistant hybrids. Efficacy of Genius, Biathlon, Biathlon Star herbicides were acceptable, while that of Refine, Basis, Titus and Pulsar were very week. Largest problems can be expected in soybean, because Pulsar and Refine are inefficient against volunteers of IMI- and tribenuron-methyl-resistant sunflower. Solution in that case could be new hybrids with CLHA-PLUS IMI gene, which showed high susceptibility against Refine.

Effective control against perennial and annual monocotyledon weed species in cycloxydim-resistant maize

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Weed control is the most critical element in the technology of maize cropping, particularly in fields infested with perennial monocotyledon weeds. The field experiment was carried out in the vicinity of Győr (North-Western Hungary) in four randomized plots, where the dominant weed species were: *Phragmites australis*, *Cynodon dactylon* and *Setaria verticillata*. The Focus Ultra (cycloxydim) herbicide were applied in different times, in one (4 liter/ha) and in shared (2+1, 2+2 and 3+2 liter/ha) doses. The data were statistically analyzed with ARM computer program (LSD, $P=5\%$). Against *Phragmites australis* the most effective treatment was cycloxydim at 2 liter/ha (early post) + Focus Ultra 2 l/ha (late post), the weed control efficiency was 92%. *Cynodon dactylon* was more sensitive to cycloxydim than *P. australis*. The weed control efficiency was 98% in case of 2 l/ha early post + 1 l/ha late post treatment. The effective dose against *Setaria verticillata* was larger than 1 liter/ha in late post usage. Cycloxydim proved to be efficient against monocotyledon weed species in cycloxydim-resistant maize. The detailed doses in early and late post usage are suggested against perennial monocotyledon weeds. The control against *P. australis* demands high attention. The cycloxydim-resistance allows effective weed control possibilities against monocotyledon weeds in maize.

Evolution of resistance to fenoxaprop-P-ethyl in *Alopecurus myosuroides* - consequences of low/high-dose selection

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Recent reports on herbicide resistance evolution point out the risk of non-target-site resistance (nTSR) in weed populations after a few generations of selection with low herbicide doses. The rate and level of resistance evolution at low-dose selection in comparison to high-dose treatments is however vague. This study compared the selection potential of low (30.5 g a.i./ha) and high (152.6 g a.i./ha) fenoxaprop-P-ethyl (FEN) doses in a sensitive *Alopecurus myosuroides* population under greenhouse conditions. The level of resistance was evaluated in qualitative and quantitative dose-response experiments (10 doses; 3 replicates; 80 plants/replicate). The qualitative dose-response results showed that a single cycle of low-dose selection with FEN significantly moved the sensitive population towards a higher tolerance. Factors ranged from 1.4 to 1.9 for the low and high dose, respectively. At the second selection, the factors increased to 1.8 and 3.5. The survival rate of the double high-dose selected population at the recommended field rate was 66%. A similar, but less pronounced trend was observed evaluating quantitative responses. To elucidate the responsible mechanisms, individual plants of all sub-populations and generations were analysed for target-site resistance (TSR) and nTSR to FEN via molecular genetic and HPLC based analysis of herbicide metabolism. The study showed the rapid increase of nTSR in a small population under greenhouse conditions. The similar level of resistance produced by a double low-dose and a single high-dose FEN selection indicates that the selection with low doses has a similar, albeit delayed potential to promote nTSR.

Changes in content of shikimic acid in GMO and non-GMO soybean variety after glyphosate application

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Resistance to herbicides is a global phenomenon challenging production in agro ecosystem. Modern science and technology give countless number of possibilities and bring about different ideas for creation of plants with additional agro economical characteristics, among which is a tolerance to non-selective herbicides. Glyphosate resistant crops (GMO) gave a new approach to weed control, but also a risk of development of alternative resistance mechanisms to herbicides. Gene introduction to plants of 5-enolpyruvat-shikimat-3-phosphat synthase with reduced affinity for glyphosate isolated from *Agrobacterium* sp. (CP4) caused higher resistance of those plants to glyphosate. By planting GMO crops there is a possibility of gene transfer by hybridization and reversed crossing to weed species closely related to planted GMO crop. That is one of the ways of development of glyphosate resistant weeds. The goal of our research was to determine differences between glyphosate tolerant (GMO) soybean variety (PAN 520) and non-GMO (EGRET) soybean by measuring amount of shikimic acid after application of glyphosate dose recommended for GMO crops. The experiment was conducted in the greenhouse under controlled conditions (22.8°C, 54.6% humidity, photoperiod 12h/12h). Glyphosate-trimesium- sulphosate (Touch down 500 gai/L) at 2 L/ha was applied with laboratory sprayer to soybean plants with first true trifoliolate-leaf developed. To measure the amount of shikimic acid in vivo plants were sampled at 2, 4 and 6 days after application. At every application date 5 plants were sampled and the whole experiment was repeated twice and calculated LSD. Amount of shikimic acid was determined by HPLC (Hewlett Packard Agilent 1100 series, DAD (Diode Array Detector), Luna-NH2 column with 5 µm diameter, flow 1 ml min⁻¹) method by Mueller et. al (2003)). The level of shikimic acid for both GMO and non-GMO soybean varieties before glyphosate application was the same (< 0.12 mg g⁻¹ of fresh weight). This showed that amount of shikimic acid does not depend on plants resistance / susceptibility to glyphosate before its application (under stress). After application of glyphosate (Touch down 500 g ai/L) at 2 L/ha susceptible soybean variety contained high levels of shikimic acid: 2.29 second day after treatment (DAT); 3.32 4 DAT and 3.59 mg shikimic acid per g-1 of fresh weight 6 DAT, while GMO soybean variety contained lower levels of shikimic acid: 0.29 2 DAT; 0.51 4 DAT and 0.24 mg shikimic acid per g-1 of fresh weight 6 DAT. When we compared untreated and treated plants, the content in susceptible soybean variety was 19.6x; 28.4x and 30.7x (2, 4 and 6 DAT, respectively) higher than values measured before herbicide application. In contrast, a difference in susceptibility between treated and untreated GMO (tolerant) plants was 2.3x; 3.9x and 1.9x. Similar conclusions regarding reaction of susceptible and GMO (tolerant) soybean varieties to glyphosate application were

made by Dinelli et al. (2006). In summary, application of recommended glyphosate dose for GMO crop had an adverse effect on susceptible soybean plants in regard to accumulation of shikimic acid where its content was 2-3x higher in comparison to glyphosate tolerant soybean varieties. Based on this experiment we confirm tolerance of GMO soybean variety to dose of glyphosate-trimesium-sulphate recommended for GMO crops.

Occurrence of glyphosate-tolerant *Commelina communis* in the Czech Republic and a prediction of its future spread

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Commelina communis L. occurs in the Czech Republic as an ornamental annual and it often escapes from cultivation and becomes feral. The same has also occurred with this species in the yards of railway stations Prague – Vysočany, Ďelákovice, Lysá nad Labem, Nymburk, Stará Boleslav, and Polepy. On these locations *C. communis* was cultivated (and in many cases still is) on the platforms. Usual weed control systems do not affect *C. communis* sufficiently so the species founded abundant populations there and it is spreading further. As other *Commelina* species, *C. communis* show natural tolerance to glyphosate, which is used on observed locations for weed management. This gives *C. communis* competitive advance against other plant species. After application of herbicide with containing glyphosate, the whole species spectrum of weeds is affected and consequently dies with the exception of *C. communis*, which shows only leaf necroses; plants regenerate and continue in flowering and seed production. This species seeds can be also found as a contamination of imported agricultural products but the cultivation is the main source of escaping into neighbouring plant communities. We also recorded the occurrence of *C. communis* in other non agricultural landscape: in one case growing in waste garden material that was left near the path at the shrub edge (Podhorní Újezd), in other case the species was growing in a forest also near the path (Děšy). *C. communis* is able to create self-reproductive populations under our conditions. As it was found in case of railway stations, *C. communis* can profit from management systems with glyphosate-based weed control methods and it can spread and colonise new locations. This poses a threat to HT crops that will be adopted in future and in which stands of *C. communis* can become a problem weed.

Supported by MSM 6046070901 and QH91093 research projects.

Efficacy of adopted measures for *Orobanche cumana* control in sunflower fields in Greece

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Sunflower constitutes a potential crop in the prefecture of Evros (North East Greece) with an increasing demand for oilseed and biofuels' production. The need for higher and permanent yield and therefore the sustainability of the crop demand a more efficient weed management. The most significant constraint for sunflower production in this region is the broomrape species *Orobanche cumana*. Even if the farmers select *Orobanche* tolerant hybrids, the holoparasite's presence remains a problem. As a result, mapping *O. cumana* spatial distribution, its different races and also the amplitude of the problem is essential. The crop is included in a rotation system primarily with grain and secondly with corn. The weed management is conducted mainly by herbicide treatments such as Treflan (trifluralin), Granstar (tribenuron methyl) and Oxyfluorfen (oxyfluorfen). During 2008-2009 period there was a great demand and preference for "Clearfield" (imazamox-resistant) sunflower in order to tackle E and F races of *O. cumana*. Intensive surveys were conducted in 20 different areas during summer 2009, where previous information on heavy broomrape infection existed. The sampling procedure was accomplished by following a zigzag pattern in 5 random locations in each field. The results were extremely encouraging for the imazamox-resistant sunflower technology, since zero broomrape infection was observed in previously heavily contaminated areas. However, the problem existed for E and F race resistant sunflower varieties in some cases. The infestation rate was low (approximately 2 broomrape stalks per 10 sunflower plants) for F race resistant varieties, while the rate was high (approximately 5 broomrape stalk per sunflower plant) for E race resistant varieties.

Resistance of silky bentgrass (*Apera spica-venti* (L.) Beauv.) to ACCase inhibitor herbicides in Poland

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In recent years the increase of weed resistance to applied herbicides was caused by such factors as: limited alternatives of crop rotation, extensive use of herbicides with the same mode of action and simplified tillage systems. Resistance of silky bentgrass (*Apera spica-venti* (L.) Beauv.) populations to ALS-inhibiting herbicides was found in weed samples collected from the north-eastern, North-western and South-western part of Poland, especially in case of large areas with a dominance of winter cereals cultivation. The aim of this study was to determine the level of resistance of *A. spica-venti* populations to ALS and ACCase inhibitors. The seed material was collected from the fields showing an insufficient effect of weed controlling after the intensive use of these herbicides. Collected seeds were tested in series of greenhouse experiments. Two or three herbicide doses were used in case of each herbicide: chlorsulfuron and mesosulfuron + iodosulfuron (ALS inhibitors), isoproturon (PSII inhibitor) and fenoxaprop-P-ethyl (ACCase inhibitor). Each experimental treatment was performed in four replications, and included: tested populations, susceptible population and untreated pots. The results of greenhouse experiments revealed the presence of weed resistant biotypes to applied herbicides. Of the 35 tested samples three biotypes of *A. spica-venti* were found resistant to fenoxaprop-P-ethyl. For these biotypes individual dose-response curves with ten doses of fenoxaprop-P-ethyl and pinoxaden were calculated. Four weeks after treatments plants were harvested and shoot fresh weight for each treatment was determined. The mean survival was expressed as percentage control compared to untreated plants. The ED_{50} for survival was calculated using non linear regression analysis. The results indicated that two tested biotypes of *A. spica-venti* were cross-resistant to two ACCase-inhibiting herbicides - fenoxaprop-P-ethyl and pinoxaden. Resistance indexes (R.I) calculated from ED_{50} values (dose-response curve) showed a high level of resistance to fenoxaprop-P-ethyl (R.I. of 5.0 and 6.4) and to pinoxaden (R.I. of 8.4 and 10.5). They were also cross-resistant to ALS herbicides, showing multiple resistance. Both biotypes of *A. spica-venti* were found resistant to herbicides from two groups with different mode of action - ACCase and ALS inhibitors and both biotypes showed cross-resistant within the same chemical group. So far, there were no reports on silky bentgrass multiple resistance in Poland. The results of these studies revealed that the resistance phenomenon of *A. spica-venti* to commonly applied herbicides might develop rapidly in the nearest future.

SESSION 2

WEED BIOLOGY

Oral presentations

Session organizers:

Kirsten Torresen & Maurizio Vurro

How weed anatomy can still serve as a tool for weed scientists

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Any plant can be a weed by definition, i.e., there is no typical structure within a plant that makes it a weed. There are, however, characteristic features which allow some weed species to survive in arable field: stolons, rhizomes, bulbs, tubers, buds on roots, seed morphology and reproductive organs. The uptake of a herbicide and its distribution within a plant depends on leaf structures and barriers between parenchyma and vascular bundles. Weediness is the ability of unwanted plants to survive in an environment managed by man. Modern weed control tools have reached a high degree of efficiency. Evolutionary principles, however, can provide an escape from man's control intentions. Some species have developed fertilization tools that enhance the exchange and rearrangement of genes. Flowers of *Amaranthus* spp. are usually unisexual. *Amaranthus palmeri* is a dioecious species with male and female plants not allowing self fertilization. *Amaranthus* species can form hybrids and they have adapted to all kinds of environmental conditions. From a morphological point of view, there are interesting characteristics that can be linked with adaptation and survival strategies. It is known that some *Amaranthus* species can survive frost due to lignified parenchyma cells and fibers. They stay erect while others disappear completely in late autumn after the first frost, because they are less lignified (Costa and DeMason, 2001). Lignification may also be a reason for herbicide tolerance of advanced stages of some weeds. Some weeds are able to recover after herbicide treatments. This ability may be explained by isolated and well protected tissue. Histological findings could explain the ability of *Amaranthus* species to recover after herbicides treatments: the phloem of older stem parts differentiates into highly lignified fibers. Sieve tubes are surrounded by these elements with high amounts of phenols. I.e. a radial transport of herbicides through the stem cannot easily be explained. A similar phenomenon occurs in *Conyza canadensis*. Secondary growth of *Amaranthus* species and *C. canadensis* are, however, completely different; but both species show enclosed phloem parts during secondary growth. Unfortunately, these morphological findings cannot be used for a proof of resistance. *Amaranthus retroflexus*, a monoecious species, shows similarities with *A. palmeri* in shoot morphology. Glyphosate resistance, however, has only been shown so far for dioecious *Amaranthus* species: *Amaranthus rudis*, *A. palmeri*, *Amaranthus tuberculatus*. Today, site of action means molecular target site or molecular receptor to some scientists. Glyphosate resistance makes obvious that simplistic mutation models are not always sufficient to explain the survival of tolerant or resistant weed biotypes.

Reference:

COSTEA M & DEMASON DA (2001) Stem morphology and anatomy in *Amaranthus* L. (Amaranthaceae) – Taxonomic significance. *Journal of the Torrey Botanical Society* 128 (3), 254-281.

Weed seed survival after silage and fermentation

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In the last decade, biomass production for energy production has assumed large proportions. In Germany, this has taken the form of fermentation of raw or silaged maize and rye for the production of biogas. Silage is required for long-term storage of raw biomass. Residues after fermentation are suitable as fertilizers for arable crops. However, there is a risk of carry-over of pathogens surviving ensiling and fermentation, potentially resulting in an increased use of pesticides or the spread of quarantine organisms. We here investigated whether, which and how many weed seeds survived ensiling and fermentation. We hypothesized that seeds with thick, hard seed coat would be best able to survive both processes.

Maize harvested in 2008 (experiment 1) and 2009 (experiment 2) was chopped into 4-5 cm pieces and ensilaged in glass jars or added to experimental 30 L batch fermenters. Weed seeds, in small-meshed nylon bags, were added during cramming and at the start of fermentation. In trial 1, bags contained 50 to 200 seeds, up to a total of 600 - 1000 seeds per species, depending on seed size: *Abutilon theophrasti*, *Amaranthus retroflexus*, *Capsella bursa-pastoris*, *Chenopodium album*, *Echinochloa crus-galli*, *Matricaria inodora*, *Fallopia convolvulus*, *Solanum nigrum*, *Stellaria media*, and *Viola arvensis*. In trial 2, bags contained 100 seeds of *A. retroflexus*, *C. album*, *E. crus-galli*, *F. convolvulus*, or *S. nigrum*. Silage lasted approximately 90 d and fermentation 30 d. Afterwards, seeds were rinsed, dried and checked for viability using 1) visual examination, 2) germination test (35 d) and 3) tetrazolium test.

After the first trial, some visibly intact seeds were found for all species after silage. Only seeds of *A. theophrasti* germinated (32%). Viable seeds (tetrazolium test) were found for *A. retroflexus* (0.8%), *E. crus-galli* (0.6%), *A. theophrasti* (additional 0.6%), *C. album* (1.7%) and *P. convolvulus* (1.5%). After fermentation, most seeds were visually identified as dead. None of the intact seeds germinated. An occasional seed of *P. convolvulus* (1.5%) and *M. inodora* (0.5%) was viable when tested with the tetrazolium test. Results from the second trial will be available shortly.

These preliminary results suggest that a small percentage of seeds of some weed species is able to survive silage and an even smaller percentage survived fermentation. Carry-over of weed seeds through silage and fermentation seems therefore possible. It may not be easy to predict which species will or will not survive, because it appeared largely unrelated to seed size or seed coat thickness.

Seed heteroblasty: how weeds exploit local opportunity

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Weeds successfully infest agricultural fields by seizing and exploiting opportunity spacetime. Local opportunity spacetime is habitable space at a particular time consisting of resources (i.e. water, oxygen), conditions (i.e. heat), disturbance (i.e. cropping practices) and neighbors (crops, weeds). Together these components are perceived as an integrated signal and act as ecological filters shaping the evolution of temporal seedling recruitment. Seedling emergence timing relative to that of the crop and neighbor weeds is the single most important determinant of agricultural plant community assembly and structure. Demographic and purely environmental representations have failed to deduce the inherent biological mechanisms (functional traits) responsible for seizing local opportunity spacetime at the time of seedling emergence, and the subsequent evolution of local adaptation. Seed heteroblasty is the variability in seed dormancy capacity among individual seeds at abscission shed by a parent plant. Seed dormancy capacity is the dormancy state of an individual seed at abscission, as well as the quantity of environmental signals (water, heat, oxygen, etc.) required to stimulate a change in state (after-ripening). Seed heteroblasty, induced by the parent plant in progeny seeds during embryogenesis, is the trait responsible for seedling emergence timing and quantity: seed heteroblasty ‘blueprints’ seedling recruitment. Field studies of 39 *Setaria faberi* populations from Iowa, USA, maize-soybean cropping systems were conducted to determine variation in dormancy at abscission (seed heteroblasty), and its relationship to subsequent behavior in the soil. The heteroblastic structure of each population as influenced by parental genotype (time of embryogenesis) and environment (year, location) was revealed in controlled germination conditions: after-ripening (AR; dark, 4°C, moist, 0-80d) followed by a germination assay (light, 25°C, 8d). The majority of individual populations were differentiated from each other, indicating fine scale local adaptation. Taken together, the 39 responses represent “seed dormancy phenotype space”. Three different generalized dormancy patterns among populations were observed: pattern 1 (low dormancy): high initial germination with low doses of AR; pattern 2 (high dormancy): low-no initial germination, little additional with increased AR; pattern 3 (intermediate) was most typical: low initial germination, increasing with increased AR. Heteroblastic responses were ranked and compared with subsequent seedling emergence. Consistent, complex, seedling recruitment patterns were strongly correlated with a population’s seed heteroblastic structure. Seedling recruitment is a hedge-bet seeking opportunity at the crucial times in life history when weeds assemble and interact with crops in the community. This functional trait is the means by which *S. faberi* forages for recruitment opportunity, and is also the means by which it maintains successful past adaptation to local opportunity. Seed heteroblasty is a germinability ‘memory’ of historically successful phenotypes: the “blueprint” enabling post-dispersal exploitation of a locality on fine temporal and quantitative scales.

Germination and onset of shoot growth of root/rhizome buds of five perennial weeds

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Compared to seed germination studies, only a little is done on germination of buds on roots/rhizomes. Such knowledge is needed to understand emergence dynamics of perennial weeds. This study aimed at investigating temperature requirements for germination and further growth. Because of possible interaction between environmental circumstances for the parental plant and germination response of root/rhizome pieces, also this factor was included.

Five weed species: *Cirsium arvense*, *Elymus repens*, *Equisetum arvense*, *Sonchus arvensis*, and *Tussilago farfara*, were dug up in autumn and planted in pots. Two populations of each species were used, growing approximately 65 km apart. From each population, plants were placed in soil outdoors in Uppsala, Sweden, and in a greenhouse kept at summer temperature. In late winter, when soil outdoors was frozen, roots/rhizomes from all plants were cut in 1 cm pieces; each containing at least one bud, but none germinated. The pieces were placed in darkness at 12 different temperatures (1/3 to 23/19 °C day/night) for 8 weeks. Mortality, germination of shoot, and shoot growth to 1 cm or more were recorded at 1, 2, 4 and 8 weeks. Results (arcsine transformed per population fraction: died:tested pieces, germinated:tested pieces, and shoot grown to 1 cm:germinated pieces) were analyzed (ANOVA and Tukey HSD test), using the two populations as replicates of each species.

For *Cirsium* and *Tussilago*, root pieces from greenhouse died soon at 1/-3°C, while those from outdoors survived, or survived longer; *Sonchus* died quickly at 1/-3°C. *Equisetum* had higher overall mortality of pieces from outdoors than from greenhouse plants; the opposite was true for the other four species. Overall germination differed significantly between species (*Equisetum* germinated the least and *Sonchus* the most) as did their responses to parental plant environment and test temperature. At 1/-3°C, only a few *Elymus* germinated. For *Cirsium*, *Equisetum* and *Sonchus*, pieces from outdoors germinated to higher extent at low temperatures than did those from greenhouse. Both from greenhouse and outdoors, all species germinated at lower temperatures than they required for growth. The fraction of germinated buds that grew differed between species and in responses to parental plant environment (with the largest difference between *Sonchus*: 30% from greenhouse, 95% from outdoors and *Tussilago*: 58% from greenhouse, 34% from outdoors), to test temperature, and to the interaction between these; *Sonchus* had the largest difference in response: growth occurred at 3/-1°C from pieces from outdoors but not at lower than 13/9°C from greenhouse.

In conclusion, perennial weed species differ significantly in their root/rhizome germination ecology, even though they co-occur within agricultural fields. For all species investigated here, soil disturbance at low temperatures may cause a seemingly inexplicably emergence flush later; either because buds on root/rhizome pieces stay ungerminated, or because they germinate but stay resting until higher temperature occur. For some species, the response

to a specific temperature at soil cultivation can only be predicted if taking the previous environment into account. In addition, there are reports that indicate possible root/rhizome dormancy characters for some of the species, which would further complicate germination and emergence predictions. In the present study, dormancy was plausible avoided by using either actively growing plants (greenhouse) or plants that should be ready to re-sprout (outdoors in late winter). Possible dormancy characters in roots/rhizomes of these species will be studied in a subsequent experiment.

Determination of morphological and genetic variation of *Echinochloa crus-galli* (L.) P. B. populations collected from different rice fields

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Echinochloa crus-galli (L.) P. B. (barnyardgrass) is an annual weed native to Asia and distributed throughout the world. The broad ecological tolerance and competitive ability of *E. crus-galli* makes it the most important weed species in rice growing areas. Many farmers are depended on herbicides for control of these weed. However herbicide resistance is becoming a problem in such kind of farming systems. Therefore, there is a need to develop sustainable weed management approaches integrating a variety of agronomic practices to suppress the weed and minimize the herbicide use. Genetic studies of plants could help us to know populations dynamics, occurrence of herbicides resistance and demographic data.

Mature seeds of *E. crus-galli* were collected from 34 different locations of rice growing areas in 2007 to compare morphological differences and genetic variation among populations. The seeds of each population were sown in pots that were then placed in screenhouse in a randomized block design. After emergence, seedlings were thinned to 5 equidistantly spaced uniform plants per pot. Morphological parameters such as germination speed, seedling growth rate, leaf area index, plant height, spikelet length, above-ground biomass, root dry weight and seed weight were measured. In 2007, mature seeds from each populations were sown. At the three-leaf stage, fresh leaf tissue was harvested from each population, frozen in liquid nitrogen, and ground for DNA extraction. The genomic DNA was isolated with the use of the DNeasy plant mini kit. Seven 10-base oligonucleotide primers were screened for their ability to produce repeatable polymorphic bands using RAPD analysis on thirty-four *E. crus-galli* accessions. Morphological similarity was examined using hierarchical cluster analysis. Genetic distance similarity was performed with NT-SYS using the Jaccard's coefficient similarity.

The parameters measured showed that there are distinct differences among populations with respect to the hierarchical cluster analysis. The cluster analysis obtained by the UPGMA method split the *Echinochloa* accessions into three main clusters A, B and C. The cluster A was further split into four distinct sub clusters. The primers produced a total of 55 repeatable bands, 41 of which were polymorphic, among the 34 populations of *E. crus-galli*. The percentage of polymorphic bands was 74%. Clustering analysis grouped the 34 populations in two distinct clusters with limited variation. The result showed that high morphological and genetically variability was found among individual *E. crus-galli* population and varied within similar geographic locations. Phenotypic and genetic variability among *E. crus-galli* populations could be influenced by agricultural practices, crop characteristics, geographic location and herbicide pressure.

SESSION 2

WEED BIOLOGY

Poster presentations

Session organizers:

Kirsten Torresen & Maurizio Vurro

Estimation of base temperature for *Sorghum halepense* rhizome sprouting

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Johnsongrass (*Sorghum halepense*) is a rhizomatous perennial weed. It spreads by seeds (seedlings) and rhizomes (ramets). Emergence is observed in spring/summer. The development of predictive models for rhizome sprouting (RS) and ramet emergence (RE) may provide important information about their seasonal dynamic and consequently for control timing. The aim of this work is to analyse the effect of temperature on Johnsongrass RS and estimate its base temperature (T_b), whose knowledge is the first step to create mathematical models for predicting ramet emergence. Rhizomes were collected in February from two north-Italian populations (Padova, Veneto region, and Mantova, Lombardy region); they were then cut into 4-knot pieces. Three replicates of 10-rhizome samples were buried in pots filled with sand and then incubated at 6 constant temperatures (12, 14, 16, 18, 20, 24 °C) in a growth chamber with photoperiod of 12/12 h (light/dark). Substrate moisture was maintained at non-limiting level for RS. Emerged ramets were counted and marked daily; the total number of ramets, sprouted rhizomes and their ratio (ramet/sprouted rhizome) were then calculated for all repetitions. Means and relative standard deviations were estimated for the 6 different temperatures and Student's t-test was performed for mean separation among different treatments. An ANOVA analysis was executed to verify the influence of temperature on emergence performances of the different populations.

RE and RS were also modelled with a logistic function. Sprouting and emergence rates (reciprocal of t_{50}) were estimated. A linear regression of those rates against incubation temperature was performed with the bootstrap method. T_b and relative standard errors were estimated as the intercept of the regression line with the temperature axis. Student's t-test was performed to identify differences between base temperatures estimated for the two populations and using both methods, i.e. modelling RS or RE.

ANOVA analysis pointed out the highly significant stimulating effect of temperature on Johnsongrass rhizome performances. Mean number of sprouted rhizomes reached maximum values with temperatures above 14 °C and 16 °C for the Padova (9.7 ± 0.6) and Mantova (7.7 ± 1.2) populations, respectively. Student's t-test showed no significant difference among means at higher temperatures. Mean number of emerged ramets was maximum at 24 °C for the Padova (25.0 ± 4.6) population and 16 °C for Mantova (17.7 ± 3.8). The ratio ramet/sprouted rhizome reached the highest value at 24 °C for the Padova (2.6 ± 0.3) population and 16 °C for that of Mantova (2.4 ± 0.7).

Estimated base temperatures did not differ between populations and methods (Padova RS $9.7 \text{ °C} \pm 1.3$; RE $10.0 \text{ °C} \pm 1.3$; Mantova RS $8.0 \text{ °C} \pm 1.9$; RE $9.7 \text{ °C} \pm 1.2$). The results confirmed the possibility of using the same thresholds for thermal time models for the two populations. These results also suggest that both methods can be used without distinction to estimate the rhizome base temperature.

keywords: base temperature, Johnsongrass, emergence modelling, perennial weeds

Pre and post dispersal environmental factors affecting germination and emergence of *Digitaria sanguinalis* (L.) Scop. in soybean crops

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Digitaria sanguinalis (L.) Scop. is a troublesome annual weed of soybean in the Rolling pampas, Argentina. The extended period of seedling establishment may explain the success of this weed, whose establishment depends on seed dormancy and germination, and on seedling emergence. These processes are regulated by pre-dispersal environmental competitive factors (light, water and nutrients availability) and non-competitive factors (temperature, light quality and humidity), and by post dispersal soil environmental factors (temperature, moisture). Pre-dispersal factors occur during the growth and the development of the seed in the mother plant and are affected by crop canopy, while post-dispersal factors are moulded by the different kinds of stubbles. Quantifying the environmental factors that regulate seedling establishment would be useful to develop efficient weed management and to reduce the use of herbicides. The objectives of this work were: 1) to study conditions that break dormancy and allow germination; 2) to study the effect of soybean crop structure (inter-row spacing and maturity group) on the crop-weed pre-dispersal environment (light and temperature) and on weed plant structure and seed germination; 3) to analyze the effect of post-dispersal soil temperature and water conditions on seed dormancy and germination. Experiments were carried out in the Facultad de Agronomía, Universidad de Buenos Aires. Chamber experiments had a completely randomized factorial design with five replications. Factors were: 1) temperature of post-maturation: (control, 5, 20 and 30°C), time of post-maturation (14, 21 and 28 days) and 3) alternating temperatures (8/16hs: 10/20°C, 15/25°C and 20/30°C). A field split plot experiment with 5 replications was carried out where the main plot was crop-weed competition (with/without soybean) and sub-plots were inter-row spacing (0.15 - 0.45 m), soybean maturity group (MG III - IV) and stubble type (soybean, corn and control). Periodically, radiation, far-red: red relationship, temperature and moisture under the canopy were measured. At the end of the experiment plant height, number of tillers, reproductive tillers and plant biomass were determined. The dormancy level of the harvested seeds was studied in chamber germination tests using alternated temperature (20/30°C, 8/16h) and light. Low (5°C) and moderate (20°C) temperatures were the best conditions to break seed dormancy. The highest germination was observed using alternating temperatures of 20°/30°C (8/16h). Crop structure of MG IV reduced light availability at the beginning (0.15m) and at the end of the crop cycle), far-red:red ratio at seed filling and mean temperature. These effects increased weed plant height, reduced the number of tillers (89%), reproductive tillers (93%) and plant biomass (94%) and affected germination of viable seeds. Seeds dispersed later in the cropping season were less dormant (15%) than seeds dispersed earlier (55%). Seeds of plants growing together with soybean

were more dormant than those from plants growing alone. Soybean crop structure affected the thermal and light environment under the canopy where the weed was growing, and affected the weed plant structure and seed dormancy. These results provide information that could be used to develop predictive models of weed establishment and to design a spatial arrangement of crop plants in order to manage seed germination during the following season.

Hydrotime analysis of the seasonal dormancy pattern of *Cirsium arvense* seeds

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Cirsium arvense (L.) Scop. is one of the major perennial and troublesome weeds of pasture, arable and ruderal areas in the temperate zone. Seed spread probably plays an important role in the infestation of new fields previously free of creeping thistle. Consequently, detailed knowledge of seed ecophysiology might play a significant role in the development of new biological methods of weed control.

The goals of our study were to determine the water relation during seasonal seed dormancy changes on the basis of the hydrotime model and attempt to describe the relationships between environmental conditions and biologically significant parameters derived from the model.

Seed lots were collected in summer and buried in the soil in autumn. Once a month one portion of the seeds was exhumed and incubated at different water potentials (0, -0.1, -0.2, -0.3 and -0.4 MPa) in Petri dishes at 26 °C. Data were transformed to germination percentages considering viable seeds. An analysis of germination rates at different water potentials based on the hydrotime model was applied. The hydrotime model describes the relation between the germination rate (GR_g) of a given percentage g and the magnitude of the difference between the seed water potential \mathcal{D} and a physiological base water potential for radicle emergence \mathcal{D}_b . The repeated probit analysis technique was used to estimate the parameter values of the hydrotime model: \mathcal{D}_H - hydrotime constant, $\mathcal{D}_b(50)$ - mean base water potential and \mathcal{D}_{Db} - its standard deviation. Therefore germination time-course curves for a seed population were obtained.

Germination of seeds exhumed from the soil over one year was low and ranged from 9 to 45%, reaching its maximum in early spring and autumn and minimum in winter and summer. The hydrotime model fitted well with the experimental data. Seasonal variations in $\mathcal{D}_b(50)$ resembled the mirror image of germination changes. The highest germination level was observed in April, which was connected with low values of all the three model parameters. In September it was lower due to high values of \mathcal{D}_H and \mathcal{D}_{Db} . However, the seeds exhibited relatively low sensitivity to reduced water potential in this month. Low germination levels in winter and summer months were largely related to a rather high value of $\mathcal{D}_b(50)$. A relationship was observed between $\mathcal{D}_b(50)$ of seeds and the mean field temperature within 30 days before their exhumation. For spring and summer months the relation was positive, and for autumn and winter months negative. This trend always changed at high water content in the soil and after long-lasting (ca. 5 months) low or high soil temperatures.

The hydrotime model proved to be a valuable tool to analyse the effect of environmental cues on the dormancy and germination of *C. arvense* seeds.

Phenological development of perennial weeds in the Netherlands

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Achieving an effective control of perennial weed species in the Netherlands is becoming increasingly problematic, especially with the decreasing number of chemical control options. The development of alternative, non-chemical control options is therefore increasingly important. The development of these control options do however require a different insight in and knowledge on the biology of these species. Insight in the species life cycle under common Dutch conditions is currently unavailable and required. Dutch farmers were asked to rank the ten most problematic weed species. The resulting list was: *Sonchus arvensis*, *Cirsium arvense*, *Rorippa sylvestris*, *Mentha arvensis*, *Convolvulus sepium*, *Rumex obtusifolius*, *Equisetum arvense*, *Elymus repens*, *Stachys palustris* and *Persicaria amphibia*.

For each of these species root pieces were collected during the fall of 2008 and planted in two fields in furrows of 5-10 cm deep in the last week of March 2009. The weeds were planted in four blocks, in rows measuring 38 m, of which 8 m was reserved for destructive measurements. Root pieces were placed 33 cm apart. The extended BBCH (Biologische Bundesanstalt für Land-und Forstwirtschaft, Bundessortenamt, Chemical Industry) scale (Hess *et al.*, 1997) was used to observe weed development on a weekly basis. For each of the plant species sixteen destructive measurements were taken (four plants per block) every month during the growing season. An area of 0.25 x 0.25 m surrounding the main stem was used as sampling area from which roots and aboveground plant parts were harvested. The destructive measurements consisted of dry weight measurements (4 hours at 70 °C, followed by a period of 24 hours at 104 °C) of stems, roots, leaves and flowers and/or seeds. Dry weights were calculated per m². Total root length and number of sprouts per root were determined from April to July.

Heat sum calculation started after the burial date, temperature was measured at 5 cm bare soil. The base temperature for each species was based on literature data or, in case no information was available, set at 0 °C. Stem emergence was calculated as a fraction of the total number of stems that emerged per species, per block. A non-linear logistic dose-response regression model was used to fit stem emergence vs. heat sums. Dry matter growth of above-ground, below-ground, stem, leaf and inflorescence dry weight were log-transformed to overcome unequal variances and were plotted versus the heat sum. From the measured above-ground dry weight and below-ground dry weight the instantaneous relative growth rate of above-ground dry weight and the instantaneous relative growth rate of below-ground dry weight were calculated. Following, quadratic polynomials were used to fit the two relative growth rates versus the heat sum. Significant differences in the timing of shoot emergence were observed between species, varying from 50% shoot emergence of *E. repens* after 228 °Cd, to 50% shoot emergence of *P. amphibia* after 350 °Cd. The dry weight growth of both above- and belowground plant parts versus the heat sum were best described by quadratic polynomials.

Plants of early emerging species, such as *E. repens* and *Sonchus arvensis* required less day degrees to reach their maximum dry weight than plants of later emerging species such as *Persicaria amphibia* and *Convolvulus sepium*. The resulting data, combined with weather data, offer us valuable information on the timing of the development of these species.

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Evaluation of allelopathic effects of alfalfa extracts on the seed germination and early seedling growth of alfalfa, wild barley, wild mustard and wild oat

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Using allelochemicals can be a method for controlling the weeds. Alfalfa (*Medicago sativa* L.) plants contain compounds that cause autotoxicity and allelopathic effect on other plants. In this research, the phytotoxic effect of alfalfa cv. "Hamedani" shoot on germination and early seedling growth of alfalfa, wild mustard (*Brassica kaber*), wild oat (*Avena ludviciana*), and wild barley (*Hordeum spontaneum*) was evaluated in a laboratory experiment. A factorial experiment in a randomized complete block design was conducted with three replications. The factors were alfalfa shoot in three levels (leaf, leaf-stem, and stem), and its extracts in five levels (0, 10, 20, 30, and 40 g l⁻¹) that were applied on Petri dishes which contained twenty alfalfa or weed seeds. Germination percentage, germination rate, root and shoot lengths were measured during and at the end of the experiment. By high concentrations of stem extract (40 g l⁻¹) the root lengths of alfalfa (53.7%), wild mustard (86.1%), wild barley (67%), and wild oat (54.0%) were significantly reduced compared to the control (distilled water). With the increase in concentration, the coleoptile appeared later and its length was also reduced in both alfalfa and the weeds, but this reduction was not significant. On the other hand, germination rate and percentage of alfalfa and the weed seeds in this study were slightly affected by alfalfa extracts while root lengths were significantly reduced. Root elongation was more sensitive to autotoxin than germination or shoot length. Results of this study show the potential use of natural plant extracts for weed control. Further experiments are also needed to investigate the allelopathic effective of this plant and to identify the active compounds involved in alfalfa allelopathy and to search their application under field condition.

Productivity of two weed species in different crop density of spring barley

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Lamium amplexicaule L. and *Viola arvensis* Murray are small annual weed species, which are the most frequent weed species in winter and spring cereals (Bond *et al*, 2007). In isolation *V. arvensis* matured around 9000 viable seeds per plant whereas in competition with spring cereals the seed number was around 100 (Wilson *et al*, 1988).

A field experiment designed to determine the productivity of these two weed species in different density stands of spring barley was conducted in field experiment at Lithuanian Institute of Agriculture in 2008 and 2009. Spring barley variety “Aura DS” was sown at: 0, 2, 4 and 6 million germinal seeds per ha. The soil of the experimental site was *Endocalcary-Endohypogeyic Cambisol* (RDg8-k2). The weed plant samples were taken at the beginning of maturation of seeds. Plant height and mass, leaf and flower number, seed per flower was measured in 15 plants of each weed species in each plot.

With increasing spring barley stand density from 2 to 6 million viable seed per hectare the number of leaves, stems, flowers and mass of *L. amplexicaule* decreased significantly. The seed rate of spring barley in range from 2 to 6 million per hectare had not a significant influence on biometrical indices of *V. arvensis*.

Higher differences in the tested indicators of both weed species were obtained between plots with and without spring barley plants. In plots without crop the average of matured seeds of *V. arvensis* was around 2000 and in plots with increasing seed rate of crop 12–28 times less. Respectively, *L. amplexicaule* matured above 400 viable seeds per plant without cereals and 25–29 times less in different densities of spring barley. The green mass of *L. amplexicaule* and *V. arvensis* in plots without spring barley was lowered by 16-71 and 13-38 times compared to plots with spring barley. The number of stems and leaves of both weeds was also the lowest in the densest stands of spring barley. *L. amplexicaule* in plots without spring barley had more, than 60 inflorescences and in increasing crop stands density 11-36 times less. *V. arvensis* plant without crop in average had about 40 flowers and 9-15 times less in different density of spring barley crop stand.

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Application of plastic seed mimics to model seed bank formation of weeds in pastures in relation to soil type and land use

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Burial depth is among major factors affecting emergence of weed-seedlings yet little information has been gathered on how seed form, shape, land use and physical soil conditions affect development of soil seed banks. Such knowledge is useful in planning management of pastures in conservation areas.

Our aim was to describe long-term (5 yrs) development of seed banks using beads of high density polyethylene as seed mimics. Two different size (1.3-1.4 mm, 3.4-3.6 mm) and shape (round, flattened) classes were used, falling into the range of seeds typical for Central-European flora and also their specific gravity coincides with that of common seeds.

Extensive pastures in Nyírség (light Humic Sandy soils) and in Bihar Plain (heavy Meadow Solonetz, silty loam texture), East-Hungary, grazed by sheep and/or dairy cattle, were selected. Exclosures and unfenced lots were compared to reveal the impact of grazing on the mimics' dispersal. Particle size distribution and organic matter content of soils were analyzed. Movement of granules was also correlated with penetration resistance determined by a drop hammer penetrometer. Collection of soil monoliths, cutting into slices, washing plastic beads over a series of sieves then sorting are the main steps of data collection. In 16 sites altogether 320,000 plastic beads were applied in 2008.

Results from the first sampling period (2009) show clear effect of seed size and of contrasting physical soil conditions on the seed mimics' penetration. 1) Coinciding with empirical data from real seed banks of pastures, our results suggest that smaller granules traveled to deeper layers in larger numbers than did the larger ones. 2) In Solonetz significantly more beads penetrated into deeper layers than in sand, which can be linked a) to the formation of more stable macropores (cracks) due to finer texture or b) to a higher activity of soil dwelling animals 3) Low recovery rates of beads in grazed plots indicate the importance of domestic livestock in dispersal of weed seeds. No significant effect of shape or of land use on vertical seed displacement was found. Funded by the Hungarian National Research Fund (OTKA T19/67748).

***Calystegia sepium* and *Convolvulus arvensis*, plants with a high capability to propagate through small, deep roots**

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Calystegia sepium and *Convolvulus arvensis* are both members of the family of Convolvulaceae. They both have a climbing, perennial habit and rank among the worst weeds in many parts of the world. These plants are able to propagate both generatively and vegetatively and are thus very difficult to control.

Germination studies have been conducted to gain a better understanding of the requirements essential for generating new plants from root pieces.

Several studies have already been carried out: in one trial series root pieces of various lengths were wrapped in damp paper (cellulose) and put into pots and in another root pieces of the same length were set in pots at different soil depths. In all studies the germination rates were observed.

Seasonal variations are recorded. First results of the experiments show that 50 % to 70 % of the root pieces with a length of 2 to 4 cm and an average diameter of 2 mm, owning one bud, can develop into new plants. The more buds the higher is the likelihood of 100 % proliferation. This point is achieved if *C. sepium* has 7 and *C. arvensis* has 5 root buds respectively.

Furthermore, several buds per root can germinate. On average, 40 % to 70 % of buds per root sprout, independent of the root length.

In addition, ca. 15 % of all small root pieces with four buds and a length of 16 to 20 cm can create new plants of *C. sepium* when in a soil depth of up to 30 cm. For *C. arvensis* 15% of root pieces with a length of 6 to 9 cm also develop into complete new plants in a soil depth of up to 20 cm. The germination rates increase in a direct correlation with the height of the soil above the roots. Overall, these studies contribute to the ongoing discussion that the cleavage of root pieces can cause a high increase of the number of these weeds.

Dormancy and germination of *Chenopodium album* seeds from different latitudes in 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.

Seeds were collected in two separate years and tested in common conditions in the Seed Science Laboratory at Reading, respectively. Results show differences and similarities observed between years and latitudes, on the basis that environmental differences of seed maturation conditions in photoperiod and temperature could influence dormancy. Ultimately, the seed characterization reported here is intended to help explain differences observed in the field.

Viability did not vary significantly with latitude, but dormancy did, seeds collected from the most southern latitudes in 2006, tending to be more dormant than those from further north. Surprisingly, the optimal constant temperature for germination was correlated with dormancy rather than latitude. The greater dormancy of the southern seed lots was associated with their germination being promoted by a combination of exposure to light and nitrate (0.01 mol/litre potassium nitrate) whereas additive effects were more common in the northern seedlots. Moist chilling for up to 49 days relieved some dormancy in a seed lot from the USA, but other seedlots were either unaffected or showed induced dormancy, the latter effect being unconnected with latitude.

Acknowledgements

The research is part of a multi-location experiment performed by the EWRS Germination and Early Growth Working Group. Dogan Isik and Roy R Nicholls carried out the germination tests in the Seed Science Laboratory at Reading, UK with funding respectively from the Turkish government and Reading University Centre for Excellence in Teaching and Learning in Applied Undergraduate Research Skills. Collaborators elsewhere are Jose L. Gonzalez Andujar of Sevilla, Spain; Diane Benoit of Québec, Canada; Adam Davis of Urbana, IL, USA; Frank Forcella of Morris, MN, USA; Federica Graziani of Perugia, ITALY; Andrea Grundy then of Warwick-HRI, UK; Laila Karlsson of Linköping, Sweden; Per Milberg of Linköping, Sweden; Paul Neve of Warwick-HRI, UK; Ilse A. Rasmussen of Flakkeberg, Denmark; Jukka Salonen of Jokioinen, Finland; Bozena Sera of the Czech Republic; Edite Sousa of Tapada da Ajuda, Portugal; Francesco Tei of Perugia, Italy; Kirsten Tørresen of Ås, Norway and Jose M. Urbano of Sevilla, Spain.

Collaborative weed modelling with Universal Simulator

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Simulation models of weed demography are surprisingly similar in design. Structured around the weed life cycle, the models differ mostly in the detail to which each component is modelled and in, whether the complexities of weather, space and genetics are included. But if so many models are similar in purpose and meaning, why have they all been developed as if in isolation with no re-use of models published elsewhere? While certain equations and algorithms are re-used, the models themselves lead isolated lives offering no possibilities to link one model directly with the other.

Weed modellers do have access to general modelling tools. They are offered as part of many software packages. However, these packages have been written primarily for and by engineers, not plant ecologists. Hence no modelling toolboxes are ready for the weed modeller, matching his often limited skills in mathematics and programming and his special problem domain covering agronomy, ecology and economy.

That weed models are still being written in all sorts of programming languages and software packages are symptomatic for the lack of an appropriate, common modelling tool. The common concepts that such tools would promote, would be beneficial to weed science as a whole, creating a common framework in which to think and formulate ideas.

What we need as weed modellers is a standardized set of tools that will enable us to collaborate and share model components, pieces of well-defined software objects that can be interchanged and combined freely: Download the annual life cycle models of species *A* and *B*, combine them with soil model *C* and weather generator *D*, and set it all in the context of cropping system model *E*. We need a way out of modelling as a purely personal, or in the best case, small-team exercise.

Universal Simulator (UniSim) is an open-source software package for collaborative ecological modelling. It is composed of a main program which is used to open and execute model specifications read from XML files. The XML files specify the components constituting a model. The functionality of these components are defined in plug-in libraries. This makes UniSim extendible and open for re-use.

UniSim software is intended for research and education. While the first scientific papers making use of UniSim are in press, it has already been used to teach students weed-modelling, both at graduate and post-graduate level. Current work concentrates on developing plug-in libraries for modelling weeds (beginning with INTERCOM and Conductance Model) and honey bees.

Thanks to European Network for the Durable Exploitation of Crop Protection Strategies (ENDURE) and International Centre for Research in Organic Food Systems (ICROFS), Denmark.

Comparative analysis of the anatomy of *Amaranthus retroflexus* L. and *Amaranthus hybridus* L.

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The anatomy of stems and leaves of two populations of *Amaranthus retroflexus* L. (AMARE₁ and AMARE₂) and two populations of *Amaranthus hybridus* L. (AMAHY₁ and AMAHY₂) was analyzed in order to contribute to a better understanding of the uptake and translocation of herbicides that could be indicative of the species evolving resistance to herbicides. Samples of the two weed species were collected from arable land of the Institute of Maize Research at Zemun Polje in 2006. Samples were taken from a number of plants (30-40) in each species and population and kept in 50% ethanol solution until permanent microscopic preparations were made. From each plant, a 5 cm excision was made from the central part of the stem, and two physiologically mature leaves were sampled. Excisions for anatomical cross sections were made from the central part of the leaf. Microscopic preparations were made by standard paraffin method (Ruzin, 1999). Paraffin molds were cut out with a LEICA SM 2000 R microtome and cross sections (5-15 µm thick) stained with the histological dyes toluidine blue, safranin and alcian blue. Permanent microscopic slides were used to analyze the anatomy of stem (stem epidermis, cortex, collenchyma, central cylinder and diameter) and leaves (leaf epidermis upper surface and underside, mesophyll, leaf thickness and bundle sheath thickness). Both weed species were found to have a typical anatomy for herbaceous dicotyledons. Differences in the anatomy between the two weed species but also between their populations were rather more prominent with regard to stem anatomy (for stem epidermis, cortex, collenchyma, diameter of stem), than leaf anatomy (only for bundle sheath thickness and mesophyll). The differences in stem anatomy between the two populations of *A. retroflexus* were statistically significant with regard to the parameters analyzed. In the case of leaf anatomy the differences were insignificant except for mesophyll thickness. In the case of two populations of *A. hybridus* differences in stem anatomy were identical as in the case of the previous populations. However, differences with regard to leaf anatomy referred to mesophyll thickness and cell layer thickness of the vascular bundle only. Such differences between the species AMARE and AMAHY as well as their populations, contribute to a better understanding of plant reactions in terms of herbicide uptake and translocation that can potentially be linked to an evolution of herbicide resistance of *A. retroflexus* and *A. hybridus* species and their populations in Serbia.

The effects of pre-emergence variation in roots of *Sonchus arvensis* L.

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To develop practical tillage- and hoeing regimes to fragment roots of perennial weeds in such a way that resulting root populations are less viable than before fragmentation, it is of paramount importance to be able to predict the consecutive performance of root-fragmented populations. To assess the effects of initial root size of perennial sowthistle (*Sonchus arvensis* L.) on sprouting and consecutive development of shoots, an outdoor box experiment was performed in Sweden 2008. The response (sprouting, in terms of emergence time and shoot numbers, and shoot growth in terms of size and flower production) were quantified as a function of root length and root weight. The experimental design comprised boxes with four length traits or combinations (all with a total root length of 1 meter): 20 roots of 5 cm, 10 roots of 10 cm, 20 roots of 5 cm, and finally with 4 x 20 cm + 4 x 5 cm, each of those boxes planted in 6 replicates.

Number of shoots per root increased with root length and root weight, but per unit root length and weight, short roots produced more shoots. First shoot emergence occurred earlier in long and heavy roots, and emergence of later shoot cohorts was delayed with decreasing root length and weight. Rosette size resulting from the first shoots per root were, for rosettes of a given age, larger for long roots than for short ones, and total rosette area per root five weeks after planting increased with increasing root length and weight. The number of flowers produced and production of mature seeds were positively related to both root length and root weight, due to the fact that short and light roots displayed a delayed sprouting. The proportion of flowers that lead to mature seeds declined rapidly with shoot emergence time.

The results showed that mechanical weed control which leads to fractionating of *S. arvensis* roots, hampers reproduction by seeds and delays the phenological development of *S. arvensis*.

Seed dormancy in *Solanum physalifolium* is influenced by stratification temperature

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Emergence timing of *Solanum physalifolium* is influenced by seed dormancy changes. Therefore, understanding the factors, e.g. temperature, which affect seed dormancy is highly valuable. An experiment was conducted to study the effect of different stratification temperatures on dynamics of seed dormancy in *S. physalifolium*. In a first step seeds were pretreated for 6 months at ca 3 °C to reduce dormancy. The treatment did, however, not increase the germinability substantially. Subsequently, seeds were subjected to stratification at different constant (4.5, 10, 15.2 and 18.6 °C) and weekly stepwise rising temperatures (4.5, 10, 15.2, 18.6, 25.4, 30.2, 35.2 and 40 °C) for a period of 8 weeks. Every week, samples of seeds were randomly selected and subjected to germination tests at 25/15 °C, 16/8 hours light/darkness (HL) or complete darkness (HD), and at 18/8 °C, 16/8 hours light/darkness (LL) for a period of 2 weeks. At termination of the germination test, numbers of germinated and dormant seeds were recorded. There were significant differences between stratification temperatures, germination condition tests and time of stratification. The interactions between stratification temperature x germination conditions and stratification temperature x time were also significantly different. For seeds stratified at constant temperatures the germinability was low and did not show a consistent pattern when tested at LL. However, germination test at higher temperatures (HL and HD) resulted in an initial increase followed by a reduction in germinability at all constant temperatures during 8 weeks, suggesting a reduction followed by an induction of dormancy. This pattern was also confirmed when testing seeds subjected to stepwise rising temperature treatment. The results showed that the germinability increased after 4 weeks when stratification temperature raised above 18.6 °C and reached its maximum at temperature of 35.2 °C followed by zero germinability at 40 °C at LL. The germinability was higher and showed an increase at lower temperatures of 4.5 °C at HL and 10 °C at HD and continued with oscillatory pattern followed by decrease at 40 °C at HD but not at HL. The germinability was slightly higher in week 1-2 and 8 when tested at HL than HD indicating that light would only contribute in stimulating seed germination of the species when seeds have higher level of dormancy. Therefore, seed dormancy and germination of the species are mainly regulated by temperature and light may exert a weaker role in regulation of germination. In conclusion, dormancy release followed by induction occurred at all tested temperatures. However, the rate of dormancy reduction was higher at higher temperatures. These results help to explain the pattern of dormancy cycle in the field. Dormancy can be reduced by increasing temperature in spring and further increase of temperature cause dormancy induction during summer.

Temperature quantification to study seed dormancy in *Solanum nigrum*

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Solanum nigrum L. is one of the most important weeds, which negatively affect both crop yield quantity by competing for resources and yield quality by contaminating harvested products. In commercial agriculture high priority is given to the control of the species. Accurate prediction of emergence timing in the field would help to control the species efficiently. To do so, it is crucial to understand the factors regulating seed dormancy and germination. The aim of the study was to quantify the effect of temperature on seed dormancy in *S. nigrum* validating and applying a simulation model. In the model, the rate of dormancy release was assumed to increase with temperature above a base temperature of 0°C until a threshold of 17.5°C above which the rate become constant. The base temperature and threshold temperature for induction of dormancy was 5.1 and 20°C, respectively. A thermal time requirement as an additional predictor for release and induction of dormancy was modified by non-linear response to momentary temperature. The model calibration and validation resulted in a good prediction of observed dormancy changes at different temperature treatments under moist conditions. The model was also applied to predict dormancy release in seeds buried in the soil outdoors. Results showed that lower temperatures have negligible effect on dormancy release. Increase of temperature up to 15°C caused increase in the rate of dormancy release but was followed by induction after three weeks. Further increase of temperature caused dormancy release followed by induction after one week. The study resulted in a finding that processes of dormancy release and induction may overlap but due to differences in temperature optimum, dormancy breakage predominates at lower and induction at higher temperatures. The model gave an insight into how dormancy dynamics of *S. nigrum* seeds under moist stratification conditions might be explained by temperature as the single driving variable. In addition, the results showed that the rate of dormancy release in seeds buried in the soil outdoors is higher than seeds buried under only moist conditions in Petri dishes. Therefore, there might be other factors in the soil affecting seed dormancy or germinability of the species. For example, soil temperature usually fluctuates during day and night in contrast to the constant temperature in the experiment with controlled conditions. In addition, buried seeds in the soil are likely to be subjected to desiccation due to changes in the soil water content. Further, presence of nitrogen in the soil may affect seed germinability as compared to seeds stratified only in moist condition in the Petri dishes. Therefore, fluctuating temperature, soil nitrogen content or fluctuation in soil water content might have affected seed dormancy or germinability of buried seeds of *S. nigrum* in the soil.

Evaluating of the germination and early growth of wheat (*Triticum aestivum*) and wild barley (*Hordeum spontaneum* Koch) in different salt stresses

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Salt stress is one of the main constructions for plant growth and development in arid and semi arid regions. Wild barley (*Hordeum spontaneum*) is one of the most noxious weeds that compete with wheat in these areas. In order to study the effects of salt stress on germination and early growth of wheat (*Triticum aestivum*) and wild barley, two separate experiments were conducted in growth chamber at the Advance Research Laboratory, Faculty of Agriculture, The University of Birjand, during 2007. Experimental design was completely randomized design with four replications. Treatments were four levels of salt stress (Osmotic potential) obtained with NaCl (-0.3, -5, -10 and -15 bars) and distilled water as control. The results revealed that at increased salt stress percentage of germination, germination rate, seedling fresh weight, radicle fresh weight, plumule fresh weight, radicle and plumule length in wheat and wild barley decreased significantly. Orthogonal comparison showed that percentage of germination, germination rate and root length of wild barley decreased more than wheat. However, plumule length of wild barley was shorter than the wheat but it was not significant. The three-parameter logistic model provided a good estimation for relationship between salt stress levels and germination response of wheat and wild barely. This model showed that germination and early growth of wild barley were more sensitive to salt stress than the wheat.

Key Words: Germination, Salt Stress, Wheat, Wild barely.

***In vitro* Regeneration of Johnson grass (*Sorghum halepense* [L.] Pers) Rhizomes**

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The Johnson grass (*Sorghum halepense* (L.) Pers) is present in the tropical and Mediterranean countries all over the continents and according to assessments it is ranked to the sixth place in the most important weeds of the world.

The last, fifth (2007-2008.) National Weed Survey this weed took the 11th place. Rhizomes and seeds of Johnson grass are capable of reproducing itself in both generative and vegetative ways, which makes difficult to use effective plant protection techniques. The reason of quick dispersion and multiplication are: the mild winters in the last decades, its importation by seeds and machines, the relatively deep autumn pluggings.

In the *in vitro* assessments of regeneration of *Sorghum halepense* rhizomes we investigated the effect different temperatures on the activity of axillary buds. *Sorghum* rhizomes originated from 25-35 cm depth of soil layers.

The Regeneration studies were carried out between August and October in 2007, at the University of Pannonia (Georgikon Faculty of Agriculture, Institute for Plant Protection, Keszthely, Hungary). The samples were collected at the new manor part of the University.

At the first trial series in 2007 from 20th of August till 11th of October the rhizomes were taken from 25-35 cm depth of soil layers. From these rhizome samples 100 pieces rhizome segments were prepared after wash.

At the second trial series from 11th of September till 18th of October in 2007 the Johnson-grass were taken from 25-35 cm depth of soil layers, we cleaned them and the lamellas were removed, which covered the axillary buds. Before placing into the thermostats, the fresh weight of the rhizome segments were measured. After this the rhizome segments were stored in desiccator for 6; 12; 24; 48 hours at 28 ± 2 °C temperature and in refrigerator (9 °C) and in freezer (-10 °C) for 6; 12; 24; 48 hours. After desiccator and refrigerator storage we measured the mass of the rhizomes. This trial was arranged in 4 replications with 10 pieces rhizome segments in each replication containing 1 axillary bud. The control rhizome segments were stored at ambient temperatures.

The average diameter of the rhizome segments were in both trial series 0,5-1,7 cm. These rhizomes segments were planted in pots with fluted filter and wadding which provided the constant humidity for the rhizomes. For the assessment of the regeneration of the rhizomes the thermostat (LP-144 type) were set in 22 ± 2 °C and for 12 days the length of the sprout shoots were measured every third days.

The results of the *in vitro* regeneration experiment we can stated, that the longest sprout of rhizomes were measured by the samples which were collected in the third decade of August. It can be explainable that the bud activities of the buds are the highest in August and September

whilst the innate dormancy (endogen) period of the rhizomes is in October, November and December.

Regarding the recorded data of the length and the weight of the shoots sprouted from the axillary buds of *Sorghum* rhizomes and stored for 6-48 hours in refrigerator and desiccator we stated that longer shoots were obtained with those rhizomes stored at lower temperatures than those ones stored at higher temperatures.

Germination of *Taraxacum officinale* influenced by seasonal variation in seed quality and microclimate

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Dandelion, *Taraxacum officinale* Weber ex Wiggers (Asteraceae) is a common weed species associated with pastures, grasslands and no-tillage cropping systems throughout its native range in Europe, and more recently introduced into North America, Australasia and elsewhere. Dandelion seeds are produced throughout the year, most of which germinate on the surface of the ground of disturbed land immediately after dispersal, and under a range of seasonal conditions. The species may therefore adopt several strategies increasing seed survival and seedling establishment.

Factors affecting germination in dandelion were studied in Czech Republic. In 2004-2006, density (no. m⁻²) of flowering capitula was established, dispersing seed collected and weighed weekly, at 5 grassy sites at Prague-Ružyně (50° N, 14° E) where flowering continued through the vegetative season. Germination of seed samples was established at 25 °C and water surplus. Seeds (from one sample of high quality stored at -20 °C) were exposed for germination on soil surface at 4 sites exposed to sunlight and 3 sites shaded by tree canopy. At each site, 5 replicates of 50 seeds put over a 20 cm² area were exposed in monthly intervals, from April to November. Each replicate was shielded from invertebrate (3 cm high plastic collar) and vertebrate (wire mesh screen) predation. Germinated seeds were counted and removed at 2-3 d intervals until no further germination occurred. Two control series by 5 replicates each were also established sites exposed to sunlight and shaded, and watered daily by 1 ml cm⁻² water. Eighty to 95 % of seeds were produced and germinability was highest (75-85 %) in May - mid June. Remaining seeds were produced mostly in mid August – mid October. Germinability was smaller (40-60 %) in seeds that were produced during the period between the two peaks. The germinability was positively correlated with seed mass and inflorescence size (both increased after rainfall). Germination from soil surface was greater on open plots (overall mean 60%) than under tree canopy (42 %) during the vegetative season (April-September). Germination occurred after rains and was sometimes delayed under tree canopy because tree canopy shielded the rainfall. In watered experiments the difference decreased to 5% of germinated seeds and 1.5 d delay in time to 50 % germination. A part of seed exposed in autumn (Sept. – Nov.) postponed germination until spring. There were more "overwintered" seeds after a cool winter (2005, winter temperature sum 27 day degrees above T_b=1.3°C temperature threshold) than mild (2004, 109 day degrees) and warm (2006, 316 day degrees) winters. Proportion of winter-germinating seed also varied with temperature.

Dandelion had a dual strategy of seed germination associated with spring and autumn peak of seed production. The average mass and germinability of the seeds are highest in the peaks. The seeds produced in spring peak germinate immediately and the massive production circumvents large post-dispersal seed and seedling predation. A part of the seeds of small autumn peak

(September – November) may overwinter. Spring germination gives an opportunity to establish seedlings under trees whose rainfall shielding canopy is still not developed. Intense post-dispersal predation is avoided by overwintering. However, the seed risks untimely winter germination which may cause mortality. Supported by the project # 521/07/0978 (GAĐR) and # CZ0002700604 (MZe).

Effect of seed coat thickness on weed seed mortality in the soil

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Models quantifying the effects of cropping systems on weed dynamics are useful tools to develop innovative cropping systems. Seed bank losses due to seed mortality in the soil are an essential function in these models. Seed mortality mainly results from seed aging and death caused by physiological or chemical damages and pathogen attacks. Mortality differs from seed persistence, which also comprises seed losses caused by germination. Persistence and mortality considerably vary among cropping systems and should be distinguished for modeling purposes. The seed mortality parameter remains to be estimated for a large number of species. As it is unfeasible to study experimentally all weed species, our objective was to search for generic relationships between seed mortality and easily measured traits characterising the species. In previous studies, seed mass, shape and the seed coat thickness have been shown to be linked to seed persistence (Thompson *et al.*, 1993; Davis *et al.*, 2008), while no correlation existed between the seed half-life and its lipid or protein content (Priestley, 1986).

Seed lots of 14 weed species with contrasted traits were buried 30 cm deep in the field and were recovered every two months. Seed viability was assessed *via* germination tests and then by seed dissection for dormant seeds. Mortality rates were computed either for the whole duration of the burial experiment or separately for the first and the second year. Eight seed traits were measured for each species using X-ray and image analysis (dimensions, shape, mass, seed coat thickness), and lipid and total protein contents were measured. We then searched for relationships between the seed mortality rates and seed traits. In addition, we looked at possible correlations between the seed mortality and the seed persistence for a large range of species given by Thompson *et al.* (1997), in order to take advantage of this large database.

During the first year of burial at 30 cm depth, seed viability only slightly decreased for most of the studied species, even for the non-dormant ones like *Matricaria perforata*. Seed losses due to germination could therefore be considered as negligible. The seed viability mainly decreased during the second year of burial, with mortality rates ranging from 1% (like *Fallopia convolvulus*) to 63% (for *Digitaria sanguinalis*) according to the species. More than 80% of seeds of some species were still viable after two years. For these last species, the choice of tillage strategies is crucial to stimulate fatal germination and limit the in-crop emergence as long as their seeds are viable.

The seed traits varied widely with seed masses ranging from 0.1 to 18 mg and shapes from spherical to elongated. Monocotyledonous species had low lipid contents while four dicotyledons (e.g. *Capsella bursa-pastoris*) had a seed lipid content exceeding 30% together with a high protein content. The seed coat was the thinnest (18 μm) for *D. sanguinalis* and *C. bursa-pastoris* and was the thickest for *F. convolvulus* (230 μm).

The seed mortality rates decreased hyperbolically with the seed coat thickness. The seed coat thickness explained 62% of the between-species mortality variability during the second year of burial. The mortality rates were not related with other seed morphological traits or the seed

reserve contents, neither with the seed persistence index. The seed coat thickness has been rarely measured and new improved technology for X-ray images proved to be very efficient for such measurements. A thick seed coat appears as an efficient protection for the seed against external aggressions caused by microorganisms and other abiotic factors. The present relationship for predicting seed mortality in the soil needs to be integrated into comprehensive weed dynamics models that take account of the remaining life-cycle processes (Colbach *et al.*, this conference).

Allelopathic effects of sunflower (*Helianthus annuus*) extracts on seed germination and growth of *Sinapis alba*, *Triticum aestivum* and *Lolium multiflorum*

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Recently, allelopathy is exploited as a weed control tool in order to reduce the use of herbicides and improve weed management strategies, both in the integrated and organic farming systems. Promising results were obtained by selecting allelopathic crop types, using allelopathic cover crops or rotational crops/crop residues. In particular, sunflower (*Helianthus annuus*) residues left in the field release allelochemicals into the soil that could affect adversely the germination and growth of crops and weeds grown in rotation with sunflower. The objectives of the study were to determine the effects of leaves and stems aqueous extracts of: (i) three cultivars (“Oleko”, “Tellia”, “Sambro”) of sunflower on seed germination and seedling growth of *Sinapis alba*; (ii) “Tellia” on seed germination and seedling growth of *Triticum aestivum* and *Lolium multiflorum*. Allelopathic extracts were prepared from leaves and stems of sunflower plants collected at about 90-92 BBCH growth stage from a field in the plains areas of central Italy (42°57’N, 12°22’E, 165 m a.s.l.). Air-dried tissue was ground to fine powder and was soaked in distilled water, for 24 h at room temperature, to give concentration of 25 g of tissue per 100 ml of water (25% m/v). After soaking, the solution was filtered through filter paper. The allelopathic potential of sunflower was determined using Petri dish and pot bioassays. The Petri dish bioassays were conducted as follows: thirty seeds of *S. alba*, *T. aestivum* and *L. multiflorum* were evenly placed on filter paper in sterilized 12-cm Petri dishes. For each tested seeds, a range of six extract solution concentrations from the leaves or stems of each sunflower cultivar was prepared ranging from 0% to 25% m/v and was added to each Petri dish. All Petri dishes were placed at 20 °C in darkness according to a completely randomised design with three replications. Percentage of germination, radicle and hypocotyl lengths of the seeds were determined 7 (*S. alba* and *T. aestivum*) and 12 (*L. multiflorum*) days after treatments. Pot bioassays were conducted as follows: pots (50 mm diameter) were filled with 65 mL of quartz sand, sown with 11, 8, 20 seeds/pot of *S. alba*, *T. aestivum*, *L. multiflorum*, respectively, and put in the greenhouse according to a completely randomised design with three replications. Pots were subirrigated to maximum water holding capacity with a range of six extract solution concentrations ranging from 0% to 12,5% m/v. After emergence, seedlings were thinned to 5 (*S. alba* and *T. aestivum*) and 10 (*L. multiflorum*) plants/pot. Water content was daily adjusted to maximum water holding capacity by subirrigation with a nutrient solution. Three weeks after emergence, plants were harvested and the above ground fresh and dry weight per pot was recorded. Data were subjected to a non-linear regression analyses by using a dose-response model and the ED levels were derived. ED levels showed that there are not significant differences among the extracts from Tellia”, “Sambro” and

“Oleko” on reduction of germination and seedling growth of *S. alba*. Stem extracts were more effective than leaf extracts, both on seed germination and seedling growth. In particular, ED90 (extract concentration that obtained 90% reduction with respect to untreated check), as average of three cultivars, showed values of 23%, 19%, 24% m/v (leaves extracts) and of 15%, 13%, 21% m/v (stems extracts) on germination, radicle and hypocotyl lengths of *S. alba*, respectively. “Tellia” extracts did not affect germination and growth of *T. aestivum*, but inhibited seed germination and plants growth of *L. multiflorum*. Allelopathic activity of sunflower residues seems to be advantageous to *T. aestivum* cultivation, as it could potentially reduces *L. multiflorum* and *S. alba* infestations, although this activity should be studied in field experimental conditions.

Sprouting capacity of underground buds of rhizomatous perennial weeds vary with season

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The rhizomatous species *Elymus repens*, *Equisetum arvense* and *Tussilago farfara* are among the most troublesome perennial weed species in Swedish agriculture. The traditional method for mechanical control of these species is stubble cultivation, stimulating the production of new shoots and thus, resulting in depletion of the rhizomes' storage nutrients. The strategy is, however, based on intensive shoot production from the rhizomes and is less effective if the sprouting capacity is reduced. The objectives of the study were to investigate whether or not there is a seasonal variation in sprouting capacity from underground buds of the three species.

Six populations of each of *Elymus repens*, *Equisetum arvense*, and *Tussilago farfara*, were collected in northern (63°) and southern (55°) Sweden. Rhizomes (2x10 cm, 1x7.5 cm and 1x15 cm for *E. repens*, *E. arvense* and *T. farfara*, respectively) were planted in 5 L pots, which were buried outdoors in Uppsala, central (59°) Sweden. Pots were exhumed every second to eighth week from August 2008 to April 2009. Aboveground biomass was removed and plants placed in a climate room at 18/9 °C for 16/8 h. Production of above- and belowground shoots was registered after four weeks. The experiment was repeated in 2009-2010.

For *T. farfara* the production of new shoots ceased completely in autumn. A pronounced difference between populations was shown, with northern populations starting the reduction in sprouting capacity as well as flower bud development earlier than did southern. *E. arvense* resumed the shoot production in November after a two-month period with no new shoots. For *E. repens* the shoot weight:rhizome weight ratio was substantially lower in mid-autumn than in winter and spring (Figure 1).

Weed control measures, such as soil tillage, aiming at depleting nutrient reserves of the rhizome system would preferably not be performed during periods when sprouting capacity is reduced. The results presented show that there is a seasonal variation in sprouting from intact rhizome systems of *E. repens*, *E. arvense* and *T. farfara*. It does, however, remain to be shown whether the reduced sprouting capacity is overrun by fragmentation, e.g. in a stubble cultivation.

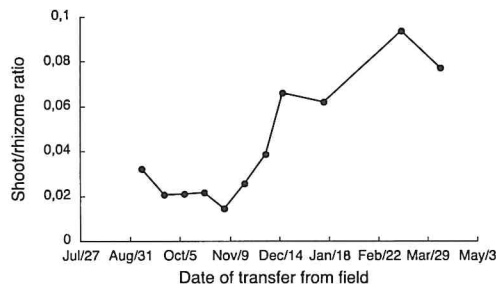


Figure 1. Shoot wt:rhizome wt ratio in *E. repens* plants transferred from the field and kept for 1 month in a climate room (18/9 °C).

Seasonal variation in sprouting capacity from underground root buds of *Cirsium arvense* and *Sonchus arvensis*

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The mechanical control of creeping perennials is based on the assumption that repeated fragmentation, most commonly stubble cultivation, will stimulate the production of new shoots and, thus, deplete the roots of their storage nutrients. This strategy will, however, be less effective during a period with reduced sprouting capacity. The objectives of our study were to investigate whether there is a variation in sprouting capacity from underground root buds of two of the most troublesome perennial weeds in Swedish agriculture, and how it varies during the season.

Six populations of each of *Cirsium arvense* and *Sonchus arvensis* were collected in northern (63°) and southern (55°) Sweden. Root pieces (1 piece of 10 and 5 cm for *C. arvense* and *S. arvensis*, respectively) were planted in pots (5 L, Ø 19.5 cm), which were buried outdoors in Uppsala, central (59°) Sweden. From August 2008 until April 2009 pots were exhumed every second to eighth week. Aboveground biomass was removed and plants were placed under forcing conditions. After four weeks, production of above- and below-ground shoots was registered. The experiment was repeated in 2009-2010.

Both species avoided sprouting during a period when new, above-ground shoots would die due to winter cold without contributing to the storage of nutrients in the roots. Thus, shoot production stopped during a period in autumn, but below-ground shoot production was resumed in November and was followed by substantially increased above-ground shoot production during winter and spring (Figure 1).

Weed control measures, such as soil tillage, aiming at depleting nutrient reserves of the root system would preferably not be performed during periods when sprouting capacity is reduced. The results presented here show that there is a seasonal variation in sprouting from the intact root systems of *C. arvense* and *S. arvensis*. It does, however, remain to be shown whether the reduced sprouting capacity is overrun by fragmentation, e.g. in a stubble cultivation.

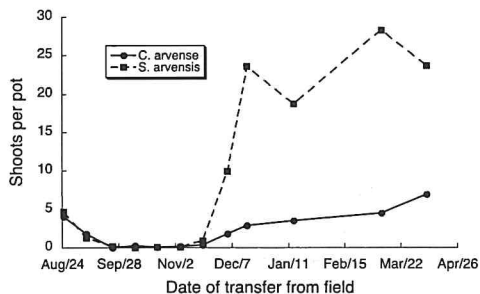


Figure 1. Number of above-ground shoots of *Cirsium arvense* and *Sonchus arvensis* plants transferred from field and kept for 1 month in a climate room (18/9 °C).

Sodium hydroxide treatments increase the seed detection of *Orobanche* in soils with different organic matter content

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Orobanche spp (broomrapes) are holoparasites that subsist on the root of many important crops and can considerably reduce yield. Detection of the presence and identification of the broomrapes in a soil is of great interest for growers in order to prevent new infestations or spreading. This is a difficult task considering the minuscule seed size (averaging 200 to 300 µm). The methods to detect seeds of broomrapes from soils are based on the weight and size of the seed, and require visual seed identification with efficiency ranks between 45 to 90%. Our experience indicates that in soils with high organic matter (OM), it is hard to detect the seed under stereo-microscope. The objectives of this study were to determine the efficiency and time detection of broomrapes seeds (*O. ramosa* and *O. minor*) in soils with low (3.8%: L) and high (18%: H) OM content using a new protocol. First, the soil was dried 2 to 3 weeks at room temperature, uniformed and processed in an agitator of sieves during 5 minutes. Then samples of 5 g of L and H soils were inoculated with 0, 2, 20 and 200 seeds of *O. ramosa* and *O. minor*, respectively. The soils samples were treated with NaOH 0.5N / 24 hr (1:2 g/ml), sieved (100 µm), dried (24 hr, 60° C), mixed with MgSO₄ (1:5 g/ml, specific density 1.16 g/ml) and centrifuged (3000 rpm/10 min). The supernatant was retained with filter paper, visualized and quantified the seeds under stereo-microscope (10 – 40 X magnification). The time of observation was registered too. The samples controls were not treated with NaOH. The results indicated that NaOH improved the efficiency of seed detection and the time of observation. Furthermore, the NaOH reduced the OM contents to 1.2 and 10.9% for L and H soils, respectively. In L soil, the efficiency of detection was improved in a 75% only in the lower inoculated level (2 seeds), while the others inoculated levels (20 – 200 seeds) we did not found difference with the samples controls. However, the treatment with NaOH in H soil increased detection efficiency in a range of 50 to 52% when the soil was inoculated with 200 and 20 seeds, respectively. In this soil we were unable to detected seeds for lower inoculated level. On the other hand, the time of observation is reduced approximately in a 50% for L and H soils with 20 and 200 inoculated seeds. The physical integrity of the broomrapes seeds was not affected by the NaOH treatment.

This work was founded by grant FONDEF D05i10027.

Detection of *Orobanche* (*O. minor* and *O. ramosa*) contaminating seed crops by using real-time PCR

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Broomrapes are holoparasitic weeds that attack important economic crops, generating significant losses in their production. In Chile, *Orobanche ramosa* and *Orobanche minor* are the main species present and affect mainly tomato and red clover, respectively. Until now, the current procedure of diagnostic methods consists of checking under stereo-microscope the presence of *Orobanche* seeds, which is time-consuming and unspecific. In this study different set of primers were designed to the ribosomal DNA region (ITS) and evaluated under real-time PCR platform using SYBR Green I technology and Taqman chemistry, in order to perform a specific detection of *O. minor* and *O. ramosa* seeds contaminating seed lots of the crops.

In both case the real-time assay was evaluated inoculated 0, 1, 3, 10 and 100 seeds of *O. ramosa* in 15 g of tomato and 30 g of lettuce seeds; and for *O. minor* the same number of seeds were mixed in 50 g of red clover seeds. For each inoculated level, 5 replications were evaluated from different ADN extraction process. The seed samples were sieved (0.5 mm X 5 min) and DNA was obtained of the total material recovered by using the Power Plant purification Kit (MOBIO). Genomic ADN of *O. minor*, *O. ramosa* and the host crops (tomato, lettuce and red clover) were included as control.

SYBR Green I and Taqman assays shows to be highly specific and sensitive, achieving to detect 1 seed of *Orobanche* per 15, 30 and 50 gram seeds of the crops tomato, lettuce and red clover, respectively. However, SYBR Green I assay show to be more robust, because it gave positive and more early signal in all inoculated level and replicates. These results allow us to ensure that real-time PCR technology represents a reliable alternative for safe and rapid diagnosis of this agricultural parasitic weed.

This work was founded by grant FONDEF (Fund for the Promotion of Scientific and Technological Development, Chile) D05i10027

Detection of *Orobanche ramosa* in soils with low and high organic matter content by using real-time PCR

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Orobanche ramosa is a parasitic weed present in some areas of central and southern Chile, which produces important crop losses in some specific tomato producing area. The opportunity of its detection in the soil is essential for designing preventive control measures.

Different set of primers were designed to ribosomal DNA region and evaluated under real-PCR using SYBR Green I technology, in order to detect *O. ramosa* seeds in two types of soils. The real-time assay was evaluated inoculating 0, 4, 40, 400 and 4000 seeds of *O. ramosa* per 10 g of soil, with low (3.8%) and high (18%) organic matter (OM) content. The soils samples were sieved (90 µm x 5 min) and their total DNA was obtained by using the PowerMax Soils isolation Kit (MOBIO) plus cleaning up with solution 7 of PowerPlant DNA isolation KIT (MOBIO). Genomic ADN of tomato and *O. ramosa* tissue plant were used as negative and positive control, respectively.

The PCR assay was performed with 45 cycles and was able to detect specific signal of amplification for 42, 36, 31 and 25 cycles with 4, 40, 400 and 4000 seeds, respectively, but only in the case of soil with low OM content. The later shows that the organic matter content strongly affect the PCR detection. To overcome this limitation, the soil samples with high OM level was treated with NaOH during 24 hr previous to total DNA extraction. This treatment allowed the PCR to detect until 40 seed/10g of high OM content. This result and the need to dilute the template (1/10 or 1/100) before running the PCR reaction, confirms the presence of inhibitors on soils with high OM content.

This method is a fast and powerful diagnostic tool to detect the presence of *Orobanche* seeds in agricultural soils. Nevertheless, additional studies are required to determine the most accurate and representative soil size sample for a reliable detection of *Orobanche* seeds in soil.

This work was founded by grant FONDEF (Fund for the Promotion of Scientific and Technological Development, Chile) D05i10027

Detection of resistant/tolerant chickpea (*Cicer arietinum*) genotypes to field dodder (*Cuscuta campestris*)

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Field dodder (*Cuscuta campestris*=*pentagona* Engelm.) is an above-ground obligate parasite on broadleaf plants including weeds, field crops, vegetables and ornamentals throughout most agricultural regions of the world. The parasite coils around the host shoot and produces haustoria that penetrate its vascular systems, extract water and assimilates, leading to severe growth and yield reduction. The wide geographical distribution of dodders and their wide range of hosts, make them amongst the most damaging parasitic plants worldwide. Field dodder control is extremely difficult as dodder seeds can remain viable in soil for a long time, and continue to germinate and emerge throughout the warm seasons. In addition, the nature of attachment and association between host and parasite requires a highly selective herbicide to destroy the parasite without crop damage.

Chickpea (*Cicer arietinum*) originated in the "Fertile Crescent" - south-eastern Turkey and spread to other parts of the world. The largest area of adaptation is in the Indian sub-continent. Chickpea is highly susceptible to field dodder, however there are no efficient available mechanical, chemical or biological means to selectively manage this parasitic plant in this crop.

The aim of this study was to detect chickpea genotypes that are tolerant/resistant to field dodder in order to identify, understand and utilize tolerant/resistant genotypes to combat field dodder parasitism.

A large collection of chickpea genotypes including local and foreign lines and varieties, all of the local commercial varieties and 5 newly developed local varieties were tested for their association with field dodder. Three experiments were conducted in pots in a controlled environment greenhouse in the winter and in a net-house in the summer in Rehovot Israel. Chickpea genotypes were subjected to four treatments: control without dodder and seeding of dodder 0, 14 and 28 days after chickpea emergence. Each treatment was replicated 3 to 10 times. Chickpea development and dodder parasitism progress were thoroughly monitored and recorded twice a week. The experiments were terminated by separating dodder and chickpea plants and determining their fresh weights.

The majority of chickpea genotypes were susceptible to field dodder parasitism at all inoculation timings; however differences in susceptibility were observed and some genotypes showed tolerance/resistance at different inoculation timings. In the highly susceptible chickpea genotypes the parasite totally destroyed the host plant. Two chickpea genotypes showed high tolerance/resistance to field dodder at all inoculation timings and were selected for further studies. The observed resistance phenomenon was in most cases characterized by the failure of the dodder haustorium to penetrate the chickpea main stem. Further studies are in progress to confirm the selected genotypes resistance under field conditions and to elucidate the mechanism(s) involved in the resistance using histological and chemical techniques.

Germination of velvetleaf (*Abutilon theophrasti* Medic.) seeds in different age and with different seed-coat colour

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The importance of velvetleaf (*Abutilon theophrasti* Medic.) has increased considerably in Hungary in the last few years.

It was established in the course of 5th Hungarian weed survey in 2007-2008 that velvetleaf was the tenth most important weed at the corn fields in Zala County. Danger of this weed can explain by the dormancy and hard seed-coat of its seeds and the competitive capacity of the plant. On the base of literature there are big differences between germination capacities of the seeds in connection with seed color.

The aim of our experiment was to study the differences of germination between light and dark colored seed, and by the age of velvetleaf seeds.

We studied the germination capacity of *Abutilon theophrasti* seeds in a thermostat of 20 °C without lighting. We examined the seeds from 1985, 1988, 1991 (from the seed collection of Plant Protection Institute) and 2008 (from our own collection). The seeds had been stored in a freezer at -15 °C. The experiment was set up at 19.01.2009. Seeds were collected in Keszthely, but in 1991 from Alsópáhok. One hundred seeds were laid into 9 cm diameter Petri dishes with watered filter paper. We used 5 ml tap water in each dishes. In experiment were four replications, so we had 32 Petri dishes all together.

The seeds were originated from following years:

	Year	colors of seed-coat
1.	1985	light
2.	1985	dark
3.	1988	light
4.	1988	dark
	Year	colors of seed-coat
5.	1991	light
6.	1991	dark
7.	2008	light
8.	2008	dark

The experiment was analyzed after 5 days. Germinated seeds were counted in every dish, and after determined the percentage of germination.

Early observation showed, that dark seed coated seeds have stronger dormancy, than light colored. In spite of these results we found that dark seeds germinated better than light ones. Percentage of germination was the lowest at seeds from 1988; we found 4% germination of

light and 27% of dark seeds. It was interesting, that the oldest seeds germinated very well (72% and 96%). 24 and 18 years old seeds germinated better than the freshly collected, because of dormancy becomes weaker by the ageing of seeds.

In our experiment determined high germination percents, so we did not find a real germination hindering hard-seed coating effect contrast with literature.

Effect of different treatments on breaking of seed dormancy in Jimson weed (*Datura stramonium* L.)

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A clear understanding on type of seed dormancy in Jimson weed (*Datura stramonium* L.), as an important weed in Iran, can lead us to its better management. In order to study the effect of different treatments on breaking of seed dormancy and germination characteristics of this weed, a lab experiment was conducted at research laboratory of faculty of agriculture, the University of Birjand in 2006. The experiment was completely randomized design with a factorial arrangement with four replicates. The first factor was four methods of seed dormancy breaking with levels of sand paper (No 2), pre-chill (15 days in 4°C refrigerator), sand paper + pre-chill, KNO₃ (0.6%) and a control treatment. The second factor was alternation of germination temperature with levels of constant (25°C) and alternate (30/20°C day/night). The results indicated that Jimson weed seeds germination were significantly higher in alternate (29%) than constant (16%) temperature. There was no significant effect between type of dormancy breaking methods and alternation of germination temperature. The best methods for dormancy breaking and most seed germination percentage of jimson weed were observed in sand paper (48%), sand paper + pre-chill (32%) and pre-chill (19%) treatments. The jimson weed germination percentage for KNO₃ and control treatments were 5% and 8% respectively. According to these results, the hard cover may be the main factor of dormancy in fresh seeds of Jimson weed.

Can recently established weeds outcompete semi-dwarf oilseed rape cultivars?

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Over the last decade, there has been an increase in the number of weeds in oilseed rape. Especially in the north-eastern part of Germany *Anchusa arvensis* (L.) M. Bieb., *Sisymbrium officinale* (L.) Scop. and several *Geranium* species have become important weeds in oilseed rape and are gaining importance in other German regions. To study the development, seed and biomass production, weed seedlings were planted into three oilseed rape variety stands.

Recently, semi-dwarf oilseed rape varieties appeared in practical cropping. So far only few studies focused on the properties of oilseed rape varieties in combination with weeds. Here, cultivars of oilseed rape differing in plant height were chosen for contrasting purposes: The normal growing variety “Viking”, the semi-dwarf variety “PR45D01” and a full dwarf rape biotype that is only used for breeding purposes. All varieties were sown at identical seeding rate in a field, arranged in randomized plots of two rows. Weed seedlings raised in a greenhouse were planted at 1.2 to 1.7 plants m⁻² per weed species directly into the plot at six-leaf stage (BBCH 16) of oilseed rape. Seed and biomass production were measured directly before harvest.

S. officinale produced more biomass and seeds per plant in semi-dwarf than in normal oilseed rape. It avoided growing below the canopy of oilseed rape of normal height by increasing dilatation growth to gather more light. Generally, *S. officinale* showed rapid growth and sometimes overgrew regular oilseed rape varieties, where it produced fewer pods, which contained more seeds (12 vs. 11) per pod. Total weed seed production was about 2775 seeds per plant in the normal height variety and 4410 in semi-dwarf rape.

A. arvensis seems to be only capable of growing larger than semi-dwarf oilseed rape. In normal rape the plants were smaller, had fewer side shoots, showed a lower biomass production and produced less seeds (about 450 seeds per plant in semi-dwarf rape vs. ~ 240 in rape with normal height). In all rape varieties the three *Geranium* species produced nearly the same amount of seeds (~ 625 seeds per plant) and showed little differences in biomass.

In contrast to conventional oilseed rape, infestation of high growing weeds is more probable in semi-dwarf oilseed rape varieties. The light-indigently *S. officinale* and *A. arvensis* show increased biomass production and higher seed production per plant in semi-dwarf oilseed rape and are certainly more competitive. *Geranium* species employ a different strategy to deal with low light intensity conditions. They are half-shade specialists and are insensitive to the growing habit of the crop. Only at high densities during rosette stage of oilseed rape could they cause substantial yield losses.

Estimating fitness and invasiveness of intermediate forms of two *Phelipanche* species found in sympatry

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The broomrape species *Phelipanche ramosa* and *Phelipanche aegyptiaca* are well-known solaneous crops' foes, constituting a species complex characterized by the same chromosome number, the same host range and morphological similarities. In many cases these two broomrape species are found in sympatry. As a consequence, interspecific crosses can take place and natural hybrids may occur. During intensive surveys recently conducted all over Greece, a tobacco zone of overlap between *Ph. ramosa* and *Ph. aegyptiaca* was traced and morphologically intermediate forms were observed. This finding was the stimulus to carry out a study on these forms in order to: a) explore their phenotypic diversification compared to the species' complex taking into account fifteen morphological characteristics, b) investigate their genetic divergence in relation to the parental species based on molecular markers, c) examine their physiological behavior during host-parasite interaction *in vivo* and application of stimulants *in vitro* and d) scrutinize the level of parasitism provoked by them on tobacco plants in the field. During field surveys the infestation level was accomplished based on a scoring scale from 0 (none infested host plant) to 6 (the majority of host plants are destroyed). The *in situ* collected broomrape plants (fresh and dry) were studied as described further. For morphological analysis the following characteristics were included: number of ramifications, central shoot length, number of flowers, inflorescence length, inflorescence compaction, corolla length, seeds per capsule, total number of seeds / shoot, capsule length, capsule width, calyx length, hairs presence on anthers, flowers colour, bracts length and shoot diameter. For molecular analysis eleven RAPD markers were used and 54 samples were screened. In order to study seed physiology of the intermediate forms, two types of experiments were conducted. Firstly, the induction of seed germination was examined *in vitro* as intrigued by two stimulants in three temperature regimes. Secondly, seed germination and tubercles' formation were studied on tomato and tobacco seedlings with the aid of polyethylene bags *in vivo*. Morphometric analysis indicated that individuals of the intermediate forms shared characteristics in-between the two *Phelipanche* species. Molecular markers revealed that intermediate forms possibly constituted hybrids derived from continuous backcrossing with the one or the other parental species. Seeds responded to the exogenously applied stimulants and to the chemical stimulus exuded from tobacco and tomato roots in a great extent. Moreover, the intermediate forms were as highly aggressive to tobacco plants as the other *Phelipanche* species while measuring the infestation level in field. The overall outcome of this thorough analysis was that intermediate forms were well-established in tobacco habitats, demonstrating a variation in fitness' equivalency to each one of the parental taxa according to the type of characters studied.

Evaluation of allelopathic potential of *Helianthus tuberosus* L. root exudates

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Allelopathy has been defined as the ability of a plant to inhibit or stimulate the growth of another plant through the release of chemicals into the environment by volatilisation, leaching, plant residues decomposition, and root exudation. Several studies have shown that *Helianthus tuberosus* L. (Jerusalem artichoke), a species belonging to the Asteraceae family can exhibit allelopathic activity. Experiments conducted with leaf extracts and degradation of plant residues into the soil have pointed out that this species affects germination of *Amaranthus retroflexus* and *Echinochloa crus-galli* by about 50%.

The aim of this study, conducted in the laboratory in 2008-2009, was to evaluate in agar medium the allelopathic potential of *H. tuberosus* towards lettuce a species sensitive to allelopathic compounds.

Tubers of *H. tuberosus* were sterilized and allowed to produce roots in plastic Magenta boxes on the agar medium (0.8% w/w), while shoot sprouts were periodically cut, to avoid competition. After seed sterilization, lettuce was directly seeded on the agar medium at the following timings: immediately after tuber tissue transplanting, 1, 2, 3, and 4 weeks after tuber transplanting in boxes with the presence or absence of tuber tissues (as control reference). At all timings, starting from 1 week after tuber transplanting, lettuce was also seeded in boxes where tuber tissues of *H. tuberosus* were removed just before seeding. Boxes seeded were kept for 14 days at room temperature and lettuce germination, root length and fresh weight of the whole lettuce plant were assessed at the end of the experiment. A complete randomized block design with 5 replicates was adopted, and the whole experiment was carried out three times.

Lettuce germination was inhibited by 37%, 35%, 29%, 15% and 30% when seeds were placed in the boxes after 1, 2, 3, and 4 weeks of tuber presence. The germination recorded in boxes in which the tuber tissues were removed immediately before lettuce seeding, showed to be inhibited by 22%, 14% and 39% at 2, 3 and 4 weeks from transplanting, respectively, while no inhibition was observed during the first week of tuber presence. Lettuce root length was reduced by 50% and 40% only when seeds were placed in the boxes with the presence of the tuber, and at one or four weeks after *H. tuberosus* tuber transplanting, respectively. The lettuce whole plant weight was similar to that of the control, with the exception of the plants grown in the presence of tuber tissues at one week from transplanting, in which about 69% of reduction was observed.

H. tuberosus tubers showed a significant inhibitory effect on germination and root growth of lettuce, in particular during the first week following the transplanting. Germination and growth inhibition were lower if the tuber tissues were removed before lettuce seeding, likely because inhibitory compounds produced by *H. tuberosus* roots rapidly diminished their activity after release.

These results may have an important implication in the choice of the species to be included in a cultural system in order to avoid inhibitory effects on cultivated the crop grown after *H. tuberosus*

P-hydroxybenzoic acid inhibited photosynthetic efficiency, yield and non-photochemical fluorescence quenching in *Lactuca sativa*

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Allelopathic interference of p-hydroxybenzoic acid (BA) was tested on photosynthetic efficiency, yield and non-photochemical fluorescence quenching in *Lactuca sativa* in a glass house study. *L. sativa* were grown in 1:1 Hoagland solution in perlite culture. After 30 days, BA was applied at concentration of 1.5, 1.0, 0.5, 0.1 mM. Quantum efficiency of open PSII reaction centers in the dark adapted leaves (Fv/Fm) significantly decreased in response to BA on 1st day (1.0mM), 2nd day (1.5, 0.5, 0.1mM), 4th day (1.0mM), and on 6th day at all concentrations. BA significantly reduced quantum yield of PSII electron transport in lettuce plants on 1st day (1.5 mM), 3rd day (1.5, 1.0, 0.5, 0.1 mM), 4th day (1.5, 1.0 mM), 5th day (1.0, 1.0, 0.5, 0.1mM), 6th day (1.5, 1.0, 0.1mM). A significant decrease in photochemical fluorescence quenching (qP) was observed on first day due to BA application (1.5 mM), 3rd day (1.5, 1.0, 0.5, 0.1 mM), 4th day (1.5, 1.0 mM), 5th day (1.0, 1.0, 0.5, 0.1mM), 6th day (1.5, 1.0, 0.5, 0.1mM) while non photochemical quenching (NPQ) was only significantly reduced under BA stress on 3rd day. Leaf protein contents of *L. sativa* were significantly reduced by highest concentration of BA (1.5 mM). These results indicate that Fv/Fm, quantum yield of PSII electron transport, and qP can be used indirectly to elucidate allelopathic influence of BA on lettuce plants.

SESSION 3
WEED DIVERSITY IN TIME AND SPACE

Oral presentations

Session organizers:

Bärbel Gerowitt & Hansjörg Krähmer

Beyond mapping – what can we learn from large area weed surveys ?

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Sparse and diverse weed vegetations can provide a wide range of ecosystem services, including conservation of soil and water resources and supplying habitats to harmless and beneficial organisms. Thus, manipulating weed species composition into a desirable and manageable direction is a basic principle of integrated weed management. Regarding the protection of arable biodiversity and rare arable weeds, management at the landscape level appears to be more important than at smaller scales. Knowledge of weed species properties and their prospering under different conditions can be derived from weed mapping approaches. Especially large scale surveys are able to detect rare species and provide a wide range of site conditions and cropping measures that can then be related to weed diversity and species composition.

Here, data on the occurrence of weed species in 1463 German oilseed rape (OSR) fields are presented. Weed species identity and density, together with 25 characteristics of sites and crop, were determined in unsprayed parts of OSR fields in autumn from 2005 to 2007. Canonical Correspondence analysis was used to quantify the relative contribution of the explanatory variables to weed species composition. Significant variables were then grouped thematically and subjected to cluster analyses. Clusters were formed on the basis of (a) OSR cropping intensity, (b) soil management and properties, and (c) climatic conditions and formed the basis of indicator species analyses. The contribution of Δ - and $\bar{\Delta}$ -diversity to the total observed species richness of OSR fields was analysed at three spatial scales; fields, county, and federal state.

Considerable differences in weed composition were found throughout Germany. Of the explanatory variables, 23 significantly effected weed species composition and, of these, 15 were still significant after correcting for effects shared with other variables. This information was used to create thematic maps showing indicator weed species as related to cropping intensity, soil properties and management and climatic conditions.

A total of 161 weed species from 33 families were recorded. Weed species richness averaged 11 ± 3.5 species per site (range 0-26) and was effected by OSR sowing date, tillage intensity, soil quality and pH, field size and location within the field. Similar results were obtained for Shannon diversity index, but not for Evenness. Apparently, diversity is mainly affected by species number. $\bar{\Delta}$ -diversity at the state and county scale contributed most to overall richness for all species or rare species alone. However, Δ - and $\bar{\Delta}$ -diversity at the field scale were most important for spatial variability of common weed species.

This research enabled us to identify the major influencing factors for the field weed vegetation as well as the contribution of OSR-fields to arable weed biodiversity. A review of other recent mapping approaches will be used to provide more methodological examples and conclusions.

Weed mapping in spring cereals in Finland - update and applications

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Regular weed surveys are valuable means for monitoring the response of weed flora to changes in rural landscapes and agricultural practices. MTT has carried out four extensive surveys of weeds in spring cereal fields; in 1961-1964, in 1982-1984, in 1997-1999 and in 2007-2009. Both conventionally and organically cultivated arable fields have been examined in southern and central Finland.

The core of the programme is monitoring the same farms and fields over the decades. We visited about 300 farms in 16 regions and investigated a total of 600-700 fields in the two recent surveys. In each field there were 10 randomly located sampling quadrats. All weed species were identified and their density and biomass were recorded.

In 2007-2009, 177 weed species were found, of which 153 were broad-leaved and 24 grass species. In conventionally farmed fields, the average species number per field was 12 and in organically farmed fields 21. This species diversity was slightly lower than ten years ago. The most frequent species in conventional herbicide-treated fields were *Viola arvensis* (83%), *Stellaria media* (65%) and *Galeopsis* spp. (59%) whereas *Chenopodium album* (96%), *Stellaria media* (94%) and *Viola arvensis* (94%) dominated in organic farming. Some noxious species like *Avena fatua* and *Galium spurium* had become more frequent during the last ten years. *Elymus repens* was still the most common and abundant grass species in spring cereal fields. The average density of weeds was 160 m⁻² in sprayed conventional fields and 519 m⁻² in organic fields. These numbers had slightly increased in both cropping systems.

Weeds have a functional role within agro-ecosystems in supporting biodiversity. The weed survey data have been used in developing an agro-biodiversity indicator that describes the interactions between the observed occurrence of 25 common arable weeds and individual groups of farmland birds, pollinators (wild bees) and phytophagous insects. The weed indicator is included in the national biodiversity indicator collection (www.biodiversity.fi).

The changes in the weed indicator values over the decades showed a declining trend compared with the 1960s for all regions and animal groups. The decline tended to be greatest in the food sources of birds and in the northern regions. Updating of the indicator with the most recent weed survey data revealed that the declining trend continued between the 1990s and 2000s in most regions. Regional differences are related to changes in the density of some functionally important weed species, e.g. *Chenopodium album*. The most recent decline is related to the changes in agricultural practices, e.g. the decline in areas with organic farming and the increase in herbicide-treated areas with cereal cropping.

The most recent weed survey was part of the monitoring programme of the Finnish Agri-Environment Support Scheme. The authorities are interested in the impact of subsidized measures, including organic cropping and sustainable use of fertilizers and pesticides, on biodiversity in agricultural areas. Some recent trends in cropping practices, including direct drilling, affect the composition of weed flora by favouring seed-propagated grass species.

Weed species composition and diversity of cereal fields under different environmental and management factors in Central Italy

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Crop production systems in Central Italy can be characterized by a considerable heterogeneity. There are huge, nearly weedless intensive fields, while many low-input agricultural systems can also be found. Similar diversity can be experienced in the geography of the region, since arable fields are distributed from the sea level to the high mountain ranges. However, traditionally managed small arable fields between extreme abiotic and topographic conditions tend to be abandoned similarly to other European countries. In this study, 76 arable fields (in total 760 x 1 square metre plots) were sampled in the regions of Marche and Umbria. Explanatory variables were recorded for each field, reflecting: 1) large-scale spatial trends, 2) site specific (local and regional), abiotic environmental conditions and 3) local biotic and field management characters. The specific objectives of this study were (a) to determine the relative importance of environmental variables and field management regime on weed species composition and richness, (b) to analyse the effects of the employed explanatory variables on the species composition.

Relationship between environmental factors and species composition of arable fields was examined by redundancy analysis. Effects of environmental variables on intensive and extensive fields are supposed to differ; therefore the data set was divided into two parts according to management regime. Importance of environmental factors was tested for the total data set and separately for the two subsets as well. Significant variables and species richness were compared between management types.

Most of the explained variation in weed species composition was related to large scale spatial trends (altitude, distance from sea, mean annual precipitation and temperature) in both intensive and low input systems. Numerous site specific, abiotic environmental conditions (physical character and nutrient content of soil, exposition and slope of fields) also explained a large part of the total variation, especially in case of low-input fields. The least variation of the whole dataset was explained by local biotic and field management characters (field size; type, rotation, cover, height of crop) and nearly all of them influenced only the low-input fields. Although, it must be mentioned that one of the most important explanatory variables (from this latter group) for the whole dataset is the regime of management (low-input or intensive). There were significant differences between the species composition and richness of low-input and intensive fields. Explanatory power of environmental variables was much stronger for low-input agricultural systems than for intensive fields.

A total of 294 weed species were recorded in the dataset of which 239 were forbs, 45 grasses, 5 trees, 3 shrubs and 2 rushes. The species richness differed significantly between the two main management types.

Our results suggest that the environmental factors and management intensity affect the botanical diversity of the investigated arable fields.

How do weed species assemblies form? The case of new farm land in Alaska

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Alaska provides a unique laboratory to study the development of agricultural weed floras since fields were first cleared in 1900 to 1985. In 2004, weed species cover was measured at ten 1-m² quadrats along a transect in each of 80 agricultural fields. Field environmental and management information collected included: field age, weed control methods, crop, elevation, latitude, longitude, surrounding vegetation type, and canopy shading. Detrended correspondence analysis (DCA) was used to ordinate fields based on weed vegetation. Spearman correlations and graphical overlays were used to examine relationships between environmental and management variables and ordination axes. Seven additional weed species became established in Alaska agriculture since 1981, bringing the total number of agricultural weed species to 64. Crop, Canopy shading, elevation, latitude and longitude were important weed flora determinants. Two crop-related groups of fields were identified based on weed flora: potatoes + vegetables and perennial grass. Non-native weed species colonized fields that were largely weed-free in 1981, when a similar weed survey was made. The agricultural weed flora of Alaska in 1981 was characterized by native colonizers on newly cleared fields and by non-native weed species on older fields. In 2004, the weed flora of all fields except two were characterized by non-native weed species and floristic variability was mainly influenced by crop type. Crop types may have influenced weed floras by different amounts and timing of tillage, planting and harvesting methods and timing, weed control methods, fertilizer use, and differences between crops in the amount of canopy shading. After establishing the newly cleared fields, farmers failed to prevent weed introductions and the opportunity was lost to farm 40,000 ha of new agricultural fields without the economic and environmental costs of mechanical or chemical weed control. The same pathways for invasion that have operated for millennia were likely responsible for the invasion of non-native weeds onto this new farmland: use of weed-contaminated farm implements and planting weed-contaminated crop seed. It is unfortunate that weed research has made great advances in weed control methods, however little progress has been made in weed prevention. European experience has shown that certain weed species are essential to the survival of desired species from higher trophic levels; However, in Alaska and other new agricultural areas, such obligatory relationships probably are uncommon. In the future, we may understand weed-crop competition and the relative importance of different weeds for biodiversity well enough to engineer agricultural systems that include the optimal mixture of weeds for Alaska. However, in the interim, prevention of new weed species introductions may be the best choice of action.

Towards the automated mapping of weed patches in arable fields

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Weeds such as black-grass (*Alopecurus myosuroides*), wild-oat (*Avena fatua*), barren brome (*Bromus sterilis*) and cleavers (*Galium aparine*) often occur in patches in arable fields. Farmers, however, frequently spray whole fields to control patches of such weeds. Given a geo-referenced weed map, technology exists to confine spraying to these patches. In spite of environmental and economic benefits, adoption of patch spraying by arable farmers has, however, been negligible. A major reason for low adoption is the difficulty of constructing weed maps. This paper describes a machine vision system designed to automate the weed mapping process. The primary focus was on identifying the weeds mentioned which typically occur in patches and which can be difficult or expensive to control.

Hypotheses tested include (1) the accuracy of weed identification by machine vision based on one or several field surveys at different growth stages will be adequate to identify weeds and weed patches with the precision needed to create herbicide application maps and (2) images required for mapping can be captured as an adjunct to normal farming operations in each field. The approach adopted was to create maps off-line for use by farmers and advisers in the subsequent growing season rather than for real-time control. Work carried out to date has sought to prove the concept that geo-referenced images captured using a computer-controlled camera mounted on farm machinery during conventional farming operations such as spraying and combine harvesting can be used to automate the process of weed mapping. A prototype machine vision system was attached to farm machinery (sprayers and combine harvesters) on two farms from June to December 2009, images being captured at times of chemical application and harvesting. Optimal times for black grass identification in wheat in the UK were from flowering until before seed shedding, detection after seeding and of early season seedlings requiring very high resolution images. Late season mapping clearly highlights failure of control and places where seed bank replenishment is likely. Accuracy of identification is being verified by geo-referenced 'ground truth' assessments in the same fields. The potential of automating the process of weed mapping and the value of this approach in comparison to real time weed detection and control, will be discussed.

Acknowledgements

The research is part of project sponsored by the UK Health & Safety Executive, Chemical Regulation Directorate and the AHDB Home Grown Cereals Authority with industrial support from Concurrent Solutions llc (Edwards); Syngenta plc (Robinson & Magri); Patchwork Technology Ltd. (Walters); Herbiseed (Morton). Academic collaborators are based at Reading University (de la Warr); Murray State University (USA, Pilgrim); The Arable Group (Miller) and Dr Peter Lutman (Consultant). We are grateful to farmers who

allowed us access on to their land (T. Scott, Cambridge and S. Beddows, Phillimore Estates, near Reading). Thanks are due to Richard Casebow and Caroline Hadley at Reading University for technical assistance.

Sown grass strips: opportunity or threat for the management of weeds in arable landscapes?

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For water quality protection purposes, the European legislation has imposed the set-up of buffer zones in arable fields located along watercourses. These buffers are 5-meter wide sown grass strips where the use of pesticides is prohibited. Sown grass strips represent new habitats in the agricultural landscape that could potentially be used by a number of arable weeds. This could either represent an opportunity (refugia) and/or a threat (source of crop infestation). In this paper, we address three questions. (1) What are the weed species (and associated life traits) favoured in these new habitats? (2) Do management strategies applied in grass strips structure weed communities? (3) Are these species able to disperse from grass strips to adjacent crops?

In a first study, vegetation of grass strips was surveyed in 77 grass strips located in two French departments dominated by arable crops, Côte d'Or (Eastern France) and Deux-Sèvres (Western France). Strips differed in terms of environmental conditions, sown species and management regimes. Our results show that the total cover of species never reached 100% in strips and that the cover of sown species was higher than the cover of weed species in 63 of the surveyed grass strips. Species richness averaged 26 in grass strips and 90% of species were arable weeds and among those, 44% were perennial. The composition of weed communities was more strongly shaped by the type of grass strips (sown species, soil characteristics) than by their management. However, sown strips where hay was exported for cattle tended to exhibit higher species richness the second year.

In a second survey, we recorded vegetation in plots located along transects running from the herbaceous field margin to the centre of fields, in paired situations in the same field, one where a grass strip was present and one with no grass strip. In the presence of a grass strip, some species from the field margin entered the first two meters of the grass strip. But there was a sharp community change between the grass strip and the crop edge (similarity 10%) and the crop edge crop exhibited a flora similar to the crop centre. When no grass strip existed, a number of species occurring in the field margin entered the five first meters of the crop (similarity 60%) and therefore the crop edge flora differed from the crop centre flora. These results seem to indicate that although grass strips are a refuge for a number of weed species, they do not enhance weed infestation in adjacent crops but are rather buffer zones as they limit the dispersion of the field margin flora into the adjacent crop.

SESSION 3
WEED DIVERSITY IN TIME AND SPACE

Poster presentations

Session organizers:

Bärbel Gerowitt & Hansjörg Krähmer

A survey of weeds used by traditional medicinal healers in Sreepur area of Magura district, Bangladesh to treat various ailments

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Aim or objectives: Traditional medicinal healers form the primary health-care providers to most of the population of Bangladesh. They mainly rely on medicinal plants, which include various weeds to treat ailments. We conducted a survey among the traditional healers of Sreepur area, Magura district, Bangladesh to gather information on the species of weeds used by them for treatment of various ailments.

Materials or subjects: Traditional medicinal healers.

Methods: Interviews were conducted with the help of a semi-structured questionnaire and the guided field-walk method where the informant pointed out the plants and provided information as to their uses. All plant species were collected and identified at the Bangladesh National Herbarium.

Results: The various plant species commonly regarded as weeds used by the traditional healers (with ailments treated or uses given in parenthesis) included *Mikania cordata* (to stop bleeding from cuts and wounds), *Sida cordifolia* (biliary problems, blood purifier, infections, diabetes), *Amaranthus spinosus* (to regularize urine and stool, lack of appetite, antidote to poisoning), and *Asparagus racemosus* (asthma during winter, to increase intelligence, to increase sperm, to increase lactation, diarrhea). These weeds are usually present on fallow ground.

Conclusions: Natural products reported from these weeds include mikanolide, deoxymikanolide, dihydromikanolide, scandenolide (*Mikania cordata*), 1,2,3,9-tetrahydro-pyrrolo-[2,1-b]-quinazolin-3-ylamine (*Sida cordifolia*), 7-*p*-coumaroyl apigenin-4-*O*- β -D-glucopyranoside, β -xylofuranosyl uracil, β -D-ribofuranosyl adenine, β -sitosterol glucoside, betalains like amaranthine and isoamaranthine, hydroxycinnamates, quercetin, kaempferol glycosides (*Amaranthus spinosus*), and steroidal saponins like shatavarins I and IV-X, asparanin A, and racemosides A-C (*Asparagus racemosus*).

A survey of weeds used by traditional medicinal healers in Thakurgaon district of Bangladesh to treat various ailments

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Aim or objectives: Weeds contribute enormously to the list of medicinal plants used by traditional medicinal healers of Bangladesh to treat different ailments. As the weed species used for treatment of ailments can vary considerably from region to region, we conducted a survey among the traditional medicinal healers of Thakurgaon district, Bangladesh to learn more about weed species used by them in their medicinal formulations.

Materials or subjects: Traditional medicinal healers.

Methods: Information was collected with the help of a semi-structured questionnaire and the guided field-walk method, and plant species as pointed out by them were identified at the Bangladesh National Herbarium.

Results: The various species of weeds used by the traditional medicinal healers (with ailments treated or use given in parenthesis) included *Mimosa diplotricha* (sexual weakness, severe pain, debility, to increase lactation, anemia, gastrointestinal disorders, skin diseases), *Oxalis lobata* (gastrointestinal disorders, impaired liver functions), *Amaranthus viridis* (swelling or edema of hands and legs), *Achyranthes aspera* (ant, bee or animal bite), *Eclipta alba* and *Cynodon dactylon* (passing of blood with urine), *Leucas aspera* (itches), *Clerodendrum viscosum* (helminthiasis), *Heliotropium indicum* (leukorrhea), *Argyreia speciosa* (headache), and *Costus speciosus* (helminthiasis). These weeds are found in fallow ground and can also prove troublesome during cultivation of vegetables. *Cynodon dactylon*, found in both cultivated and fallow ground, is a serious weed to deal with.

Conclusion: Natural products reported from these weeds include eclalbatin, ecliptasaponin, daucosterol, stigmasterol-3-*O*-glucoside, coumestans like wedelolactone and demethyl-wedelolactone (*Eclipta alba*), phenylacetaldehyde, (*E*)-2-nonenal, (*E*, *Z*)-2-nonadienal, heliotrine (*Heliotropium indicum*), hexadecanyl-*p*-hydroxycinnamate and scopoletin (*Argyreia speciosa*).

A survey of weeds used by traditional medicinal healers in Shalikhha area of Magura district, Bangladesh to treat various ailments

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Aim or objectives: Weeds contribute enormously to the medicinal plants used by traditional medicinal healers of Bangladesh for treatment of different ailments. We conducted a survey among the traditional medicinal healers of Shalikhha area, Magura district, Bangladesh to learn more about weed species used by them in their medicinal formulations.

Materials or subjects: Traditional medicinal healers.

Methods: Information was collected with the help of a semi-structured questionnaire and the guided field-walk method, and plant species as pointed out by them were identified at the Bangladesh National Herbarium.

Results: The various species of weeds used by the traditional medicinal healers (with ailments treated or use given in parenthesis) included *Heliotropium indicum* and *Achyranthes aspera* (allergy), *Amaranthus spinosus* (to increase sperm), *Argyreia speciosa* (headache), *Lygodium flexuosum* (irregular menstruation), *Tinospora cordifolia* (stomachache), *Cissus quadrangularis* (bone fracture, fatigue), *Cynodon dactylon* (blood with cough, blood with urine, fatigue, burning sensations during urination). The weeds are present on fallow ground and some like *Cynodon dactylon* can pose serious problems to growers of vegetables, paddy, and wheat.

Conclusions: Reported constituents of some of these weeds include phenylacetaldehyde, (E)-2-nonenal, (E, Z)-2-nonadienal, heliotrine (*Heliotropium indicum*), 7-p-coumaroyl apigenin-4-O-β-D-glucopyranoside, β-xylofuranosyl uracil, β-D-ribofuranosyl adenine, β-sitosterol glucoside, betalains like amaranthine and isoamaranthine, hydroxycinnamates, quercetin, kaempferol glycosides (*Amaranthus spinosus*), hexadecanoyl-p-hydroxycinnamate and scopoletin (*Argyreia speciosa*), antheridiogens, O-P-coumaroyl-dryocrassol, dryocrassol, tectoquinone, kaempferol, kaempferol-3-β-D-glucoside, β-sitosterol, and stigmasterol (*Lygodium flexuosum*), β-ecdysone, octacosanol, amritosides A-D, syringin, cordiol, cordioside, cordiofolioside, jatrorrhizine, and tinosporide (*Tinospora cordifolia*), and 6-O-[2,3-dimethoxy]-trans-cinnamoyl catalpol, 6-O-meta-methoxy-benzoyl catalpol, picroside, quadrangularin A, pallidol, quercitin, quercitrin, β-sitosterol, and β-sitosterol glycoside (*Cissus quadrangularis*).

Orobanche Survey in Tomato and Tobacco Field in Samsun, Turkey

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Tomato (*Lycopersicon esculentum* Mill.) and tobacco (*Nicotiana tabacum* L.), are major products for economic proceeds, and it is widely growing in Black Sea Region of Turkey. However, the yields are very low due to several constraints such as pathogens and competition with parasitic weeds of the genera *Orobanche* and *Phelipanche* (broomrapes). Parasitic weeds have an important role among these factors.

This study was conducted to obtain more information about the distribution and the effect of the parasitic weed in tomato and tobacco fields. Therefore, In this survey, 102 tomato and 124 tobacco fields were screened for intensity of infestation by *Orobanche* species during 2007-2008 growing season. In addition to that interviewed were conducted with 130 farmers in order to identify their knowledge of the parasitic weeds and their control methods against to this species. One hundred - thirty farmers were randomly selected for detailed interview in each village and county.

Only *Phelipanche ramosa* (L.) Pomel (syn. *Orobanche ramosa*) was determined among broomrape species infested tomato and tobacco growing areas. The frequency of broomrape was found 22.33 %, the number of broomrapes branch for a tomato plant in root was 1.14 and the average of population was 2.32 plants/m². The density of broomrape infection was found 16.6 %, the average number of broomrapes branch for a tobacco plant in root was 0.32 and the average of population was 1.93 plants/m². In interviews, the ages of farmers were mean 49.33 (for tobacco), 43.51 (for tomato) and also experiences of their 30.33 and 17.15 respectively. Of the total number of respondents mean 73 % were educated up to the primary level. The most of the tobacco grower were found as landowners (mean 54.38 %). A total of 60 per cent of farmers expressed interest in trying other on-farm activities to supplement their tobacco. Primary education, off-farm income, and smaller farm size were associated with the number of actions taken. In interviews, control methods are used by farmers except hand-pulling in case of broomrapes infestations. When asked about their interest to test different control methods, the majority of the tobacco and tomato farmers prefer for hand-pulling (95 %, 72 %) and tillage (5 %, 6 %), but none of them apply the chemical respectively. Results of this study indicated that farmers were lack of knowledge about control method, germination and biology of *Orobanche* and *Phelipanche* genus. Hand pulling is the only method that the most of farmers apply to control the broomrapes in tobacco and tomato fields also, it has been determined that *P. ramosa* L. has a risk for tomato and tobacco production in Samsun Province.

This project was supported by TÜBİTAK-KAMAG (grant number 106G077)

Environmental factors determining weed species composition of cereal and stubble fields in western Hungary

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Recent investigations in Europe indicated that the most important factor in determining weed species composition in arable fields was the type of crop. Similar studies however dealing with the same crop type within an entire vegetation period are missing. Accordingly, for this purpose the investigation of weed vegetation of cereal fields and their stubbles would offer favourable opportunities.

This work surveyed the weed vegetation on extensively managed arable fields in western Hungary, based on 1698 records collected between 1995 and 2005. From these data set altogether 184 records (112 from cereal and 72 from stubble fields) were selected, for which during the fieldwork soil samples were also collected. Phytosociological samples were set up according to the method of Braun-Blanquet, the size of individual plots was 50 m². While cereals were surveyed between the middle of May and the middle of June, stubbles were studied between the middle of August and the end of September. For each plot, a list of environmental variables was compiled, including altitude, mean annual temperature mean annual precipitation, soil pH and soil texture. Relationship between environmental factors and composition of weed vegetation were analysed by redundancy analysis (RDA). The effect both gross and net, of each explanatory variable to species composition using Monte-Carlo tests was undertaken. Separate analyses with single environmental variable were done to assess the gross effects. The net effects (effect of particular variable after partialling out the effect of all other variables) were tested by partial-RDA, where all other environmental variables were used as covariates.

Altogether 309 species were recorded, 248 in cereal and 178 in stubble fields. The gross effects of all variables on species composition were highly significant. Together these variables explained 26.99% of the total variation in species data. Most variation in species composition was explained by the aspect (cereal vs. stubble), followed by soil pH, mean annual precipitation, soil texture, mean annual temperature, and altitude. Separating the cereals and stubbles, the gross effects of all variables on species composition was 23.89% by cereals and 22.02% by stubbles. In these cases, soil pH became the most important factor. The net effects of particular explanatory variables on weed species composition were also significant.

Species associated with cereals e.g. *Veronica triphyllos*, *Anthemis ruthenica*, *Myosotis stricta*, *Cerastium glomeratum*, *Vicia villosa*, *Arabidopsis thaliana*, *Scleranthus annuus*, *Anthemis arvensis*, *Apera spica-venti* and *Aphanes arvensis* were winter annuals, while species associated with stubbles e.g. *Stachys annua*, *Anagallis foemina*, *Fallopia convolvulus*, *Ajuga chamaepitys*, *Reseda lutea*, *Silene noctiflora*, *Gypsophila muralis* and *Juncus bufonius* were summer annuals. Our results suggest that during the long vegetation period, cereal weed communities dominated by winter annuals are replaced by stubble-field weed communities dominated by summer annuals. This seasonal change may also have the same important effect on weed species composition as crop types.

Evaluating the effect of landscape elements on weed flora composition using classical and innovative indices

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The presence of landscape elements in agro-ecosystems may affect weed flora composition in crops, and diversity indexes can be used for comparing fields surrounded by varying amounts and types of landscape elements.

The aim of this study was to set up an approach to assess diversity and its link with landscape elements in the agro-ecosystem. The abundance and diversity of weeds, in terms of both seedbank and actual flora, was evaluated in fields on organic farms located in an area of the Italian pre-Alps with various landscape elements. Evaluations were made utilizing the classic concise indices of population structure based on species abundance only, together with the Rényi diversity, which considers a scale parameter, and the Quadratic diversity Index, the complete calculation of which is stressed, from rationale to construction of matrices of “distances” quantifying the differences between species and calculation rules. Five matrices of weights were defined according to life-form, periodicity, ecological type, seed dispersal and seed longevity. The description of the landscape structures surrounding the fields was done with a simple quantification of their complexity.

Results show that in general, high values of species richness are correlated with high diversities and low dominances, but the rule has no general validity. This is a consequence of the low correlation between species richness and diversity (or dominance), which also depends on the “concentration” of the density in one or a few prevalent species. With the classical diversity indices it is therefore difficult to set a unique criterion of “equilibrium”, and the approach to quantify a multidimensional concept such as biodiversity with a single number can be limitative.

The Rényi diversity introduces a diversity profile for a variable scale parameter and adds a further dimension to the analysis that can overcome this limit. However, when compared fields belong to the same type of agro-ecosystem, differences in Rényi diversity are low. The sensitivity of this index to the pattern distribution of individuals is lost when, for further elaborations, such as factor analysis, a central value (mean or 50th percentile) is used.

The Quadratic diversity, which takes into account biological or ecological aspects, is able to emphasise and isolate the “best and worst fields” and can provide really new information on “equilibrium” and new criteria for ranking the community complexity. The calculation of Quadratic Entropy is simple and can be done “step-by-step by hand” and this allows its meaning to be fully caught. This index can highlight well-balanced or very simplified communities, but it is very sensitive to the assigned importance of the relationship between species by the definition of the matrix of the distances.

On the one hand a particular combination of species proportion and distances without codification on the desirability, for example an invasive anemochorous species in a particular agro-ecosystem, can produce misleading results, but on the other this obliges the quantification of the complexity of a community to be approached with the Quadratic Entropy in a very rational way, and thus to have a sound reason for either accepting or rejecting it.

Multivariate analysis and description of weed abundance and weed competitiveness in North China Plain winter wheat production systems

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China produces more than 100 million tons of winter wheat per year on an area of 30.5 million hectares, which makes China one of the leading wheat producers worldwide. The main Chinese winter wheat production area is the North China Plain (NCP), usually with a double cropping system of winter wheat and maize. Weed control in this area typically comprises a combination of mechanical and chemical methods, but the input of herbicides is rather high. Furthermore, many farmers lack profound knowledge of weed control practices and the range of available herbicides on the market is limited. Under the objective of improving the weed management practices in the NCP in future, we started to survey the distribution of weeds in this area in 2009 in order to get a first impression about the site-specific weed composition, as well as their geographic distribution and influencing factors. In 2009 the survey took place on 35 winter wheat fields that were randomly selected within the Provinces Hebei and Shandong. The surveyed parameters comprised weed density, relative weed height, frequency and uniformity of the weed species occurrence per sampling-site (biotic variables). Furthermore, a competitive value per species and sampling-site was calculated depending on species density, species abundance, uniformity and relative species height. The surveyed abiotic factors comprised soil pH, soil CaCO₃ content, soil texture, irrigation intensity, crop density as well as geographic information. Data were analyzed with a canonical correspondence analysis to identify the major factors influencing the abundance and competitiveness of weeds. The sampling-sites will be surveyed again in spring 2010.

The results of the first year survey showed, that the most abundant and competitive weed species in North China Plain winter wheat production systems is *Descurainia sophia* L., followed by *Capsella bursa-pastoris* L., *Lithospermum arvense* L., *Chenopodium album* L., *Galium aparine* L. and *Aegilops squarrosa* L. According to the canonical correspondence analysis the major influencing factors on the abundance of *Descurainia sophia* and *Capsella bursa-pastoris* are soil pH and soil CaCO₃ content. The abundance of *Aegilops squarrosa* and *Alopecurus japonicus* L. is mainly influenced by soil texture as they are most abundant on soils with a high sand content. Agronomic factors like crop density and irrigation intensity had a significant effect on the abundance of *Silene conoidea* L. and *Chenopodium serotinum* L.. Furthermore, the high competitiveness of *Descurainia sophia* and *Lithospermum arvense* can be explained by low crop densities and a soil pH above 7.

In summary, the survey indicates that the most abundant weed species in NCP are dicotyledons, while monocotyledons seem to play a minor role. Moreover, agronomic factors seem to have a lower impact on the abundance of weed species as on their competitiveness. The information

derived from this survey will be included into a decision support system for weed management in NCP following weed-crop competition studies, population dynamic analysis and dose-response experiments with those species. It is expected that this information results in higher weed control efficacy and herbicide savings by determining the need for weed control methods and improving timing, dosage and herbicide selection.

Management of vegetation cover in orchard margins: effect on plant biodiversity

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In agricultural landscapes field margins can play many roles, and also have environmental functions. These areas may contain valuable species that provide a range of important ecological services.

In the *Parc Agrari* of the Baix Llobregat area (Barcelona, NE Spain), orchard margins are not very large and historically have been managed in different ways. A two-year study of the margins of five orchards (1 sweet cherry, 2 peach and 2 apricot) was performed to examine the effect of different mowing treatments on the biodiversity of the margins. At the beginning of the experiment, in November 2006, all the margins showed a spontaneous vegetation cover that was mechanically cleared once a year. Each margin was split into five plots (8/10 m * 1/2 m) randomly arranged to test five mowing treatments (T1 no mowing, T2 one mowing in spring, T3 one mowing in autumn, T4 two mowings in spring and autumn, and T5 three mowings in spring, summer and autumn). In spring, summer and autumn, three times per year, before mowing, plant composition was obtained in each plot by surveying four regularly distributed permanent quadrats (0.25 m²). The mean biodiversities were compared using a mixed analysis of variance followed by Tukey's honestly significant difference (HSD) test after natural logarithm transformation of data ($P=0.05$). The main factors "orchard" and "treatment" (five levels each), together with the interaction between them, were considered fixed effects. The effect "quadrat" and its interactions with the other main effects were considered random effects.

During the study we observed 123 plant species belonging to 32 botanical families. Poaceae (21.1%), Asteraceae (19.5%), Fabaceae (9.8%) and Lamiaceae (6.5%) were the most widely represented. The mean biodiversity ranged from 5.42 to 6.91 species per quadrat.

There were nine species that were recorded 100 times or more (considering all orchards, all treatments, all quadrats and the six surveys conducted). Ordered by constancy they were: *Oryzopsis miliacea* (349 times), *Convolvulus arvensis* (253), *Foeniculum vulgare* (159), *Sonchus oleraceus*, *Cynodon dactylon* (126), *Mercurialis annua*, *Torilis arvensis*, *Galactites tomentosa*, and *Rubus caesius* (100). The species *O. miliacea*, *R. caesius*, *F. vulgare*, *C. dactylon* and *C. arvensis* are perennial.

All the sources of variation considered were significant ($P<0.05$) except the interaction orchard x treatment. In spite of the wide variation between orchards and treatments, the highest values of mean richness were observed in the spring surveys (6.79 in 2007 and 7.07 in 2008).

The statistical analysis showed that T1 and T2 presented a lower significant biodiversity than T4 ($P=0.05$); the fourth mowing treatment slightly increased the biodiversity. From this point of view, it seems unnecessary to manage the margin with more than two mowings per year.

Acknowledgments: this work was financially supported by the Parc Agrari del Baix Llobregat.

The effect of conversion to organic farming on weed species composition in cereals

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We investigated the effect on weeds infestation during conversion to organic farming in order to better understand the effects of weed management. The aim of the study was to determine the changes of weed species composition and infestation in spring barley and winter wheat cultivated in the period of conversion of conventional production system to organic system.

An experiment with a 4-year crop rotation (winter wheat-potato-spring barley-lupine) was carried out from 2006-2009 under organic and conventional conditions on experimental fields of the Institute of Plant Protection – National Research Institute. The following factors were taken into consideration in the experiments: I – production systems: conventional, organic (in conversion); II – sowing method: recommended sowing rate (spring barley 350 seeds·m⁻²; winter wheat 450 seeds·m⁻²), increasing sowing rate (spring barley 420 seeds·m⁻²; winter wheat 800 seeds·m⁻²), stripe-row sowing (spring barley 350/525 seeds·m⁻²; winter wheat 530/800 seeds·m⁻²) with mechanical cultivation including no sowing areas; III – cereal cultivars (spring barley: Antek, Refren; winter wheat: Wydma- no aristate, Mewa- aristate), Each experimental factor was examined in four replications. Experimental plots of organic system that had been studied in weed species infestation were twice postemergence harrowing in weeding harrow and plots of conventional system were sprayed with herbicides. All experimental plots were excluding of hand hoeing, hand root out. The weed species composition was compared using Shannon index of species diversity and index of species domination described by Simpson after earing of cereals.

The segetal flora of the studied in both crops were represented by: *Agropyron repens*, *Anchusa arvensis*, *Aperaspica-venti*, *Capsella bursa-pastoris*, *Equisetum arvense*, *Geranium pusillum*, *Matricaria maritima*, *Viola arvensis*. Only spring barley were weeds as: *Chenopodium album*, *Echinochloa crus-galli*, *Plantago major*, *Polygonum lapathifolium* and only winter wheat were: *Centaurea cyanus*, *Chamomilla suaveolens*, *Papaver rhoeas*, *Stellaria media*, *Thlaspi arvense*, *Veronica hederifolia*. The number and mass of weeds differed in the years as a result of different weather conditions and effectiveness of weed control in production system. The results of performed studies revealed that at the time of conversion of conventional production system to organic one the value of weed species biodiversity index was higher as compared to conventional cultivation of cereals. In case of conventional cultivation, the value of species domination index was the highest for monocotyledonous weed species with a dominance of *A. spica-venti* in winter wheat, and *E. crus-galli* in spring barley. Considering the period of conversion of conventional production system to organic it was found that most common weeds were dicotyledonous with a dominance of *M. maritima* and *V. arvensis* in winter wheat, and in case of spring barley the dominant species were *C. album* and *M. maritima*. Increasing of sowing rate the conversion from conventional system to organic system resulted in the decrease of weed species domination index. In stripe-row sowing system the dominance of dicotyledonous weeds were also recorded as a result of insufficient effectiveness of weeding equipment.

A market-based payment scheme for conservation of weed species diversity in arable systems

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During the last decades, agri-environment scheme targeted at conservation of declining arable weed diversity and associated ecosystem services could often not achieve the desired ecological benefits or suffered from a lack of acceptance due to insufficient economic incentives. This is partially due to the fact that farmers incur heterogeneous opportunity costs to supply arable diversity on their fields. These private opportunity costs are usually unknown to the conservation agency as they include any costs related to the adapted management and associated reduction in crop production. However, estimating these costs is critical for the acceptance and uptake of a conservation payment scheme.

We used a regionally-scaled market-based agri-environment scheme (AES) to pay farmers for the supply of weed species diversity in arable cropping systems. The payment scheme, that comprised a combination of a payment by results approach with an auction mechanism, was established in the project region in Lower Saxony, Germany. To comply with the requirements of the scheme, at least 10 different dicotyledonous weed species had to be present in the field. Scheme compliance was verified in 100 m² plots located in the field centre. Within the project, two consecutive auctions of payment contracts with a fixed budget were conducted. Within these auctions, each farmer submitted a sealed bid with an associated payment he was willing to accept for the production of high weed diversity on his field. Bid prices were accepted from the lowest bid upwards until the budget was exhausted. To verify whether the contracted farmers complied with the statutory requirements, on-the-spot inspections of participating fields and conventionally managed reference fields were conducted at the end of the contract period.

In our study, we aimed to evaluate the ecological effectiveness of the project AES by examining whether the project scheme was successful in enhancing weed species number on AES fields. Second, we tested whether participating farmers faced heterogeneous opportunity costs for the production of high weed diversity. And third, we investigated how farmers' bid prices reflected the potential heterogeneity in their opportunity costs.

On-the-spot inspections revealed that weed species number was significantly higher on AES fields compared to conventionally managed reference fields indicating a high ecological effectiveness of the project scheme. *Stellaria media*, *Myosotis arvensis* and *Lamium purpureum* were the most prevalent weed species on AES fields. Interviews with participating farmers indicated that they developed individual crop management strategies in order to supply the predefined level of arable weed species diversity. On AES fields, fertiliser and input of herbicides with high efficiency against dicotyledonous weeds was reduced.

Participating farmers had heterogeneous opportunity costs for the production of high weed diversity ranking from €21 per ha to €485 per ha with an average of €125.5 per ha. Fluctuations

in opportunity costs were mainly caused by varying income foregone through yield reductions on AES fields. Contrary, variable costs as another component of opportunity costs differed only slightly between AES and reference fields. Mean bid prices of farmers were generally higher than mean opportunity costs. Outcomes of our project auctions therefore indicated that farmers' bids were not exclusively based on opportunity costs but that other factors such as transactions costs, potential production risk or maximisation of information rent additionally influenced bid price calculation.

The long-term effect of tillage systems on weed diversity in a wheat-leguminous rotation

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Weeds are becoming a focus of conservation in arable crops not only because of their intrinsic value, but also because of their importance as food, cover or reproductive sites for other species. Margins of arable fields usually maintain a large diversity of plants. However, within fields, plant diversity is generally low and mostly enhanced by weed occurrence. Thus, weed diversity has an important role in maintaining functioning of agro-ecosystems. However, we still lack information about the impact of agronomic practices on weed diversity and especially on their long-term effects. Tillage has traditionally been a key component of weed control. However, conventional tillage can eventually lead to soil loss through erosion. Conservation tillage techniques, including reduced tillage and no-tillage, minimize the impact on soil structure and soil biota. Our study aims to understand how the intensity of tillage shapes weed diversity through years. The experiment was conducted at El Encin Experimental Station (Alcala de Henares, Spain) during 22 years. The cropping system was a 2-year rotation of winter wheat (*Triticum aestivum* L.) and vetch (*Vicia sativa* L.). Three treatments, namely conventional tillage (CT), reduced tillage (RT) and no-tillage (NT), were compared in a randomized block design with four replications. Every year weed species were identified and counted in 10 samples per plot. Data were used to calculate species richness (S), Shannon's diversity index (H') and Pielou's evenness index (J'). Repeated-measures ANOVA was employed to compare tillage systems in terms of these biodiversity indices. S and H' were both influenced by the tillage system, whereas J' was not. Richness was highest in RT and lowest in NT systems. NT system had also the smallest Shannon index, while RT and CT systems displayed similar values. Results suggest that tillage affects weed diversity (measured as Shannon's diversity index), but it occurs as neither a clear shift through the years on the degree of species evenness nor in the number of species between tillage systems. However, RT holds, generally every year, more species and thus it could be a good strategy to maintain weed diversity. Results also support that the interpretation of weed diversity data needs long-term studies to avoid bias due to the interaction with climatic variables or other agronomic practices. Finally, other descriptors that take into account the identity of the species would be necessary to address adequately the effect of tillage on the weed community as well as to help develop strategies that make compatible the enhancement of weed diversity with an economically sustainable crop production.

Acknowledgements This work has been partially funded by FEDER funds and the Spanish Ministry of Innovation and Science (Projects AGL2007-65698-C03-03 and AGL2010-544).

Study of weed seed bank under maize and sunflower crops

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Soil of agricultural land and ruderal sites contains permanent store of different weed species seed. The term "seed bank" refers to the reservoir of viable seed in soil able to shoot under corresponding conditions. Determination of weed seed bank is significant for study of weed population dynamics, as well as for their planned control.

In the period 2008-2009 in two localities in Vojvodina, Zabalj and Zmajevo quantitative and qualitative analysis of weed seed bank was performed under maize and sunflower crops. Soil samples were taken by the end of vegetation period, from each plot, diagonally in several replications from depth of 0-10cm, 10-20cm and 20-30cm (Conn, 1987 and Sharatt, 1998). Data were statistically processed in the program Statistica 8.

In locality Zabalj, under maize crop seed of 12 weed species were determined of which the most numerous were seeds of *Polygonum lapathifolium* (775 seeds/m²), *Sinapis arvensis* (525 seeds/m²) and *Polygonum aviculare* (156 seeds/m²) at depth of 20-30 cm. The highest number of all separated seeds of weed species was in the layer of 20-30 cm. In sunflower crop, the most abundant were seeds of *Polygonum lapathifolium* (175 seeds/ m²) at depth of 20-30 cm, followed by seeds of *Sinapis arvensis* with 81 seeds/ m² and *Amaranthus retroflexus* with 75 seeds/m² at depth 0-10cm. During 2009 in locality Zmajevo under maize crop seeds of 15 weed species were determined, of which *Amaranthus retroflexus* showed high dominance at all studied layers with 834 to 626 seeds/ m². Greater abundance showed seeds of weed species *Datura stramonium* (84 seeds/ m²) and *Chenopodium album* (76 seeds/m²) in soil layer of 10-20 cm, as well as *Sorghum halepense* and *Solanum nigrum* in the layer of 20-30 cm. In sunflower crop of 15 seeds of found weed species in surface soil layer dominated *Amaranthus retroflexus* (268 seeds/ m²). From this layer the higher quantity of *Datura stramonium* (175 seeds/ m²) and *Sorghum halepense* (31 seeds/ m²) seeds were also separated. In the middle studied soil layer besides seeds of *Amaranthus retroflexus* and *Datura stramonium* dominant were also seeds of weed species *Echinocloa crus-galli* with 66 seeds/ m².

In the locality Zabalj, the highest frequency had seeds of *Polygonum lapathifolium*, *Polygonum aviculare* and *Sinapis arvensis*, and at the locality Zmajevo, *Amaranthus retroflexus*. The average number of separated seeds of all weed species in both of these localities was the highest in the deepest soil layer of 20-30 cm.

In locality Zabalj, in sunflower crop, the highest frequency had seeds of weed species *Polygonum lapathifolium* and *Amaranthus retroflexus*, and in Zmajevo seeds of *Amaranthus retroflexus* and *Datura stramonium*. The highest percentage of all separated seeds was in the top arable layer, which indicates to insufficiently deep soil cultivation.

Key words: weed seed bank, maize, sunflower

Impacts of recent agriculture intensification on the weed communities of wheat crops in the Rolling Pampa (Argentina)

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Floristic shifts in weed communities are a particular case of ecological succession reflecting temporal variations in soils, climate, and agronomic practices. In the Pampas of Argentina, weed communities have responded to several environmental changes since late 19th century. Particularly, agricultural systems have been profoundly transformed during the last two decades. For instance, the use of fertilizers and herbicides have increased, as well as the adoption of no-tillage and genetically modified crops. We studied the changes that the weed communities of wheat crops have experienced after the recent transformation of cropping systems in the Rolling Pampa.

Using two sets of weed surveys carried out in 1996/1997 ($n = 40$) and 2003/2004 ($n = 41$), we compared species richness and floristic and functional compositions of the weed communities of wheat crops. Total species richness was 68 in 1996/1997 and 62 in 2003/2004. Mean species richness at field scale was lower in 2003/2004 (7 S.E.M. = 0.9) than in 1996/1997 (14, S.E.M. = 0.6, $P < 0.001$). Species richness of annuals decreased between surveys (1996/1997: 9, S.E.M. = 1.3; 2003/2004: 4, S.E.M. = 0.6, $P < 0.0001$), whereas the richness of perennial species did not significantly change (3, $P = 0.34$). Forty two species occurred in both surveys, 26 species were present only in 1996/1997 (*Avena fatua*, *Bowlesia incana*), and 20 only in 2003/2004 (*Urtica urens*). Sørensen similarity between both surveys was 65%. A group of cool-season species, which were widely recognized as common weeds of wheat crops in the 1980s and early 1990s, importantly reduced their frequency between both surveys (*Carduus acanthoides*, *Chenopodium album*, *Cirsium vulgare*, *Coronopus didymus*, *Lolium multiflorum*, *Fallopia convolvulus*, *Stellaria media*), or even were absent in the second survey (*A. fatua*). A perennial forb species (*Gamochaeta pensylvanica*) noticeably increased their frequency from 13% to 46% between surveys. Moreover, frequency of volunteer soybean seedlings increased from 25% to 32% during the studied period.

We think that weed shifts observed in wheat crops have been resulted from the widespread adoption of both no-tillage and standardized chemical weed control. In the Rolling Pampa, land management change from traditional plowing to no-till agriculture has affected the persistence of weed seeds in the soil. Thus, in no-tillage systems, recently dispersed seeds are concentrated near the soil surface facing higher risk of predation, and are also more exposed to unfavorable microclimatic conditions that often reduce germinability. Moreover, weed control in wheat crops has become almost exclusively based on a single post-emergent, herbicide formulation (Metsulphuron Methyl 60% + Dicamba 48%). This herbicide is highly effective to control the species that have reduced their frequency during the studied period. Our results not only contribute to understand how technological changes in agricultural systems affect weed community structure, but also show the impoverishment of weed flora after the recent increase in agriculture intensification.

Is the high variance of weed species richness between fields caused by landscape effects?

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During the last decades, weed species richness in fields has decreased as a consequence of agricultural intensification, in particular increases in the size of arable fields and the removal of linear landscape elements.

The objective of this study was to describe and analyse weed diversity as a function of management and landscape structure effects. Weed flora surveys were carried out on 176 plots inside fields randomly distributed in the district of Doberan in Mecklenburg-Western Pomerania, an agricultural region in northern Germany that is characterized by large homogeneous fields and intensive management. Both conventional and organic fields grown with prevalent crops (oilseed rape, small grain cereals) were investigated. Per field herbicide abandoned and sprayed plots (in each case one) were arranged to determine species numbers and their relative dominance. All plots were situated at least 30 m away from field margins. Ten landscape indices describing patch and edge structure and like perimeter-area ratio, habitat type diversity and percentage cover of land use were calculated for circles with a radius ranging from 100 m up to 2500 m around the investigated plots with help of the geographical programme ArcGIS (version 9.2, extension V-LATE) and analysed using linear regression models.

Species richness, measured as species numbers, was accompanied by a high variance (13.6 ± 6.3) in the data set. Species numbers were significantly higher in organic and conventional plots without herbicides than in conventional sprayed plots. Surprisingly there were no significant differences in species richness between organic plots and conventional unsprayed plots. Perhaps the type of management is not of prior importance. Species richness was significantly and positively related to the landscape indices describing spatial structure, namely number of patches (NP), Shannon-Diversity index, and mean patch edge (MPE). These indices represent linear refuge habitats for weeds. As expected, proportion of arable land is negatively correlated with species richness. In general, including landscape characteristics within a 100m circle radius provided the best explanation of species richness. However, only 14 % of the total variation was explained by the multiple linear regression models.

These preliminary results indicate that it is difficult to relate species richness to landscape characteristics if the landscape is relatively homogeneous. Further analyses will be employed to evaluate the effects of location and management factors.

Weed Surveys and Weed Mapping in Europe

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Biodiversity is one major topic in several global sustainability campaigns. Weeds are regarded as important elements of disturbed soil surfaces. Some weeds are classified as rare and are members of “red lists”, i.e. lists of endangered species. Unfortunately, a good overview of which species occur where in Europe is missing. Recent changes of weed species have not been documented on larger areas, with only a few exceptions: Finland, Czech Republic and Hungary. Most existing weed distribution maps are not satisfactory as they don’t show frequencies of weeds nor the severity of infestation. A group of scientists has recently started to evaluate data that have been collected over more than 50 years, primarily in Eastern European countries. This group has become the new EWRS Weed Mapping Working Group in December 2009. Tasks of the new working group are:

- Compare and combine data from weed surveys in actual maps
- Document population dynamics and regional weed changes
- Derive predictions for weed problems in selected areas and on selected sites
- Communicate developments in defined segments and compare them with developments outside the EU
- Find common and most efficient rules and tools for the assessment and documentation of data

One of the first achievements of this group are draft maps of the most common weeds in cereals, corn and oilseed rape. These are derived from national surveys. A publicly accessible server was provided by the University of Hohenheim. A preliminary agreement on software and methodology was achieved. Data will be exchanged via excel files, maps will be prepared with local software.

Regional coordinators have been nominated:

T. Hyvönen and A. Auskalnis for Scandinavia and Baltic countries

J. Recasens, P. Barberi, C. Moonen. for Spain, Portugal, France and Italy

M. Zajac and A. Auskalnis for Poland, Belarus and Ukraine

S. Lvoncik and M. Kolářová for the Czech Republic, Slovenia, Slovakia and Austria

B. Rubin and A. Uludag for Israel, Turkey, Jordan, Egypt and Greece

K. Hanzlik for Germany, Benelux, Great Britain and Switzerland

I. Dancza for Hungary, Romania and Moldova

M. Meseldzija for Serbia, Croatia, Bosnia, Montenegro and Bulgaria

The presented poster shows the first working group results. The most common weed species are shown for the most important crops in Europe. Some weeds with a wide ecological amplitude occur all over Europe, e.g. *Echinochloa crus-galli* or *Chenopodium album* in corn. *Avena sterilis*, *Lolium rigidum*, and *Setaria* species are apparently more common in mediterranean cereal areas whereas *Apera spica-venti*, *Alopecurus myosuroides*, *Poa annua*, *Galium aparine* and *Viola arvensis* are more widespread in Northern Europe.

The effects of nitrogen fertilizers on sports grass weeds

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The ensurance of quality lawn consisting of great density, trample-durable and free from weeds grass is a basic requirement on football pitches. The degrading role of the monocotyledonous weeds and also that of the broadleaf ones are also significant.

One of the most remarkable weeds of weed species occurring even along with the intensive maintenance or becoming inhabited as a consequence of this maintenance is the Annual Bluegrass. Its blooming and dispersal of pollens mean a constant human allergy factor parallel to the changes in the composition of the useful grass plant stand.

We set a nutrient provision research on the lawn of a pitch maintained intensively both by traditional and controlled nutrition transmission nitrogen fertilizers and also by complex fertilizers containing nitrogen, phosphorus and potassium.

The aim of the research was the examination of quality changes including the evaluation of the changes in proportion of sports grass and grass weeds.

The location of our research was the lawn of the center pitch in FTC Stadium on Üllői Road in Budapest. The watering and cutting of it was the local caretaker's responsibility.

The ethnic composition of the lawn is: Perennial Ryegrass 20%, Kentucky Bluegrass 10%, Annual Bluegrass 20%, Creeping Bentgrass 30-40% and others 10%.

The N-agent released: 100; 150; 200 kg/ha

Applied fertilizers:

- 1) Ammonium-nitrate ($\text{NH}_4 \text{NO}_3$) fertilizer with traditional nutrient transmission (released several times from spring to autumn).
- 2) Controlled nutrient transmission:
 - a. a short-term longevity Sportmaster fertilizer (released several times from spring to autumn).
 - b. a medium-term longevity Sierrablen fertilizer (released twice a year).
 - c. a long-term longevity Sierrablen fertilizer (released once a year).

According to the findings we can conclude that

- the release of the ammonium-nitrate fertilizer agent in a dose of 100; 150; 200 kg/ha has increased the proportion of valuable grass species compositions and particularly that of the Perennial Ryegrass and the Kentucky Bluegrass. The cover on the pitch containing 40-50 % useless Creeping Bentgrass got restrained by 30% as a result of the presence of Perennial Ryegrass and Kentucky Bluegrass.
- with the release of the traditional N nutrient and also with the improvement of nutrient provision, the spread of the Annual Bluegrass can be extorted from the lawn as well as with the controlled nutrient transmission fertilizers, however, the effects of these are a little moderate.
- the dicotyledous weeds did not react in a reliable way to the provision of nutrients therefore we can conclude that their appearance can be related to the applied cutting

method and the injuries caused in their use. The White Clover reacted both to the nutrient provision and the fertilizer used. We stated that the traditional fertilizer in larger dose had better effects on extorting it than the controlled nutrient transmission complex fertilizers.

- due to the long-lasting effect of controlled nutrient transmission fertilizers there was a gradual advance in the growth of coverage created by grass species such as Perennial Ryegrass and the Kentucky Bluegrass.

Spatial and temporal evolution of *Sorghum halepense* patches as a function of their size and plant density

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The aim of this study was to assess the influence of patch size and plant density in the spatial and temporal evolution of *Sorghum halepense* patches in irrigated maize crops. For this purpose, two separate experiments were conducted in a 4 ha maize field which was free from *S. halepense*. The experimental design included a sufficient space between *S. halepense* patches to prevent them from getting together over time due to their growth. Tillage was performed always in the same direction along the experiment time to evaluate the effect of cropping practices on the expansion of the patches. A herbicide treatment with atrazine (Gesaprim FW, 0.96 kg a.i. ha⁻¹, Syngenta) plus metolachlor (Dual Gold, 0.96 kg a.i. ha⁻¹, Syngenta) was applied pre-emergence. In 2008, these two herbicides were substituted by isoxaflutol (Spade, 100 g a.i. ha⁻¹, Bayer).

In the first experiment, three replicates of patches with different sizes (from 1-to-100 m²) but identical plant density (10 plants m⁻²) were artificially established by sowing rhizomes. The initial patches had a quadrate shape with sizes of 1 m², 10 m², and 100 m². In the second experiment, we used three replicates with three plant densities ranging from about 4-to-60 plants m⁻² with the same patch size (10 m²). Monitoring of patch size and shape was performed visually by walking around the perimeter of each patch with a DGPS equipment. Plant density was determined by counting *S. halepense* tillers in quadrats regularly spaced (1 m) within all crop rows.

The results showed that patch growth was basically in the direction of tillage, with a length-to-width ratio of about 3. Patches showed little displacement in the opposite direction and in both sides. The initial size had significant effects on the evolution of patches, with relatively higher growth in the smaller patches. On average, small patches have had an absolute growth during the first year of 19 times with respect to initial size, while large patches increased their size only twice. Medium size patches had an intermediate behavior with an absolute increase in size of about 6 times. On the other hand, although plant density did not significantly affect the spatial expansion of the patches of *S. halepense*, there was a significant effect on the rate of population growth. Indeed, after two years plant densities became equal regardless of initial plant density.

These results remark the importance of patches that may not be considered by farmers because of their small size or density. If they are not controlled, they can expand rapidly throughout the entire field.

Climate change and weeds - population dynamics of two annual weeds in different temperatures

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Climate change will mediate shifts in the range sizes of the arable weed species in Europe. Fennoscandia region can be assumed to gain new weed species in future since several noxious species are missing there currently. The assessment of the weed establishment risk requires information on the ability of the species to maintain populations in the new region.

The present study aimed at exploring the potential success of two annual arable weeds – *Amaranthus retroflexus* and *Echinochloa crus-galli* – in Southern Finland as a consequence of climate change, and to identify the most critical life-history traits to population performance. Both species are currently common arable weeds in Central Europe and potential future weeds in Scandinavia. The population dynamics of these species were modelled with the aid of stochastic matrix population models that incorporated variation in survival, growth and fecundity. All models were parameterised based on greenhouse and field experiments conducted under different temperature and competition regimes in Southern Finland 2008-2009. A comparison of population maintenance was conducted between the temperatures of current climate and the predicted future climate (difference 3 °C) in ideal conditions without competition, and also in more realistic conditions where weeds were competing with a crop species (either maize or barley).

We found that *A. retroflexus* and *E. crus-galli* were able to form viable populations in both the current and predicted warmer climate when growing without competitors. However, competition with a crop plant, particularly with barley, considerably reduced population growth rate also in the warmer climate, with seed survival and survival to a reproductive stage being the most critical traits to population performance. Overall, our results suggest that *A. retroflexus* and *E. crus-galli* may be able to establish and maintain viable populations in arable lands in Scandinavia in future.

Current weed spectrum in selected areas of the Czech Republic

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Intensive farming leads to changes in the species composition of the agrophytocoenosis. The aim of this work is to assess the current state of species diversity and the composition of weed communities.

In 2006–2008, the phytocoenological survey was carried out in selected areas in the Czech Republic. The agricultural companies have applied conventional farming systems with chemical weed control. A standardized Braun-Blanquet cover-abundance scale was used. The size of one phytocoenological relevé was 100 m². Monitoring was performed during fully developed vegetation periods. In total, 131 phytocoenological relevés were recorded (53 relevés in winter cereals, 50 in spring cereals and 28 in sugar beet).

In winter cereals, we found 0–24 weed species (in total 83 species), the average number of weed species in one relevé was 9.23. *Viola arvensis*, *Fallopia convolvulus*, *Polygonum aviculare*, *Apera spica-venti*, *Avena fatua* and perennial weeds (*Cirsium arvense*, *Elytrigia repens*) occurred most frequently. A significant expansion of dandelion (*Taraxacum* spp.) was noticed.

In spring cereals, 1–27 weed species (in total 101 species) were found, the average number of weed species in one relevé was 13.04. *Chenopodium album*, *Fallopia convolvulus*, *Viola arvensis*, *Polygonum aviculare* and perennial weeds occurred most often.

In sugar beet, 0–22 weed species were found (in total 61 species), the average number of weed species in one relevé was 7.71. Annual late spring weeds (*Chenopodium album*, *Amaranthus retroflexus*, *Echinochloa crus-galli*, *Amaranthus powellii*) and perennial weeds (*Cirsium arvense*, *Convolvulus arvensis*, *Elytrigia repens*) occurred most frequently. Currently, cross-breeds of *Beta* species (weed beet) cause considerable problems.

This work was supported by the Ministry of Education, Youth and Sports - project MSM6046070901.

Influence of crop rotation diversity and nitrogen fertilization on actual weed vegetation in maize-based cropping systems

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Crop rotation can be considered a cultural practice for weed management. Therefore, a weed evaluation was performed at the Interdepartmental Centre for Agro-Environmental Research 'E. Avanzi' of the University of Pisa, Italy. Three triennial and two biennial maize-based rotations were compared against continuous maize in a long-term field trial. Three different nitrogen levels (0, 200 and 300 kg N ha⁻¹) were included. Post-emergence herbicide treatment consisted in 40 g ha⁻¹ nicosulfuron and 243.8 g ha⁻¹ dicamba. We hypothesized that increased number of crops in rotation and crop diversity would reduce weed abundance (percentage coverage) with respect to continuous maize cropping. Similarly, weed abundance would increase with increasing nitrogen rates.

Ground coverage of all weed species was recorded before and after the weed control in the maize plots and weed total biomass was recorded at crop harvest. Relative frequency and relative coverage were calculated to identify important species. Analysis of variance was performed to detect rotation and nitrogen effects on weed abundance.

Maize plots in 2009 hosted 27 species before weed control and 20 weed species after weed control. Before weed control 3 species represented 87% of the total weed cover, whereas after weed control only 2 species represented 96%. Both relative frequency and coverage of *Cynodon dactylon* increased after weed control. Frequency of *Cyperus rotundus* was not affected by weed control but its coverage decreased. *Xanthium strumarium*, *Polygonum aviculare* and *Solanum nigrum* were controlled sufficiently.

Winter wheat in rotation with maize decreased weed coverage with respect to the maize continuous crop in both biennial and triennial rotations whereas soybean either increased weed coverage or remained unchanged with respect to continuous maize. This effect was stronger after weed control than before weed control treatment. The lower weed cover in rotations with winter wheat was due to the lower cover of monocots in these plots. This is likely due to higher efficacy of monocot control during the winter wheat phase.

Despite lower weed cover after herbicide application in N0 plots, weed biomass at harvest was higher than in N200 and N300 plots. Maize plots in maize-wheat (biannual) rotation and second-year maize in maize-maize-soybean rotation or maize-maize-winter wheat rotation produced less ($p < 0.001$) weed biomass than in maize monoculture (biannual) or in maize-soybean biannual rotation.

Overall it can be concluded that soybean in rotation with maize has a negative effect on weed abundance and this effect decreases in time; weed abundance in second year maize in the M-M-S rotation is similar to that in maize grown as a continuous crop. Winter wheat on the other hand increases weed control and this effect is stronger as the percentage of winter wheat in the rotation increases.

Changes in Central German arable weed communities over the last 50 years – a semi-quantitative study

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Diverse arable weed communities are among the most threatened vegetation types in Central Europe with its intensively managed fields. However, few studies are available on long-term trends in arable weed vegetation and we thus investigated changes in plant community composition and diversity over the last 50 years. We selected 10 regions in Central Germany representing calcareous, sandy and loamy soils, where vegetation relevés from the 1950s and early '60s were available. For each region, about 40 relevés were chosen and resampling in 2009 took place at the same sites as the historical surveys. Sampling was carried out in nested plots of 25, 50 and 100m², and one relevé each was sampled at the field margin and in its inner part. Otherwise, sampling followed the standard method of BRAUN-BLANQUET. After "taxonomic emendation" data were analysed by means of univariate (ANOVA) and multivariate (DCA) statistics. Information on plant functional traits was taken from standard databases (KLOTZ & BRIEMLE 2002).

Our relevés differed considerably from the historical samples, the main trends were:

- The inner parts of the fields were extremely species-poor and lacked characteristic and other diagnostic species rendering placement of communities in the traditional syntaxonomical system impossible.
- Richness along field margins was clearly higher compared to the fields' interior but still lower than in the historical vegetation samples.
- Functional diversity (based on analysis of plant functional traits) declined strongly; geophytes, plants with large seeds (e.g. *Adonis aestivalis* L., *Centaurea cyanus* L.) and species highly adapted to specific historical land use practices (e.g. *Agrostemma githago* L.) showed disproportionately higher losses.
- Rare species declined dramatically in frequency but also in abundance as inferred from cover values.
- If averaged over the whole data set, neither cover nor frequency of neophytes showed any change over time, while archaeophytes declined strongly.
- Certain monocotyledons (e.g. *Anisantha sterilis* (L.) NEVSKI, *Alopecurus myosuroides* HUDS.) increased in both abundance and frequency especially on the field margins, and have now become "problem weeds".
- "Gene erosion" was apparent on the level of the crop plants, where diversity of cultivated species decreased during the last decades.

Our semi-quantitative analysis points to dramatic changes that are apparently related to the agricultural intensification and homogenization from the 1960s onwards. Trends were

qualitatively similar in all regions, but magnitude of change differed with fields on loamy or even calcareous substrates showing more pronounced losses than those on sandy sites.

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Survey for *Leptochloa* problems in rice paddy fields in Valencia (Spain)

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Spain is the second rice producer in Europe after Italy with a crop surface of about 115,000 hectares. Valencia is a traditional rice production area in Spain. Valencia's rice paddy surface is established around 15,000 hectares. Paddy fields are located in an protected area with high environmental value surrounding the Albufera lagoon.

The main rice problems in the Valencian paddy fields are those caused by weed competition, specially grasses such as Barnyard grass (*Echinochloa* spp. complex) and Redrice (*Oryza sativa* L.) Chemical control and hand-weeding are widely used by farmers.

During field work in 2005 grass plants that appeared in a paddy field in Sueca (Valencia) were classified as *Leptochloa fusca* ssp. *uninervia*. During the same year, other plants of the same type were collected by farm advisors from northern paddy fields around the area. In 2006 more fields in which this grass was present were seen and with more weed density than the previous year. Since then, problems due to *Leptochloa* are more frequent and other subspecies was identified, such as *Leptochloa fusca* ssp. *fascicularis*.

The aim of this study was to determine the distribution and severity of infestations of plants of the *Leptochloa* genus in paddy fields in this area. For this purpose a survey for detecting *Leptochloa* plants in paddy fields was carried out during 2008 and 2009. Geographical Information System (GIS)-based maps and distribution maps were developed in order to study and understand the expansion and severity of infestations of these weeds in the paddy fields.

This paper shows the evolution, distribution and severity of infestation of both *L. fusca* ssp. *uninervia*. and *L. fusca* ssp. *fascicularis* in this particular area in recent years. *Leptochloa* plants were found in 5.3 % of 2,236 paddy fields checked in 2008; and 12.1 % of 2,836 paddy fields checked in 2009. In 2008, 38 % of infested fields had a severity equal to or greater than three on a scale of five. This value increased to 40% in 2009. *L. fusca* ssp. *uninervia* was the most frequent of both subspecies and it caused more severe infestation problems in paddy fields. The results of this study confirm that these weeds are widely distributed in this area and represent a serious threat to the rice paddy fields in Valencia.

Detection of *Cirsium arvense* L. in cereals using aerial multispectral imaging

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Site specific weed management systems provide considerable potential for herbicide savings, however the weed distribution must be known. Manual weed mapping is time consuming and many automated methods that should allow fast and reliable mapping of weed populations are therefore developed. The objective of this study is to find algorithms for the detection of *Cirsium arvense* in cereals using airborne high resolution multispectral imaging. The imaging of three winter wheat fields infested with *C. arvense* was realized in July 2007, just before harvest. The images were taken from helicopter using a three-band (R,G,NIR) multispectral camera at spatial resolution of 0.1 m. Ground truth data were collected by ground imaging using a SLR camera. Aerial images were transformed to reflectance values, NDVI and DVI vegetation indices were then calculated. Radiometric calibration was based on five ground targets placed in the centre of the imaged area. Ground-truth data were coregistered with aerial images and the percentage area covered by *C. arvense* was then calculated for every pixel. For this purpose, ground pixels with coverage of *C. arvense* lower than 25% were marked as “non-thistle” and pixels with coverage of *C. arvense* higher than 25% were marked as “thistle”. Similarly, the pixels in analysed aerial images with an index (NDVI or DVI) value higher than the defined threshold value were classified as thistle. The classification accuracy was calculated by comparing each pixel with corresponding ground truth data and was defined as percentage of correctly classified pixels from all classified pixels. Pearson’s correlation coefficients between NDVI and coverage of *C. arvense* were calculated and the best threshold value of vegetation indices, which provides the highest accuracy of classification, was determined. Correlation coefficient ranged from 0.781 to 0.851 according to field. Optimal threshold value of NDVI varied from 0.41 to 0.47. Using of these threshold values for the classification resulted in 85.5 % - 90.5% overall classification accuracy. DVI provided the correlation of $r = 0.779 - 0.870$. For DVI, the classification accuracy ranged from 83.5% to 92.5 % with threshold value of 0.130 - 0.156. DVI provided better correlation with coverage of *C. arvense* than NDVI if other green vegetation (weed species or moss) was present in lower part of the canopy. Omission errors were caused partially due to presence of white pappus on the seed heads of mature plants of *C. arvense*. Choosing of optimal phenological stage with mature crop and minimum pappus on heads of *C. arvense* is therefore important for imaging.

Acknowledgements: This work was supported by National Agency for Agricultural Research project no. QH71099 and by MSM6046070901 project.

Keywords: remote sensing, multispectral imaging, weed detection, *Cirsium arvense*, cereals

The influence of environmental factors on weed spectrum

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In 2006-2008, a phytocoenological survey was carried out on selected farms across the Czech Republic. These farms were chosen in different climatic and soil conditions practicing conventional or organic farming. In total, 290 phytocoenological relevés in winter and spring cereals, and root crops were recorded (158 in conventional and 132 in organic farming). One relevé of 100 m² size was recorded in each field. Species dominance was assessed by Braun-Blanquet scale. The influence of environmental factors on the occurrence of individual weed species was tested by multivariate analysis CCA (Canonical Correspondence Analysis) in programme Canoco for Windows 4.5.

In total, 172 weed species and 28 crop volunteers from 33 families were found. The natural conditions, type of farming, and crop type explained together 12.3 % of the total variability in collected data. Different natural conditions (altitude, precipitation and temperature) had the highest influence on weed spectrum and explained together 6.9 % of total variability. The second most important factor was crop (3.4 % of total variability). The type of farming explained 1.7 % of the total variability.

The warmest, semi-arid region was characterized especially by the occurrence of thermophile summer annual species like e.g. *Echinochloa crus-galli* and *Amaranthus* sp. The temperate region with chernozem soils was typical for thermophile weed species indicating soils with high calcium content like e.g. *Sinapis arvensis* and *Silene noctiflora*. In hilly regions, species indicating colder areas and moist, acidic soils like e.g. *Galeopsis tetrahit* and *Gnaphalium uliginosum* were prevalent.

Weed spectra in individual crops reflected their specific vegetation season and growth characteristics.

For conventional farming, the occurrence of volunteers and weeds with wide ecological amplitude was typical. In organic farming, species sensitive to herbicides or intolerant to intensive farming practices occurred; perennial species were found predominantly in fields with lower intensity of soil tillage. There, some rare species occurred as well.

This work was supported by the Ministry of Education, Youth and Sports - project MSM6046070901.

Migration of *Artemisia vulgaris* to maize cultivation fields in the region of south-west Poland

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There was recorded a considerable change in the structure of farming grounds consisting in the increase in the area of idle land and fallows from 107 thousand hectares in 1996 to 181 thousand in 2004. That fact made it possible for the species which had not been met so far in particular agrocenoses to migrate from ruderal areas. One of the mentioned undesirable species occurring there in high amount is a perennial plant *Artemisia vulgaris*, producing underground rootstocks. Its easy migration results from the lack of competition on the side of segetal weeds and, therefore, brings about a danger to ecological balance. Recently, in the region of south-west Poland there has been observed a significant increase of weed infestation involving *A. vulgaris*, especially on maize plantations using simplified cultivation methods, as well as in cereals and winter rape, particularly on light soils which was connected with restoring fallow soils to agricultural purposes. Inappropriate choice of herbicides in terms of the state and degree of weed infestation often led to the phenomenon of compensation. In the year 2005-2009 there was conducted floristic investigation according to Braun-Blanquet method in this region. On the basis of phytosociological photographs taken in three systems of maize cultivation—ploughing, simplified and ploughless there was compared the mode of *A. vulgaris* spreading. In the conditions of field experiment there was examined chemical control of this weed occurrence in the same systems of cultivation. Competitive power of annual and perennial forms of the analysed species in relation to *E. crus-galli*, *Chenopodium album*, *Viola arvensis*, *Anthemis arvensis*, *Veronica persica* and maize was investigated on micro-scale plots.

The frequency of occurrence and coefficients of ground cover with weeds allowed to thoroughly assess actual hazard to crop maize caused by *A. vulgaris* and remaining dominant species of weeds. Coefficient of ground cover for this species in the ploughless system increased by 791 as compared to the ploughing one and there was reported considerably higher contribution of perennial individuals featuring a profoundly developed root system. In the simplified tillage system coefficient of ground cover amounted 525 and maize phytocenosis was poorer both in perennial individuals of *Artemisia vulgaris*, and the annual ones – there recorded 13 plants in total, while in the plowing system their number was merely 5 with one perennial individual. The best effect of weed control in three agricultural systems was observed after application of herbicides foramsulfuron + jodosulfuron with adjuvants in the mixture with mesotrione in comparison both to standard efficacy and to control treatment without any herbicides introduced. In the case of micro-scale plot experiments competitive power of annual *A. vulgaris* individuals and the perennial ones was highest in weed community, resulting in its compensation.

Resembling patterns of weed diversity in maize fields of Brittany (France) and the Rolling Pampa (Argentina)

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Field edges usually harbor more species than the cropped area that they delimit. The distribution pattern of arable plants in field edges is strongly affected by the agricultural management and the heterogeneity of the surrounding farmland mosaic. To test this hypothesis, weed species occurring in both edges and the core area of fields cultivated with maize have been surveyed in Pleine-Fougères (Brittany, France), and afterward compared with similar surveys previously obtained in Rojas (Rolling Pampa, Argentina). Brittany farmland has smaller fields usually delimited by an intricate network of woody hedgerows. Pampean farmland is more homogeneous due to larger fields and sparser networks of wire-fencerows. We here define field edge as the 8 m strip of the cropped area neighboring with the non-cropped boundary strip that set the limit with the adjacent field. Weed species richness was additively partitioned into Δ -, Δ -, and Δ -diversity components, calculating Δ -diversity as the difference between Δ -diversity and mean Δ -diversity. Total species richness was 59 and 51 in Pleine-Fougères and Rojas, respectively. The Δ -diversity of field edges was greater than in the core of fields in both sites, whereas mean Δ -diversity of field edges was only higher in Rojas. Mean Δ -diversity did not differ between sites ($P = 0.319$), while the effect of field habitat was marginal ($P = 0.063$). Site and field habitat effects on Δ -diversity were highly significant ($P < 0.0001$), but there was no significant interaction between both factors ($P = 0.504$). Average Δ -diversity differed between sites (Brittany: 34.5; Rolling Pampa: 21.2) and field habitats (field edge: 32.2; field core: 23.5). Interestingly, Δ -diversity of both field cores in Brittany (29.6) and field edges in the Pampas (25.0) did not differ. Our results confirm previous findings in Western Europe that Δ -diversity reflects the turnover of weed species among fields due to the greater heterogeneity of surrounding landscapes. Moreover, our results also suggest that the weed richness of field edges in both sites would be maintained through apparent dispersal from non-cropped field margins. More importantly, our findings extend current evidence by having compared weed assemblages from the well-known Armorican landscapes with those from the homogeneous and extensive landscapes distinguishing the Pampas of Argentina.

Adapting trait-based approach to the study of weed communities: the case of the SLA-LDMC trade-off

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Ecological studies have widely been based on biological traits to study the effects of environmental factors on communities. Using trait-based approach to study the effects of agricultural practices on weed communities could potentially be a promising way to understand weed dynamics.

The Specific Leaf Area (SLA, leaf area to leaf dry mass ratio) and the Leaf Dry Matter Content (LDMC, leaf dry weight to leaf fresh weight ratio) are two foliar traits that are known to be involved in the trade-off between rapid resource acquisition (*e.g.* Grime's R- and C- strategists) and resource-conservative stress tolerance (*e.g.* Grime's S-strategists). As such, using these traits could lead to a better understanding of weed adaptive strategies to environmental conditions, *i.e.* to agricultural practices. To evaluate the relevance of these two traits in agrosystems, a study on SLA and LDMC trade-off have been conducted on 2 long term trials involving two agricultural practices, *i.e.* intensity of tillage and nature of organic N fertilization.

The protocols used in ecology were first adapted to the cultivated field context. Agrosystems are characterized by high disturbance frequency and intensity, which implies that community dynamics are shaped by the successive germination of cohorts. To address these limitations, SLA and LDMC measurements were pooled according to their phenological stages for each species. Such methodological adaptation is important for statistical analysis, since trait attribute variations can be important between phenological stages at the intraspecific level.

For each treatment, plants sampled on the different replicated plots were pooled since low weed density was observed for each individual plot, which would not allow a robust statistical analysis. Both traits were measured using a standardized method: after sampling, plant stems were cut and stored in the dark into water at 4°C during at least 6 hours to allow good leaf hydration before trait measurements. Fully expanded leaves without serious herbivore or pathogen damage were considered for each sample: the leaf area index was measured using a planimeter ; fresh and dry mass (after oven-drying at 80°C) were then measured.

The first analyses lead to few interesting preliminary conclusions. At the intraspecific level, SLA and LDMC values are variable but differences between species for a given phenological stage were observed. However SLA and LDMC values of sampled species are comparable. Using linear models, significant negative correlations were found between SLA and LDMC: as demonstrated in several contrasted ecological environments, the trade off for resource acquisition is also effective in agrosystems as well as in natural ecosystems.

The tillage system influenced resource allocation in weed communities : higher SLA values were found for superficial treatment than for ploughing or direct drilling treatment. However, the nature of organic N fertilization did not influence resource allocation. These results show that SLA-LDMC are relevant traits for agroecological studies since they allow to capture resource allocation variations in the agrosystem.

Analysis of weed flora of cereals at the organic farm in Gyula, Hungary

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The importance of organic farming has been increasing for years all over the world. This development is due to the increasing claim for healthy food products. The organic farming has been present in Hungary since 1986. The quarter of the total organic farming area is involved in cultivation of cereals in this country. The most important cereals are the winter wheat and the spelt wheat.

The growing and cultivation systems of the organic farming differ from the commonly used methods of conventional farming at some points, e.g. the organic farming employs more frequent tillage and disregards the usage of chemicals (herbicides). This dissimilarity can cause differences in agricultural conditions and in weed flora.

During the survey we investigated the effect of different weed control methods on weed composition on the fields in spelt wheat.

Our aims were to answer the following questions:

(a) Which are the typical weed species of cereals grown organically, and what is the extent of their coverage?

(b) Which weed species are the most problematic for this farming system?

The surveys were made in 2009, four times between March and June, in four fields. The field-margins – the area within 2m distance from the edges of the field – and the inner area were both investigated. Two assessments were done in the margins, and four in the inner areas of each field. Weed flora was expressed as number of weed species and percentage weed coverage.

The degree of weed coverage was low during the whole vegetation period in each field. The average weed coverage was the lowest in March and highest in June.

The weed flora was variable during the studied period. The most frequent weeds were winter annuals (*Stellaria media* *Galium aparine* and *Veronica* species) at the first time. From the second time the perennial species (*Cirsium arvense* *Convolvulus arvensis* and *Lathyrus tuberosus*) became the most problematic weeds. The presence of summer annuals also increased until the fourth time but did not hit the percentage of perennials.

Our studies proved that agronomical and mechanical methods are suitable for minimizing the harmful effect of weeds to a tolerable level. Methods used in organic farming can substitute herbicides effectively.

Effects of weed dynamics between conventional and organic cultural systems

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Organic farming has grown in importance during the last 20 years in Italy. Weed management is generally more critical in organic than in conventional farming, as only non-chemical means can be applied. In these conditions, the knowledge of the effect of organic cultural system on weed population dynamics appears essential to optimize weed management.

The aim of this study was to determine at field scale the weed evolution in time, in conventional and organic cultural systems. The study was carried out in north western Italy over the period 2004-2007, in a crop-rotation including wheat, pea, maize and wheat. The following three cultural systems were compared: conventional (CONV; reference system); organic system based on the use of farmyard manure (OFM); organic system based on the use of a combination of green manure and intercropping (OGI). In both organic systems weed management was carried out applying stale seed bed technique combined with mechanical interventions with spring tine harrowing, inter-row harrowing and ridging. In conventional system weeds were controlled by means of herbicides.

Over the period of the study, seed bank resulted quite stable in the conventional system, while it increased by about 5 % in both organic.

Weed density assessed in OFM increased during the monitored period: in wheat it increased, by about 300% (from 74 to 254 plants/m²), while in pea an increase of about 30% (from 220 to 340 plants/m²) was recorded. Weed density increased also in OGI, both in wheat (56%) and pea (300%).

A clear effect on weed density in maize due to the cropping system was not observed. In this crop the weed presence was more influenced by weather conditions. The year with the highest infestation was 2005 which had a density roughly twice that recorded in the other years, in all cropping systems.

Weed composition did not vary remarkably in the conventional system while an important increase of perennial weeds, such as *Cirsium arvense*, *Sorghum halepense*, *Convolvulus arvensis* was observed in organic systems. A notable increase of annual grasses, such as *Echinochloa crus-galli*, *Panicum dactyloides* and *Setaria viridis*, has also been recorded, in particular in organic maize, because of the limited activity of the mechanical means against these weeds.

Payments by results for arable weeds - What influences farmers' willingness to participate? Results from case study scenario analyses in North-East Germany

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There is increasing evidence of a decline in arable weeds as part of agro-biodiversity in Europe over the last decades. Their occurrence can be supported in agri-environment schemes (AES). In Germany the effectiveness and efficiency of such schemes is unsatisfactory. Effectiveness describes the extent to which the environmental performance of farmers (Output) achieves the intended conservation goal (Outcome). Efficiency is defined as the minimization of the expenses of the conservation agency (Input) for a given environmental performance of farmers (Output). The concept of payments by results is considered as a possible solution to enhance the effectiveness of AES, as the payment is directly linked to outcome effects. Thus, it is in the farmer's own interest to select plots of high environmental value for participation. However, the variability of individual Opportunity Costs increases, which makes it more difficult for the ES buyer to estimate sufficient PES. Still, designing effective AES does not lead to an efficient scheme implementation, if farmers are not willing to participate. Compared to AES of grassland arable fields provide quite different framework requirements for designing such schemes. The poster will discuss why payments by results combined with a more differentiated design of payments for environmental services like auctions (instead of fixed payments) and a farm individual, spatial variability of plots under contract within the contract period (instead of spatially fixed plots) might abate these deficiencies. The theoretical remarks will be framed by results of case studies showing wide fluctuations of individual Opportunity Costs of participation in an outcome-oriented scheme design on arable land in North-East Germany (-36 € to 430 €). Farm individual costs and risks of participation were estimated on the basis of management data of three conventional cropping farms cultivating winter grain (*Triticum*, *Hordeum vulgare*, *Secale cereale*) and oilseed rape (*Brassica napus*, 2002-2006). The Opportunity Costs were deduced from Gross Margins calculations of three extensive management scenarios. As crucial factors involved we considered costs and risks of weed provision with regard to field crops, management strategies and site conditions.

Weed community changes during the last decade in semi- arid cotton crop using spatial temporal analysis

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A number of initiatives have been implemented to meet cotton growing concerns, due to negative side effects of the intensive land-use practices over the past 15 years. Through this study the spatial and temporal variability regarding the frequency and density of the main weeds, were compared between two sampling periods in Karditsa's prefecture (the main cotton zone in Greece). The surveys were conducted during 1995-1997 and 2007-2009 in numerous cotton fields. The exact position of each sampling site was recorded using a GPS device and the collected data were entered in a geodatabase in order to proceed to extended analyses using GIS capabilities. During the first survey (1995-97) 15 weed species were recorded belonging to 11 botanical families while in the second survey (2007-09) 17 weed species were recorded belonging to 9 botanical families. In general, the rank of the main weeds, estimated by their frequency and density, varied widely within the two surveyed periods. Particularly, the most important weeds during the 1st sampling period in diminished rank were, *Solanum nigrum*, *Chrozophora tinctoria*, *Convolvulus arvensis*, *Cyperus rotundus* *Xanthium strumarium* and *Cynodon dactylon* whereas, in the 2nd sampling period the rank was formed as follows: *C. rotundus*, *C. arvensis*, *C. dactylon*, *S. nigrum* and *Portulaca oleracea*. Between the two periods *C. rotundus* populations increased remarkably while the annual weeds performed a decline in their occurrence. The survey obviously indicated that the perennial weeds consist the major problem in cotton fields as they were not consistently controlled by the usual applied cultural practices. Furthermore, their overall contribution to the weed flora in cotton fields may be due to their ability to compete successfully other weeds or to prohibit their emergence because of their allelopathic potential. On the other hand, someone may be assumed that the high abundance of the perennial weed species could be attributed to the increased herbicide's efficacy on annual weeds. Taking into consideration that the spatial distribution of weeds depends at a great part on spatially variable safe sites necessary for initiating germination and ensuring growth to maturity we studied the role of abiotic factors. Actually, the concept that the spatially variable safe sites are related to soil heterogeneity as well as to water content we studied their effect on weed abundance. According to our approach, climatic conditions, soil properties, the irrigation method and the herbicides application were included in the geodatabase and were spatially correlated with the weed flora records to determine spatial and temporal differences.

Weed seed bank changes in long-term winter wheat monoculture

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A soil seed bank consists of all viable seeds and vegetative organs present on and in the soil. Seed bank of weed species vary greatly in composition and density in the soil in association with cropping history, tillage or crop rotation. The results were obtained from long-term winter wheat monoculture in Hrusovany near Brno (Czech Republic, 49°2'12.37"N; 16°35'33.72"E). The impact of herbicide treatments was compared in a field trial. The active ingredients (MCPA, flurenol, mecoprop, dicamba) were applied against broadleaf weeds at the beginning of the trial. Herbicides (e. g. chlorphenprop-methyl or flumprop-isopropyl) against *Avena fatua* were used from 1971 onwards. The soil cores for analyses were taken within a soil sampler with a diameter of 6.4 cm in the years 1967, 1971, 1975, 1980 and 1985. The separation of seeds includes elutriation (extraction by washing). The elutriation method is based on washing the soil sample placed on sieves with running water when a proportion of non-elutriated particles remain on sieves: mineral (sand, grits, etc.) and organic (seeds, post-harvest residues, roots, etc.). In the first decade twelve soil cores were analysed from each variant, in the second decade nine. The number of seeds of weed species in a soil profile (0-0.3 m) was evaluated. The detected seeds were classified into the categories "entire" and "healthy". The category of "entire" seeds included the seeds that appeared visually intact. Seeds were considered "healthy" when they were firm and resistant to pressure of the preparation needle.

The number of entire and healthy seeds increased in the herbicide treated as well as in the untreated variant within 18 years of trial duration. The increase of healthy seeds (972 % - untreated variant, 454 % - treated variant) was higher than that of entire seeds (473 % - untreated variant, 236 % - treated variant). The application of herbicides reduces the number of weed seeds (entire seeds – 41 %, healthy seeds – 52 %). The number of weed species decreased in both variants (in the untreated variant – from 27 to 20 and in the treated variant from 28 to 22). The changes in the composition of weed species were similar in the treated and the untreated variant. A seed reduction for the species *Sinapis arvensis*, *Chenopodium album* and *Avena fatua* could be observed. On the other hand the number of seeds of *Amaranthus retroflexus* and *Papaver rhoeas* increased. The herbicide application reduced the number of weed seeds in the soil but not the weed composition.

Acknowledgement

This study was supported within the research project of the Ministry of Education, Youth and Sports of Czech Republic, as part of the research project - 2B06124 "Reducing the impacts and risks to the environment and provide information for informed decision-making methods of precision farming" and by the Research plan No. MSM6215648905 "Biological and technological aspects of sustainability of controlled ecosystems and their adaptability to climate change" financed by the Ministry of Education, Youth and Sports of the Czech Republic.

Influence of crop rotation on weed infestation in winter wheat

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Agronomic and environmental factors, such as crop rotation, tillage, cover crops, soil type, moisture, herbicide use, etc., all affect weed communities. The objective of this study was to evaluate the long-term influence of crop rotation on the actual weed infestation. A field trial was carried out in the sugar beet production region in Ivanovice na Hané (Czech Republic). The long term average annual precipitation is 564 mm. The long term average temperature is 8.6 °C. The altitude is approximately 230 m above sea level. The soil on the experimental field is loamy chernozem. Three crop rotations with a different percentage of cereals (33.3%, 50.0%, 66.6%) were compared. The first crop rotation involves 33.3% of cereals. Crops are grown in this order: lucerne – first and second year, followed by winter wheat, silage maize, sugar beet and spring barley. The second crop rotation has 50.0% of cereals and crops are grown: pea, silage maize, winter wheat, winter wheat, sugar beet, spring barley. The third crop rotation with 66.6% of cereals consists of winter wheat, pea, winter wheat, spring barley, sugar beet, spring barley.

Experimental plots were cultivated by conventional technology. Ploughing to a depth of 0.22 m and seedbed preparation were practiced in all crops. The number of weed species and their density was counted on 1 m² plots in twelve replications for each variant. Counting was always taken before herbicide application in winter wheat grown in 2000, 2001, 2002 and 2004. Results were evaluated by methods of Analysis of Variance, Least Square Difference method (LSD) and Canonical Correspondence Analysis (CCA). The highest weed infestation was found out after lucerne as a forecrop (33.3% of cereals). On the other hand the lowest weed infestation was recorded after pea as a forecrop (66.6% of cereals). The results were statistically highly significant. Involvement of lucerne in crop rotation supports the following weeds: *Lamium amplexicaule*, *Medicago sativa*, *Veronica agrestis* and *Veronica polita*. When the percentage of cereals in crop rotation was equal or higher 50%, the occurrence of *Galium aparine* was increasing. The results show that an increasing percentage of cereals reduce the density and diversity of weeds.

Acknowledgement

This study was supported within the research project No. 1B53045 “Development of effective methods of weed control with minimal negative effect to diversity of weeds societies a negative risk of contamination of soil and plant production by residues of herbicides“ funded by National Agency for Agricultural Research, Ministry of Agriculture, Czech Republic and by the Research plan No. MSM6215648905 “Biological and technological aspects of sustainability of controlled ecosystems and their adaptability to climate change“ financed by the Ministry of Education, Youth and Sports of the Czech Republic.

Survey of ecological characteristics of weed flora in the maize fields of Saveh regions

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Identifying weed in corn farms is expressed as most basic action in weed management, as use of the information help in integrated-management of weed control, by reduction in consumption of herbicides and cost. With this 120 hectares out of 5000 hectares land were planted with corn in 26 different regions of Saveh. The local weeds were identified and sampled three times.

The result showed 38 weed species from 16 families *competing* with corn in all experimental regions of Saveh *Amaranthus sp*, *Portulaca oleraceae*, *Hibiscus trionum*, *Convolvulus arvensis*, *Alhaja camel-rum*, *Heliotropium sp*, *Xanthium strumarium* were the most important wide leaf species and *Setaria sp*, *Echinoclea crus galli*, *Cyprus sp*, *Sorghum halepense* were the most important narrow leaved species of corn farms in this region.

Also the results of experiment showed that variety and density of weeds in corn farms of Saveh varied such that 25 species were found in Looiin moor. Sinak region and Ojagh moor located towards East of the city had minimum plant diversity (11 species) due to high PH of soil and water. It seemed that high PH of water and soil, different alternation of implant, altitude, variation in soil texture in farms and usage of different herbicides influenced variety and density in an effective manner. It is hoped that this information would be helpful appropriate management for weed control to avoid economic loss.

Urban ecosystem weeds of the Goos-Crystal

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Anthropogenic influence on the flora of the central part of Russia is the consequence of unconscious or conscious bring by the man strange plants, which stands adventives, if it becomes native. Majority of such species spread intensively and becomes harmful for man, also for the native flora and fauna. Many alien and ruderal plants, in general, annuals, gradually becomes weeds.

Goos-Crystal is the small industrial town (central Russia, Upper Volga Basin), district centre of the Vladimir region. It's area is 43 km², population – 62.7 thousands people.

There Crystal Plant, Glass plant, Plant for the production of Veterinary Preparations, Plant for the production of Glass Fiber in the Goos-Cristal.

Floristic composition of the different types of the synanthropic habitats has been investigated in 2008-2009. As result full list of these ecosystems is consists of the more than 300 species of vascular plants, 63 of them are weeds. Composition of the weeds belongs to 20 families and 50 genera. Leading families on the quantity of the species are: Asteraceae (16 species), Bracciaceae (12 species), Gramineae (5 species), Polygonaceae (4 species), Cariophyllaceae (4 species).

Railway habitats was more rich of the different weeds, especially, alien. 16 species (e.g. *Poa annua*, *Polygonum aviculare*, *Berteroa incana*, *Arabidopsis thaliana*, *Lactuca tatarica*, *L. serriola*, ect.) are most common in the all types of the anthropogenical ecosystems. 6 species of the weeds are rare (e.g. *Hyoscyamus niger*, *Amaranthus blitum*, ect).

Ambrosia trifida and *Ipomaea hederecea* belongs to noxious and quarantine weeds. Two big populations of the *Ambrosia trifida* was found in roadside near the chicken farm in the east surrounded of the town. Single plants of the *Ipomaea hederecea* was recorded in the disturbed habitats in north of the town once. Features of the naturalization of these species are not still clear.

In the total, composition of Goos-Crystal urban ecosystem is so rich of weeds. Monitoring quantity and feathers of weeds must be continuing.

SESSION 4
WEED ECOLOGY

Oral presentations

Session organizers:

Lammert Bastiaans & Euro Pannacci

Evolution in action: the role of evolutionary thinking in weed biology and management.

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Agricultural weeds represent the ecological and evolutionary response of the native and introduced flora of a region to the challenges and opportunities presented by crop cultivation. The notion that weeds adapt in response to selection pressures imposed by crop and weed management is neither new, nor controversial. Over 50 years ago, the eminent plant ecologist John Harper noted that weeds were ‘species which have been selected by the very cultural practices which were originally designed to suppress them’. While weed adaptation is recognised by weed scientists and is clearly evidenced by the widespread evolution of resistance to herbicides, I argue, as others have, that a greater degree of evolutionary-thinking in weed biology and management can help in designing more sustainable weed management that reduces selection for weedy traits. Within this framework, the objective of reducing the impacts of the most competitive, resistance-prone weeds is wholly reconcilable with the aim of maintaining a diverse weed flora that delivers biodiversity and ecosystem services benefits within agroecosystems.

In the paper, I firstly consider how much we really know about genetic variation in weed species and what this knowledge may contribute to weed management. The lack of evolutionary-thinking in weed science is demonstrated by reviewing studies in herbicide resistance which, in my view, have become overly concerned with describing resistance at the expense of studies to examine the process of selection for resistance. Some novel approaches in resistance research are presented. The wider benefits of a greater integration of weed science with evolutionary ecology are considered in terms of understanding weed life history evolution in response to selection in agroecosystems and the implications of this wider understanding for modelling weed population dynamics are considered. A greater understanding of weed adaptation will also help us to answer questions about the likely impacts of climate change on weedy and invasive plant species. Looking to the future, the potential future contributions of ecological genomics to weed biology is discussed. There has been concern expressed in the UK and elsewhere about the decline of weed research, perhaps now more than ever, it is timely to review how we approach weed science and ask the question ‘why is the study of these economically and ecologically important plant species not at the forefront of research in evolutionary ecology?’ If it were, this could contribute fundamental insight into plant ecology and evolution, reinvigorate the discipline of weed biology and, most importantly, deliver real benefits for weed management in agroecosystems.

Weed seed burial rate as affected by seed size and crop environment, and consequences for predation risk

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Seed losses due to predators can be huge and can strongly affect weed population dynamics. Seeds are most vulnerable to post-dispersal seed predators when exposed on the soil surface, but can enter the soil matrix via tillage or natural processes. The latter processes are important in no-till systems and in the period between seed shed and tillage in conventional systems. Here, we studied and quantified variation in seed burial as influenced by seed size and crop type, and estimated the potential consequences using a simulation model.

Between August and October of 2004 and 2005, sets of ceramic beads, resembling seeds in size and density, were scattered on the surface of two small arenas (25 cm Ø) inside crop plots in a cropping system experiment. Visible beads were counted immediately after application and twice per week thereafter. New sets of beads were applied as soon as most beads had disappeared from the soil surface. Generalized linear mixed regression models were fitted to counts of visible beads.

Beads were incorporated into the soil matrix in one of four ways: 1) fast incorporation immediately following dispersal, 2) gradual incorporation into the soil/litter matrix, 3) sudden disappearance due to rain, and 4) coverage by crop residue following harvest or by application of manure. The bigger the seed, the longer the duration of residence on the soil surface. Both the instantaneous loss from the soil surface following dispersal (I), and the subsequent gradual burial of beads (b), decreased from forage crops to small grain cereals to corn and soybean. If seed shed commences at the same time, the duration of seed exposure to seed predators is potentially longer in corn and soybean than in the other crops. In contrast, seed removal by predators was shown to be higher in forage crops than in row crops. Combining crop-specific seed shed, seed burial and seed predation patterns for *Setaria faberi* (giant foxtail) into a simulation model resulted in high estimates of predation rates of *S. faberi* in corn, soybean and alfalfa (approx. 60-65%), but considerably lower rates in triticale (35%).

Seed characteristics interact with crop environments to create distinctive predation risks. The fact that seed availability differed among crop environments suggests that it can be manipulated to maximise predation risk. However, additional research is required to identify which soil and crop characteristics should be targeted.

Factors affecting the spatial distribution of *Sorghum halepense* in maize fields

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This study describes the distribution patterns of *Sorghum halepense* populations present in 38 commercial maize fields located in three major maize growing regions of Spain. A total of about 232 ha were visually assessed from the cabin of a combine during harvest. The data collection system involved a differential geopositioning system (DGPS) receiver with Omnistar correction, and a rugged pen computer with a program specifically written for this application. The software could assign three categories based on visual assessments of *S. halepense* infestation levels: 0 for areas without plants; 1 for areas with an estimated density of 1 to 7 plants m^{-2} ; and 2 for areas with more than 7 plants m^{-2} . Thus, the data files included the DGPS coordinates and the value selected by the operator in each moment (x , y , *infestation level*). Characterization of weed patches consisted in assessing their area, perimeter and projection in the direction of tillage as well as in the perpendicular to tillage. Patch anisotropy was studied by comparing the projection in the direction of tillage and the projection in the direction perpendicular to tillage. Information on whether the patches were adjacent to field margin (either parallel or perpendicular to the direction of tillage) or away from the margin was also collected. Finally, relationships between some important independent variables related to cropping systems or management practices and a dependent variable (abundance of *S. halepense*) have been tested.

The results showed a higher proportion of infested area with low density than high density of *S. halepense*, with average values of 11.4% for level 1 and 4.7% for level 2. However, important differences were observed between fields, with infestation rates ranging between 0% and 50% in both infestation levels. With respect to the spatial distribution of *S. halepense*, most of the infested area was concentrated in a few large patches with irregular shape, while small patches ($<1,000 \text{ m}^2$) represented only 27% of the infested area. Agronomic management seems to be the main factor explaining the spatial distribution of *S. halepense* in the studied fields. Among them, tillage was the most important variable affecting the patch shape: the length-to-width ratio of patches was >2 in the tillage direction. On the other hand, higher levels of infestation were observed close to the sprinkler lines in sprinkling irrigated fields. Regarding the location of patches within the plot, zones near the field margins had a higher risk of infestation than zones in the middle of the fields: *S. halepense* infestation decreased with increased distances to the field border.

Because a few patches, located in some predictable zones, represent most of the seriously infested area, site-specific treatments of these zones could reduce herbicide inputs until more reliable and precise detection and mapping systems become available.

Weed functional traits on the Broadbalk long term experiment

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The Broadbalk long term experiment at Rothamsted research was set up in 1843 and includes continuous winter wheat plots that have never received herbicide and have different fertiliser treatments. The plots now have contrasting weed communities adapted to the different soil conditions dominated by autumn germinating annual species including a number of national rare weeds. Annual weed surveys have been done on these plots since 1991 to record weed community dynamics and biomass samples were taken in 2004 and 2009 to quantify the relative proportions of species on each plot. As part of the latter sample, plant functional traits were also measured on the weeds. These were; maximum height, specific leaf area (SLA), leaf nitrogen content and leaf dry matter content (LDMC). Data on seed size were also obtained from the seed database held at Kew Gardens, UK. These data were used to analyse the shifts in the abundance of functional traits across the fertility gradient using the values for the community weighted means (CWM). For perennial systems, the weight of evidence suggests that plant community assembly in environments with contrasting fertility is driven by leaf traits that mediate a trade-off between resource acquisition and conservation. These trends were not evident in the annual weed flora on Broadbalk; community weighted means for SLA and LDMC showed no response to the fertilizer treatments. However, significantly positive and negative trends were observed for the CWM of height and seed mass respectively as fertility increased. These data were used to support the hypothesis that weed community assembly on Broadbalk has been driven by suites of traits that determine the relative ability to capture above and below ground resources.

Impact of energy cropping systems on weed flora composition: effects of new crops and crop rotations

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Energy cropping for biogas production has the greatest impact on regional net product and implies the strongest modifications in regional land use compared to other green energy technologies. Biomass production creates many new options within the existing land use systems. Examples include: new crops or crop mixtures can be grown, new crop rotations can be used and harvest dates can be modified. However, in agricultural practice, these novel options are hardly used. Biogas production is based on mainly one crop: maize, which is grown partly in monocultures and regionally with high shares.

The objective of the “EVA”-project is the promotion of cropping options for energy crops under different environmental conditions in Germany through comparisons of their economic, ecological and energetic effects. Additionally, solutions should be highlighted, which are “optimised” in relation to the three target variables. As one part of this project, effects of different crops and crop rotations on weeds were quantified with on-farm field experiments in three important agricultural regions in Germany. In each region five energy crops were investigated. The energy crops were selected according to their growing period and crop stand architecture. The resulting data were used to feed a habitat model, based on crop dynamics and architecture to assess crop and crop rotation effects. Among the new crops, special regard was given to sorghum crops for biogas use. Assessments on novel crop rotation alterations focused on the potential increase of maize or related crops, the re-introduction of perennial grasses and the effects of bi-cropping systems.

We found that the effects of new energy crops on weed composition are carried by dynamic and structural traits of the crop. Modifications within weed flora composition are related to changes in the vegetation period, harvest dates and the crop stand architecture. Hence, sorghum crops have habitat functions similar as maize crops, differing mainly in: i) the at least 3-4 week delayed sowing time and ii) a higher crop density and more intense shadowing. The increasing share of maize and similar crops within crop rotations benefits weed species which flower in late summer, species which prefer higher temperature. Weed species of the *Polygonaceae* family benefit specifically. While early summer species, like *Asteraceae*, we be restricted. Including perennial crops into the crop rotation favors perennial weed species, early summer flowering species and especially species of the *Asteraceae* family. Due to the early harvest of the primary crop, bi-cropping systems affect first of all the early summer flowering therophytes and may impede their seed ripening. The secondary crop has a similar species composition but different dominance structure as maize. The implications of these changes will be discussed for weed control purposes as well as for ecological functions of the weed flora.

FLORSYS: a mechanistic model of cropping system effects on weed flora based on functional relationships with species traits

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Models quantifying the effects of cropping systems on weed life-cycles, in interaction with environmental conditions, are invaluable tools to evaluate and design integrated cropping systems. In the past, we have developed such a model called *ALOMYSys* for a single grass weed species. The objective of the present paper was to extend the *ALOMYSys* model to a multi-specific weed flora. The present paper presents the structure of the new model called *FLORSys* and, particularly, the innovative modelling approach for parameterising such a complex model for numerous and contrasting species.

The generic structure of the model was developed by studying a few model plants (e.g. *Alopecurus myosuroides*) in detail. Mechanistic functions were established to describe each individual process. The seed bank distinguishes dormant vs. non-dormant seeds distributed over 30 cm. Seeds die over time. Dormancy depends on season, seed age, depth and prior stimulation by light. Non-dormant seeds germinate after seed shed, rain or tillage. Germinated seeds die without emerging if they were buried too deeply, if the soil dries after germination or if their shoot is hindered by soil clods. After emergence, both weed and crop seedlings are placed on a 2-D sample map. Plants are represented as tubes of varying heights and diameters. Each day, the light available in each point of this 3-D canopy is calculated, followed by light interception and biomass accumulation. The phenology of each plant is simulated with a degree-day model to determine when the first seeds reach maturity. Seed production is then calculated as a function of plant biomass. New seeds are shed onto soil surface during natural seed release or during plant-destroying management operations.

Crop rotation and management interfere with the different processes. For instance, tillage (including mechanical weeding in crops) moves seeds between soil layers, depending on the tool, tillage depth and soil structure; it also exposes seeds to light and stimulates their germination if the soil is sufficiently moist; lastly, it destroys and damages germinated seeds and emerged plants, depending on the tool, tilling depth and speed, plant size and location, as well as soil moisture. Other cropping system components are crop species and variety, sowing date, density and inter-row width, herbicide applications, mowing as well as harvesting operations.

In a second step, relationships for predicting model parameters were established by studying experimentally a limited number of contrasting and representative weed species. If possible, functional relationships between parameters and species traits were used. For instance, the seed mortality rate was predicted from the seed coat thickness and potential pre-emergent shoot length was correlated to the species seed mass. Otherwise, more general information available in data bases was used. For instance, base temperature could be related to the soil temperature averaged over 30 years during the ten days preceding the usual emergence onset

period (e.g. beginning of March for *Polygonum aviculare*) provided by a database. New weed species can now be easily added to FLORSYS by simply measuring the species trait (e.g. seed coat thickness or seed mass) or collecting information from data bases (e.g. usual emergence onset period).

The authors are now evaluating FLORSYS by comparing its simulations to independent observations from greenhouse and field experiments. FLORSYS will then be used by scientists and extension services to design environmentally-friendly cropping systems for weed control.

SESSION 4
WEED ECOLOGY

Poster presentations

Session organizers:

Lammert Bastiaans & Euro Pannacci

Influence of crop rotation, fertilization and pesticide use on weed infestation, yields and resource efficiency

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Since 1998 a long term field trial regarding different crop rotations, application of nitrogen fertilizers and pesticides are conducted at the JKI - Dahnendorf experimental station. The station is located in the state of Brandenburg (Germany) about 50 km South-West from Berlin. The annual average temperature was 9.5 °C and precipitation was 584 mm (mean of the last 12 years) with prolonged dry periods at the end of spring and in early summer.

The field trial contains two crop rotations

- a** peas – winter barley – winter rye – white clover (fallow) - winter barley – winter rye
- b** continuous cropping of winter rye.

In both crop rotations the experimental treatments are:

- 1** no fertilizers - no pesticides
- 2** no fertilizers - with pesticides (herbicides, fungicides, insecticides)
- 3** with fertilizers (100 kg N/ha aside from peas and with clover) - no pesticides
- 4** with fertilizers (same as 3) - with pesticides (same as 2, but also application of

growth regulators).

The influence of the crop rotation regarding the weed infestation was strongest for treatment **1** and declined with fertilizer and pesticide use, e.g. from 55 plants/m² *Matricaria spp.* in treatment **a1** to 3 plants/m² in treatment **a4**. Continuous cropping of winter rye **b** promoted *Vicia hirsuta* and *Cirsium arvense* while crop rotation **a** caused more *Matricaria spp.* The difference in weed infestation between crop rotation **a** and **b** decreased with nitrogen and pesticide use. In the treatment **4** only small difference was found between the two crop rotations **a** and **b**.

The yield of winter rye at treatments **a1** and **a2**, 5.2 and 6.6 t/ha respectively, was much higher than in treatments **b1** and **b2**, 4.5 and 4.9 t/ha respectively. In treatment **4** no relevant yield difference between the crop rotations **a** and **b** (i.e. 8.7 and 8.8 t/ha, respectively) was found. That indicates an increased importance of crop rotation while nitrogen fertilization and pesticide use is limited like in treatments **1**, **2** and **3**.

The resource efficiency assessed as net energy output (GJ/ha) was higher for treatments **a1**, **a2** and **a3** than for **b1**, **b2** and **b3**, while in treatment **4** nearly no difference was found (i.e. 123.7 to 124.5 GJ/ha, respectively).

The impact of crop rotation to weed infestation and yield was highest if no fertilizer and pesticides were used. These rotational impacts weakened for the usage of nitrogen fertilization and pesticide use. Regarding winter rye the continuous cropping **b** is still comparable to crop rotation **a** but only for the treatment **4**.

Can weed seeds avoid predation by harvester ants?

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During the last three years, many studies have indicated that harvester ants (*Messor barbarus*) are responsible for harvesting and destroying almost the entire seed production of weeds in dryland cereals under direct drilling in North-eastern Spain. The presence of ants is favourable because it may allow for a reduction in herbicide use that may result in 1) a reduction of costs, 2) a reduction in the environmental burden caused by herbicides, and 3) it may favour diversity in agro-ecosystems. Despite the presence of harvester ants, certain weeds continue to persist in high densities in dryland fields and can pose a threat to cereal production. An important mechanism is de-synchronous timing of weed seed shed.

The timing of weed seed shed has been determined using so called “seed traps”. The seeds of major and rare weeds were collected in 36 points of three fields, one in the area of Agramunt and two (i.e. “Border” and “Virus” fields) in Villanova de Bellpuig, in 2009. The traps were placed in 9 transects, with four traps per transect, and exposed during 8 weeks. We hypothesized that weed seed predation on the soil surface was significant and we used the scenario without seed burial. Seed shed was variable in time and among fields. When expressed as numbers of seeds per m², estimates of total seed production were 89327 in Agramunt, 49 in “Border” field and 55 in “Virus” field. The high seed production in Agramunt was related to the dominant weed species *Papaver rhoeas* and *Bromus diandrus* compared with “Virus” and “Border” fields in Villanova de Bellpuig. Peak seed production occurred on 17 June in Agramunt, and 21 May and 4 June in “Border” and “Virus” fields respectively. The cereal harvesting in Agramunt significantly increased seed shed on 22 June. The total weight of the produced seeds were 62 g/m² in Agramunt, 0.13 g/m² in “Virus” field and 0.12 g/m² in “Border” field. Peak seed weight was on 17 June in Agramunt and on 11 June in “Virus” and “Border”. Seasonal patterns of the proportion of seed predation were similar in all fields: high in April, May and June and lower after harvest. The ranking of weed species changed over time. However, *Bromus diandrus*, *Lolium rigidum* and *Papavers* seeds suffered less predation. This research may yield practical tools to optimize the functioning of natural weed control through seed predation and to manipulate weed species composition. Weeds may avoid seed predation by shedding during periods of low ant activity, such as in late summer or winter.

The competitive ability of some rice varieties on barnyardgrass (*Echinochloa crus-galli* (L.) P. B.)

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Weeds are the most important constraint in rice production, causing considerable yield losses depending on weed species and rice cultivars. The use of herbicides were intensive control methods since past three decades in many countries, but herbicides resistance in weed and their adverse effects on the environment has been main concern in last years. For this reason, it is important to find alternative and sustainable weed management methods. Variation among cultivars in their ability to compete with weeds is raising interest for many crops. The development of competitive rice cultivars would provide a safe and environmentally tool for integrated weed management.

Field experiments were conducted in 2007 and 2008 Black Sea Research Institute experimental area in Samsun. The field was prepared using the standard practices for drill-seeded rice recommended in the region. Five popular rice cultivars including Osmancik, Koral, Negis, Kizilirmak and Karadeniz were used in competitions experiments. After *E. crus-galli* was broadcast, rice cultivars were drill-seeded to a depth of 4-5 cm. Plots were 3 m wide by 4 m long rows. Experimental plots were arranged in a randomized complete block design with four replications. The actual seeding rate was adjusted for each cultivar to account for differences in seed weight and viability. The initial densities of rice cultivars and *E. crus-galli* were recorded at 15 DAE and target densities of *E. crus-galli* were arranged as 5, 10, 20, and 30 plants/m². At the end of experiments, the effect of different densities of *E. crus-galli* was determined on rice grain yield, seedling growth, leaf area, tillering number, plant height and root weights. Data were subjected to ANOVA, and means were separated using the LSD test.

Data from both seasons have clearly shown the effects of different rice varieties on suppressing *E. crus-galli* was variable. The cultivars by different densities of *E. crus-galli* interaction were significant. Regression models of rice yield in function of *E. crus-galli* densities indicated a linear relationship for all cultivars. Kizilirmak rice yield was more negatively affected by increasing *E. crus-galli* densities than other cultivars. Yield reduction with *E. crus-galli* density of 20 plants/m² was 9.0% in Koral, 12.5% in Negis, 23.1% in Osmancik, 23.8% in Kizilirmak and 38.3% in Karadeniz. Root weights of cultivars were similar across the cultivars. Koral was taller at maturity than the other cultivars. These cultivar was the most suppressive cultivar among them for grain yield, seedling growth, leaf area, tillering number, plant height and root weights.

Our results shown that taller cultivars are more competitive with *E. crus-galli* than short cultivars.

*This project was supported by TÜBİTAK- TOVAG (106O307)

Evaluation of a two-parameter model for prediction of corn yield loss under different redroot pigweed densities and irrigation regimes

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The relative leaf area of weeds is a good predictor of the outcome of weed-crop competition. A two-parameter model [$Y_L = ((qL_w)/(1 + ((q/m) - 1)L_w))$] was taken by basing yield loss estimates on relative weed vigor, measured as leaf area. A field study was conducted during May to October 2008 at the Agricultural Research Station of Shiraz University. The experimental plots were designed according to split plot and each treatment was replicated three times. Six weed densities (0, 10, 20, 40, 60, and 80 weeds m⁻²) and three different irrigation regimes were selected: T1= increasing soil moisture content in root depth to field capacity, T2=T1+25% and T3=T1-25%. Irrigation interval was 10 days for all treatments. Pigweed leaf area was measured at 6 and 8 weeks after planting (WAP). Results revealed that corn grain yield loss varied with weed density and irrigation regime. Values of the relative damage coefficient of weeds (q) were smallest in T2 irrigation regime (0.58 for 6WAP and 0.86 for 8WAP) compared with T1 and T3. The predicted maximum yield loss values (m) varied between 0.55 to 0.70 for 6WAP and between 0.57 to 0.66 for 8WAP on the basis of irrigation regime and weed density. Corn yield loss increased linearly as pigweed relative leaf area increased. In conclusion, the early observation of pigweed relative leaf area could be used as an adequate predictor of corn yield loss (r^2 varied from 0.91 to 0.96) and the precision of the predictions was not influenced by the leaf area sampling dates.

Weed seed consumption by adult and larval carabid beetles of *Amara* (Coleoptera: Carabidae)

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Many carabid beetles (Coleoptera: Carabidae) are known to feed on plant seeds, but the level of specialization on this food differs. Data on consumption capacities of individual carabid species and their stages are scarce. This is the first study in which seed consumption is assessed for all larval instars and adults of ground beetles.

Three species of *Amara* with syntopic occurrence, *A. aenea* (DeGeer), *A. familiaris* (Duftschmid) and *A. similata* (Gyllenhal) were examined. Larvae of all three instars (i.e. L1, L2 and L3) and adults were fed seeds of either *Stellaria media* (L.) Vill., *Capsella bursa-pastoris* (L.) Med. or *Taraxacum officinale* Wick. ex Wigg. for three days in a laboratory (no-choice consumption experiment).

In all species seed consumption varied with diet, although *A. aenea*, the most omnivorous species, consumed all offered seed diets in all life stages. All three larval instars of granivorous *A. familiaris* almost exclusively fed on seeds of *S. media* and the adults also ate significantly more of this than other seeds. *A. similata* consumed mostly seeds of *C. bursa-pastoris* in the first instar and adult stages, whereas the larvae of the later instars seemed to be unspecialized on particular seed diet. Differences in seed-specific consumption between larval instars in granivorous carabids are reported for the first time. In general seed consumption increased with instar. The overall daily seed consumption pooled across species of carabid and seed was on average (mean \pm SE) 0.7 ± 0.1 in L1, 4.5 ± 0.4 in L2, 13.1 ± 0.8 in L3 and 13.7 ± 1.1 in adults; the daily seed consumption by the older larvae was therefore comparable by that of the adults (see table).

We suggest that larvae may be important consumers of seed in the field and should not be forgotten when seed predation is assessed. However, a simple linear extrapolation of seed consumption in the field based solely on carabid population density (as estimated in the field) and known individual seed consumption rates (as estimated in the laboratory) should be treated with caution as field conditions are complex and variable (e.g. weather, physiological variation etc.).

Supported by CSF grant # 526/09/1436.

Weed seed predation in sugarbeet

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Limiting weed seed input will eventually result in seed bank reductions, which can have a strong regulatory effect on weeds population dynamics. Seed input can be limited via increased seed mortality. Crop phenology influences the activity patterns of seed predators as well as the phenology of weeds, causing crop-specific seed mortality rates. We hypothesized that more seeds would be predated in late harvested sugarbeet than in early harvested small-grain cereals, for which data are already available.

We measured seed removal in two sugarbeet fields in 2001 and one sugarbeet field in 2002, using series of seed cards, each containing 30 *Chenopodium album* seeds, from July/August till crop harvest in September/November. Weed seed shed was measured in 2002, using seed traps.

The rate of seed removal was low in July and August and increased gradually up to harvest. This pattern was crop-specific because consistent over fields and years. However, there was a large difference in the level of predation between the years, which was probably caused by high weed seed production in 2002, which caused satiation of seed predators. The timing of seed production differed enormously between weed species. The peak in seed shed preceded the peak in seed predator activity by approximately 20 to 60 days, which is very different from the situation in small grain cereals. Vertebrates were responsible for almost all seed losses.

Assuming equal predation rates among weed species, the estimated total seed loss per year will vary from 0.26 to 0.83 between species. The variability is entirely caused by differences in weed phenology (timing of seed shed) and seed size (duration of seed exposure on the soil surface). Seed preference, which was ignored in the estimation, may cause additional variability between species. Predation risk was highest for early maturing weed species with large seeds (> 3 mm) that were exposed for a long time, and smallest for early maturing weed species with small seeds (<1.5 mm) that were buried more rapidly.

Although weed phenology has been studied extensively, very little is known with respect to the timing of seed shed, signifying a huge gap in our knowledge of weed ecology. As hypothesized, the sugarbeet crop provided better temporal overlap between predator activity and weed seed production, resulting in potentially higher seed losses than previously reported for small-grain cereals, maize or soyabean.

Effects of municipal waste compost, manure, and fertilizer on growth and competition of weeds with corn

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Field experiment was conducted in 2008 at the research field of Agricultural College of Shiraz University, Shiraz, Iran to investigate the effects of urban waste compost, manure and fertilizer on competition of weeds with corn. Experimental design was split plot factorial with 3 replications. Main plots were weedy and weed-free, sub-plots were nitrogen fertilizer (0 and 200 kg N ha⁻¹), and sub-sub-plots were factorial application of municipal waste compost (0, 25 and 50 t ha⁻¹) and manure (0, 25 and 50 t ha⁻¹) with all possible combinations. Results showed that highest corn grain yield was obtained from weed free, 200 kg N ha⁻¹, 50 t compost and manure ha⁻¹, which had no significant difference with weed free, 0 kg N ha⁻¹, 50 t compost and manure ha⁻¹ and weed free, 0 kg N ha⁻¹, 50 t compost and 25 t manure ha⁻¹. The lowest grain yield was obtained from weedy plots without organic or inorganic fertilizer that had no significant difference with weedy plots, 200 kg N ha⁻¹, 50 t compost and manure ha⁻¹. *Convolvulus arvensis*, *Malva sylvestris* and *Amaranthus retroflexus* were the dominant weeds species. *Amaranthus retroflexus* had maximum dry weight. Maximum weed dry weight was obtained from 200 kg N ha⁻¹, 50 t compost and manure ha⁻¹. There was a highly significant correlation between corn grain yield and weed dry weight ($r = 0.72$). Corn leaf chlorophyll content was higher in both organic and inorganic fertilized treatments than unfertilized treatments, and also higher in the weed free treatments than weedy treatments.

Stepwise analysis of safflower seed yield and its components under different redroot pigweed densities and irrigation regimes

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A field experiment was conducted in the 2008 growing season at the experimental farm of the College of Agriculture, Shiraz University, Shiraz, Iran, to evaluate the effect of redroot pigweed (*Amaranthus retroflexus*) density and irrigation on safflower (*Carthamus tinctorius*) seed yield. Treatments included: five weed densities (0, 3, 6, 9 and 12 plants m⁻²) and three irrigation levels (100, 75 and 50% of field capacity, FC). The experimental design was split plot with irrigation and weed density as main factor and sub-factor respectively.

Stepwise regression analysis showed that the number of head plant⁻¹ explained 87% and 88% of the variations in seed yield at 100 and 75 percent FC irrigation levels respectively. On the other hand, at 50% FC treatment, biological yield (measured as dry matter per unit area) explained 88% of variations. It appears that increasing drought stress level from 100 to 50% FC, may cause increased stimulation of remobilization of assimilates from stems and other vegetative organs, thereby resulting in better contribution of biological yield in seed yield. With increasing weed density from 0 to 3 and 6 plant m⁻², the relative importance of head number plant⁻¹ as a variable contributing seed yield increased (partial R²=0.97, 0.77 and 0.72 respectively). The order of contributing variables in seed yield was changed with increase in weed density and consequently seed number head⁻¹ had a more significant effect on seed yield at 9 and 12 weed m⁻² respectively with partial R² of 0.98 and 0.92. Pearson correlation results revealed that seed yield had positive correlation with head plant⁻¹ (r = 0.80), seed head⁻¹ (r = 0.73), 1000 seed weight (r = 0.46) and biological yield (r = 0.87).

Effects of drought stress on water relations of safflower under different redroot pigweed densities

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In order to evaluate the effects of drought stress on water relations of safflower (*Carthamus tinctorius*) under different redroot pigweed (*Amaranthus retroflexus*) densities, an experiment was conducted at the research station of the College of Agriculture, Shiraz University in 2009. The experimental design was split plot with three levels of drought stress (100, 75 and 50 percent of field capacity) as main plots and four levels of weed density (3, 6, 9 and 12 plants m⁻²) as sub-plots. Results showed a significant reduction of safflower water use efficiency under weedy condition. With increasing weed density, percentage of water applied per unit area increased however per capita rate of water consumption of pigweed decreased significantly. In each drought stress level, safflower water use efficiency decreased with increasing weed density. Both pigweed biomass and safflower seed yield showed a significant decrease as drought stress level was increased.

Weed seed predation as influenced by tillage

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Given increasing prices for pesticides, ever lower availability of active substances and increasing numbers and spread of herbicide resistant or tolerant weeds, alternative weed management options are needed. Weed seed mortality due to predation can have a strong regulatory effect on weeds population dynamics. Seeds can be eaten by ground beetles, birds and rodents.

The aim of the study was to investigate the effect of tillage intensity on weed seed predation. The study was conducted at two sites in northeastern Germany during autumn 2008. Seed cards containing forty seeds of *Lolium multiflorum* were exposed to predators in square areas (10 by 10 m), which were positioned in field strips that had been either ploughed, shallow tined, or no-till. Seeds on the cards were counted every other day over a period of 16 days. Half the seeds on each card had been boiled to prevent germination. Seed predation over time [removed seeds card⁻¹ 2 d⁻¹] was described and parameters quantified.

Seed consumption accumulated over 16 d was variable between treatments (15 – 97%) and fields (23 – 45%). In field 1, seed predation was negatively correlated with tillage intensity, while in field 2 the correlation was almost positive. The difference in response could be related to the tillage history of the fields; all of field 2 had been ploughed annually, whereas the strips in field 1 not. The difference in predation from cards with and without enclosure cage indicated that predation by vertebrates was negligible, except in field 1 where seed predation by rodents was substantial in no-till and shallow tined strips. Multiple years of low or no tillage and higher winter wheat coverage could have attracted the rodents. In field 2, ground beetles activity-density was three times higher than in field 1. Possibly, the density of beetles was really higher or the lower food density forced the beetles to increase mobility. Invertebrates strongly preferred boiled seeds in field 1. Boiling softens the seeds after which they may be easier to handle and consume. In field 2, seed predation was too low to detect significant differences. Vertebrates showed no preference at all. A GLM (generalized linear model) analysis of seed predation resulted in R² of 0.15 (site and boiling accounted for) and 0.40 (site, boiling and tillage method accounted for) for cards with and without cages, respectively. A logistic model yielded parameters estimates for intensity of predation and the time required by predators to find the seed cards.

The results suggest that tillage regime can influence weed seed predation and should be taken into account when designing more sustainable weed management strategies.

Allelopathy of some weed species influenced by environmental conditions

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Most spreading, difficult to control weeds seem to be allelopathic and it is supposed to play a determinant role in their excellent competitiveness. However, the real role of allelopathy is controversial in the competition of plants and in non-herbicidal weed management methods. One of the main reasons of antinomic estimation of allelopathy is its changeability: the allelopathy of plants or microorganisms is expressed in different degrees and manners in several experiments. The allelopathy of several weed species influenced by environmental factors (e.g. water supply, nutrition, temperature) has been studied. The aim of our experiments was to find out the real effects of these factors on allelopathy.

Weeds (*Xanthium italicum*, *Datura stramonium*, *Abutilon theophrasti*, *Ambrosia artemisiifolia*) were grown under controlled conditions at several levels of water supply and nutrition in greenhouse. Samples were collected at 4-5 leaves stage, then were dried and ground. Bioassays were conducted in a Hotpack illuminated chamber at two levels of temperature (10°C and 20°C), test plants were *Lepidium sativum*, *Zea mays* and *Helianthus annuus*. Measurements of some allelochemicals (2-phenylpropionic acid, 4-hydroxybenzoic acid, trans-4-hydroxy-3-methoxycinnamic acid, p-coumaric acid, trans-cinnamic acid, chlorogenic acid, coumarin) in weed samples were made by a Merck-Hitachi HPLC apparatus.

The studied factors had significant effects on allelopathy observed on test plants; however, results depended on either donor or test plants. In most cases shoot extracts had stronger inhibitory effects than root extracts. The drought stress of donor plants caused stronger inhibitory effects in cases of all weed species. The level of nutrition could also modify allelopathy. In case of *X. italicum* (as donor plants) a higher level of nitrogen supply increased allelopathy on test plants, and the strongest inhibitory effect was observed when drought stress and a higher level of nitrogen supply were combined. Inhibition became stronger at low germination temperature in case of maize, but cress and sunflower did not show enhanced sensitivity against extracts. The quantity of allelochemicals changed in samples of weeds grown with several water and nitrogen supply, but clear relation with those factors was not observed. Timing of sample collection in a day also had significant effect on the quantity of allelochemicals.

Some conditions may have significant effects on allelopathy, so if they are taken into consideration in allelopathic research methods, they may contribute to getting more accurate results in that area. A uniform methodology including some environmental factors may make the experiments more reproducible, but it must be based on the knowledge of main factors affecting allelopathy.

Effect of cutting management on spectrum and abundance of pre-dispersal seed predators in *Cirsium heterophyllum* flower heads

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Melancholy thistle (*Cirsium heterophyllum* (L.) Hill.) is considered as an ecologically important species, but also as a weed in wet meadows. It usually dominates localities with high level of ground water and in flooded areas, where it is an important component of so-called “wet *Cirsium* meadows”, included in the Natura 2000 Networking Programme. It is also a highly competitive perennial weed in extensively managed meadows and pastures, where the clonal colonies of *C. heterophyllum* can decrease forage quality considerably. The melancholy thistle supports a rich and diverse fauna of insect herbivores and associated predators and parasitoids. Pre-dispersal seed predation is one of the significant factors causing seed mortality directly on the mother plant and consequently preclude dispersion of thistles on new localities. The main question addressed here is which type of grassland management fosters occurrence and abundance of pre-dispersal seed predators, utilizing thistle flower heads for their growth and development.

In total, 300 flower heads from 300 randomly chosen *C. heterophyllum* plants were collected in an upland meadow “Pralouka” in the “Jizerské hory mountains” (Bohemia borealis, Liberec env., 50°48'N, 15°21'E, altitude 895 m a.s.l.) at the beginning of July 2008. Three different grassland managements have been applied since 1998: (C0) no cutting; (C1) cutting in July every year and (C2) cutting in July every second year. Complete and ripe flower heads were taken from the plants and put in paper bag separately, and stored under laboratory conditions (25°C, 40% relative humidity). The diameter of the receptacle and length of the bract of each flower head were measured two months after collecting. Consequently presence, number and species of pre-dispersal seed predators and associated parasitoids were recorded (parameters: prevalence, intensity and abundance).

The type of management affected flower head size and seed number in all seed categories (healthy, damaged and undeveloped seeds). There were no significant differences between both cutting treatments in flower head characteristics. On the contrary, the (C0) treatment had significantly bigger flower heads. The type of management did not affect the prevalence of pre-dispersal predators (87% of flower heads attacked in average). Seeds were destroyed by high parasitization and therefore generative reproduction potential was significantly reduced. The main groups of pre-dispersal predators in all three management strategies were Tephritidae and Cecidomyiidae (Diptera), Curculionidae and Nitidulidae (Coleoptera), and Tortricidae (Lepidoptera). Cecidomyiidae and Nitidulidae were the dominant groups that seemed to be able to exclude other flower head-inhabiting species.

Preliminary results show that (C0) management may promote pre-dispersal seed predators in melancholy thistle via providing better sources for their development (bigger flower heads provide more food and more space for insect larvae). On the other hand, both cutting management strategies (C1) and (C2) can reduce dispersion of *C. heterophyllum* and consequently helps to prevent deterioration of forage quality.

Supported by the project No. 521/07/0978 of the Grant Agency of the Czech Republic and project No. CZ0002700604 of the Ministry of Agriculture of the Czech Republic.

Soil characteristics influence granivorous ant populations in dryland cereals

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Predation of weed seeds can be important as a tool in sustainable weed management. Harvester ants (*Messor barbarus* L.) are the main weed seed predators in semiarid dryland fields in north eastern Spain, however, ant nest densities and concomitant predation rates vary considerably across fields. Factors that influence ant nest density are largely unknown. The purpose of this study was to relate ant nest density in 42 dryland cereal fields in the Agramunt region, NE Spain, to edaphic, topographic and crop management factors, and to develop a model that will help to predict where harvester ants will be abundant and thus predation rates high. Ant nest densities were determined in 50 by 50 m areas in each of the 42 fields, of which 36 had been managed without tillage (NT) for a period of 1-25 years and six had been tilled conventionally (CT). Preliminary results indicate that the number of *M. barbarus* nests initially increased with the number of years of NT and peaked at around 12 years of NT. Certain soil characteristics, such as soil moisture content, percentage big stable aggregates (8 – 1 mm) and percentage organic matter, peaked at the same time. Other factors, such as altitude and percentage of coarse silt were negatively correlated with ant nest density. This preliminary analysis suggests that the highest densities of ant nests can be expected in low-laying fields with around 12 years of NT and a low percentage of coarse silt.

Weed suppression ability of three spring barley varieties at different plant density

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The competitiveness of the crop against the weeds is a very important parameter for the growth and propagation of the weeds. Increase of crop competitiveness ability may improve weed control without additional costs and negative influence on environment. One low cost cultural weed control option and important component of integrated weed management systems is to grow competitive crop varieties. The best weed suppressors were often the better yielding varieties. Barley cultivars that gave priority to height had a competitive advantage over those that allocated more resources to leaf growth. The suppression of weeds by increasing sowing density in cereals has been noted in a number of studies.

The influence of plant density on weed suppression and grain yield of spring barley varieties Aura DS, Barke and Gustav was investigated in two field trials conducted at the Lithuanian Institute of Agriculture in 2008 and 2009. The soil of the experimental site is *Endocalcary - Endohypogleyic Cambisol* loam. Conventional soil tillage was used. Spring barley was sown at 200 400 and 600 viable seeds per m². The preceding crop of spring barley in both years was spring wheat. Spring barley was sown in the second half of April with a plot size of 2.2 by 10.0 m. The plots were replicated four times and arranged randomly. Annual dicotyledonous weeds *Chenopodium album*, *Viola arvensis*, *Lamium purpureum* prevailed in the field.

The higher and significant differences in weed biomass were obtained between plots with 200 and 400 germinable seeds per m². The influence of increasing seed rate from 400 to 600 viable seeds per m² on weed biomass depended on spring barley variety. Differences in leaf area index (LAI) between seed rates depended on variety of spring barley. Significant differences between 200, 400 and 600 viable seeds per m² were found in spring barley var. Aura. Highest plants of spring barley were also of var. Aura. No significant differences in LAI were obtained between different plant densities of spring barley var. Gustav. The highest grain yield was obtained in spring barley of variety Gustav. Better indicator of competitiveness of spring barley against the weeds in our cases was plant height and LAI compare to grain yield of spring barley. Also plant density especially from 200 to 400 germinable seeds per m² had significant influence on spring barley competitiveness against weeds.

Importance of volunteer oilseed rape in winter oilseed rape stands

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When cultivating oilseed rape with specific requirements for ingredients and qualities, e.g., high contents of erucic acid, changed design of fatty acid etc., volunteer rape plants of previous crops with different characteristics are of concern. Seeds lost before and during harvest remain viable in the soil for a long time. Volunteer rape plants in a crop of oilseed rape seed are usually impossible to control. If the volunteers flowered or set seeds unwanted traits could be transferred via pollen to the rape crop, or the grain yield could be contaminated with undesired seeds. The risk for such contamination was investigated for volunteer oilseed rape plants developing within a crop of oilseed rape. Two types of field experiments were conducted from 2006 until 2009 at the experimental station of the Julius Kühn-Institut at Braunschweig.

In one test series (Experiment 1), the dynamics of emergence and growth of volunteer rape in a crop of oilseed rape were monitored. In artificial gaps in the crop from emergence until blooming stage, the infestation with volunteers depended on the seed rain from previous crops and on the duration of the cultivation break from rape seed. One to two volunteer rape plants per m² emerged under practice-usual cropping conditions. When the entire grain harvest of a previous crop of rape seed remained in the field about 10 volunteer plants per m² were found. After an extended break of cultivating rape seed of more than 10 years, only 0.1 plants per m² were detected. Most of the volunteer rape plants emerged simultaneously with the cultivated oilseed rape; both volunteer and crop plants developed similarly under these conditions.

In another test series (Experiment 2), volunteer rape seeds were sown at different times in relation to crop establishment into a crop of oilseed rape without artificial gaps to demonstrate the development of the volunteers under natural competition conditions. In this experiment, only volunteers developed to fruiting that were sown simultaneously or directly after sowing of the crop of oilseed rape. These volunteers produced fewer seeds per plant than the crop oilseed rape plants (volunteers: 1147 seeds/plant; crop oilseed rape: 3125 seeds/plant). Also, the germination rate of the volunteers was lower than for the crop oilseed rape plants (volunteers: 76%; crop oilseed rape: 90%).

In summary, the capacity of volunteers to emerge (Experiment 1) and the seed set of the volunteers (Experiment 2) allowed for contaminating the crop oilseed rape seed lots by volunteer rape seed to an intolerable extent.

Weed suppression ability of two winter wheat varieties as affected by sowing time

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Winter wheat sowing time is an important factor for grain yield and amount of weeds in the crop. The delay of sowing time reduced both indicators. At higher crop densities different crop varieties significantly reduced weed reproductive structures.

A field trial designed to compare the competitive ability of two winter wheat varieties against weeds sown at three dates was conducted at the Lithuanian Institute of Agriculture in the growing season 2008-2009. The soil of the experimental site is *Endocalcary-Endohypogleyic Cambisol*, pH 6.8, sandy loam. Winter wheat cultivars Ada and Zentos were sown at three successive 10 days' intervals from September 10 to October 1 at a rate of 400 viable seeds per m². The main parameters of winter wheat crop development, including biomass, were assessed during the growing season. Biomass, stem length, number of flowers per plant of weed species *Thlaspi arvense* and *Viola arvensis* were measured and evaluated in different winter wheat stands and in 3 plots 2x1 m in size without any crop. No weed control was applied in this experiment.

A delay of sowing time exerted a significant influence on the reduction of winter wheat stem length. No significant differences were found in grain yield between the tested cultivars. Early sown winter wheat produced the highest grain yield 7.0 t/ha for cv. Zentos and 6.6 t/ha for cv. Ada. A delay of sowing by 10 and 20 days decreased grain yield in average by 15 and by 20 percent compared to early sowing. Canopy height was taller in winter wheat cv. Ada than in cv. Zentos by 10 cm at early sowing date, and no height differences were found at later sowing dates. Leaf area was measured at growth stage BBCH 37 and 45 by WinFolia and leaf area index (SunScan) was higher for cv. Zentos. *Viola arvensis* biomass in winter wheat cv. Zentos decreased by 7-9 times and in variety Ada by 4-8 times, compared to weeds growing without a crop. The influence of sowing time on *Viola arvensis* biomass was not significant. Biomass, height and number of leaves of *Thlaspi arvense* plants consistently decreased with a delay of sowing time, and no significant differences were found between the plots with and without a crop.

Effect of plant height and relative time of weed emergence in relation to yield maintenance and weed suppression by *Rht* lines of winter wheat

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The Green Revolution in wheat led to higher yields and harvest indices especially associated with genes connected with straw shortening (*Rht*). How does straw shortening affect crop competitiveness against weeds? In addition, the *Rht* genes achieve their effect either by reducing sensitivity to gibberellins or by reducing production of gibberellin, and so time to emergence may be increased in such lines given the link between gibberellins and cereal seed germination.

Field experiments were carried out at Reading, UK in 2007/8 and 2008/9 growing seasons. Near-Isogenic Lines (NILs) of wheat varying for reduced height in a Mercia cultivar background (*rht* (tall), *Rht*-B1b, *Rht*B1c, *Rht*-8c +*Ppd*-D1a and *Rht*12 of wheat), were tested for competitiveness against weeds. In addition, high and low vigour crop seed was used in the second season to explore the effect of relative time of emergence in greater detail. The cultivated oat, *Avena sativa*, was used as a model weed so that different times of weed emergence relative to crop emergence could be achieved easily. To explore the dynamics of competitiveness, the oats were planted at various times of plant growth to investigate the impact of different times of weed emergence relative to the crop.

As expected, higher wheat yields were obtained as the time of emergence of the model weed was delayed relative to the time of emergence of the semi-dwarf wheat line, *Rht*-B1b, and the cv. Mercia. Greatest yield losses were, however, observed in the dwarf cultivars, *Rht*-B1c and *Rht*12, whereas much smaller yield losses were observed in the semi-dwarf *Rht*-B1b and in cv Mercia. In terms of weed suppressiveness, weed dry matter was maximised in competition with the dwarf *Rht*-B1c and *Rht*12 lines, whereas in cv Mercia and *Rht*-B1b, weed dry matter decreased as the relative time of emergence of the weed was delayed.

Acknowledgment: We are grateful to IRQUE Project funding at The Eastern University of Sri Lanka for a PhD Scholarship awarded to K. David-Harris.

Effects of soil pH on competitive ability and leaf nutrient content of corn (*Zea mays* L.), *Amaranthus retroflexus*, *Setaria viridis*

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In small plot trials which was appointed on the maize large field we searched for answer, what happened in the competitive ability of the maize, the dicotyledonous (*Amaranthus retroflexus*, AMARE) and the monocotyledonous (*Setaria viridis*, SETVI) weeds in relation to changes of the soil pH (7,3 pH Röjtökmuzsaj; 6.1 pH Sopronhorpács ;5,2 pH Horvátzsidány). We assigned homogeneous, well-established parcels in the mentioned three different large fields in 3 repetition. On the experimental fields the maize hybrid was the same one, with early maturity. Thus the treatments were the follow in the fields with different soil pH: 1) maize free from weeds; 2) maize + AMARE; 3) maize+SETVI; 4) maize +AMARE+SETVI ; 5) AMARE; 6) SETVI; 7) AMARE+ SETVI. There were three replicates of each treatment at each soil pH. Density of the weeds everywhere was 5 plants/m² which is above the critical density. Other weeds were removed from the plots by hand. Leaf samples were collected for nutrient analysis just after corn silking (2 leaves from 10 plants per treatment). After harvesting we measured the maize yield (t/ha) and the aboveground dry weight of the weeds for 10 plants (kg/m²). We measured the Ca, Mg, Mn, Zn /by atomic absorption spectrophotometry on a dry-ash extract / content of leaf tissue of corn and its weeds, the results were analysed with correspondence analysis, with NuCoSA software.

It was found that the competitive ability of the maize is not depend on the soil pH, but the yield of maize is decreasing by the effect of competition at all pH levels. Soil pH had little effect on the levels of Ca or Mg either in the presence or absence of competition. *Amaranthus retroflexus* had higher percentages of Ca, Mg and Mn in leaf samples at all soil pH levels than *Setaria viridis*. The Zn, Mn content of *Amaranthus retroflexus* leaves had higher levels at pH 5,2 than at pH 7,3. Level of Mg and Ca of *Setaria viridis* leaves decreased with decreasing soil pH, but levels of Mn and Zn increased. The maize leaf content of Ca, Mg decreased, Mn and Zn in the leaves increased with decreasing soil pH. It was found that the relative competitive ability of *Amaranthus retroflexus* and *Setaria viridis*, but not the maize is depend on the soil pH.

Lots of authors have demonstrated that in most cases reactions of plant following pH decrease are connected with increasing of the access to manganese and decreasing of the access to calcium. So, our results are consistent with literary attitude.

Evaluation of weed species diversity and community composition in various corn (*Zea mays* L.) and bean (*Phaseolus vulgaris* L.) intercropping densities

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The field study was conducted to evaluation the effect of various corn-bean intercropping densities on weed population during 2009 growing season at the Agricultural Research Station of Ferdowsi University of Mashhad, Iran. The experiment was set up in completely randomized blocks with three replications. The experiment compared 8 treatments: corn intercropping with bean at the common density of bean plus 10%, 20% and 30% increased in bean density, bean intercropping with corn at the common density of corn plus 10%, 20% and 30% increased in corn density and control treatments (sole crops of corn and bean). This experiment was conducted in a low input production system. To weeds and crops sampling, each experimental block be divided to equal part then weeds and crop measured at their parts, separately. Weeds sampling were performed at three stages: in the beginning, the middle and the end of growing season then weeds were counted in each quadrat and their dry weight was also determined separately.

The results indicated that intercropping treatments in comparison with sole cropping lead to reduce weeds damage. Increasing of crop plant density lead to formation of closer canopy and weeds total dry weight due to radiation interception by the crop canopy and less available light for the weed reduced. As the highest and the lowest of weed dry weight was related to the sole corn treatment (29.2 g m^{-2}) and in the bean intercropping with corn at the common density of corn plus 30% treatment (5.0 g m^{-2}), respectively. Corn and bean intercropping had significant effects on yield. The highest and lowest amounts of bean biological and economical yield were obtained in the sole cropping of bean with 5.3 and 1.6 t ha^{-1} and bean intercropping with corn at the common density of bean plus 30% with 2.7 and 0.7 t ha^{-1} , respectively. The highest amounts of corn biological and economical yield were obtained in the sole cropping of corn with 14.7 and 7.3 t ha^{-1} , respectively and the lowest for their in the bean intercropping with corn at the common density of bean plus 10% treatment with 7.8 and in the bean intercropping with corn at the common density of bean plus 30% treatment with 3.5 ton/ha , respectively. The highest (1.56) and the lowest (0.77) land equivalent ratio also was obtained in the intercropping of corn with common density of bean plus 10% treatment and in the intercropping of bean with corn at common density of corn plus 30% treatment, respectively.

Thus this work contributes to improve current understanding of how crop–weed communities are assembled and may help in developing weed management practices that are environmentally sound.

Using weed dynamics models for evaluating and designing integrated cropping systems

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Our aim is to propose a simulation-based methodology for evaluating and designing innovative cropping systems for integrated weed management. Using models instead of conducting experiments allows to explore numerous combinations of factors and to evaluate alternative management strategies *ex ante*, under a wide range of climate and soil conditions, without any constraints of space and time. Required tools are models simulating weed dynamics in cultivated fields as a function of cumulative cropping system effects, in interaction with environmental conditions. An example of these tools is the mechanistic model ALOMYSYS for *Alopecurus myosuroides* Huds. (blackgrass), an annual grass-weed frequently found in autumn-sown crop rotations. A methodology for designing and evaluating integrated weed management strategies was proposed, using blackgrass dynamics indicators simulated with ALOMYSYS and environmental impact indicators estimated with other models. The methodology was illustrated with case studies from a farm survey carried out in Côte-d'Or (France). Thirty-one farms were chosen, based on stratified sampling considering the production system (organic vs. conventional), the farming system (mixed crops vs. mixed crop-livestock farming) and the soil characteristics, in order to identify representative cropping systems accounting for various production constraints. For each system, a series of prospective scenarios was tested, aiming at controlling blackgrass at short and long term, with a reduced environmental impact. Selected indicators were (1) blackgrass seedling emergence, seed production, and viable seed bank in soil, (2) water pollution risks due to herbicide use, (3) energy consumption due to input manufacture and cultural operations, and (4) soil structure. The tested scenarios comprised no-till systems, the introduction of mouldboard ploughing and alternative crops into the rotation, delayed sowing dates, and replacing herbicides by mechanical weeding.

Results for conventional cropping systems showed that herbicides cannot be replaced solely by mechanical weeding for an efficient weed control. When mechanical weeding was combined with additional modifications, weeds were controlled as well as in the herbicide-based reference system. Weeds could only be controlled in no-till systems if a permanent cover crop was maintained below the crop and after harvest. Water pollution risks could be greatly reduced. Energy consumption was not as high as expected, particularly in organic systems, because of reduced herbicide and nitrogen use.

Using weed dynamics models for *ex ante* evaluation is an interesting way to produce a set of innovative cropping systems for integrated weed management, which will have to be tested afterwards in field condition before proposing them to farmers. The list of assessment indicators needs to be complemented by agronomical (e.g. diseases, yield), environmental (e.g. nitrate leaching) and socio-economic indicators (e.g. economic profitability, labour organisation). The methodology will be improved by using FLORSYS, the generic and multispecific update of ALOMYSYS, that allows evaluation on a wider range of weed species.

Competition between maize and *Sorghum halepense* (L.) Pers. in additive experiment

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Sorghum halepense is one of the worst perennial weeds in maize fields in Hungary. It can be found all around the world and is believed as a serious problem in 53 countries. Based on the data of the Fifth National Weed Survey *S. halepense* is on the 11th place in the dominance order of weeds. The aim of our trial was to study the competitive effect of *S. halepense* on the growth and yield of maize under field conditions.

In a field experimental trial the following nine treatments were compared: 1) untreated weedy control, 2) weed-free control, 3) hoeing once at 3-4 leaf stage of maize, 4) hoeing once at 6-7 leaf stage of maize, 5-8) 1, 2, 5 and 10 plants of *S. halepense*/m², 9) Motivell Turbo D (40 g/ha nicosulfuron+180 g/ha dicamba+640 g/ha bentazone+0,6 l/ha Dash HC adjuvant). At the flowering of maize the height of 10 maize plants was measured in each plots. Maize was harvested and representative yield-measuring was carried out. Data of plant height and yield were analysed statistically by an analysis of variance.

The maize height was lower by nearly 20% on the untreated weedy plots, as compared to weed-free control, the stem of the maize was thin and only a few maize-ears and tassels were seen at the time of the evaluation. A 10% decrease of maize height was measured on the plots infested by 10 plants of Johnson grass. The height of maize was significantly reduced on these plots as compared to the weed-free control. The highest yield loss was measured on the weedy plots, where the yield was half of that detected on the season-long weed-free ones. The yield was reduced by 38% and 35% on the experimental area infested by 10 and 5 of *S. halepense* plants, respectively. The efficacy of Motivell Turbo D for *S. halepense* control was excellent, no injury effect was observed. Neither herbicide treatment by Motivell Turbo D nor *S. halepense* at 1 and 2 plant density per m² reduced the yield. Smaller yield was harvested on the plots hoed at 6-7 leaf stage of maize compared to the yield of the plots hoed when the maize had 3-4 leaves. It means the longer weed infestation period causes higher yield loss.

Based on our results the post-emergence weed control is highly recommended. It should be carried out (either mechanical or chemical one) at 4-5 leaf stage of maize. No yield loss was caused by 1-2 *S. halepense* plants in one square meter so the weed control is not suggested from economical respect. On the other hand, as the control of *S. halepense* is expensive the best solution is to prevent the higher level infestation of *S. halepense* on the fields and to remove this weed when its density is only 1-2 plants on one square meter.

Competition between *Datura stramonium* L. and maize under field condition

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Jimson weed (*Datura stramonium* L.) can cause long-term problems for the farmers when it appears. Due to its aggressive growth and population expansion, it can entirely inhibit the growth of crops. In the country-wide surveys of the 12 most noxious weed species in Hungary (1986-1989), the presence of *D. stramonium* was detected on more than 150000 hectares. In terms of the order of dominance, it took the 7th place in maize in late summer, while it is the 9th most important weed on the summarized list of wheat-maize survey (Fifth National Weed Survey, 2007-2008).

The majority of agricultural competition studies are based on the additive experiments. In additive experiments two species are grown together, the density of the crop is maintained constant, while that of the weed species is varied. The aim of our experiments was to study the interaction between maize and *D. stramonium* in additive experiments. Small plot (15 m²) experiments in randomized blocks with three replicates were set up on Ramann brown forest soil with clay illuviation, at Keszthely (Hungary), in spring 2007. The treatments were the followings: 1) Untreated weedy control, 2) Weed-free control, 3) *D. stramonium* 1 plant m⁻², 4) *D. stramonium* 2 plant m⁻², 5) *D. stramonium* 5 plant m⁻², 6) *D. stramonium* 10 plant m⁻². Hand hoeing was continuously applied to maintain weed-free control plots. Plots of the treatments 3 to 6 were kept free from weed species – except *D. stramonium* – and weed density was also continuously checked. At the beginning of maize flowering (15 July) the height of 20 representative crop individuals were measured in each plot. Maize harvest happened on 21 September. The crop yield was calculated to the 14 % wet content for maize grains. Analysis of variance (ANOVA) was used to evaluate the results with an alpha-error of 5 %.

The height of maize was significantly reduced in all treatments as compared to weed-free control plots. The greatest (92%) yield loss was observed on weedy control plots, as compared to weed-free control ones. In the maize - *D. stramonium* competition studies the average yield proportionally decreased as the weed density increased. Intraspecific competition between *Datura* plants was not observed. *D. stramonium* at densities of 1, 2, 5 and 10 plants m⁻² caused a significant, 31, 43, 59 and 63% reduction of maize yield. Based on the results of similar experiments carried out in maize fields, *D. stramonium* is believed to be the second most aggressive weed species after *Xanthium italicum* and followed by *Ambrosia artemisiifolia* and *Abutilon theophrasti*.

Competition between grain sorghum and weeds during early growth along a water gradient

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Stressful levels of water availability influence weed-crop interactions and may interfere with or enhance weed control. The present study investigated competition under water stress during early growth, at two different nutritional levels, between an Ethiopian grain sorghum and three serious non-native weed species, which occur in the same environment. The weeds, *Parthenium hysterophorus*, *Verbesina encelioides* and *Tagetes minuta*, all belong to *Asteraceae* but differ in morphology.

Plants were grown individually and in pairs in pots in a greenhouse and after six weeks of growth, they were harvested and morphological characters were measured. Of the individually-grown plants, Sorghum plants were largest; *Tagetes* on average 70% of the weight of Sorghum, *Parthenium* 30% and *Verbesina* 25%. On average, Sorghum lost 13% of weight due to competition, *Tagetes* and *Verbesina* lost ca 30% and *Parthenium* ca 45%. *Tagetes* caused the largest loss on Sorghum weight, and *Parthenium* the least. *Tagetes* also reduced the leaf size and number of nodes on Sorghum. Root/shoot biomass ratio of Sorghum increased when competing with *Tagetes* or *Parthenium* and decreased when competing with *Verbesina*.

Despite significant overall competition effects both of weeds on Sorghum and of Sorghum on weeds, inherent differences among species and different responses to water and nutrient availability, the relative effect of competition on crop and weeds was not affected by nutritional levels or by the water availability treatment (100, 80, 60, 40 and 20% of the water holding capacity of the substrate). In conclusion, of the three weeds, *Tagetes* was the most serious early competitor with Sorghum, irrespective of water or nutrient availability treatment.

Observing invertebrate seed predators by infrared photography

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IR-photography was tested as a method for identifying night-active seed predators in the field. The study was conducted in a conventional cropped wheat field in northeastern Germany for a two week period in early summer. An IR-camera (Nikon D80 IR) and an IR lamp were placed 40 cm above the soil surface, attached to a laptop for camera control and image saving. Photos with an image area of ca. 3000 cm² were taken from 10.15 PM until 5.25 AM every 30 seconds. Photos were analysed manually by counting arthropods in an inner plant- and litter-free circle and in a surrounding circle that contained wheat plants. Both circles had an area of ca. 600 cm².

Depending on the experience of the observer and the number of invertebrates, it took two to five hours to analyse the 860 photos of a single night. Images of two nights (day 7 and 14) were not analysed because parts of the images were completely filled with ants that were busy transporting prey or because photos were missing. Seeds of *Lolium perenne*, *Brassica napus*, *Vicia tetrasperma*, *Thlaspi arvense* and *Chenopodium album* were offered on bare soil on a sand bed, whereby only the first three species were clearly visible under IR-light. Invertebrates were grouped in “large” (bodylength > 7 mm, mainly carabids) and “small” (mainly ants). In 12 nights, 332 large and 3699 small invertebrates were counted; of these 18 large and 1584 small invertebrates were observed in the center. The activity in the center was significant lower than in the outer circle (wilcoxon-test, $p < 0.01$), although it wasn’t clear whether this was caused by the fact that invertebrates avoided bare soil due to the lack of canopy cover or because of illumination by the IR-lamp. Invertebrate activity as determined by image analysis was highest in the first week of the study, which correlated well with activity as determined by pitfall-trapping. Activity during the night was highest between 11.00 PM and 1.00 AM and decreased towards sunrise. Seed predation was not observed. Nevertheless, IR-photography was useful at revealing or confirming patterns in predator activity. Manual image analysis is time-consuming; for long series of images, automated or semi-automated methods will be required.

Determining critical period for weed control in beans in East Anatolia Region of Turkey

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Dry beans have been produced over 100 000 ha area in Turkey although the area has decreased for the last decade. They are important cash crop in the East Anatolia Region of Turkey. Weeds are among limiting factors in bean production as in many other field crops. Hand weeding and hand hoeing are common practices due to smaller size of individual fields. On the other hand, chemical control is an option depending on scarce family man-power. Not only difficulties finding man-power but also saving energy require timely weeding and applying IWM (Integrated Weed Management), which is environment friendly and cost effective method in weed control. Critical period for weed control (CPWC) is an important element of IWM systems because timely application of control methods increases controlling weeds and decreases crop losses as well as helps for economical decisions. CPWC has been studied in many crops. It has not been reach a common conclusion for CPWC for a crop. So, there have been needs for further studies under varying conditions such as climate, soil, and management.

CPWC in dry beans under the conditions of East Anatolia Region of Turkey was studied in 2005 and 2007. Natural infestations of weeds were used. *Amaranthus retroflexus*, *Chenopodium album*, *Cirsium arvense*, and *Convolvulus arvensis* were the most common weed species. Beans were sown in late May and harvested in late September. Experiments were set in RCBD with four replications. The characters were 2, 4, 6, and 8 week weed free and 2, 4, 6, and 8 weeks weedy in addition to season-long weedy and season-long weed free plots. Beans harvested and dried. Relative yield for each character was calculated as a percentage of season-long weed free character. Relative yield data were subjected to ANOVA and non-linear regression analysis.

Effect of years on bean yield did not differ significantly. The effect of treatments was not depended on year but there was significant difference among treatments. Data of two year were pooled. CPWC was estimated using Gompertz equation ($\text{Relative Yield} = 103 * \exp[-1.05 * \exp(-0.62 * \text{Weeks after sowing})]$) for weed free treatments and logistic equation ($\text{Relative Yield} = [(1 / \{\exp(0.66 * (\text{Weeks after sowing} - 3.58)) + 1\}) + 1.55] * 100$) for weeding treatments. CPWC was calculated from estimated equations as 0 to 4.8, 0.5 to 4.1, or 1.7 to 3.3 weeks depending on allowable yield losses, respectively, 2.5, 5.0, or 10.0 %.

Weed seed predation and predators' abundance during winter-wheat growing season

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Predation of weed seeds is considered as an ecological process that could contribute to integrated weed management and as such is receiving increasing attention among weed scientists. So far, studies show that weed seed predation can be highly variable and, because only few studies have been carried out during long periods of time, it is difficult to assess the potential impact of predation on individual weed species and IWM. Longer-term studies are also needed to get a full picture of the range of seed predators and their respective contribution to seed predation for individual weed species over a season. We conducted such monitoring during the winter-wheat crop growing season and after its harvest.

Predation rates and abundance of seed-eating carabid beetles were recorded during ten 1 week-long sessions scattered from May till October 2009. Spatial variations were assessed at two spatial scales i.e. at the within-field level (12 experimental plots per field) and at the landscape level (3 winter-wheat fields within a landscape). Each plot ($n = 36$) consisted of 4 seed cards under vertebrate exclusion cages with 5 weed species (*Alopecurus myosuroides*, *Capsella bursa-pastoris*, *Galium aparine*, *Veronica hederifolia* and *Viola arvensis*) and 1 pitfall trap for carabid beetles.

We recorded an overall significant predation rate ($> 25\%$). Our results show that weed seed predation rates were rather stable in space but did vary greatly during the season with three peaks of predation, one in the very beginning of the growing season, one just before harvest and one at the end of the survey. There were significant variations among weed species predation rates. Seeds of *V. arvensis* were the most predated with an overall 50% predation rate, a value that would be high enough to impact the dynamics of the species. Seeds of *C. bursa-pastoris* and *A. myosuroides* were less predated (25%) whereas *G. aparine* and *V. hederifolia* were the least predated. These preferences observed in the field matched results from cafeteria experiments realized with seed-eating carabids at the beginning of the survey. The early and late-season predation peaks were related to the abundance of carabid beetles. *Poecilus cupreus* and *Anchomenus dorsalis* were the most abundant species during the early season predation peak while *Pterotichus melanarius* and *Harpalus rufipes* clearly dominated during the late season peak. Relations between the abundance of individual carabid species and predation rates of individual weed species are developed in the poster.

This results confirm that (1) weed seed predation cumulated over a season can reach levels that could potentially impact weed species that are the most predated and (2) there are clear links between one hand the abundance of seed-eating carabids and the rate of predation and on the other hand a good match between the preference of carabids for individual weed species and the predation rates of these weed species in the field.

Competitive and allelopathic interferences between soybean (*Glycine Max (L.) Merr.*) crop and annual wormwood (*Artemisia annua L.*) in field conditions

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Annual wormwood (*Artemisia annua L.*) interferes with soybean (*Glycine max L.*) crop growth and yield through competition and allelopathy. Allelochemicals released by the weed may affect the crop directly or indirectly through nitrogen fixing symbionts (*Bradyrhizobium japonicum*). Crop management generates stresses in the plants that can enhance the amount and the physiological effects of allelochemicals produced by the donor plants. Most studies on weed-crop interference through allelopathy were conducted in laboratory conditions using manipulative techniques, and few experiments, investigated the competition and allelopathy under field conditions. The objectives of this work were (i) to study allelopathic and competitive interferences between annual wormwood and soybean crop under field conditions (ii) to describe the crop response to weed interference using different mathematical approaches and (iii) to analyze the relative change of competition and allelopathy when sublethal doses of herbicides are sprayed.

Field experiments were carried out in the Faculty of Agronomy, University of Buenos Aires (Argentina) in two consecutive years. A split plot experimental design with three replications was used. Weed-crop density levels (competition) were assigned to the main plots while allelopathy and herbicide levels were assigned to the sub-plots. An additive model was used to study competition. Thus, competition levels were: pure soybean (40 plants m⁻²), soybean (40 plants m⁻²) and annual wormwood (2, 4 and 8 plants m⁻²) and pure annual wormwood (8 plants m⁻²). Allelopathy levels were (i) with and (ii) reduced allelopathy (with activated charcoal to adsorb the allelochemicals) and herbicide levels were: (i) with and (ii) no glyphosate application. In vegetative stage (V4) glyphosate in sub lethal dose (1/8) of commercial dose (3 kg ai ha⁻¹), was applied according to the treatments. Dry biomass of soybean, weight and number of nodules of soybean and dry weight of stems, leaves and inflorescences of wormwood were recorded.

The best models describing the relative soybean biomass/relative weed biomass and relative soybean yield/ relative weed biomass relationships at maturity were the exponential and logistic models respectively. Without herbicide, soybean yield decreased in response to the increase of relative biomass of wormwood when allelopathy was reduced. With allelopathy, soybean yield remained stable as weed relative biomass increased and nodules were larger than reduced allelopathy. In contrast, with herbicide the relationship between soybean yield and relative biomass was opposite with allelopathy and reduced allelopathy. Without herbicide the allocation to yield was higher with allelochemicals.

These results indicate that in the range of crop-weed densities explored, the use of herbicides to improve soybean competitive ability in presence of an allelopathic weed, such as annual wormwood, could produce a synergistic effect of competition and allelopathy to the crop.

Efficiency of empirical models to predict of wheat and wild oat (*Avena fatua* L.) competition for nitrogen at vegetative growth stage

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A research greenhouse was carried in 2008 at the Faculty of Agriculture, Ferdowsi University of Mashhad, Iran to compare two empirical models to predict wheat and wild oat (*Avena fatua* L.) competition at different levels of nitrogen. A factorial experimental design with three replications was used: the first factor was five densities of wild oat (0, 2, 4, 6 and 8 plants per pot) in competition with wheat (at constant density of 8 plants per pot); the second factor consisted of five different levels of nitrogen (1, 4, 8, 12 and 16 mM). The experiment was finished at the end of vegetative growth stage of wheat based on monoculture treatment at 8 mM of nitrogen.

Comparison of weed density and relative leaf area models showed that relative leaf area model had more coefficient of determination and less residual mean squares. So it had better estimation of wheat dry weight loss at vegetative growing stage. The parameters comparison of this model at different levels of nitrogen demonstrated the increase of wild oat disadvantage by raise in nitrogen levels. The relative damage coefficient (q) by two- parameter model of relative leaf area showed that wild oat was more competitive than wheat.

Competition between Jimson weed (*Datura stramonium* L.) and Chitti bean (*Phaseolus vulgaris* L.)

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Simulation of competition between bean and weeds using empirical models has important role in weed management programs of bean production. An experiment was conducted at National Bean Research Station of Iran, in 2006 in order to evaluate competition between Jimson weed (*Datura stramonium* L.) and Chitti Bean (*Phaseolus vulgaris* L.).

The experimental design was a randomized complete blocks with a factorial arrangement with three replicates. Treatments were four different weed densities (4, 8, 12 and 16 plant m⁻²) and three times of weed emergence (at crop emergence, at first trifoliate leaf stage and at third trifoliate leaf stage of bean); a weed-free treatment as control was included. Bean density was 40 plants m⁻². Cousens (1985) rectangular hyperbolic empirical model of weed density was used to simulate yield crop loss.

According to evaluation of coefficient of determination, remain mean square (RMS) and standard errors of estimated parameters of model an acceptable simulation of bean yield loss just when fitted to data of separated relative time of weed emergence was found. The model estimated 1.3 plants m⁻² of jimson weed as economic weed threshold density for 7% of acceptable yield loss. Jimson weed threshold densities based on this economic damage were 1, 1.1 and 3.1 plant m⁻² in first to third relative time of emergence, respectively.

Estimation of yield loss of Chitti bean (*Phaseolus vulgaris* L.) caused by Jimsonweed (*Datura stramonium* L.) interference with use of descriptive model based on density and relative time of weed emergence

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An experiment was conducted in National Bean Research Station of Iran in 2006, in order to estimate of yield loss of Chitti bean (*Phaseolus vulgaris* L.) caused by Jimson weed (*Datura stramonium* L.) interference, by using Cousens descriptive model of density and relative time of weed emergence.

The experimental design was a randomized complete block with a factorial arrangement in three replicates. Treatments were four different weed densities (4, 8, 12 and 16 plant m⁻²) and three times of weed emergence (at crop emergence, at first trifoliate leaf stage and at third trifoliate leaf stage of bean) in competition with bean (40 plant m⁻²) and a weed free treatment as control.

Results indicated the sever sensitivity (71% losses) of bean yield in competition with Jimson weed. at 16 plant m⁻² when it emerged at crop emergence. The Cousens descriptive model of density and relative time of weed emergence had acceptable estimation of bean yield loss caused by Jimson weed and there was no significant difference between observed and estimated data when a linear regression analyses was used. According to estimation of this model, the economic threshold of Jimson weed density (for 7% of bean yield loss) were 0.8, 1.6 and 2.5 plant m⁻² at first, second and third relative time of weed emergence respectively.

Simulation of Bean (*Phaseolus vulgaris* L.) yield loss in competition with Jimson weed (*Datura stramonium* L.) by empirical models using early observations of relative leaf area

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An experiment was conducted in National Bean Research Station of Iran in 2006 to evaluate the possibility of an early estimation of bean yield loss in competition with Jimson weed for a better weed management. The experiment design was a randomized complete block with a factorial arrangement in three replicates. Treatments were four different weed densities (4, 8, 12 and 16 plant m⁻²) and three times of weed emergence (at crop emergence, at first trifoliate leaf stage and at third trifoliate leaf stage of bean) and a weed free treatment as control. Bean density was 40 plant m⁻². Kropff & Spitters one-parameter and Kropff & Lots two-parameter empirical models were used to estimate crop yield loss by using of relative leaf area of weed at 20, 35, 50, 65 and 80 days after crop emergence. Results showed the both models had acceptable estimation of crop yield loss, however, according to remain mean square, two-parameter model estimate it better. This model estimated the maximum yield loss of bean for 78% and its relative damage coefficient (q) was 2.64 which showed Jimson weed was the better competitor. Both models had their best estimation when they fitted to the leaf area data at bean flowering stage (50 days after crop emergence).

Yield and yield components of winter canola (*Brassica napus* L.) affected by control and interference durations of weeds natural population

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An experiment was carried out at research field of Tarbiat Modarres University, Tehran, Iran in 2004-5 to investigate the effect of the duration of competition of weed natural population on yield and yield components of winter canola (*Brassica napus* L. cv. Okapi). Fourteen experimental treatments which divided into two sets were arranged in randomized complete blocks with three replications. In the first set, the crop was kept weed-free from canola emergence time to two-leaf stage (V2), four-leaf stage (V4), six-leaf stage (V6), eight-leaf stage (V8), initiation of flowering (If), %50 of pod set (%50Ps) and final harvest (H). In the second set of treatments, weeds were permitted to grow with the crop until above mentioned stages and then related plots kept weed free till end of season. Furthermore two additional treatments known as whole season control and whole season weed infested were established. At mentioned phenological stages in interference treatments weeds were removed, separated by species and dry weight measured. During canola growth cycle trend of plant height and dry matter distribution were also studied. At the end of canola growth cycle grain yield and yield components were determined.

Results showed that extending interference duration and limiting weed control duration significantly decreased all canola yield components except 1000 grain weight .Furthermore extended weed interference duration up to canola 4-leaf stage decreased 20-70% of grain yield in compare to whole season control. Delayed weed control up to early rosette stage creates decreasing trend in canola grain yield. According to Gompertz and logistic equations, critical period of weed control in canola with %5 accepted yield loss was estimated between 25-70 days after emergence of canola.

Critical period of weed competition in maize in north-western Italy

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In conventional cropping systems, herbicides are commonly considered as the most reliable tools for weed management in maize. The sustainable use of herbicides requires the knowledge of weed-crop interactions in order to choose the most suitable product and the best period of its application. Particularly important appears, on this purpose, the knowledge of the critical period of weed control (CPWC). The CPWC is defined as the interval when it is essential to maintain a weed-free environment to prevent crop yield loss; its described by two variables of weed-crop competition with weeds: the weed-free period required (WPR) and the length of the tolerated competition (LCT).

The research was conducted in Carmagnola (north-western Italy) in 2007 and 2008. In both years weed infestations were mainly composed by *Chenopodium album*, *Portulaca oleracea*, *Panicum dicotomiflorum*, and *Echinochloa crus-galli*. In the treatments aimed at the determination of the WPR, plots were maintained free from weeds for growing durations, ranging from 10 to 60 days after emergence (DAE). In the treatments aimed at the determination of the LCT, weeds were let to develop for growing periods from the emergence of the crop up to 60 DAE, and then removed. Season-long weed-free plots and untreated plots were also included as reference. In all trials the treatments were arranged according to a randomized complete block design with 4 replications. Maize was seeded on 30th April in 2007 and on 2nd April in 2008. Crop emerged 11 days after seeding (May 11th) in 2007 and after 20 days (April 22nd) in 2008. In both experiments maize was seeded at a row distance of 75 cm and at an average seed density of 7.4 seed m⁻².

The weather conditions of the two years were remarkably different, with lower temperature regime and higher rainfall during the early crop stages in 2008. The yield losses recorded in the always infested plots in comparison with the weed-free plots were 44% and 64%, in 2007 and 2008, respectively. Considering an accepted level of yield losses of 2.5%, it was possible to estimate a CPWC, only in 2007, which ranged from 10 to 24 DAE, corresponding to 3-6 leaf stage maize, or 80-213 GDD (Growing Degree Days). In 2008, a proper CPWC was not identifiable, as a weed removal carried out in a specific moment (22 DAE) already resulted in a yield loss lower than 2.5%.

The results of these experiments pointed out the need to prevent weed growth during the first 25 days after maize emergence. This was particularly important in early seeded maize and with unfavorable conditions, which limited crop growth and favored weed competitiveness.

Study of competitive ability of four weed species and two wheat cultivars under glasshouse condition

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Weed-crop competition takes a variety of forms. Intensity of competition depends on the spatial relations between a plant and its neighbors and on both the effects of those neighbors on resource availability and the ability of that plant to compensate for these effects via plasticity in architecture and physiology. Despite the enormous amount of work that has been done on competition, the mechanisms of competitive interactions between plants remains poorly understood. Because weed-crop competition is generally for light, much of the recent works have focused on canopy structure and light competition.

In order to study the weed-crop competitive interactions, four weed species with different morphologies (*Sinapis arvensis*, *Descurainia sophia*, *Hordeum spontaneum* and *Avena fatua*) and two wheat cultivars with different competitiveness ability (Pishtaz, more competitive, and Tabasi, less competitive cultivar) were used as competitors or target plants. The experiment was set up in a randomized complete block design with three replicates in greenhouse benches. Each pot had different densities of a single species (0, 2 and 4 plants per pot for *Sinapis arvensis* and 0, 4 and 6 plants per pot for other weed species) surrounding one central wheat plant. The pots were top-watered and maintained at field capacity. Day length was 14 h with the natural photoperiod being extended by lamps. Temperature was 25°C and 20°C for day and night respectively. Plant height, leaf area index, dry matter and light absorption were measured for each target. Light measurements were made at top of the wheat plant and pot surface using PAR sensors (Licor Co.). Analysis of variance (ANOVA) test was performed on derived parameters.

ANOVA results for wheat aboveground biomass and plant height revealed significant differences among wheat cultivars. Plant height increased in cv Pishtaz (more competitive cultivar) as weed density increased. No significant differences were found between weed species. Light penetration decreased in wheat canopy as weed density increased. Because leaf area index was more in Pishtaz than in Tabasi, light penetration into Pishtaz canopy was lower with *Sinapis* neighbor. In addition, wheat had greater LAI with *Descurainia* and *Hordeum* neighbors than with *Sinapis* and *Avena* neighbors. However, each species produced a different canopy structure. Pishtaz canopies were taller and contained more leaf area than the Tabasi canopies. The most striking differences in canopy structure of weeds were between *Sinapis* and *Descurainia*. *Descurainia* was the only neighbor which had similar effects on all target species.

Dry matter, yield and nitrogen efficiencies of corn (*Zea mays* L.) under redroot pigweed (*Amaranthus retroflexus* L.) densities in the south-western of Caspian Sea region

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Field studies were conducted in 2007 and 2008 at the research field of Agricultural Faculty of Islamic Azad University- Astara branch (North of Iran) to examine the effects of redroot pigweed (*Amaranthus retroflexus* L.) on corn (*Zea mays* L.) grain yield (GY), dry matter (Dm), nitrogen recovery efficiency (NRE), nitrogen use efficiency (NUE) and nitrogen utilization efficiency (NUEt). The experiments were established as a split plot arranged in randomized complete block design with three replicates. The main plot was nitrogen rate (0, 100, 160 and 220 kg N ha⁻¹) and the sub plot was Redroot pigweed density (0, 5, 10 and 20 weeds m⁻²). Combined analysis showed that Corn GY and Dm were 2.1 and 8.9 t ha⁻¹ in control (without N application) and they increased 128.6, 328.6 %; 30.3, 52.8%; 13.3, 23.3% at 100, 160 and 220 kg N ha⁻¹, respectively. Dm at 160 kg N ha⁻¹ was more when N used 220 kg N ha⁻¹. Corn GY was not significantly affected by changing N rate from 160 to 220 kg N ha⁻¹ but corn Dm, NRE and NUE reduced. NUE was increased 60.5% due to N changing from 100 to 160 kg N ha⁻¹ but NRE was not affected. NRE and NUE were decreased 38 and 38.4% at 220 kg N ha⁻¹, respectively. Also, the changes of NUEt at different N rate were similar to NRE and NUE but not affected by nitrogen rate. It was 33.6 kg dry matter kg N⁻¹ up taken. The most corn GM, DM, NRE and NUE were observed at 160 kg N ha⁻¹. Also, the effect of Redroot pigweed density on corn GY, NRE and Dm was significant. NRE was 42.2% in weed-free condition but its reduction ranked 32.0 and 39.3% for weed densities of 10 and 20 plant m⁻². NUE was 45.4 kg grain kg N⁻¹ at control and there was no difference between 0 and 5 weeds m⁻². It decreased at other weed densities. There was no difference between weed densities on NUEt. It measured 74.1 kg dry matter kg N⁻¹ up taken. Corn GY loss was 3.7% at 5 weeds m⁻² but Dm was not affected by this density. Corn GY and Dm reduction ranked 48.8, 56.1% and 17.6, 24.4% for 10 and 20 weeds m⁻², respectively. There was no difference between 0 and 5 weeds m⁻² on NRE, NUE and NUEt but the upper densities reduced them. The interaction between nitrogen rate and redroot pigweed density showed that N adding reduced corn GY and DM in all redroot pigweed densities. Corn GY was 2.6, 5.8, 12.3 and 12 ton ha⁻¹ at control (sole corn) for 0, 100, 160 and 220 kg N ha⁻¹, respectively. Corn GY losses were 3.9, 30.8 and 38.8% at 0 kg N ha⁻¹, 12.1, 25.9 and 32.8% at 100 kg N ha⁻¹, 1.6, 50.4 and 56.1% at 160 kg N ha⁻¹, 2.5, 60.8 and 72.5% at 220 kg N ha⁻¹ for weed densities of 5, 10 and 20 weeds m⁻², respectively. The highest corn GY was observed 12.3 t ha⁻¹ at 160 kg N ha⁻¹ for weed free condition. Corn Dm was 9.6, 12.4, 14.5 and 15.9 t ha⁻¹ at 0, 100, 160 and 220 kg N ha⁻¹, respectively for control. No difference between 0 and 5 weeds m⁻² on corn Dm up to 160 kg N ha⁻¹ but it was decreased 3.2% at 220 kg N ha⁻¹. Up to 10 weeds m⁻² decreased corn Dm 10.4 and 9.7% at 0 and 100 kg N ha⁻¹ but this loss was more at upper N application and ranked 11 and 34% at 160 and 220 kg N ha⁻¹, respectively. Also corn Dm was decreased 19.8, 17.8, 14.5 and 40.9% at 0, 100, 160 and 220 kg N ha⁻¹, respectively for 20 weeds m⁻². The highest corn Dm was observed 15.9 ton ha⁻¹ at 220 kg N ha⁻¹ for sole corn.

SESSION 5

INVASIVE PLANTS AND BIOCONTROL

Oral presentations

Session organizers:

Christian Bohren & Paul Hatcher

Classical biological control of Japanese knotweed – lessons for Europe

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This study set out to investigate the feasibility of using classical biological control (CBC) against one of the worst weeds in Europe, namely Japanese knotweed (*Fallopia japonica*). In addition, the procedural aspects of what would become the first official release of a weed biocontrol agent in any European country were elucidated.

Guided by molecular biogeographic evidence, field surveys were carried out in Japan (the plant's native range) and revealed a suite of severely damaging insect and fungal natural enemies. Extensive host-range testing reduced the list of potential safe agents from 186 insects and 40 fungi to just one representative from each taxon. The host range of the prioritised psyllid, *Aphalara itadori*, was examined using choice and no-choice oviposition and development studies. This research, which used 89 plants selected on a centrifugal phylogenetic basis, revealed that this sap-sucker is a true knotweed specialist, suitable for consideration for release into the environment and for integration into knotweed management plans. There then followed the application of this research to the requirements of the regulatory framework in the UK which necessitated considerable discussion with various bodies within the British Government and those of the Devolved Authorities. It also required the development of a 5 year monitoring plan. Addressing all of the regulatory requirements required the generation of considerable amounts of data and information, some which are not normally or have never been generated in typical classical weed biocontrol research programmes. Although the use of pest risk analysis tools requires the consideration of the agent as a “beneficial pest”, a true oxymoron, it worked surprisingly well.

This was a prototype programme for Europe, testing a representative country's attitude and regulatory framework. It involved the production of a pest risk analysis (based on the EPPO template), an application through national legislation (the UK Wildlife and Countryside Act), the production of peer-reviewed publications, expert committee consideration, further commissioned peer review and public consultations prior to final ministerial judgement, which at the time of writing has not been given. It is proposed that although there is room for some streamlining in the process, this licensing approach has proved to be effective and robust and should be applicable to similar programmes in Europe. This is important since CBC has considerable potential for controlling this and other targets in Europe, especially those impacting on Water Framework Directive requirements in habitats where chemical use is all but impossible in most member states. A further conclusion is drawn that a classical biocontrol programme's team needs to deliver more than just pure science, since effective communication and negotiations in the public and political arena can provide more and varied challenges than the traditional scientific ones.

Non-chemical management methods against invasive knotweeds (*Fallopia* spp.) – impact on target weed and recovery of native diversity

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Exotic knotweeds (*Fallopia* spp.) are considered to be among the most serious invasive exotic weeds in Europe and North America, causing significant damage to native ecosystems. Several methods are used to manage *Fallopia* invasions in natural areas; however, their effect on the target weed and on native biodiversity is poorly supported by experimental studies.

In May 2005, we started a replicated long-term experiment comparing three non-chemical management methods at a field site in Belfort, France. The methods selected included two cutting regimes (one cut or six monthly cuts during the growing season) and a combination of cutting in the first year followed by covering ground with “géotextile”, a vegetable fiber matting.

After three seasons, *Fallopia* above-ground biomass on plots with ‘monthly cutting’ and ‘géotextile’ was reduced by 94% and 90%, respectively, compared to control plots. Cutting *Fallopia* once a year also led to a reduction in above-ground biomass at the end of the second season, but not to differences in the following spring.

Native vegetation responded positively to decreased *Fallopia* above-ground biomass, with cover and plant species richness being highest in plots where *Fallopia* was regularly cut. Morphospecies richness and biomass of invertebrates and, for some feeding guilds also abundance, tended to be highest in plots where *Fallopia* was cut six times during the growing season.

Our results suggest a rapid and positive response of native vegetation and fauna to *Fallopia* removal; hence even a low-input management scheme helps to mitigate the negative impact of *Fallopia* invasion on native biodiversity.

Biological control in integrated management of *Ambrosia artemisiifolia* for Europe

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Like no other plant, common ragweed, *Ambrosia artemisiifolia*, has raised the awareness of invasive plants through most of Europe. Common ragweed, which is an annual herbaceous plant native to southern North America, was first recorded in Europe in the mid 1800s, but only since the early 1940s has this plant begun to spread. Common ragweed produces highly allergenic pollen and has become the prime cause of hay fever in many European countries. Ragweed also has increasingly become a major weed in agriculture, presently ranking number one weed in several crops in Croatia and Hungary, including sunflower. Various European countries have put in place early detection and management schemes, but there are no sustainable integrated control strategies to reduce its abundance in heavily infested areas. One such management tool is biological control, i.e. the use of specific natural enemies by favouring either naturally occurring antagonists (conservation and augmentative control), or by introducing host-specific agents from the area of origin of the plant (classical biological control). Classical biological control against ragweed has been attempted in Russia, the Ukraine and former Yugoslavia, but has failed to give successful control so far. In contrast, biological control was most successful in Australia. In this talk we will give an overview on the current state of biological control of common ragweed worldwide and present a strategy to further explore the use of this environmental friendly and cost effective method for Europe. Special emphasis will be given to the integration of biological control into current management strategies.

Is genetic diversity a prerequisite for successful plant invasion? What do we know about the ecological genetics of common ragweed (*Ambrosia artemisiifolia* L.)

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Common ragweed (*Ambrosia artemisiifolia* L.) as an invasive weed has a great impact on the environment. There is no doubt that Hungary is one of the most heavily infected countries with ragweed. In spite of its magnitude there is a considerable lack of information about its ecological and evolutionary dynamics, population and/or genetic diversity. In the recent years a growing amount of studies have utilized molecular genetic tools to study the histories, processes and problems of plant invasions. Herein we aim to overcome at least some of the problems by analyzing samples from Hungarian ragweed populations and comparing them with others collected from the Carpathian basin and from its native range from North America and Canada. In summary, 192 samples were analyzed with two different multi-locus methods; inter-simple sequence repeats (ISSRs) and one new gene-targeting method start codon targeted (SCoT) polymorphism. We tested 16 ISSR and 16 SCoT primers which produced 345 reliable fragments. In the replicate experiments a high level of polymorphism and genetic diversity was detected among and within the analyzed ragweed populations. This high genetic diversity presumably predisposed common ragweed to succeed at establishing, persisting and dispersing in the novel habitats. The invasive populations in the Carpathian basin probably arose from multiple introductions from different native range regions and accumulated genetic diversity that facilitated local adaptation. The further study of genetic diversity in ragweed populations may help to predict the potential of invasive populations to evolve resistance to management practices, such as herbicides or biological control.

Agents for the spread of *Ambrosia artemisiifolia* L. in Europe

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Ambrosia artemisiifolia (Common Ragweed) is an annual invasive seriously affecting human health. Its European distribution increased in area during the last decades, presumably along linear landscape structures (waterways, highways), whereas its population density increases rather locally (in agricultural systems). So far, quantities of dispersed seeds during both linear and continuous expansion processes are not known for Ragweed.

To have a clue of the importance of different dispersal processes we tested the dispersion of seeds along highways by seed traps positioned at increasing distances from the edge of established populations. In another experiment we counted the number of achenes transported by harvesters and reapers from infested to non infested crop fields, and along road verges.

Seed traps along roads resulted in relatively low numbers of seeds dispersed by directional turbulences caused by vehicles. But more sophisticated experiments - finished in March 2010 - will give more precise figures.

Mean number of seeds on mowers that cut road verges was 28 seeds/100 g dry organic matter. The analyzed matter was collected from the fly-cutters and chain curtain of the mowing machines. Seeds were tested for germinability resulting in rates of 66%, on average. Such high germination rates are known from ragweed populations in highly infested areas like agricultural crop fields and ruderal habitats.

High numbers of achenes were attached to machines lining up pumpkin for mechanical harvest and to joined mulchers: on average, 7500 attached achenes per vehicle were counted when the machines left the fields.

The dispersal of achenes by mulchers, harvesters and reapers used for harvesting crops contribute to the higher local/regional density of Ragweed populations. Contrariwise, achenes attached to vehicles on highways or directionally distributed by vehicles slipstreams may contribute rather to intermittent and linear expansion of common ragweed area, thus enabling the establishment of new populations far away from sources in not yet infected areas.

When population genetics meets biological control of the invasive swallow-worts (*Vincetoxicum nigrum* (L.) Moench and *V. rossicum* (Kleopow) Barbar.)

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We explored the population genetics of two European swallow-worts belonging to the Apocynaceae that have become established in the eastern United States and Canada. Population genetic data concerning both native and introduced populations are being used to pinpoint introduced population origin, and to examine spread of both species, all data that are becoming increasingly important for conducting rigorous specificity tests in the time frame of a biological control program. Population genetics of the weeds in their native and introduced ranges was assessed using chloroplast DNA sequencing and the inter simple sequence repeat (ISSR) marker approach. Both species have much lower cpDNA haplotype and ISSR loci diversities in the introduced range relative to the native range, suggesting that the introduction imposed a strong bottleneck in population size. Modern North American populations were compared with historical ones from herbarium collections for reconstructing invasion history of the two weeds. Results confirmed that the historical cpDNA haplotype found in both species was identical to the modern one. For both species, one major genotype was responsible for invasion and spread in North America. Native populations sharing the same exact multilocus genotype detected in introduced populations have already been identified for *V. rossicum*. Identification of source populations is achieved for *V. rossicum* but has yet to be found for *V. nigrum*. By integrating population genetics, the ongoing biological control program using exotic natural enemies is moving forward. Study cases with such extreme lack of variation within invasion process are seldom documented; therefore these two cases represent ideal test assets for theories in evolutionary processes underlying invasiveness.

Key-words: biological control, cpDNA, intersimple sequence repeats (ISSR), invasiveness, *Vincetoxicum*.

SESSION 5
INVASIVE PLANTS AND BIOCONTROL

Poster presentations

Session organizers:

Christian Bohren & Paul Hatcher

Trying to tame wild gingers

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Hedychium or wild ginger species, as they are often known, are showy and fragrant perennial herbs which were highly prized and extensively cultivated throughout Europe's "hot houses" in the nineteenth century. As a result of global trade, a number of species were transported to warmer climates and subsequently three species, *H. gardnerianum* (Kahili ginger), *H. flavescens* (yellow ginger) and *H. coronarium* (white ginger), have escaped cultivation and become naturalised. Originating in the eastern Himalayan range, these plants have become aggressive colonizers of indigenous forest habitats in their introduced range, whilst also exhibiting ecological and altitudinal adaptability. *Hedychium gardnerianum* has been nominated as among the "world's 100 worst invaders".

In the worst affected countries, such as Hawaii (USA) and New Zealand, conventional control methods are labour intensive, short term and often difficult to implement given the inaccessibility of affected sites. In many instances, high value, unique ecosystems are under threat and many monotypic stands are already considered lost causes with management efforts concentrating on outlier populations. The delicate ecosystems of the Macaronesian Archipelagos of the Azores, Madeira, Canaries, and La Réunion have also been invaded and wild gingers threaten many endemic and rare species of plants and animals. So significant is the environmental and economic impact in New Zealand and Hawaii that in 2008, a consortium of sponsors funded CABI scientists to undertake a project to investigate the potential for biological control of wild gingers.

A thorough review of the scientific and botanical literature, as well as historical herbarium records of the three target species, provided geographical focus and consequently a brief scoping survey to the Indian Himalayan foothills was undertaken. Wide varieties of *Hedychium* species were encountered, including the target species, and all were subject to significant natural enemy pressure. Extensive insect damage to seeds, flower heads, leaves and stems and symptoms of pathogenic infection were observed. Natural populations of the target plants were often found growing in high humidity environments, at forest margins and on steep banks, as inconspicuous members of the native flora and without evidence of invasive behaviour exhibited in the introduced range.

With such a tantalising natural enemy pressure on the target weeds, more funding was secured for 2009 and two further and more targeted surveys were carried out in Sikkim, India, across the plant's growing cycle. A broader suite of natural enemies was encountered, with some agents showing specialised and specific host associations.

The project findings and future prospects for biocontrol are discussed and opportunities for affected European stakeholders to join the international consortium are highlighted.

**Efficacy and host range of thistle tortoise beetle
(*Cassida rubiginosa*) for biological control of Canada thistle
(*Cirsium arvense*)**

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Canada thistle (*Cirsium arvense*) is a noxious weed and one of the most problematic weeds in field crops, orchards, vegetables, pastures and grasslands in Iran. The thistle tortoise beetle (*Cassida rubiginosa*), an herbivore insect, seems to be an effective agent for suppressing the biomass and survival of Canada thistle. Feeding 20 insects on each plant reduced total biomass and seed production by 78% and 94%, respectively. Host range studies on *Cassida rubiginosa*, which feeds actively on this weed as larva and adult, were carried out in 20 crops with two methods of no-choice and multiple-choice, and in 22 weeds through field surveys. The results showed that plant feeding and female ovipositor by the beetle were observed in Russian knapweed, common Russian thistle, bull thistle and Canada thistle. Green Thistle beetle fed on safflower but only about 5% of plant shoots were eaten and only in no choice treatments; however this beetle did not deposit any eggs on sunflower. Green thistle beetle could be a promising classical biocontrol agent for Canada thistle in grasses, natural grasslands, agricultural fields and pastures.

Keywords: Biological control, Herbivory, Natural enemies, Weed

The alien weed flora of the argentine pampas: disentangling the ecological and historical patterns involved in its formation

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Naturalization of plant species introduced into a region is limited by several geographic, biotic, and abiotic barriers that regulate their colonization, perpetuation and dispersion. In agro-ecosystems, these ecological filters define the size of the regional species pool of alien weeds that may assemble communities at field scale. We studied how the species richness of alien weeds has increased in the Pampas of Argentina from early agriculture expansion to the present (1877-2007).

The Pampas are one of the most extensive and productive areas of agricultural commodities in the world, thanks to their favorable climate and fertile soils. Our study is based on a comprehensive biographical revision including floras, handbooks, scientific and technical publications. We only listed alien species that have been reported to occur in annual field crops, horticultural crops, and temporary, implanted pastures. Since we focused our study on arable weed, alien species occurring in fruit plantations and woodlands were not included in the list. Species number was accumulated according to the year of first report of an alien species to occur as an arable weed in the region. The accumulated species richness of alien weeds was 260 for all the study period. Most alien weeds were annuals (153, 53% of all aliens) and native from Eurasia (203; 78% of all aliens from all continents). We have identified three periods of richness accumulation of alien weeds. Richness first sigmoidally increased (1877-1935). These periods coincides with the notable increase of rural population from ca. 270,000 people to ca. 1.3 millions between 1869 and 1914 by mostly European farmers, developing of railroad network, and introduction of row-crop area in the Pampas, suggesting high propagule pressure, dispersal, and open-site availability. Simultaneously, arable land devoted to sown cereals and linseed also increased from 4.7 to 13.6 million ha between 1899 and 1914, whereas alfalfa area increased from 1.3 to 7.4 million ha during the same interval. This extraordinary increase of the arable land area provided safe sites for the colonization of weed seed contaminants that were unintentionally sown with crops. Nowadays, an important share of the arable weed flora of the Pampas is comprised by many weed species belonging to the arable flora of Mediterranean Europe, which had been entered the country as seed contaminants.

Alien weed richness continued to linearly increase during the second phase (1937-1969: 1.6 species per year), while there were not significant change during the third stage (1970-1999: 0.3 species per year, $P = 0.06$). No new alien weed species has been documented after 1999. The turning point (1969 CI 95% = 4.9) coincide with the start of agriculture intensification, which have implied the increase of herbicide use and the implementation of phytosanitary measures to prevent the presence of weed seed contaminants in the seeds of annual field crops, horticultural crops, and pastures entering the country and in national commercialization as well. These preventive practices have hence constrained propagule pressure and receptivity of cropped areas. Our results highlight the importance of anthropic factors in modulating the introduction of alien plant species into agricultural regions and their naturalization as arable weeds.

The Biological Control of *Impatiens glandulifera* in the UK

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Impatiens glandulifera, commonly known as Himalayan balsam, is a highly invasive annual herb, native to the western Himalayas, which was introduced into the UK in 1839. Over the last 100 years Himalayan balsam has spread rapidly throughout the UK colonising riparian systems, damp woodlands and waste ground. The plant can reduce native plant diversity, retard woodland regeneration, outcompete native plants for space, light and pollinators and increase flood risk. Current traditional control methods are fraught with problems and often unsuccessful. Recent research has shown that in its native range *I. glandulifera* grows in clusters of 30 - 60 plants no more than 1.5m tall and is attacked by an array of arthropods and plant pathogens which exert considerable damage to the population. This is in stark contrast to the impoverished fauna and mycoflora found on the plant in its introduced range.

Since 2006, populations of Himalayan balsam have been surveyed throughout the plant's native range (the foothills of the Himalayas, Pakistan and India) and numerous natural enemies have been collected and identified. In particular, two plant pathogens (a stem and leaf infecting rust species and a *Septoria* leaf spot) and two stem boring beetles have considerable potential as biological control agents. This paper will review the research conducted to-date and examine the future testing procedures which will be conducted on potential agents to ensure they are host specific to the target and thus safe for the release and subsequent control of Himalayan balsam in its introduced range.

Field emergence and biomass production of *Ambrosia artemisiifolia* L. (common ragweed)

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Based on the summarized results of weed flora of wheat and maize in late summer (Fifth National Weed Survey, Hungary, 2007-2008), *Ambrosia artemisiifolia* L. (common ragweed) is the most important weed of arable lands in Hungary. The highest mean cover is 5.33 %. If uncontrolled *A. artemisiifolia* could cover more than 5 % of the majority of arable fields in Hungary. The seasonal pattern of field emergence of *A. artemisiifolia* and the effect of emergence time on pollen, seed and shoot dry weight production was examined in the settlements of Kaposvár (Somogy county, Hungary) in 2008 year.

Field emergence of *A. artemisiifolia* showed seasonal changes under these conditions with a beginning end of March. The germination peak was in the first half of April. After that time the germination decreased but it occurred continuously until the beginning of July. From middle of July until the end of November emergence of *A. artemisiifolia* seedlings were not observed at all, suggesting that *Ambrosia* seeds were in secondary dormancy due to the hot dry period in summer season. During this period av. 48 *Ambrosia* seedlings were counted for a square meter.

Emergence time greatly influenced the length of phenophases, the pollen and seed production and the dry weight of *A. artemisiifolia* shoots. When the seeds emerged later, the vegetative phenophase (time between emergence and flowering), the pollen and seed production and dry weight of *A. artemisiifolia* shoots considerably reduced. Data of pollen and seed production and dry weight considerably varied between individuals even inside the same emergence period. This suggests that emergence time is only one but not the most important factor determining biomass production of *Ambrosia* plants.

When the plants were grown without intra- and interspecific competition, their average pollen, seed production and shoot dry weight varied between 383 million – 25 milliard (pollen grain plant⁻¹), 40273 – 2843 (seed plant⁻¹), 32 – 1298 (gram plant⁻¹) respectively, depending on emergence time. These values are far more higher as mentioned earlier in the literature, suggesting that *A. artemisiifolia* – if it can grow undisturbedly - has much stronger biological potential than in competition with other individuals and species.

The effect of stubble treatments on common ragweed (*Ambrosia artemisiifolia* L.)

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Common ragweed (*Ambrosia artemisiifolia* L.) is the most important weed species of Hungary. This invasive alien species causes serious yield losses of arable crops and also human health problems. Besides its harmful effect in agriculture, *A. artemisiifolia* is a significant cause of allergic rhinitis. The pollen is responsible for more allergic diseases than all other allergenic plant species. Regarding that the majority of pollen amount in the air derives in Hungary from the untreated cereal stubbles in August and September, the professional stubble treatments are essential to prevent pollen and seed production of common ragweed.

Different herbicides at normal dosages were used for treatments of oat stubbles three weeks after harvest, at the beginning of August. By that time *A. artemisiifolia* cover reached 80 % and its phenological growth stage was BBCH 51. Efficacy of herbicides was evaluated 7, 14 and 40 days after treatments (DAT). Herbicides caused different symptoms on *A. artemisiifolia*. The most rapid and drastical effect could be observed due to diquat-dibromide and glufosinate-ammonium treatments, which resulted in total necrosis of *Ambrosia* plants. Auxine-type herbicides as fluroxypyr, dicamba, 2,4 D and MCPA caused strong top deformation and later necrosis of *A. artemisiifolia* shoots. Mesotrione and topramesone treatments resulted in whitening of top of the shoots. The effect of glyphosate, topramesone, topramesone+dicamba and florasulam+clopyralid+fluroxypyr herbicides was 100 % for *Ambrosia* control. Other herbicides (diquat-dibromide, glufosinate-ammonium, MCPA and bentazone+dicamba) also provided a very good effect between 95 and 99 %. The efficacy of dicamba alone and florasulam+ 2,4 D combination was still good (90 %). The efficacy of imazamox and fluroxypyr was not sufficient (80 %). Sulfonylureas (rimsulfuron, nicosulfuron, foramsulfuron, tribenuron-methyl) and mesotrione gave no sufficient control of *A. artemisiifolia* (< 50 %).

ECO-VIA - A project for the development of a herbicide based on microbial metabolites

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Weed management is particularly difficult in areas having civil or industrial uses, such as recreational or archaeological parks, pavements, roadsides, or railroads, where the use of chemical herbicides is mostly banned, and other control methods have limited or costly applications.

Recently a research project named ECO-VIA has been approved and financially supported by the Regional Governorate of Lombardy, within a specific programme for the development of the competitiveness of small and medium enterprises. The main aim of the project is to develop the technologies to obtain a natural herbicide based on the bioactive metabolites produced by a plant pathogenic fungus. The project, unique in Italy and probably the first one in Europe, will last two years and will involve four Italian research institutions (CNR, University of Naples "Federico II, University of Milan "Bicocca" and ENEA), a local administration (Alzano Lombardo) and a SME (Scarpellini) specialized in the realization and management of green areas.

This project originates from the results obtained in previous studies, which showed the potential of a fungus, *Ascochyta caulina* isolated from the weed species *Chenopodium album* and proposed as mycoherbicide for the biological control of this weed, to produce some broad-spectrum phytotoxic metabolites.

The main aims of the project are to investigate the methods for the production, purification, application, and formulation of the mixture of bioactive metabolites, and their eco-toxicological properties, in order to reach the ambitious goal to make the toxin utilizable at an industrial level, and then to produce an environmentally friendly natural herbicide.

The project will be developed following three main phases: applied research, pre-industrial development, and economic and business valorisation. They will be arranged in a logical series of activities which includes:

- maximization of toxin production and lowering of the production costs;
- large scale purification of the toxin mixture;
- identification of fast and cheap chemical methods to analyse toxin quality and fermentation yields;
- evaluation of the mode of application and efficacy of treatments in greenhouses, controlled environments and open fields;
- evaluation of the eco-toxicological effects of toxins to non-target organisms;
- study of persistence and mobility of toxins in soil and water, stability due to biotic and non biotic factors, and potential bio-accumulation;
- selection of proper surfactants and additives to obtain better formulations;
- set-up of a pre-industrial protocol for the production and purification of the bioactive metabolites, economically and technologically sustainable.

The project will also consider technology transfer and the use of public opinion.

A look at ploidy level of *Vincetoxicum nigrum* (L.) Moench and *V. rossicum* (Kleopow) Barbar. (Apocynaceae) from the perspective of a study of their invasion success

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Aim: This study aimed to document precisely the patterns of chromosome counts and/or ploidy level variation of *Vincetoxicum nigrum* (L.) Moench and *V. rossicum* (Kleopow) Barbar. (Apocynaceae) following their introduction and dispersion in the U.S. and Canada. *V. nigrum* is native to southwestern Europe whereas *V. rossicum* originates from Ukraine and southwestern Russia. Both species are invasive in natural areas, abandoned pastures and rural sites in the U.S. and Canada. The hypothesis that species invasiveness had been induced by a switch in ploidy level was addressed.

Materials & Methods: DNA ploidy levels of *Vincetoxicum nigrum* and *V. rossicum* (Apocynaceae) were determined by chromosome counts in root tips of seedlings and flow cytometric analysis from fresh foliar tissues.

Results: Chromosome and flow cytometric analyses in this study confirmed ploidy uniformity within native and introduced ranges of all species. In *V. nigrum*, individuals from France and U.S. were all tetraploid ($2n = 4x = 44$). In *V. rossicum*, individuals from Russia and U.S. were all diploid ($2n = 2x = 22$). *V. rossicum* shared the same ploidy level as the phylogenetically closely related species *V. hirundinaria* Medik, that is sympatric to *V. nigrum* and *V. rossicum* in its European native range but is not known to be naturalized in the northeastern U.S. Nuclear DNA content (pg/2C) at the species level averaged 1.27 in *V. nigrum* and 0.65 in *V. rossicum*. This is the first report of DNA content values for the genus.

Main conclusions: Our data showed that the invasive spread of North American populations of *V. nigrum* and *V. rossicum* was not triggered by differences in ploidy level. Alternative explanations should be sought.

Key words: genome size, invasive plant, ploidy, *Vincetoxicum nigrum*, *V. rossicum*.

Meaningful application of the new 454 large scale pyrosequencing based-technology (Roche GS-FLX 454) to the identification of microsatellites for small-scale research projects

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Microsatellites or simple sequence repeats are DNA sequences that consist of tandem repeats of 1-6 nucleotides. Because of high levels of polymorphism, ease to use and co-dominance, they are generally seen as the most pertinent markers to study at a fine scale level the genetic structure and demographic history of invasive weed populations and their natural enemies. However, their development using the classical microsatellite-library by enrichment remain typically time consuming and labor intensive, impeding their generalization at the level of small-scale research projects. We considered in the present study the extent to which the new generation sequencing such 454 Life Sciences/Roche GS-FLX pyrosequencing based-technology, could lead to a rapid, more efficient and less costly way to identify microsatellites for a small-scale research project than the classical microsatellite-library by enrichment. This system relies on fixing nebulized and adapter-ligated DNA fragments to magnetic DNA-capture beads in an oil-aqueous mixture emulsion. The DNA fixed to these beads is then amplified by PCR and each DNA-bound bead is placed into a fiber optic chip for pyrosequencing into the GS FLX System. DNA was sourced from *Ceutorhynchus assimilis* (Coleoptera: Curculionidae), one natural enemy of the invasive weed, *Lepidium draba* sp *draba*, (Brassicaceae). From the resulting 12,000 sequences data after one run only, we were able to identify 333 microsatellite markers that have sufficient long flanking sequence for primer design. In contrast, only 16 potential microsatellite markers were discovered following sequencing of 93 clones of a previous classical microsatellite-enriched library for a comparable cost. This new strategy is substantially more rapid and cost-effective than classical methods and can be easily applicable to small scale research project.

Key-words: microsatellites, 454 technology, protocol, weeds.

Influence of competing vegetation and the cutting regime on the population density and flowering characteristics of *Ambrosia artemisiifolia* L.

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Ambrosia artemisiifolia L. (common ragweed) is an annual neophyte. This Asteraceae has been introduced from North America and causes problems to human health and crop yield losses in its introduced range. Persistent soil seed bank (with up to 40 year-viability) and high seed production (up to 30000 per individual) make the control of ragweed especially difficult. One approach to solve this problem is emptying the soil seed bank and preventing massive seed production. Non-chemical sustainable management solutions have to be developed for the control of this species.

In a pot experiment we tested the competitive effect of sown vegetation (grown from different commercial seed mixtures) on Ragweed of different seed densities. Additionally, we applied four different cutting regimes: a: 1st cut in June; 2nd cut in September; b: 1st cut in August, 2nd cut in September, c: 1st cut in June; 2nd cut in July, 3rd cut in September d: 1st cut in June, 2nd cut in August, 3rd cut in September. Response variables were Ragweed population size, phenology of flowering and the number of flowers indicating seed production. The measurements were done just before the cuts, i.e. before the first cut 8 weeks after the sowing, 13 weeks, 16 weeks, 21 weeks, and ending in autumn 26 weeks after the sowing.

We found lower germination rates for Ragweed plants growing in Mixture 2 with relatively higher proportions of *Lolium perenne* and no clover) than in the Mixture 1 (0.2 and 0.4, respectively), with smaller proportion of *Lolium perenne* but with clover. Between the observation terms 1 and 2 we found 65% (Mixture 1) and 64% (Mixture 2) Ragweed-mortality. This negative trend slowed down after the second term but continued until the end of the experiment, which resulted in major decrease in number of individuals or complete eradication of Ragweed for all groups. Ragweed plants cut twice (in June and in September) could develop their female flowers and reach highest levels of maturation of seeds before the next cutting.

The use of simultaneously sown competing vegetation showed to be very effective in reducing Ragweed density growing in newly constructed roadside situation. Seed set cannot be prevented if the time gap between subsequent cuts is too long (13 weeks or more). These results provide important tools for the development of efficient management methods, especially against the populations along roadsides.

Human-mediated, stratified dispersal of an invasive grass, *Microstegium vimineum*

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For invasive species management, preventing the spread of invasive species into new areas is critical, as eradication is often difficult, if not impossible, once populations are well established. The importance of human activity for the spread of invasive plants has long been recognized, but quantification of the impact of the vectors involved is lacking. We present a conceptual framework and ongoing experiments and models to understand the rapid spread in North America of the invasive exotic *Microstegium vimineum* (Japanese stiltgrass) at local and regional scales. Detailed small-scale experiments provide the data to model the natural spread of *Microstegium* using maximum likelihood techniques. The dynamics of new infestations of *Microstegium* were studied by establishing 30 patches in 2003 in different habitat types (roadside, intact forest, disturbed forest and wet meadow areas); subsequent population growth and spatial expansion were monitored until plots were terminated in 2006. We developed a spatial model of patch growth, using maximum likelihood techniques to estimate dispersal and population growth parameters. These models predict dispersal parameters ranging from 0.18 m to 1.86 m, depending on the habitat, which imply spread rates several orders of magnitude slower than actual large-scale observations.

Forested roads, along which *Microstegium* grows abundantly, are often unpaved and are subject to frequent maintenance activities such as road grading. We conducted a series of experiments involving seed proxies placed along roads before grading operations. We then attempted to relocate seeds along the roads up to 1 km in either direction from the starting location. Results indicate that road grading can move propagules along road networks much more rapidly than natural patch expansion, with some seed proxies travelling over 200 m in a single event. In general, the distribution of seed proxies we observed was fat-tailed, with a small but significant portion of seeds travelling further distances, while most remained closer to the source.

Roadside studies show that the off-road distribution of *Microstegium* is very strongly associated with road structures such as road culverts. Ongoing work in road culverts documents their role in spreading invasives from roadside corridors into the forest interior. Using seed proxies placed above culverts, we observed that water flow through ditches and culverts is a primary mechanism of movement of propagules across the road and into outwash fans. These highly disturbed areas are excellent habitat for the establishment of *Microstegium* populations. Experiments are currently underway which address the speed with which this movement into the forest takes place.

Spatially explicit models are being used to bridge the gap from local to regional scales. Preliminary models demonstrate that regional patterns of invasion are driven by stratified dispersal: rapid spread along roadsides is followed by much slower expansion into the forest interior. These results highlight the need to explicitly address human-mediated spread when managing invasive species, as this likely determines the speed of an invasion, rather than the natural dispersal abilities of the species.

Analysis of intervarietal competition in a ruderal weed *Achyranthes aspera* L. in pure and mixed populations

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Achyranthes aspera var *argentea* Hook.f. and *A. aspera* var *aspera* L. are sympatric, ruderal, troublesome weeds of plains in India, however, the latter exhibits wide spread distribution and higher population density in nature as compared to the former. Hence, competition between the two varieties was evaluated by growing 3, 6 and 12 plants per pot equivalent to 66, 132 and 264 plants m⁻² respectively in pure populations and 12 plants per pot following de-Wits replacement series in mixed populations. In pure populations, biomass production per plant was 8, 4 and 1.4 g in *A. aspera* var *aspera* and 1.8, 2.5 and 1.4 g in *A. aspera* var *argentea* at 3, 6 and 12 density per pot respectively. Biomass production per pot was 24.5, 24.1 and 16.4 g in the former and 5.3, 14.8 and 16.3 g in the latter variety at the same density levels respectively. Similar trend was observed with respect to reproductive potential in response to density stress of both the varieties. In mixed populations, biomass production per plant was 7.6, 9.2 and 7.2 g in *A. aspera* var *argentea* with the increase in density of *A. aspera* var *aspera* whereas it was 3.9, 4.1 and 1.9 g in the latter with the increase in density of the former variety. Achene production was nil in *A. aspera* var *aspera* in presence of *A. aspera* var *argentea*, however, it was slightly reduced in the latter in presence of the former. On the basis of these observations it may be suggested that *A. aspera* var *aspera* accumulates more biomass as compared to *A. aspera* var *argentea*, however, the former is more sensitive to density stress whereas the latter can absorb high density stress. In mixed populations, *A. aspera* var *argentea* tremendously suppresses the growth of *A. aspera* var *aspera* whereas the latter has negligible effect on the former. Replacement diagram curves of both the varieties exhibit fast growth rate of *A. aspera* var *argentea* in first two months which is followed by senescence whereas *A. aspera* var *aspera* shows better growth in the later stage of life cycle. Although, the former appears to be a superior competitor in the early growth phase, the higher yield, the delayed active growth phase and relatively longer growth period of the latter may be partially responsible for its higher density than that of the former in nature.

Soil impoverishment caused by weediness of invasive weed species *Iva xanthifolia* (Giant sumpweed)

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In this paper we present results for determination of soil nutrient depletion caused by high populations of *Iva xanthifolia* Nutt (Giant sumpweed). These results are a part of the investigation on spreading, bio-ecological characteristics and suppression of *I. xanthifolia* in Vojvodina region in Serbia. *I. xanthifolia* is a newly introduced, invasive weed in this area; (first reports confirm its presence in 1960).

I. xanthifolia is abundant in non cultivated sites, but in the last ten years it infested field crops as well. *I. xanthifolia* is very well adapted to good soil conditions. Plants complete their life cycle including seed set in years with good weather conditions. The number of plants observed in field crops was up to 600 per m². The objective of our investigations was *I. xanthifolia* plants from field and from ruderal sites. We sampled total of 30 fully matured plants from farm fields and 30 fully matured plants from non cultivated sites (10 plants from each of the 3 replicates). The average height was 297,70 cm with 1506,27 g fresh weight, 425,27 g dry weight, 264,40 leaves per branch, and 14,70 branches per plant. Fresh/dry mass ratio was 1: 0,27 - 0,3 (100 g of fresh material after air drying weighed 27-30g)

Nitrate (N), potassium (P) and sodium (K) were analysed in air dried plant material separately in shoots and leaves, using Kjejdal, spectrophotometric method and flame photometric method respectively. Average amount of N measured was 1,43 % (1,39 -1,64 % in shoots and 1,23 -1,49 % in leaves; Measured P value was 0,41-0,45 % in shoot and leaves with average of 0,43%; and the average content of K was 0,26 % (0,23- 0,27% in shoots and 0,21-0,29 % in leaves). The ratio of N, P, and K in *I. xanthifolia* was 1,00: 0,30: 0,18. These results combined with results from the experiment in sugar beet - treated with different herbicides, were used to calculate (estimated) soil nutrient depletion in N, P, and K of *I. xanthifolia*. In the experimental plots of the herbicide trials (22 different herbicides in 4 replications) the number of *I. Xanthifolia* ranged from 5 plants (in treated plots) to 630 plants /m² in control plots. Their weight ranged from 0,97 to 190,80 g per plant (611,10 to 4063,50g perm²).

From the amount of N, P and K in plant material we calculated an estimated nutrient loss caused by *I. xanthifolia* of 31 kg/ha N, 8 kg/ha P and 253,6 kg/ha K. Compared to a standard mineral fertilizer NPK 15:15:15 we conclude that *I. xanthifolia* takes NPK 15:15:15 254 - 1690 kg/ha in one vegetation period. These results indicate the importance of prevention of *I. xanthifolia* spreading especially in agricultural land.

Occurrence of *Eriochloa villosa* (Thunb.) Kunth in Hungary

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Eriochloa villosa of Asian origin is an annual invasive alien spreading all over the world and causing great damages of economic importance on arable lands. Adventive distribution of this species has been observed in North-America since 1940s'. *E. villosa* is considered as a casual species in North and Central Europe. It has been spreading in only SW Romania since 2006. The first population was discovered in a maize field during the "Fifth National Weed Survey on Arable Lands" in Hungary near Gesztely, a village 15 km NE of Miskolc (N Hungary) in July 2007 by János Madarász and Péter Partosfalvi. The identification of the species was carried out by István Dancza (Ministry of Environment and Water, Budapest) and Prof. Hildemar Scholz (Botanischer Garten und Botanisches Museum Berlin-Dahlem). In the first year the size of the infested area was between 250 and 300 m². Moreover the following weed species appeared on the area together with *E. villosa*: *Echinochloa crus-galli*, *Digitaria sanguinalis*, *Abutilon theophrasti*, *Amaranthus chlorostachys*, *Cirsium arvense*, *Chenopodium album* and *Setaria pumila*.

In 2008 this weed species was found in cultivated sunflower field and in stubble-field near the locality of the first registered focus. In 2009 *E. villosa* was observed in a new parking place in the city of Miskolc. Based on the new locality was clarified seeds of *E. villosa* was imported from a gravel-pit and its surroundings near Miskolc.

Based on literature data *E. villosa* can be considered as a potential invasive weed in Hungary. The control in time shall basically aim to prevent mass distribution of *E. villosa*. This poster presents morphology, biological characters, life cycle, distribution and possible control measures of *E. villosa* in Hungary. Relevant herbarium sheets can be seen at the Hungarian Natural History Museum Department of Botany in Budapest.

Invasive Plants in Swiss Agriculture – Risks and Problems

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Swiss agriculture is characterized by an enormous diversity in climates, soil types and cultivation systems. One third of the country's surface is covered by prairies, ranging from the pioneer alpine vegetation down to the natural and artificial prairies in the lowlands. One third of the agricultural land is used as small scaled arable fields and permanent crops (~ 290 000 ha).

3000 plant species are found in Switzerland. 305 of them are neophytes of which 45 are defined as invasive. The Swiss Commission for Wild Plant Conservation CPS/SKEW has established the so called "Black List" (for abundant or dangerous species) and the "Watch List" (for species under vigilant observation), as S. Rometsch explained. Most of the species of the "Black List" are also listed in the "Ordinance on the Handling of Organisms in the Environment" as forbidden plants. Commerce and handling of these plants is forbidden; and contaminated soil cannot be moved.

A close collaboration between farmers, cantonal Plant Protection Services, the CPS/SKEW and the Federal Research Station was established. This collaboration was originally based on the obligation to control *Ambrosia artemisiifolia* in agriculture.

The abundance and describes the importance to agriculture of the most important invasive neophytes in Swiss agriculture are described. These are the species: i) *Ambrosia artemisiifolia*, for its highly allergenic pollen, ii) *Cyperus esculentus*, which is abundant in some regions, iii) *Senecio inaequidens*, which is highly abundant along motorways and railway lines, vi) *Abutilon theophrasti*, which is rare in a few fields and v) *Phedimus stoloniferus*, which is recognized as invasive in one region of Switzerland.

Furthermore, other species are problematic. For example, *Reynoutria* is a problematic weed for those farmers who are contracting maintenance for public green and natural reserves. It is rarely abundant in arable fields. *Buddleja* is abundant as pioneer plant in alluvial zones, in construction sites as well as in private and public gardens. It is a popular ornamental plant. *Cyperus* is an invasive in a few regions. Its abundance increases costs for weed control, especially in areas where farmers and vegetable growers exchange their fields. *S. inaequidens* is until now rarely found in prairies or arable fields. It contains the same pyrrolizidines as the toxic *Senecio jacobaea*. The pressure of this perennial weed to agricultural land is high. *Abutilon* is very rare and well controlled, while *Phedimus* is presently abundant in one single region; practical control methods are still under development.

Solidago is quite abundant in wild flower strips, established for governmental subsidized ecological compensation areas. *Solidago* is not an important weed in arable fields and prairies, but can be a problem in nature reserves.

Neophytes are generally well controlled in Swiss agriculture because of its small scaled structure and the vigilance of well trained farmers.

Control of *Reynoutria japonica* – Results of Pot Trials with Herbicides

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Reynoutria japonica syn. *Fallopia japonica*, *Polygonum cuspidatum* (Japanese knotweed) is a large, herbaceous perennial plant, native to eastern Asia in Japan, China and Korea. In North America and Europe the species is very successful and has been classified as invasive in several countries. Japanese knotweed is widely distributed in Switzerland. It is frequent in riparian zones, in nature protected areas, as well as along traffic ways and edges of forest and pastures. At the research station Agroscope Changins-Wädenswil ACW several herbicides have been tested on their efficacy on Japanese knotweed in pots.

In a first series of experiments in 2008 pieces of rhizomes dug along a small stream nearby the research station were planted into 25 l pots with soil substrate. The variability in growing size of potted rhizomes was very high. Herbicides were applied at 50-70 cm and 70-100 plant height in four repetitions with a knapsack sprayer, 200 l/ha, nozzles "Teejet 80015", 4 bar. In a second series of experiments in 2009 we used potted *Reynoutria* plants grown in vitro from tissue culture. The variability of growing size of these plants was smaller. Herbicides were applied as in the former year and in addition some herbicides were applied with a watering can using normal registered dosage per hectare.

Results of the first trial series showed that total kill of the above-ground plants does not guarantee a total kill of the rhizomes. Herbicides are not able to kill an established rhizome of Japanese knotweed in one vegetation period.

Japanese Knotweed is a frequent colonizer of temperate riparian ecosystems, roadsides and waste places. It forms thick, dense colonies that completely crowd out any other herbaceous species. The success of the species has been partially attributed to its tolerance of a very wide range of soil types, pH and salinity. Japanese knotweed has a large underground network of rhizomes. In order to eradicate the plant the rhizomes need to be killed. Since Japanese knotweed is very frequent in Switzerland the pressure to use herbicides for eradication increases continuously. An effective method to control Japanese knotweed locally is needed. In riparian zones, nature reserves and other fragile zones the use of herbicides is in Switzerland strictly prohibited by law. But Japanese knotweed often grows in these zones where mechanical control is difficult or almost impossible. For effectively damaging or eradicating a rhizome locally a herbicide may be used timely limited together with mechanical control methods. The combination of chemical and mechanical control methods may damage a rhizome effectively and prevent rapid regrowth.

The effect of human disturbance on common ragweed (*Ambrosia artemisiifolia* L.) spreading in semi-natural grasslands

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Common ragweed (*Ambrosia artemisiifolia* L.) is one of the most important alien weed species in Hungary. It spreads more and more intensively, and it occupies bigger and bigger areas. Ecological investigations have been made in Bőszénfa (Somogy county, Hungary) in several natural, semi-natural grasslands and grass seeding stands used for deer pasturing in order to examine the effects of different human activities as fertilisation, pipeline construction, manure deposition, deer feeding, silage deposition, as well as the effect of grass sowing on common ragweed appearance and spreading. In each location 2x2 m control plots (undisturbed plots with no human intervention, with common ragweed coverage $\leq 1\%$) and 2x2 m concerned sample plots (with higher ragweed coverage) were investigated.

The test plots were:

S1- natural grassland dominated by *Lolium perenne* (undisturbed plot and tree-cutting expansion plot);

S2- natural grassland dominated by *Lolium perenne* (undisturbed plot and pipeline construction affected plot);

S3- semi-natural grassland dominated by *Festuca pratensis*-*Lolium perenne* (undisturbed plot and manure deposit concerned plot);

S4- semi-natural grassland dominated by *Festuca arundinacea* (undisturbed control and manure deposit concerned plot);

S5- semi-natural grassland dominated by *Lolium perenne* (undisturbed control and deer feeding concerned plot)

S6- natural grassland dominated by *Lolium perenne* (undisturbed control and silage deposit concerned plot);

S7- *Trifolium pratense*-*Lolium perenne* seeding (2007);

S8- *Trifolium pratense*-*Lolium perenne* seeding (2009);

S9- *Trifolium pratense*-*Lolium perenne* seeding (unsuccessful seeding in 2007, re-seeding in 2009).

In all plots plant species were recorded and cover percentages were estimated for each species.

The various human activities increased the common ragweed coverage in all concerned sample plots compared with the undisturbed plot of the same habitat. The ragweed coverage varied from 1-90%, depending on the type of human activity: tree-cutting expansion of the territory increased the ragweed coverage with 1% (S1 plots); pipeline construction with 5% (S2 plots); manure deposit in the vicinity of the sample plot with 25-50% (S3 and S4 plots); deer feeding with 75% (S5 plots). The highest common ragweed coverage was observed in

the plot near the silage deposit, compared with the undisturbed control plot (90%, S6 plots) (probably because of the disturbance caused by silage transport). In drilled grass seeding increased coverage of common ragweed was observed. The measure of the increase depended on the seeding success (S7 plot: 90%, S9 plot: 45% grass coverage). In the successful seeding plots the ragweed coverage increase was 5% (S7 plots), while in the unsuccessful seeding plot a coverage of 50% (S9 plots) was observed. Another connection was observed, between the seeding date and the ragweed coverage. The successful seeding made in May of 2007 showed 5% common ragweed coverage increase (in 2009), while the successful seeding made in May of 2009 showed 50% increase. In consequence, abundance of common ragweed can seriously increase in some cases in natural, semi-natural grasslands and grass seeding stands as human activities increase.

A multi-disciplinary approach to the study of the host specificity of Italian populations of *Psylliodes* cfr. *chalcomerus* (Coleoptera: Chrysomelidae)

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The stem-boring flea beetle *Psylliodes* cfr. *chalcomerus* is distributed in Central Europe and Asia and its presence is registered in its native range on different species of Asteraceae, i.e. *Onopordum acanthium*, *Carduus nutans* and *Centaurea solstitialis*, considered to be troublesome weeds in the U.S. In fact, they currently infest millions of acres across the U.S., causing millions of dollars of damage every year as they reduce forage availability and quality and displace native vegetation.

P. cfr. chalcomerus was generally considered to be associated to *C. nutans* and in 1997 an Italian population of the flea beetle was released in Kansas, Maryland and Texas for the biological control of the weed.

In 2001 two sympatric populations of the insect were found in Krasnodar region (South Russia) on *C. solstitialis* and *O. acanthium*. Laboratory and field host range tests, together with genetic analysis, carried out in the last few years demonstrated the probable existence of two or more distinct forms within the *P. cfr. chalcomerus* taxon, having different levels of host specificity but indistinguishable by morphological traits. In particular, the *C. solstitialis* biotype was demonstrated to be genetically well differentiated and strictly associated to the host plant.

The aim of this research is the study, using a multi-disciplinary approach, of Italian populations associated with *O. acanthium* and *C. nutans*, in order to select highly specific biotypes to be used in biological control programmes for these weeds in the U.S.

Biological observations and host range tests were performed in 2009 in laboratory conditions with populations collected in two localities of Central Italy. No choice experiments were carried out with single females allowed to feed and oviposit on leaves of the target weeds and of other species belonging to the family Asteraceae. Results indicated that all the populations analysed (two associated to *O. acanthium* and two to *C. nutans*) showed a significant preference for their relative host plants.

Genetic analysis and morphological studies are ongoing to demonstrate if this ecological specialization also reflects a genetic and morphological differentiation among the populations studied, with the aim of clarifying the controversial taxonomic situation of the *P. cfr. chalcomerus* taxon.

Explorations in Central Asia and Mediterranean Basin for the selection of specific biological control agents for *Onopordum acanthium* (Asteraceae)

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Scotch thistle, *Onopordum acanthium* (Asteraceae), is a biannual thistle of Eurasian origin. It was accidentally introduced in North America in the late 1800s. It occurs in most of the western states especially in rangelands, pastures and disturbed soils. When abundant, it reduces forage availability for livestock and wildlife.

Since 2007 several explorations and survey trips to discover new potential biocontrol agents for the weed were carried out in Italy, Spain, Bulgaria, Turkey and Iran. Several species of arthropods were preliminarily selected during the surveys. Among them, the root-boring weevil *Trichosirocalus briesei*, recorded and collected in Central Spain, and already introduced in Australia was very promising, and was studied for its probable introduction in the U.S. The damage it causes is mainly due to the larval root and crown boring at the rosette stage of the weed. Laboratory host range tests and life cycle observations, carried out on *O. acanthium* and on related plant species, showed a clear preference of the weevil for the target species. Moreover, genetic analysis is in progress to clarify its controversial taxonomic status, as it belongs to a complex of morphologically similar species.

Another promising candidate agent, the noctuid moth *Eublemma* sp., is attacking the target weed at the same stage of young rosette; the larva feeds into the crown, damaging the stem bud.

Among the insects attacking the flowerbuds, the weevil *Larinus latus* showed a high specificity for *O. acanthium* in laboratory trials carried out with different populations. The adults of this species and two other *Larinus* species found in Turkey lay eggs into the flowerbuds of the target species and larvae develop into the flowerheads destroying all the seeds before their spread.

Other candidates are the flea beetle *Psylliodes* cfr. *chalcomerus* and the weevil *Lixus cardui*, both associated with stems and leaves. Laboratory host specificity tests and genetic analysis are in progress to evaluate the host range of selected biotypes of both potential biocontrol agents.

A new species of *Aceria* eriophyoid mite associated with the target weed was recorded for the first time in Western Turkey. This mite produces galls on the stem, the upper leaves and the young flowerbuds, with a great impact on the fitness of the attacked plant and on its seed production.

Selection of specific candidates for the biological control of *Salsola tragus* (Chenopodiaceae) in the U.S.

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Russian thistle, *Salsola tragus* (Chenopodiaceae), a troublesome weed infesting the drier regions of western North America, is native to Central Asia and widely distributed throughout the Palearctic Region. It infests rangelands and semi-arid pasture lands, croplands, residential, disturbed and industrial areas.

Numerous explorations and survey trips have been carried out in Italy, Spain, Bulgaria, Russia, Turkey, Tunisia, Kazakhstan, Greece, Egypt, China and Iran between 2003 and 2008, to select new biocontrol agents for Russian thistle. Several arthropod species and two pathogens associated with the target weed have been selected.

Preliminary host range tests carried out in quarantine in the US and a final open-field host range test at the ENEA facilities in Rome, Italy, completed the screening of the very promising agent *Aceria salsolae*, an eriophyoid mite which produces galls on the stems and the flowers of the target weed, with a severe impact on its fitness.

In the last year, preliminary studies on the biology and host specificity have been carried out on the stem-boring weevils *Lixus incanescens* and *L. rosenschoeldi* and the root-boring weevil *Cosmobaris scolopacea*.

Different biotypes of *L. incanescens* have been collected respectively in Iran and Central Turkey on *S. tragus* and one population of *L. rosenschoeldi* was found and collected in Sicily (southern Italy) on *Salsola kali*. Preliminary host specificity tests, performed in 2008, showed that *L. rosenschoeldi* and two biotypes of *L. incanescens* from Central Turkey, have a narrow host range restricted to the genus *Salsola*. Morphological observations, combined with population genetic studies, are ongoing to better understand the “complex” *L. incanescens*.

Specimens of *C. scolopacea* at larval and adult stage have been collected during explorations in Italy, Spain, USA, Iran, Bulgaria and Turkey. The different populations have been analysed from morphological and genetic points of view to clarify the taxonomic situation of this species. Data show that a population from South Italy (Sicily) is genetically different from the others: preliminary laboratory host specificity tests showed a narrow host range of this biotype, compared with other *C. scolopacea* populations. Additional bioassays in no-choice and choice conditions are in progress to better determine if the Sicilian biotype of this weevil has the necessary host specificity to be selected as potential agent for the biological control of Russian thistle.

Achieving effective control of *Rhododendron ponticum* L.

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The introduction of non-native species into new habitats, compounded by favourable environmental conditions and a lack of associated natural enemies such as specialised arthropods and pathogens, frequently permits a species to become invasive. Such invasions often have severe impacts on the biodiversity and integrity of the affected new habitats as well as on local economies. In Ireland one of the most serious invasive alien species which poses threats to the local biodiversity is *Rhododendron ponticum* L. Once established on a susceptible site rhododendron can kill other plant species in the ground vegetation layer and prevent the regeneration of trees and shrubs thereby also indirectly affecting the local fauna.

Effective rhododendron control can greatly increase the economic and ecological value of invaded land and this project aims to contribute to this goal by improving our understanding of the autoecology and invasion dynamics of the species and by assessing control options. An improved understanding of why the species is such an aggressive invader in certain situations will give us a better platform for developing tools for the planning of landscape level control programmes.

The specific project objectives are:

- Mitigation against the re-invasion of *R. ponticum* on disturbed sites. It has been suggested by Cross (1981) that in an undisturbed site without the actions of grazing animals rhododendron cannot successfully compete with native pioneering species such as birch and holly. To test this hypothesis we have cleared and fenced a field site invaded by rhododendron and re-planted the area with birch and holly, while protecting it from grazing animals.
- Investigation into seed germination and longevity. Cross (1975) stated that rhododendron seeds germinate more readily on disturbed sites. To test that hypothesis we are conducting experiments into the effect of shade and the depth and type of substrate on rhododendron seed germination.
- Assessment of the biocontrol potential of the native fungal pathogen *Chondrostereum purpureum* as a cut-stump treatment to prevent re-sprouting. Work previously undertaken in North America, the Netherlands and Finland showed *C. purpureum* to be successful in controlling invasive alien and native tree species (Shamoun and Hintz, 1998; De Jong, 2000 and Vartiainen et al, 2008). Building on this work, the research will assess Irish isolates of *C. purpureum* for their pathogenicity and virulence towards *R. ponticum* and for their efficacy in reducing re-sprouting with a view to developing a potential future mycoherbicide.
- Characterisation of the fuel properties of rhododendron. This experiment will determine the calorific value, moisture content and chemical content of rhododendron wood with the view to possibly recuperating removal cost by selling timber for fire wood.

- Quantification of biomass potential of rhododendron. We are conducting sampling of rhododendron on a range of different sites in order to create a biomass table that can be used to estimate the live biomass for a range of sites and densities of rhododendron. A live biomass table can be used to estimate removal costs.

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Successful invasion of *Senecio inaequidens* in the Czech Republic and germination biology of its naturalised population

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Senecio inaequidens (Asteraceae) is being currently one of the most successful plant invaders in Europe, spreading fast from north-west into the other parts of the continent. It was found for the first time in the Czech Republic in 1997. Our field monitoring took place in Podbaba area (first record of *S. inaequidens* in 2002) in the north – western suburban part of the Prague city in 2006 - 2008. Exponential increase of plant numbers (89 plants in 2006 compared to 1292 in 2009) of *Senecio inaequidens* was found at this location. Plants are growing here in rocky terrain along the railway embankment. Their easy wind-caused dispersion and also air drift caused by trains is helping this species to spread into surrounding areas.

In laboratory tests of seed biology with material originated from population mentioned above, positive photoblasticity (light promotes germination) of *Senecio inaequidens* achenes was recorded. In all treatments (100 achenes per Petri dish, air temperature in climatic chambers 5; 10; 15; 20; 25; 30°C, four replicates) we found significantly higher germination rates under conditions of light compared to permanent darkness. Optimal temperature for germination was pointed out between 15-20 °C, when germination reached 90 percent. Small-pot trial of seed emergence from different depths showed that highest values were obtained from achenes laying on the soil surface (70% emergence). On the other hand, seeds are able to emerge from deeper soil layers. We found nearly 10 % seedlings emerging from 50 mm depth.

Species shows high numbers of individuals and in infested patches also high dominance. Plants are highly fertile, average seed production of about 20 000 seeds per plant was counted. As our results show the achenes are able to germinate under different temperature and light regimes and seedlings can occur even if seeds are placed into deeper soil layers. In recent years, many other locations with *S. inaequidens* occurrence were found, mostly along the railway or motorways. This shows that species is successfully invading the Czech Republic with human mediated dispersal in disturbed areas.

Supported by MSM 6046070901 research project.

Eco-physiological traits underlying invasion success in *Centaurea stoebe* L.

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Introduced organisms face new biotic (mainly release from specialist natural enemies) and abiotic (change in climate and soil conditions) selection pressures in their new range. Plasticity is the ability of a single genotype to express different phenotypes depending on environmental conditions. If the plastic response of an organism to altered conditions is not only a passive change resulting from e.g. resource limitations, but comprises an active physiological change that enhances fitness, it can be selected for and therefore is adaptive. Adaptive plasticity of morphological or eco-physiological traits may contribute to the fitness homeostasis (greater survival) of invaders in variable environments. *Centaurea stoebe* L., spotted knapweed, exists in two cytotypes, diploids and tetraploids. It is native to Europe and invasive in North America. Previous studies comparing native and invasive populations of *C. stoebe* showed a distinct shift in the cytotype distribution towards exclusively tetraploid cytotypes, and a niche shift towards drier and warmer conditions in North America. Reduced specific leaf area (SLA), thicker leaves, higher biomass, improved water content regulation and lower carbon isotope discrimination are eco-physiological traits thought to improve invasion into dryer and warmer habitats. Our results indeed indicate that tetraploid plants might cope better with drought conditions than diploids through increased tolerance to water stress. This is in line with several studies showing that increased ploidy level might represent an advantage under stress conditions. Here, we focus on some eco-physiological traits, specifically on SLA, underground and aboveground biomass, water-use efficiency using ^{13}C discrimination, leaf-nutrient concentrations (N, C) and stomatal conductance, potentially involved in invasion success of tetraploid *C. stoebe*. These traits are assessed under field conditions with differential climatic and soil conditions that mimic typical situations of the native and introduced range, and in the greenhouse under control and water-stress treatments. We are especially interested in differences of genetic variation between cytotypes for plasticity in these eco-physiological and as well as in fitness traits. The common garden pot experiment, where the three geocytotypes (EU 2x, EU 4x, NA 4x) of *C. stoebe* are grown under two contrasting climate conditions and three different soil conditions that reflect the most crucial differences between the two ranges, will allow us not only to test for differences in phenotypic plasticity between the geocytotypes, but also to disentangle effects of soil versus climate conditions and to investigate whether plasticity in morphological and physiological traits is correlated with their ecological distribution in the field. Such a correlation would indicate local adaptation of the geocytotypes in the native range and adaptive evolutionary change in the introduced range as high adaptive phenotypic plasticity is expected to increase the invasion success.

Investigation of invasive weed species biology in Slovenia and testing of herbicide efficacy for their control

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Data on weed species biology and population dynamics is crucial for a successful weed management and are available for the majority of economically most important domestic weeds in Slovenia. Contrary to that, for many invasive weed species that have recently started to invade the Slovenian territory the existing knowledge is insufficient. They could become a threat to our crop production, therefore methods and strategies for their control need to be studied.

Three field trials were conducted in 2009 in maize fields situated in different locations in the central and eastern parts of Slovenia to study the biology (life cycle and phenology) and chemical control of different invasive weed species. The following annual seed propagated invasive weed species were included in the study: *Ambrosia artemisiifolia*, *Ambrosia trifida*, *Amaranthus viridis*, *Amaranthus rudis*, *Bidens pilosa*, *Bidens frondosa*, *Bidens subalternans*, *Bidens bipinnata*, *Setaria faberii*, *Acalypha virginica*, *Sycious angulatus* and *Iva xanthiifolia*. Seeds of these species were sown on experimental maize stands to carry out the standard trials for testing herbicide efficacy, to study the species phenology and to evaluate their effect on maize yields. Weed seeds used in trials were collected from plants that originated from Slovenia. Efficacy of herbicides based on dicamba, foramsulfuron, mesotrione, nicosulfuron, pendimethalin, prosulfuron, rimsulfuron, terbuthylazine, tembotrione and some others applied singly or in mixtures was determined. Efficacy rates for the specific weed species varied as follows: AMBEL (55-98 %), AMBTR (50-98 %), AMAVI (82-100 %), AMATA (75-100 %), BIDPI (74-100 %), BIDSU (85-98 %), BIDBI (55-100 %), BIDFR (81-100 %), SETFA (55-100 %), ACCVI (73-100 %), SIYAN (92-98 %) and IVAXA (52-100 %).

The trial results have led us to conclude that all of the studied weed species could successfully develop in the Slovenian maize fields. In some cases they succeed in producing seeds despite being treated with herbicides. Their competitive ability is high enough to significantly interfere with the maize stand development and to cause significant yield losses. From the results of herbicide efficacy trials it could be concluded that there are enough efficient herbicides registered in Slovenia to perform a successful control of all studied alien invasive weed species.

After the completion of the study the trial sites will be carefully monitored during the following seasons to detect the further development of populations of weed species which have been sown to be able to study the population recovery after first year of chemical control and to prevent the further weed dissemination.

Alien weeds unintentionally introduced in Argentina through alfalfa seed importation: contributions for a historical study of weed flora formation

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Weed seed contaminants of crop seeds are important sources of alien weeds entering a region. Hence studying the alien weed species contaminating crop seeds imported to Argentina may contribute to the historical reconstruction of the weed flora formation in the Pampas since the agriculture expansion during the late 1800s. This aim may also help to identify the ecological factors that had been involved in the regulation of both the colonization and the naturalization of alien species of weed unintentionally introduced as crop seed contaminants.

Here, we have reviewed the literature on weed seed contaminants of crop seeds; particularly focusing on alfalfa. Seeds of 102 species were detected in alfalfa imported mainly from Italy in early 1900s. Most of them were recognized as weeds of field crops and naturalized species into semi-natural habitats and wastelands. The most frequent and abundant species observed as seed contaminants of alfalfa were *Plantago lanceolata* L. (ribwort plantain) and *Setaria viridis* (L.) P. Beauv. (green foxtail). Concurrently, both species were also conspicuous contaminant of alfalfa seeds in the United States in the same period.

P. lanceolata and *S. viridis* had disparate success of naturalization in the Pampas. During the first two decades of the 20th century, both species were not observed neither as weeds of field crops and pastures nor in wasteland and semi-natural habitats. First collected in a wasteland in the surroundings of Buenos Aires in 1910, *P. lanceolata* was first reported as a weed in an alfalfa field in the northern Pampas in 1920. Interestingly, seeds of *P. lanceolata* contaminating alfalfa seed exported from Argentina increased from 13% to 38% between 1932 and 1938. Perpetuated by sowing contaminated seeds, *P. lanceolata* became abundant in alfalfa crops during the 1950s and was recognized as a troublesome weed in this crop. Although herbicides and seed-cleaning have importantly reduced its abundance as weed of pastures, *P. lanceolata* is now widespread naturalized in semi-natural habitats since the late 1960s from the north-western, Andean tropics to Tierra del Fuego in southern Patagonia. Although widespread in pasture lands across Argentina, *P. lanceolata* is not longer a troublesome weed in alfalfa. However, both the report on the evolved resistance of *P. lanceolata* populations to glyphosate in South Africa, and the probable inception of glyphosate-resistant alfalfa cultivars in Argentina, may create conditions where *P. lanceolata* become again a noxious weed in pasture lands.

Conversely, *S. viridis* did not become a problematic weed in Argentina. First collected in 1898, *S. viridis* is nowadays considered casual for the flora of central Argentina, from the Pampas to the Andes and northern Patagonia, mostly occurring in ruderal habitats, such gardens, road verges, and wastelands, and rarely observed as common weed. Our findings suggest that the naturalization of alien weeds is mainly determined by biotic factors, such as life history, germination and reproductive output, after the propagule flux was reduced or even stopped due to the cleaning of crop seeds.

Successful control of invasive vine *Mikania micrantha* by restructuring the plant community

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Mikania micrantha H.B.K (hereafter referred to as *Mikania*), a herbaceous vine native to tropical and Central America belonging to Asteraceae, is a notorious invader in Southeast Asia, southern China, the Indian subcontinent and the Pacific Islands. Most research into managing *Mikania* has involved mechanical removal, chemical control and biological control. However, mechanical removal was impractical for large areas, chemical control was not long lasting, and biological control was impeded by uncertainty of its ecology safety. To find a practical and environmentally-friendly solution, research on restructuring invaded plant communities commenced in 2001 and was followed by long-term monitoring of a 10 hm² permanent plot established in Neilingding Island, a small island offshore Shenzhen city and Hong Kong, where *Mikania* was found rampant since the 1990s. The restructuring disregarded whether the composition or function of restructured community was in accordance with the process of natural vegetation dynamics; rather it aimed simply on planting saplings of selected tree species that were able to grow under *Mikania* stress and eventually suppress *Mikania*. Eighteen fast-growing regional tree species were selected and a total of more than 6000 saplings of these species were planted in a heavily infested area to change the environment of the site. Each species was planted in small clumps. Weeding was performed only in the first one or two growing seasons. Results showed that the planted tree species varied in tolerance to *Mikania*. Certain species could grow better than the others and form a closed canopy, completely suppressed the invasion of *Mikania* and the growth of other weeds. Among them, *Macaranga tanarius* and *Heteropanax fragrans* had the strongest resistance. Their saplings grew well under *Mikania* stress without further human intervention and never were completely covered by *Mikania*. Some other planted species, such as *Liquidambar formosa* and *Schima superba*, could hardly survive in the same condition. Six years after the restructuring, clumps of planted species showed varied effects on *Mikania*. *Cinnamomum burmanni* was the best in suppressing seedlings and saplings of *Mikania*. Nine years after the restructuring, most restructured stands grew well and created an environment not suitable for *Mikania* to grow. Some *Mikania*-tolerant trees had dispersed their seedlings. Thus, the restructuring had not only terminated the damage of *Mikania* once and for all but also became the core of tree expansion. It suggests that the existence of local tree species which saplings are able to survive *Mikania*, low cost management without herbicide spraying is promising, and the identifying such tree species from regional flora is needed.

Computer-assisted collection of GPS data for monitoring of plant species distribution along roadsides

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The objective of the study was to develop a system for collecting geo-referenced data on distribution of plant species along roadsides. The system was proposed for species easily recognisable at convenient distance and had to satisfy the following requirements: (1) allowing data collection by car driving at a speed not interfering with traffic, (2) continuous tracking of the travel during which the monitoring is performed, and (3) to use low-cost materials and, possibly, software released under GPL (General Public License).

The system hardware is very simple and composed by a laptop and a cheap GPS receiver that sends position data to the first through a bluetooth connection. GPS data are managed using GpsDrive (www.gpsdrive.de), a navigation system written under the GPL license that displays on the laptop the actual lat-long positions and permits tracking and data point collection. This application can be easily installed in Linux environment. An older version is also available for Mac OSX.

While tracking is carried out automatically, data points (called waypoints in GpsDrive and similar navigation software) recording needs few keyboard inputs that can be reduced to a single key event (eg. space bar pressing) by creating shortcuts (e.g. using Xmacro or AutoKey in Linux, QuickKeys in Mac OSX). GpsDrive stores track and waypoint data in simple text files that can be easily handled with common text-editors. With few elaborations, data can be made suitable to viewers, such as Google™ Earth, or GIS software.

This system has been tested both on Linux Ubuntu 8.04 and Mac OSX 10.5.8 during a survey of common ragweed (*Ambrosia artemisiifolia*) presence along a part of the road network of Piemonte region (NW Italy). A team formed by two persons monitored, in two different trips, a total of about 500 km roadsides, driving at traffic speed and collecting about 2500 data point of *A. artemisiifolia* presence. The species was mostly distributed as dense populations growing along segments of the monitored roadsides. The infested segments had a length varying, on average, between 250 and 2500 m. Only in few cases *A. artemisiifolia* was observed as smaller populations or as single individuals. According to the first results, it seems that the ecotones represented by roadsides force the species to spread mainly along a narrow strip close to the road edge.

The activity of looking at the roadside for presence of the plant to be monitored requires a certain visual effort that is intensified by the car movement and that can lead to motion sickness, especially in susceptible people. The problem can be strongly reduced by frequent alternations between driving and monitoring activity, in particular in the case of intensive monitoring programs. This system proved to be relatively cheap and suitable for programs of monitoring at various scales.

Explorations and preliminary host range tests for the selection of specific candidates for the biological control of perennial pepperweed, *Lepidium latifolium* (Brassicaceae)

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Perennial pepperweed, *Lepidium latifolium* (Brassicaceae) (PPW) is a herbaceous, semi-woody perennial of Eurasian and Central Asian origin that has been introduced in North America around 1900 as a contaminant of sugar beet seeds. It is now widely distributed in the western USA, coastal New England, Mexico and Canada. It is usually associated with river banks, drainage ditches and subirrigated pastures, but it can invade also open fields, roadsides and residential areas.

Since 2006 several explorations and survey trips to discover new potential biocontrol agents for the weed have been carried out in Turkey, Kazakhstan, China and Iran. Several species were preliminarily selected during the surveys. Among them is the root-mining weevil *Melanobaris* sp. n. pr. *semistriata*, found in eastern Turkey. No-choice oviposition and larval development tests demonstrated a rather broad host acceptance by this species, probably due to the unusual egg-laying behaviour showed by females in quarantine conditions. Further experiments, such as a multiple choice cage test and open field test in choice conditions in the area of origin, are needed.

Host-specificity tests with the flea beetle *Phyllotreta reitteri* indicate that this stem-miner attacks several plant species other than PPW under no-choice conditions and in seven species, including three species native to North American (*Lepidium densiflorum*, *L. huberi* and *L. oblongum*), complete adult development was recorded. Three species (*L. densiflorum*, *L. huberi* and *Nasturtium officinale*) were also accepted for egg-laying under single-choice conditions. We therefore decided to conduct additional multiple-choice field cage tests.

Very promising is the chloropid stem mining fly *Lasiosina deviata* collected in central Turkey. Results of an open field choice test, carried out in the same area for 2 years, clearly indicate a very narrow oviposition host range, only associated with the target weed.

A new species of eriophyoid mite, *Metaculus lepidifolii*, was sampled during last field trips to Turkey carried out in 2008 and 2009. This species, if in large numbers, can prevent flowering and/or seed production of the target weed. In addition, most eriophyoid mites are highly host specific. Preliminary open field host range test carried out in central Turkey during the spring and summer 2009, showed a very restricted host range, only limited to the target weed species. Therefore, it is considered a new promising potential agent for the biological control of perennial pepperweed.

Developments in biological control of perennial sow-thistle (*Sonchus arvensis*) with plant pathogenic fungi and their metabolites

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Perennial sow-thistle (*Sonchus arvensis*) is a problematic weed in some countries in Europe and North America. Minimal tillage systems favor its spread across the field by underground shoots that are capable of producing new plants. Increased levels of chemical herbicides are usually required to control the weed. For these reasons some new approaches, for example the development of bioherbicides or natural herbicides, can be explored to broaden possibilities for *S. arvensis* control.

The tasks of our research were: 1) to investigate the biodiversity of fungi inhabiting the weed; 2) to screen the culture collection of fungi isolated from *Sonchus* spp. on virulence to the weed and on production of phytotoxic metabolites; 3) to evaluate the biocontrol potential of highly virulent fungal species; 4) to isolate and characterize phytotoxins produced by selected fungal strains.

The field surveys have been carried out since 1995. More than 20 fungal species were identified on diseased and dead plants of the weed. About 130 fungal strains were isolated in pure culture, identified and screened for phytotoxic activity and virulence. To study phytotoxic activity the fungal strains were grown on liquid media for 2 weeks and then the activity of the culture filtrate was evaluated by leaf disk puncture bioassay. The virulence of different fungi was studied using leaf disks. Experiments on host range and biology of selected fungal strains were conducted on whole plants in a controlled environment. Phytotoxic metabolites of selected microorganisms were produced by both liquid and solid fermentation to be extracted with organic solvents and purified by chromatographic techniques.

The typical set of diseases of *S. arvensis* was presented by powdery mildew (*Erysiphe cichoracearum*), rust (*Coleosporium tussilaginis*) and mildew (*Bremia sonchicola*). The species less abundant but more appropriate for inundative biocontrol were *Alternaria sonchi*, *Ascochyta tussilaginis*, *Cercospora sonchi*, *Phoma exigua* var. *exigua* (syn. *Ascochyta sonchi*), *Septoria sonchi* and *Stagonospora cirsii*. All these species were virulent to *Sonchus arvensis* by laboratory and greenhouse tests. Moreover, they were found to be producers of phytotoxic metabolites. Some of such compounds were isolated and characterized both chemically and biologically. For example, cytochalasins (e.g. cytochalasin A, cytochalasin B, deoxaphomin) were isolated from several strains of *P. exigua* var. *exigua* as main metabolites. This finding together with unstable virulence of the fungus allowed us to reject this pathogen from our research program despite that it was found to produce other toxins, such as ascosochine. Highly virulent strains of *Alternaria sonchi* and *A. tussilaginis* demonstrated some potential

for the development of a bioherbicide in terms of narrow host range but some restrictions due to problems of inoculum production. These fungi as well as *Cercospora sonchi* and *Stagonopora cirsii* produced conidia under near UV light only. This problem is quite general and should be solved by using mycelia as inoculum or by development of new technologies of conidia production.

In conclusion, at the present time natural herbicidal compounds produced by fungi seem more suitable for development as new means of control of perennial sow thistle than living microbes. The funding by EU and Russian Fund Basic Research is gratefully acknowledged.

Study on biological activity and mode of action of phytotoxic nonenolides produced by *Stagonospora cirsii*, a pathogen of Canada thistle (*Cirsium arvense*)

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Phytotoxins produced by microorganisms have been considered as template structures for the development of new synthetic herbicides. These natural compounds were also found to be potent in discovering new molecular targets of herbicides. Nonenolides (ten-membered ring lactones) are a group of physiologically active metabolites produced by fungi. These compounds demonstrated antibiotic, antifungal, antitumoral and other interesting activities. Some fungal species belonging to the genera *Ascochyta*, *Diplodia*, *Drecheslera*, *Fusarium* and *Phoma* were shown to produce phytotoxic nonenolides (e.g. pinolidoxins, diplodialides, pyrenolides, fusanolides, putamonoxins, herbarumins) causing leaf necrosis or/and strongly inhibiting root growth in sensitive plants. Due to their potential practical application a special attention is given to organic synthesis of these compounds. However, their mode of action has not been studied.

Recently, we isolated two new phytotoxic compounds, namely stagonolide (SA) and stagonolide H (SH) from liquid and solid culture of *Stagonospora cirsii* (a pathogen of *Cirsium arvense*), respectively. Their chemical structure was characterized as nonenolides. The main task of the work was to investigate their biological activity as well as to perform a preliminary study on their mode of action.

Phytotoxic activity of stagonolides was evaluated by leaf disk puncture assay and root growth inhibition assay using well expanded leaves and seedlings of different weeds and crops. Antimicrobial assays were done with standard paper disk technique using yeast fungi, Gram positive and Gram negative bacteria as test organisms. Electrolyte leakage assays were done using leaf disks of Canada thistle treated with SA and SH and incubated for 4 and 24 hours under continuous light or darkness. The leaf disks incubated under light were also subjected to cytological studies. Cell division and mitosis in onion root tips after treatment with SA were observed microscopically after fixation with ethanol-chloroform mixture and staining with acetocarmine.

Both SA and SH caused necrotic lesions in leaves of different plants, however, they differed in selectivity. SH was more selective than SA, affecting leaves of *C. arvense* more than leaves of other plant species. Only SA was found to be a root growth inhibitor (IC₅₀ = 5 µM) affecting cell division resulted in the appearance of binucleate cells in root tips of onion. SA showed weak antimicrobial and zootoxic activity, while SH did not show these biological activities. The analog of SH, curvulide B showed no biological activity at all. Phytotoxic activity of SA

was light-independent and it did not cause strong electrolyte leakage from leaf cells of *C. arvensis* whereas the action of SH was opposite. According to *in vivo* spectrometry both toxins were able to alter optic properties of leaves of *C. arvensis* and, hence, the concentration of photosynthetic pigments in leaves of the weed. At the cytological level it was found that SA did not affect the integrity of biological membranes but caused the coalescence of chloroplasts in mesophyll cells. It was supposed that SA affected cytoskeleton in roots and leaves of sensitive plants. SH is rather responsible for increased level of active oxygen, interfering with the work of the photosystem II or inhibiting antioxidant systems in plant cells. The funding by Russian Fund Basic Research (project Д 08-04-01354) is gratefully acknowledged.

Isolation and biological characterization of phytotoxic metabolites produced by *Phoma chenopodiicola*, a pathogen of lamb's-quarters (*Chenopodium album*)

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The annual weed *Chenopodium album* is widespread in Europe and North America. Due to high yield of seeds it became a troublesome weed in Europe and North America. Two fungi were patented as mycoherbicides for biocontrol of the weed: *Ascochyta caulina* in Canada and *A. caulina* in Europe. However, the pathogens had a good effect mainly on juvenile plants and no commercial product was developed. The alternative strategy attempted was to isolate herbicidal metabolites produced by these fungi. Ascochyline, hyalopyrone and pyrenolide A were identified in cultures of *A. hyalospora*. Ascaulitoxin, its aglycone, and trans-4-aminoproline were phytotoxic compounds isolated from *A. caulina*. The application of these latter toxins (1 mg/mL) in mixture with sub-lethal doses of chemical herbicides showed synergistic effect in control of *C. album*. In this work we used the pycnidial fungus *Phoma chenopodiicola* that is a common pathogen of *C. album* causing necrotic leaf lesions with purple borders. It was supposed the fungus produces phytotoxic metabolites responsible for the described disease symptoms. The aim of the research was to provide a scientific basis for production and isolation of phytotoxins produced by *P. chenopodiicola*.

In order to evaluate the dynamics of phytotoxic activity of culture filtrate and to select the best medium composition a strain of *P. chenopodiicola* was grown on three different liquid media as a static culture for 4 weeks. The effect of modified pH of culture filtrate on extraction of phytotoxins with different solvent was studied. Production of bioactive metabolites was also evaluated by growing the fungus on solid substrates: potato-dextrose agar and pearl barley. Bioactive metabolites were extracted from these dried substrates colonized by *P. chenopodiicola* mycelium with acetone–water mixture followed by extraction with ethyl acetate after evaporation of the acetone. Preliminary purification of phytotoxic metabolites from crude extracts was done by repeated column chromatography in silica gel and preparative TLC. Biological activity of extracts and its chromatography fractions was characterized by leaf disk-puncture assay using well-expanded leaves of *C. album* and *Cirsium arvense*.

The fungus showed the highest phytotoxic activity when grown for 14 days on M-1-D liquid media. Maximum yield of dry matter (70 mg/L) in ethyl acetate extract was obtained from culture filtrate produced on modified liquid Czapek medium after 4 weeks of incubation. Modification of original pH of culture filtrate (pH 7.8) by its acidification (pH 5.5 and 2.5) decreased yield of dry matter as well as its phytotoxic activity. The good yield of extractive substances (about 2.5 g/kg) and high level phytotoxic activity of extracts was found when the fungus was grown on pearl barley. Further purification of bioactive metabolites from the last extract by column chromatography allowed to obtain 10 homogenic fractions. Yield of the phytotoxic fraction (Rf 0.3–0.5 in chloroform–isopropanol 9:1) was about 100 mg/kg. It was further fractionated by preparative TLC to give subtractions 1 (Rf 0.33–0.35) and 2 (Rf

0.35–0.42), both about 10 mg/kg yield, that were phytotoxic to both weeds tested. Large scale production and chemical characterization of the phytotoxins is in progress. In conclusion, in this work we were able to show that *P. chenopodiicola* is capable of producing non-selective herbicidal metabolites and developed approaches to produce them in large scale. The work was supported by Committee of Science and Education at Government of Saint-Petersburg and Russian Fund of Basic Research (project № 08-04-01354).

The effect of soil disturbance and seed addition on the abundance of *Ambrosia artemisiifolia* L. (ragweed) in different habitats

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A. artemisiifolia is a noxious agricultural weed and the most important allergenic plant in central Europe and North America. Hungary is one of the most infected country in Europe. While *A. artemisiifolia* is mostly considered as a problem of agricultural lands, where it is primarily handled with weed control measures, it also occurs in various additional habitat types throughout the landscape. Factors contributing to its success in these non-crop habitats and possibilities of its control have not yet been fully explored.

We studied the effect of disturbance and propagule availability on the abundance of *A. artemisiifolia* in a fine-scale field experiment in different habitat types of the Kiskunság region, a heterogeneous cultural landscape in central Hungary. We assessed variability in factors as soil characteristics, light conditions, and landscape history that may be important. We covered all major non-crop habitats in the region: open and closed natural grasslands, natural poplar forests, open and closed secondary grasslands, and black locust and pine plantations, and clearcuts with afforestation. In 1m x 1m plots we conducted digging (disturbance) and sowing (propagule availability; 200 seeds per plot), and had combined treatments and controls, at 8 habitats, at 8 replicates in each habitat type (64 sites, and 256 plots in total). At each site we measured soil characteristics (texture, humus content), light availability (LAI), and checked past land use.

In sites where *A. artemisiifolia* was present in the soil seed bank, soil disturbance alone was enough to trigger a high abundance. Although over half of the sites were previously ploughed, *A. artemisiifolia* was present only in sites that were ploughed even in the 1980s or afterwards. This is probably due to the relatively recent spread of the species in the last three decades.

In sown but undisturbed plots, *A. artemisiifolia* emerged in low numbers and reached very low cover. In dug and sown plots, *A. artemisiifolia* emerged in all habitat types, and could even reach high cover in all habitat types except for closed forests (poplar and pine stands). In grassland habitats, *A. artemisiifolia* cover was negatively related to soil sand content. Out of the forest types studied, *A. artemisiifolia* had significant cover in of the black locust stands, probably due to the favourable light conditions in spring.

Our results confirm previous field observations that soil disturbance is favourable for *A. artemisiifolia* and activates its dormant seeds in the soil. These results also show that even if this mosaic landscape is highly infected by *A. artemisiifolia*, some habitat types are still free from it. However, in case of soil disturbance and available seeds all habitat types are prone to *A. artemisiifolia* colonisation. Lands that were ploughed in the last 2-3 decades are likely to have high *A. artemisiifolia* cover from the seed bank if they are cultivated again (e.g. afforestation). These results suggest a further potential for *A. artemisiifolia* spread, especially in case of hectic, spatially and temporally variable land use. In particular, old-fields should be treated with caution during land-use planning.

Control of *Ambrosia artemisiifolia* on non-cultivated land – effects of different cutting and herbicide regimes

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Ambrosia artemisiifolia is an invasive annual weed causing human health problems as the pollen gives strong allergic reactions. The species is growing on both agricultural and on non-cultivated land like building lots or road verges. On non-cultivated areas, both conventional and alternative weed control methods must be taken into account to control the spread of viable seeds of *A. artemisiifolia* to other regions. (Why should viable seeds not be spread into other regions, characterise the species) In a joint EUPHRESKO-project (<http://www.agrsci.dk/ambrosia/home/team.html>) different control measures were evaluated. We studied two potential habitats (grass and gravel sites) at three different locations (Denmark, Germany, and Switzerland (mention the institutes)). Control measures were i) two times cutting (plant stage), ii) three times cutting (plant stage), iii) cutting + herbicide application (at same date?), and iv) herbicide application + cutting (at same date?), carried out at an a) early (BBCH 21-25) and a b) late (BBCH 55) growth stage (what about three times cutting?). The herbicide treatment consisted of the application of 1200 g a.i./ha of Mecoprop-P.

In the grass experiments *A. artemisiifolia* was facing additional competition by dense (give a value) vegetation, whereas on the gravel sites nutrient deficiency was apparent (what about *Ambrosia* development?). Treatments including herbicide application were the most effective on both surfaces, by reducing phenological development, plant height and biomass of *A. artemisiifolia* significantly. The cutting-treatments had also negative effects (explain negative effects in terms of plant height in cm) on growth and development (plant stage?) in most of the experiments independent of the frequency; however, in Denmark plant growth was enhanced by cutting (according to instructions to prepare abstracts figures and tables are not allowed). The developmental stage at the time of treatment had almost no effect but we found significant interactions between growth stage at the time of treatment and control method. Our results showed that *A. artemisiifolia* is controlled most efficiently by a combination of herbicide application and cutting. Control measures can be applied at any time (= growth stage) (what about dispersal of grains?). Cutting helps to prevent further spread by slowing down phenological development, thereby possibly inhibiting pollen production and seed set.

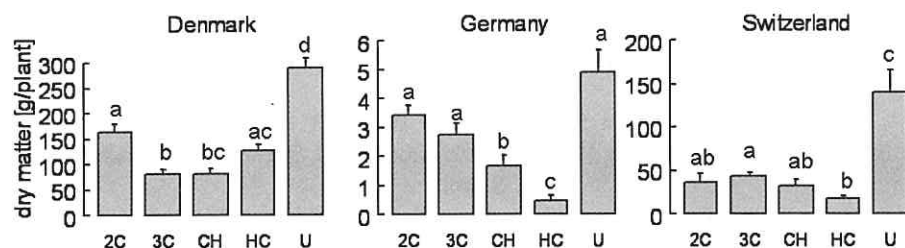


Fig. 1 Effects of different control strategies on *A. artemisiifolia* dry matter on gravel sites. Control strategies: 2C = two times cutting, 3C = three times cutting, CH = cutting + herbicide, HC = herbicide + cutting. Means \pm SE, different letters indicate significant differences (ANOVA, TukeyHSD). Note the varying y-axes.

SESSION 6
NON-CHEMICAL TACTICS AND STRATEGIES

Oral presentations

Session organizers:

Bo Melander & Svend Christensen

Crop rotation and weed management

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Although crop rotation is often mentioned as an important component of weed management strategies, tools for optimizing the weed-suppressive function of crop rotations are still lacking. The long-term character of this strategy, the complexity of competitive relations between crop and weed and among weed species, and the variety of weed-promoting and weed-suppressing conditions and events that are involved, complicate this matter. Simulation models can help to quantify the contribution of individual system components and identify and resolve the mechanisms of crop rotation that are responsible for reducing the weed problem, thus offering scope for systems optimization.

Worldwide, agriculture is dominated by a limited number of major crops and, as a consequence, present-day agriculture is characterized by lack of diversity. Scaling up to larger farm sizes, mechanization, and the availability of synthetic inputs, particularly fertilizers and pesticides, have promoted and facilitated this reduction in crop diversity. Reversely, uniformity is often mentioned as one of the main causes of the large dependency of current cropping systems on pesticide use, of which the herbicidal control of weeds is a clear example. The vulnerability of systems that largely rely on just a single weed control measure is an important incentive to advance the use of alternatives.

Crop rotation is the practice of growing different crops, in recurring succession, on the same land as opposed to planting the same crop time after time. Particularly with regard to the conservation of soil fertility and the minimization of the negative effects of specialized soil-born pests and pathogens, the use of crop rotations has clear advantages. The alternation of host with non-host crops breaks the life cycle development of monophagous pests and specialized pathogens, resulting in decreased population levels and reduced damage. For weeds the situation is less evident, as, with the exception of parasitic weeds, weed species are biologically not as intimately connected to a crop as specialized pests and pathogens. Still crops and their associated management often create favourable conditions for growth and reproduction of specific weed species, whereas they inflict serious stresses on others. In addition, crops often facilitate the use of a specific range of weed control measures. Consequently, crops are often accompanied with their own characteristic weed flora.

By maintaining a uniform set of conditions for a prolonged period of time, monocultures promote the proliferation of one or just a few weed species that are perfectly attuned to the growing cycle and growing conditions of that crop. In contrast, crop rotations will generally result in more diversified weed communities, whereas they also will be able to avoid situations where a single dominant weed species threatens an entire system. But will a more diverse weed community be less threatening? Finding an answer to questions like this, requires fundamental insight in the relation between crop rotation and weed community dynamics. In the current study, a modelling approach was used to identify the main determinants of the effectiveness

of crop rotation from a weed management perspective. The acquired insight in the weed suppressive mechanisms of crop rotation served as a basis for cropping systems optimization, involving aspects like the type, number and order of crops in a crop rotation. Finally, benefits for weed management were weighed against possible detriments or restrictions related to the implementation of more weed-suppressive crop rotations. In this way the potential of crop rotation as a weed management tool was evaluated for a range of cropping systems.

Diversifying crop rotations with perennial forage crops for Integrated Weed Management

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Diversifying crop rotations may be essential for Integrated Weed Management. We tested if and how perennial forage crops changed the weed species composition.

First, weed communities were compared between six annual crops (wheat, rape, pea, maize, sunflower, sorghum) and perennial alfalfa (*Medicago sativa*, 2-6 years) in a large scale survey (3 years, 632 fields in western France). Pairwise multivariate comparisons (ANOSIM) showed that differences in species composition were greatest between perennial and annual crops followed by contrasts between spring and summer sown annual crops.

Second, comparisons of weed communities before, during, and after perennial alfalfa crops suggest that weed community trajectories are strongly affected by the inclusion of perennial crops. Wheats following alfalfas were characterized by reduced frequencies of several noxious weeds, particularly upright and climbing annual species, while some biennial and perennial broad-leaved species had been promoted. These differences were consistent to, and may be comprehended by, the weed community trajectories during the perennial crop.

Third, population dynamics of 16 major annual weed species were analyzed in a 2.5-year field experiment comparing annual and perennial crops with contrasted crop management options varying by crop species (*Medicago sativa* vs. *Dactylis glomerata*), sowing date (autumn vs. spring), and cutting frequency (3 vs. 5 cuts per year). All nine crop treatments were managed without herbicides. Initially sown weed seed banks of *Alopecurus myosuroides*, *Bromus sterilis*, *Fallopia convolvulus*, *Galium aparine*, *Lolium multiflorum*, *Papaver rhoeas*, and *Sinapis arvensis* showed increasing tendencies in annual cereal crops but decreased or remained stable in the different perennial crop treatments. Densities of several other species decreased in all crop treatments and only few species showed increasing seed banks in perennial crops: *Capsella bursa-pastoris* and *Chenopodium album* in spring sown perennial crops; *Stallaria media* in autumn sown perennial crops. *Veronica persica* and *Geranium dissectum* were the only species that showed increasing seed banks both in some perennial and annual crop treatments.

These experimental results globally agree with the large scale weed surveys on commercial fields and indicated that the impacts on weed communities are mainly caused by the absence of soil tillage, the strong levels of competition (during the whole vegetation period) and frequent hay cuttings in the perennial forage crops.

Keywords: Temporary grassland, ley crop, *Medicago sativa*, lucerne, weed functional group, species traits, community assembly, biodiversity.

Flame weeding on hard surfaces: the effect of time intervals between flaming treatments.

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The aim was to find a time interval between flame treatments that could optimize the control of *Lolium perenne* and *Poa annua* on hard surfaces. Flame weeding controls a wide range of annual weeds, but plants with protected meristems, such as grasses, pose a special problem because of the ability to regrow post treatment. Therefore, repeated treatments are necessary. *Lolium perenne* and *Poa annua* are common grass weeds on hard surfaces. We present data from a semi-controlled experiment in pave stones with well-established *Lolium perenne* and *Poa annua* plants. The effect of time intervals (3,7,14,21,28 or 35 days) between flaming treatments was studied. The first flame treatment was carried out in July 2008. Above and below ground biomass of 72 plants per treatment were harvested and weighted with regular intervals to investigate how the plants reacted on flaming in relation to the compensation point of the plants, compensatory growth and seed production. Regrowth after the second treatment was measured as above ground biomass two weeks after the second treatment. Flaming significantly decreased plant biomass and percent flowering plants. Regrowth after the second treatment was lowest when there were 7, 28 or 35 days between treatments (*Lolium perenne*). The low regrowth when there was long time between treatments may be due to natural senescence. This part of the study will be repeated in 2010. Knowledge on the reactions of *Lolium perenne* and *Poa annua* to flaming provided by this study can help improve practical advice regarding the control of these species.

Tolerance to flaming of *zoysia tenuifolia*, *cynodon dactylon* and *paspalum vaginatum*

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An innovative solution for vegetative establishment of warm-season turfgrass species (for instance Genus *Cynodon*, *Zoysia*, *Stenotaphrum*, *Eremochloa*, *Paspalum*, *Axonopus*, *Distichlis*, *Pennisetum*) seems to be field transplanting of seedlings (similar to vegetable transplanting). This technique is an Italian patent (called "Erbavoglio system") and gives the advantages of sodding (the use of pallets or rolls of pre-established turf) with lower costs. On the other hand, these species, when transplanted, can suffer from weed competition during the first period of establishment. A long term experiment, started in July 2009, is being carried out with the aim of assessing the tolerance of three different warm-season transplanted turfgrasses to open flame treatments, *Zoysia tenuifolia* Willd. ex Thiele *Cynodon dactylon* L. Pers. and *Paspalum vaginatum* Sw. during the first 5 weeks of development, in the perspective of application of selective thermal weeding interventions. The plants were grown in a greenhouse and transplanted in 30 cm high 23,5 cm wide and 5 cm deep pots, containing peat based substrate. Four plants were hand transplanted in each pot. The thermal treatments were performed with a test bench equipped with a belt conveyor driven by an electric engine (which allows to move the pots with a speed varying between 1 and 9 km h⁻¹), a 25 cm wide rod burner and a LPG feed group that allowed to operate with different values of pressure, ranging from 0 up to 0.5 MPa. LPG dose per unit surface was obtained by combining the different speeds with the different working pressures. For each species different doses and different frequencies of treatment were tested. The frequency of treatment was also differently distributed along the time. Digital images were analyzed with an automated procedure, originally programmed in MATLAB3, and later developed into a web-based software (www.imaging-crops.dk), with the aim to assess crop canopy one week after treatments. Crop biomass was assessed at the end of the cycle. In order to find a relationship between the doses of LPG and the plant cover percentage, non-linear regression was performed fitting a 3 parameters log-logistic model. Biomass loss was described using a yield loss-Michaelis Menten model ("R" software, "drc" package – Ritz & Streibig, 2005). *Cynodon dactylon* was the most sensitive species showing on average a 50% reduction of the canopy using about 15 kg ha⁻¹ of LPG, a maximum biomass loss of 75% with one treatment and 100% with two or more treatments. *Paspalum vaginatum* appeared the most tolerant showing on average a 50% reduction of the canopy at about 30 kg ha⁻¹ of LPG, a maximum biomass loss of 65% with one treatment and 100% with two or more treatments. *Zoysia tenuifolia* showed on average a 50% reduction of the canopy using about 25 kg ha⁻¹ of LPG, while biomass sampling and data processing are still on-going. However, selective flame treatments seem possible for warm-season turfgrasses, if applied with an adjusted dose. Obviously further experimental work is needed. This research was funded by the Ministry of Agricultural, Food and Forestry Policies of Italy. Project: "Sistemi avanzati per la produzione vivaistica di tappeti erbosi di specie macroterme ad uso multifunzionale a basso consumo idrico ed energetico".

Testing sensors to develop algorithms for automatic adjustment of the harrowing intensity

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July, 2010

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Three field experiments in winter and summer wheat and in summer barley were conducted in 2008–2009 to investigate effects of different direction, timings and intensities of harrowing on selectivity and crop yield. Selectivity is the ratio between weed control percentage and crop soil cover percentage immediately after harrowing. Crop – and weed coverage, weed density were measured before and after harrowing, using bi-spectral camera technology. *Alopecurus myosuroides*, *Galium aparine*, *Matricaria chamomilla*, *Polygonum convolvulus* and *Lamium purpureum* were the dominant weed species. A sensor measuring the vertical power transmission was used to calculate the soil resistance to the forward movement of the harrow. A microcontroller was used to measure the analog input values of soil resistance and control the harrowing intensity. The data of the field trials were used to develop a decision algorithm /decision support system to vary the harrowing intensity in real-time, based on continuous data acquisition with the soil-, weed- and crop sensors. The algorithm aims to achieve highest selectivity of weed harrowing at each location in the field. Results show high variability in weed- and crop coverage and soil resistance within the fields which indicates that a permanent adjustment of the intensity is necessary. An 80 percent weed control was achieved with 10 to 40 percent of crop soil cover. Soil resistance was higher in winter wheat than in summer barley and wheat thus higher intensity was needed to get the same selectivity. Harrowing before the 3-leaf stage in summer wheat reduced selectivity and increased crop damage. The best settings of harrowing resulted in an increment of grain yield in 1–1.5 tons per hectare in winter wheat, and 0.5–1 tons per hectare in summer wheat, compared to the untreated plots. In summer barley there was a yield reduction due to increasing harrowing intensity, mainly due to low weed competition. These intensity adjustments are to be applied for achieving site-specific weed harrowing in future experiments.

Keywords: image analysis, soil resistance, soil coverage, harrowing intensity, selectivity, automatic adjustment

Effectiveness of joint filling materials for weed control in paved areas

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The recent phase out of herbicidal use on public pavements by the Flemish government triggers the development of new alternative weed control strategies. Besides the search for effective non-chemical curative methods, there is also a need for weed preventive strategies on pavements. In this study, different joint filling materials for pavements were assessed for their effectiveness in weed control.

The experiment included seven standard construction materials, and three innovative fillers that were specifically designed for weed prevention. Tested standard materials were: fine white sand, sea sand, porphyry (grain size fractions 0-6.3 mm and 2-6.3 mm) and limestone (0-2 mm, 0-6.3 mm and 2-6.3 mm). The weed preventive fillers used were Rompox®-easy (polymeric bound sand) and two types of Dansand® (sodium silicate enriched sand and sodium silicate enriched stone dust). All joint fillers were mixed with fine compost up to six levels i.e. 0 (=pure), 5, 10, 20, 40 and 80 % compost by volume. These levels were designed to simulate in situ organic pollution of joints. The study was conducted as a growth chamber pot trial. Joint fillers and compost levels were arranged in a **randomized complete block design** with four blocks. Weed suppressive ability of joint filler materials was tested by examining the growth response of four test species (one species per pot trial) in pure or polluted filler substrate. Selected test species were *Taraxacum officinale*, *Poa annua*, *Plantago major* and *Trifolium repens*, all dominant, hard to control weed species on pavements. After sowing, pots were kept for 30 days at fixed diurnal temperature and light regime (16h photoperiod at 25°C followed by 8h in darkness at 15°C). Pots were watered twice a day by automatic sprinkler irrigation (1.4 mm of water per day). Weed seedling emergence was weekly counted and weed dry biomass was determined 30 days after sowing.

Rompox®-easy and Dansand® significantly reduced weed biomass, irrespective of pollution level or test species. Within standard joint fillers, pure fine white sand and the coarser materials (limestone as well as porphyry) reduced biomass, but their inhibitory effect dropped quickly once organically polluted. Contrary to the other standard fillers, fine limestone (0-2 mm) showed a long-lasting inhibitory effect on weed growth: the total biomass remained low even at higher pollution levels (up to 40% compost by volume). Sea sand reduced seedling emergence of all species tested, especially when pure or slightly organically polluted. Within standard joint fillers at the 80% pollution level, weed biomass of all species tested was lowest in pots filled with sea sand, except for *Trifolium repens*. For this species the inhibitory effect of sea sand was lost at higher pollution levels. By contrast, limestone and porphyry (0- 6.3 mm) inhibited weed growth of *Trifolium repens* at all pollution levels.

In conclusion, weed preventive ability of joint fillers was highest for the innovative materials

based on polymeric or sodium silicate enriched sands. Within standard materials, fine limestone (0-2 mm) and sea sand are promising fillers for weed prevention due to their ability to reduce weed biomass even in highly polluted circumstances. The weed inhibitory effect of joint fillers is species dependent. This highlights the need to determine the impact of joint fillers on weed growth for all common species found in paved areas. Overall, these results show an opportunity for weed prevention by using suitable joint fillers in the construction of pavements. The use of fillers showing long-lasting weed suppressive ability might reduce total adverse environmental impact of curative weed control by reducing its frequency required to *keep weed* density at an *acceptable level*.

SESSION 6

NON CHEMICAL TACTICS AND STRATEGIES

Poster presentations

Session organizers:

Bo Melander & Svend Christensen

Impact of type and quality of organic amendments on size and composition of the weed seed bank

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Depletion of the soil seed bank is important in overcoming yearly weed infestations. In addition to improving the soil quality, organic amendments of soils may affect weed seed survival, emergence, growth, and reproduction. This study evaluated the effects of 4 year-long applications of eight different fertilizer regimes on size and composition of the weed seed bank in a field under sequential cropping. Fertilization systems tested included: farmyard manure; vegetable fruit and garden waste (VFG) compost; two types of farm compost differing in C: N ratio; cattle slurry; mineral fertilizer and two treatments without fertilization (one with a crop and one without). Organic fertilization systems (manure, slurry and three compost types) tested differed in the quality of the applied organic matter but not in quantity of applied organic carbon. Crop growth was levelled out on all fertilized plots by applying extra mineral N. By this design, differences in seed bank composition and density can reasonably be attributed to the type or quality of organic fertilizer. All amendments were supplied before sowing or planting. Seed bank sampling took place in May 2009 to a depth of 10 cm. The weed seed bank was analysed with the seedling emergence method. Microbial biomass and composition were determined by analysis of phospholipid fatty acids. Data were analysed using ANOVA and multivariate statistics.

The impact of the presence or absence of a crop or fertilization was very significant. After 4 years of sequential cropping, unfertilized and uncropped plots showed a fivefold higher total weed seed bank density than unfertilized cropped plots. Compared to fertilized cropped plots, unfertilized cropped plots showed a two to fourfold higher weed seed bank density. Within fertilized plots, seed bank densities were lowest in plots which were continuously amended with recalcitrant composted organic materials e.g. VFG and farm composts. These plots showed highest values for fungal biomass and fungi to bacteria ratio. In addition to influencing total seed bank density, type and quality of the applied fertilizer also affected species-specific seed bank density. Within fertilized plots, plots amended with more stable carbon compounds, in particular VFG and farm compost plots, showed lower seed densities of *Lamium purpureum*, *Poa annua* and hard seed coat possessing species *Chenopodium album*, *Capsella bursa-pastoris* and *Solanum nigrum* than plots amended with more readily decomposable compounds (slurry) or synthetic fertilizer. Indeed, persistent species are more vulnerable to management actions that reduce physical integrity of the weed seed coat such as the use of organic fertilizers that stimulate microbial breakdown. Finally, fertilizer form and quality also influenced weed flora composition. Four weed communities could be distinguished from the multivariate seed bank analysis. The first one is characterized by *Chenopodium polyspermum* and *Polygonum maculosa* and is related to mineral fertilization.

The second community is characterized by *Poa annua* and *Sonchus oleraceus* and is linked to fertilization with farm compost with high C:N ratio. The third community is characterized by *Galinsoga quadriradiata*, *Cardamine hirsuta* and *Cerastium glomeratum* and is related to fertilization with compost with low C:N ratio e.g. VFG compost. The fourth community is characterized by *Plantago major* and *Gnaphalium uliginosum* and is associated to manure or slurry amendments. In conclusion, fertilizer management might be a promising sustainable tool in integrated weed control strategies aiming at depleting the soil seed bank. The depletion effectiveness largely depends on the type and quality (e.g. decomposability) of the organic fertilizer indirectly affecting soil microbial community composition and activity.

Crop tolerance to broadcast flaming

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Propane flaming could be an effective alternative tool for weed control in organic cropping systems. However, crop tolerance to broadcast flaming must be determined first in order to optimize the proper use of propane dose. Objective of this paper was to summarize baseline information from several studies on crop tolerance to broadcast flaming. A series of over 15 field experiments were conducted in 2008 and 2009 utilizing six rates of propane and six agronomic crops in Nebraska: maize (*Zea mays* L.), sorghum (*Sorghum halepense*), soybean (*Glycine max*), and winter wheat (*Triticum aestivum* L.). In addition, tolerance of three maize types to flaming was also compared, including field maize, popcorn (*Zea mays* L. var *everta*) and sweet maize (*Zea mays* L. var *rugosa*).

Flaming treatments were applied utilizing a custom built flamer mounted on a four-wheeler moving at a constant speed of 6.4 km h⁻¹, and propane pressure was changed in order to deliver propane doses that included: 0, 12, 31, 50, 70 and 85 kg/ha. Flames were positioned directly over crop rows in order to purposely cause crop injury, thus test crop tolerance to broadcast flaming. Crop response to propane flaming was evaluated in terms of visual injury (1, 7, 14 and 28 days after treatment-DAT), effects on dry matter (28 DAT), various yield components (e.g. in maize: plants m⁻², ears plant⁻¹, cob length, kernels cob⁻¹ and 1000-kernel weight) and grain yield. The response of different crop growth parameters to propane dose was described by various forms of the log-logistic model and graphs were made utilizing R program and the *drc* statistical package.

Overall response to flame varied depending on the species, growth stage and propane rate. Grassy type crops (maize, sorghum) were more tolerant than the broadleaf crops (soybean). The most tolerant maize type to broadcast flaming appeared to be sweet maize. Based on yield components tested, the V7 stage was the most tolerant, while V2 was the least tolerant stage for broadcast flaming in sweet maize. A 5% yield reduction (e.g. threshold level) in sweet maize was evident with 23, 25 and 36 kg ha⁻¹ of propane for V2, V5 and V7 growth stages, respectively. Field maize flamed at V5 stage was the most tolerant for broadcast flaming, whereas V2 stage was the most susceptible to flaming. The maximum yield reduction in field maize with the highest propane dose of 85 kg ha⁻¹ were 3% for V5, 11% for V7 and 17% for V2 flaming stage. Of all maize types tested, popcorn was the most sensitive to broadcast flaming regardless of the flaming stage.

Soybean flamed at cotyledon stage showed much higher level of tolerance to flaming compared to any other growth stages. Flaming negatively affected all yield components of winter wheat, therefore due to unacceptable yield losses, the use of broadcast flaming in winter wheat is not recommended.

Of all crops tested, broadcast flaming has the most potential for use in maize types (field maize, sweet maize and popcorn) and sorghum.

Cultural practices to manage weeds in winter cereals under no tillage in dryland fields

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The introduction of direct drilling and zero tillage more than 25 years ago in the Ebro Valley region in north-eastern Spain revealed some difficulties in weed control. Since chemical control is not enough to manage some weed species, research on alternative cultural methods is required. In the 2008-09 season, the influence of three sowing dates (20 October, 7 November & 10 December 2008) and two barley varieties (cv. 'Hispanic' and cv. 'Sunrise') on total weed emergence and cereal yield were analyzed in a field under direct drilling. Main weeds recorded were *Bromus diandrus*, *Galium parisiense*, *Papaver rhoeas* and *Lolium rigidum*. By delaying the sowing date, total weed emergence was significantly reduced, because previous weed emergence had been eliminated with glyphosate. In June, plots sowed in November and December had, respectively, 86% and 94% less total weed emergence compared to plots sowed in October, the common sowing date in the area. Higher yields were obtained in November and December (from 4257 to 5118 kg/ha) in both varieties, and lowest in October (from 2572 to 3732 kg/ha). Results also indicated that the choice of cereal variety can be an important factor in relation to the sowing date to improve weed control through better crop competition. Optimizing the yield through the cereal variety choice can ensure the economic sustainability in dryland cereals. These preliminar results indicate that cultural practices such as sowing date and choice of cereal variety can be implemented in weed management for rainfed cereals under direct drilling in north-eastern Spain.

Ecological methods of weed management in Cumin

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Two field experiments were carried out in order to evaluate the effects of planting date, weed control method and date of weed control on weed number and weed biomass and yield and yield components of cumin (*Cuminum cyminum*) in the experimental research field of the Faculty of Agriculture during 2006 and 2007. Treatments included planting date (30 December, 20 January and 30 February), weeding date (first true leaf, start of branching and beginning of flowering stages) and weed control method (hand weeding, fire treatment and control). The results showed that there were significant differences in the number of weeds between different sowing dates, weeding dates and control methods. The highest mean density and biomass of weeds were obtained on the planting date, 30 February. The first planting date caused the lowest mean weed biomass and the highest cumin yield, compared to later planting dates. Delaying sowing date decreased the straw yield, number of umbellets per umbel, number of seed and biological yield. The highest cumin yield was achieved for the planting date of 30 December and the lowest for the 30th of February. Hand weeding treatment contained lower mean weed density and weed biomass compared to fire treatment. Fire treatment reduced weed growth in the first half of growing season, however, hand weeding significantly reduced weed density and biomass in the second half of cumin growing season that is more critical for seed filling and therefore, highest cumin seed and straw yields were obtained with hand weeding.

Effects of solarization, straw mulch and hand-weeding on weed seed-bank

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Today, problems associated with herbicide application have increased the interest in non-chemical weed control methods. Reducing weed seeds in the soil is essential for long term weed management. To study the effects of soil solarization, barley straw mulch and hand weeding on weed seedbank, a field experiment was conducted at Research Farm of College of Agriculture, Ferdowsi University of Mashhad, Iran during 2007-2008 growing season. This experiment was based on a randomized complete block arranged as a split-split plot design with three replications. Clear and black polyethylene sheets and non-solarized control were arranged on main plots. A different straw mulch rates (0, 300 and 600 g m⁻²), and weeding treatment were in the sub-plots and sub-sub plots, respectively. Polyethylene sheets were laid on moist soil surface on 6 August 2006 and were removed after 6 weeks. Then, barley straw mulch was spread uniformly over the plots. Soil samples were systematically taken in all plots, during mid-June in 2007. A total of 19 weed species were recorded in all treatments which were mainly annual broad leaved species. Results indicated that solarization with clear sheets had 1.8 times less seed density than the control plots. Common purslane (*Portulaca oleracea*) seed germination and purple nutsedge (*Cyperus rotundus*) emergence were stimulated by clear polyethylene treatment, but *C. rotundus* leaf sheaths were scorched under the mulch. Application of straw mulch decreased weed seed population, as the highest and the lowest seedbank size were obtained in control and 300 g m⁻² straw mulch, respectively. However, there were no significant differences between 300 and 600 g m⁻² straw mulch. Hand weeding had a significant effect on weed seed density and in no-weeding plots it was 3 times greater than weed control plots. The interaction between soil solarization, straw mulch and weeding on seedbank size was significant. The lowest number of weed seeds was observed in clear polyethylene, 300 g m⁻² straw mulch and weeding plots. Based on these results, it seems that integrated weed management applying solarization with clear polyethylene, barley straw mulch and hand weeding are very effective strategies for weed seed bank reduction.

Effects of tillage, crop residue and nitrogen on rape seed weed biomass

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In order to evaluate of the effects of tillage, crop residue and nitrogen on rape seed weed biomass, a field experiment was carried out at the Research Station of the College of Agriculture, Shiraz University, Shiraz, Iran located at Badjgah in 2008-9. The experimental design was a split-split-plot arranged in randomized complete blocks with 3 replications. The treatments were types of crop residues (wheat, rapeseed) as main plot, tillage in two levels [conventional tillage (mold board plow with 1 disking) and reduce tillage (chisel plow with 1 disking)] as sub plot and 3 levels of nitrogen (0, 75 and 150 kg ha⁻¹) as sub-sub-plot. A control treatment (no residue) was also included in the experiment. Results indicated that the different methods of tillage had no significant effect on weed biomass. Compared with control (no residue), the application of wheat and rapeseed residue increased weed biomass. With increasing level of nitrogen from 0 to 75 and 75 to 150 kg ha⁻¹, weed biomass increased at various plant growth stages. Interaction between residue and nitrogen showed that with increasing level of nitrogen in both rapeseed and wheat residue, weed biomass increased at each plant growth stage of rapeseed. Wheat residue had the highest effect on weed biomass compared to rapeseed residue.

Effects of tillage, crop residue and nitrogen on the oil percentage under weed and weed free conditions

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The purpose of this work was to study the effects of tillage, crop residue and nitrogen on rape seed oil percentage under weed and weed free conditions. This research was conducted at the Research Station of the College of Agriculture, Shiraz University Shiraz, Iran located at Badjgah in 2008-9. The experiment was a split-split-plot design with three replications with crop residue management (wheat, rapeseed) as main plots, tillage methods [conventional tillage (mold board plow with 1 disk) and reduce tillage (chisel plow with 1 disk)] as sub-plots and nitrogen levels (0, 75 and 150 kg ha⁻¹) as sub-sub-plots. A control treatment (no residue) was also included in the experiment. Results indicated that at both weedy and weed free conditions, the different methods of tillage had no significant effect on the oil percentage of oil seed rape. Under weedy conditions, wheat residue application compared to the seed rape residue and control (no residue), caused an increase in the oil percentage of seed rape by 18.33% and 17.98%, respectively. Under weed free condition, using wheat residue increased oil percentage about 4.79% and 4.43% in comparison with seed rape residues and no-residue respectively. The maximum oil percentage (32.07) was obtained by applying wheat residue. Under both weed and weed free conditions, results showed that with increase in level of nitrogen, oil percentage significantly decreased significantly.

Wheat mulch effects on the control of *Solanum nigrum*, *Portulaca oleracea* and *Amaranthus retroflexus*

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Allelopathy has a rather unexploited potential in integrated weed management. Several crop plants and specific varieties have the ability to produce and exude allelochemicals into their surroundings and to suppress the growth of weeds. This variation in allelopathic potential between genotypes can be used in the search for crop cultivars with enhanced allelopathic properties. Under that point of view, the evaluation of some important and local cultivars of durum wheat (*Triticum turgidum* ssp. *durum*) for their performance as a mulch for weed control was the subject of this study. One preliminary field and two greenhouse experiments were conducted during 2008-2009 in Agrinio region and Benaki Phytopathological Institute, respectively, in order to study the effect of ten durum wheat cultivars and local landraces, used as cover crops, on the emergence and growth of black nightshade (*Solanum nigrum*), pigweed (*Portulaca oleracea*) and red-root amaranth (*Amaranthus retroflexus*). In all cases, wheat cultivars were incorporated into the soil (10 cm depth) at the beginning of stem elongation and ear emergence. After 20 days, 0.5 g m⁻² black nightshade, 1 g m⁻² pigweed and 1.2 g m⁻² amaranth were dispersed uniformly (all seeds were of high germinability > 75%). Weed emergence and early growth were studied, while the plants were harvested 30 days after sowing. Our results showed that the dry weight of black nightshade, pigweed and red-root amaranth was reduced by 15 to 86 %, 17 to 90 % and 5 to 80 %, respectively, in wheat mulched plots compared with non-mulched plots. Weed emergence was also reduced by 5 to 60 % in all cases, and in most cases inhibited root growth was seen. Significant varietal differences in terms of their allelopathic activity as mulches were also indicated in the field. Biomass of the weeds was more intensively reduced (in total > 65 %) by the mulches of the varieties Kontopouli, Ntopia Heraclion, Papadakis, Meridiano and Levante. The results of the present study clearly highlight the differences between the several wheat cultivars regarding their allelopathic action suggesting that some of them could be used as a cover crop for weed suppression in subsequent crops (e.g. maize, cotton), in order to minimize herbicide applications and rates.

Integrated weed management in maize cropping using fertilizer and row space management

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In order to evaluate the effect of row spacing and optimized timing of nitrogen application on maize yield and its effectiveness against weeds, an experiment was conducted in Marvdasht Shiraz, Iran in 2008. The experiment consisted of four row spacing (50_60_70, and 80_ cm) and nitrogen fertilizer used in the following way: N1: all fertilizer applied at planting, N2: 2/3 applied at planting and the remaining 1/3 at the 8 – leaved crop growth stage, N3: 1/3 of the fertilizer was applied at planting, 1/3 at the 8-leaved growth stage and 1/3 before tasseling, N4: no fertilizer at planting and 1/2 the total amount at the 8-leaved stage and 1/2 before tasseling. The results showed that spacing and split application of nitrogen significantly affected competitiveness between weed and corn. The highest number of ears per m², biological yield and Crop Growth Rate (CGR) obtained from N2 and 60 cm row spacing, while the weed biomass, weed number per m², weed CGR and Relative Growth Rate (RGR) were lowest in this treatment. The highest weed biomass and CGR were observed at 80 cm row spacing and the N1 treatment. Number of kernels per ear was highest at 70 cm and the N2 treatment. In conclusion the results showed that using 60 cm row spacing and split application of N fertilizer can significantly increase maize, competitiveness against weeds.

Keywords: competitiveness, weed interference, fertilization, weed management

Weed problems on pavements

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Weeds on pavements in urban areas are unwanted mainly because they cause an untidy appearance and at worst structural damage. Municipalities and other public authorities responsible for the maintenance of pavements invest considerable funds and time into keeping pavements clear of unwanted weed growth and in a good state of maintenance. In addition to regular sweeping, glyphosate spraying is the predominant method of weed control in most European towns, usually requiring two applications per year for satisfactory control. However, herbicide use on hard surfaces is under pressure due to the risk of leaching of herbicides into ground water and nearby surface waters. These concerns have influenced policy making in some North European countries leading to federal restrictions in the use of herbicides on hard surfaces. Many municipalities in the Netherlands, Denmark and certain regions of Germany and Sweden have now restricted use of herbicides and there has been a shift towards alternative non-chemical methods. However, these methods are less effective than glyphosate and an optimisation of non-chemical methods would require an improved knowledge about the pavement flora to be controlled, especially the species composition, growth pattern and coverage of the pavement. Consequently, we surveyed the flora on pavements in five North European towns (Braunschweig (DE), Malmö (SE), Næstved (DK), Royal Leamington Spa (UK) and Wageningen (NL)) by recording weed species and their coverage in 56 sampling points randomly placed in each town. The points were scattered over three zones, industrial, residential and town centres, and weeds were recorded at several dates in 2005 and 2006. No weed control was applied during the survey apart from sweeping. Weed coverage increased during the survey (averaging 1.4% in late 2006) and was highest in the towns having the strictest policies on herbicide use. Industrial zones were mostly more weedy than the other zones with 3.5% weed coverage on average and more weed coverage (averaging 2%) was found along the pavement edge away from the road. *Poa annua* was the most frequently recorded species followed by mosses, *Sagina procumbens* and perennial grasses. Grasses and other species frequently found, notably *Taraxacum officinale*, should receive particular attention when planning a non-chemical weed control campaign on pavements.

Weed control on pavements; progress in application technology

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Herbicide weed control on pavements has the lowest direct costs to control weeds compared to available non-chemical methods. However, side effects of herbicides on pavements (e.g. run-off to surface water) can be large when used without specific emission reducing measures. In this paper data are shown on efficacy, costs and side effects of different methods and strategies for weed control on pavements under Dutch conditions. An Environmental Life Cycle Assessment shows that the environmental effect of a herbicide control system depends to a large extent on the amount of herbicide run-off. And run off is determined by the amount of use and rain conditions. The paper also presents data of project on sustainable weed management on pavements. The objective of the project was to develop a management system that gives a substantial reduction of herbicide run-off while maintaining good level of control at acceptable costs. Surface water, efficacy and cost monitoring in this SWEEP-project (www.dob-verhardingen.nl) showed that the environmental and economical targets could be achieved. This system is mandatory in the Netherlands by law since 2007 when glyphosate is used on pavements. About 30 municipalities and terrain owners and four weed control contractors have certified their weed control according to the SWEEP system today. Finally, data of experiments in 2008 and 2009 on innovative technologies for application of glyphosate to weeds will be presented. The technologies were tested under practical conditions, to determine herbicide use and efficacy. The following technologies were tested: sprayers with weed sensors (Weed IT and Weedseeker), controlled droplet application (CDA) systems (Mantis and Micron systems) and weed wipers (Greentouch and Rotofix). Herbicide use differed between technologies, but was also influenced by weed density. Herbicide use by the sprayers with sensors on strips of about 100 m length was 0.06 and 0.26 L Roundup evolution per ha, with smallest use for the Weed IT. The CDA systems used 1 L per ha (non selective application) on these strips. The weed wipers used about 0.05 L per ha. In an additional dose response experiment, efficacy of glyphosate was higher when applied with a CDA system than with an air pressure sprayer.

Could the *Desmodium* ‘push-pull’ system for *Striga* control in Africa work on *Phelipanche ramosa* and *Orobanche crenata*?

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Approximately 1% of all flowering plants are parasitic, representing over 3000 species in 16 plant families. Among the greatest biological constraints to food production in sub-Saharan Africa are the parasitic weeds, *Striga hermonthica* and *S. asiatica*. In Mediterranean countries, the parasitic weeds, *Phelipanche* spp. and *Orobanche* spp. are important constraints. The aim of this ongoing project is to determine whether the ‘push-pull’ system developed by ICIPE, which controls both maize stemborer and *Striga* in maize crops in Western Kenya, could be adapted for the control of *Phelipanche* and *Orobanche*. In the “push-pull” system a forage legume, *Desmodium intortum* (green-leaf) or *D. uncinatum* (silver-leaf), is planted between the rows of maize. The *Desmodium* leaves produce a chemical which repels stemborer moths from the maize crop, but the roots also exude two allelochemicals that influence the growth and development of *Striga*. One allelochemical stimulates seed germination. The key element is, however, that a second allelochemical from the *Desmodium* roots prevents attachment of the *Striga* haustorium to the roots of the maize host.

The question addressed in this paper is: Do root exudates from *Desmodium* spp. have analogous effects on *Orobanche* parasitism? This question is being answered by a series of experiments. In a glasshouse experiment, water from pots containing *Desmodium* plants on an upper bench is being used to water pots containing host plants on a lower bench. This is achieved by watering the *Desmodium* to excess and piping the water which has passed through the *Desmodium* pots to the pots containing the host plants. Systems being tested include pea with *Orobanche crenata*, tomato with *Phelipanche ramosa* and, to test the system, millet with *S. hermonthica*. Both silver-leaf and green-leaf *Desmodium* species are being tested. With appropriate dilution, exudates of both *Desmodium* species stimulate seed germination of *O. crenata* and *Ph. ramosa*. Results from the pot experiment show that there may be some reduction in attachments of *Ph. ramosa* on tomato, but results obtained so far for *O. crenata* on pea are less clear. Applications of the system to vegetable crops will be discussed.

Acknowledgement. We are grateful to the Libyan government for a PhD Scholarship awarded to M. Shrif.

Weed flora in paved areas in relation to pavement type, weed control and environment

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By 2015 all herbicide use on public pavements in Flanders will be phased out. This ban on chemical treatment highlights the need for more research into weed control on paved areas. Indeed, weed growth and applied weed control strategies on paved areas have not extensively been studied in Flanders up till now. The objectives of this study were (1) to explore the species composition of pavements in relation to various environmental conditions and (2) to determine the impact of different weed control methods on vegetation composition.

In autumn 2008, a vegetation survey was conducted on 163 public pavements with small paving elements at 34 locations across Flanders. On each of these pavements, botanical composition of the weed flora in paving joints was determined in 50 random sampling quadrats of 25 cm x 25 cm. Species importance (%) was calculated according to the combined frequency-rank method of De Vries (i.e. an indirect measure of species biomass in total weed biomass). A score for picture quality for weed growth was calculated based on average weed coverage of joints and vegetation height. In addition, for each pavement a set of environmental conditions was determined: light intensity (sun, semi shade, shade), environmental setting (urban, suburban, park, rural, woody), function (footpath, cycle track, parking place, gutter), intensity of use (high, moderate, low). A set of technical characteristics was measured: pavement width, type of the paving elements (conventional concrete pavers, draining concrete pavers, clay bricks, concrete tiles, cobbles and large concrete gutter components), dimensions of the paving elements, joint width (narrow: 0-2 mm, intermediate: 2-5 mm, wide: >5 mm). Data on the applied weed control methods were obtained through direct personal interviews with the pavements administrators or contractors. The weed control treatments were classified into four groups: (1) chemical weeding (different active ingredients but mainly glyphosate); (2) mechanical weeding e.g. brushing (steel weed brushes), sweeping (synthetic cleaning brooms), mowing and hand weeding; (3) thermal weeding e.g. burning, hot water, hot air and (4) no weeding.

Apart from *Musci* (present on 95.1% of the pavements), the five most important plant species in paving joints were *Poa annua* (90.8%), *Sagina procumbens* (79.8%), *Conyza canadensis* (73.6%), *Taraxacum officinale* (63.8%) and *Plantago major* (57.1%). This seems well in accordance with studies in other European regions.

The intensity of use, joint width, light regime and pavement type all had significant effects on the botanical composition of the vegetation and/or on the general perception of the street scene. Heavily trampled pavements with narrow joints showed highest picture quality or lowest weediness. Unshaded pavements showed highest importance of perennial weeds.

Furthermore, shifts in weed flora composition were observed caused by repeated use of any

weed control method. Continuous application of thermal weed control methods favoured annual and biennial monocotyledonous species (mainly *Poa annua*), compared to pavements without weeding or with chemical weeding. The importance of mosses was significantly higher in pavements treated with chemical herbicides (mostly glyphosate), than in pavements with non-chemical weed control or no weeding. These results suggest that a more optimal weed control on pavements might be achieved by alternating weed control methods possessing different modes of action and by optimal design of pavements.

Weed species respond differently to laser

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Previous research has shown that a laser beam directed towards the apical meristem can be an efficient weed control method. Laser technologies need to be further developed to be used for weed control and more documentation on the biological effect of laser is also needed. The objective of the present study was to determine the dose-response of laser treatments on different weed species and growth stages.

A series of experiments – each including 2 or 3 weed species and representing in total 11 different weed species were carried out during 2009. The weed species were sown in boxes in a glasshouse and transplanted to 1 L pots with one plant per pot after emergence. The laser treatments were carried out at the cotyledon stage and two of the species were treated at the 2-leaf stage as well. A 5 W laser operating at 532 nm was used for the treatments. The laser beam was focused on the centre of the plant by aiming with a red laser pointer. The spot size was 1.8 mm in most experiments however 3 different spot sizes (1.8, 3.0 and 5.0 mm) were included in two experiments. The operator controlled the deflection angle of a RayLase RLA 2-mirror unit to obtain the correct bearing upon the target. Each experiment included 8 to 10 treatments with irradiation durations from 4 to 2000 ms (equivalent to 0.01- 5.6 J mm⁻² with the 1.8 mm spot). The plants were harvested 2 to 3 weeks after treatment, and fresh and dry weights were recorded. The fresh weight results were subjected to non-linear regression analyses using a log-logistic dose-response model.

The most susceptible weed species were *Tripleurospermum inodorum*, *Papaver rhoas* and *Solanum nigrum* followed by *Veronica agrestis*, *Apera spica-venti* and *Lolium perenne*. Weed species with relative large cotyledons like *Brassica napus*, *Silene noctiflorum* and *Centaurea cyanus* were less susceptible. A high variation between replicates indicated that targeting was a critical parameter that needed to be improved. The efficacy was improved by increasing spot size which may be due to a higher probability in targeting the meristem. The efficacy of the laser treatments was affected by the location and area of the apical meristem, the spot size and the plant growth stage.

Response of common ragweed (*Ambrosia artemisiifolia*) to broadcast flaming

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Ambrosia artemisiifolia L. (common ragweed) is an annual species in the Asteraceae from the prairie regions of North America, which was introduced into Europe in the second half of the nineteenth century and has since invaded many countries where it is now considered a serious threat, invading field crops and open disturbed habitats or roadsides. Besides being a weed in various cropping systems, common ragweed is also considered a major allergenic plant due to abundant production of pollen, which causes severe health problems in humans. Propane flaming could be an additional tool to control ragweed in crop and non-crop (urban) areas. However, ragweed tolerance to propane flaming at different growth stages must be determined first to optimize the use of propane. Field experiment was conducted at the Haskell Agricultural Laboratory of University of Nebraska, Concord, NE in 2009 to determine common ragweed response to five propane doses applied at three growth stages: V4 (4-leaf), V14, and V26. The propane doses included were 0, 13, 22, 42, and 81 kg/ha. Flaming treatments were applied utilizing an ATV mounted flamer moving at a constant speed of 6.4 km/h. Ragweed response to propane flaming was evaluated in terms of visual injury ratings at 1, 7, and 14 DAT and dry matter reduction after 14 DAT. Dry matter reduction was expressed as a percentage of untreated plants. Response of ragweed to broadcast flaming varied among growth stages and propane dose. In general, the level of ragweed control decreased as the weed height increased. Of all growth stages, the V4 stage was the most susceptible to flaming, followed by V14 and V26 stages. Based on dry matter reduction, only 15 kg/ha propane was needed to obtain 90% control of ragweed at V4 stage, compared to 119 and 108 kg/ha for V14 and V26, respectively. We believe that flaming has a great potential to effectively control ragweed in both crop and urban settings.

Can volunteer spring turnip rape (*Brassica rapa* ssp. *oleifera*) be managed in organic farming?

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There is a need for increased production of oilseed crops in organic farming for protein feed or edible oil. Spring turnip rape has the largest potential cropping area of these crops at high latitudes. However, large seed losses during harvest and development of secondary dormancy under certain conditions turn oil seed crops into weeds in subsequent crops. The aim of this study was to investigate if volunteers of spring turnip rape (*Brassica rapa* ssp. *oleifera*) can be managed in organic farming by cultivation after harvest or mechanical control in spring cereals. Preliminary results from this study are presented here. Four field trials at two sites, established in 2006 and 2007, were conducted with autumn harrowing 0, 2, 4 or 0+2+4 weeks after sowing of spring turnip rape (simulated seed loss from harvest). Harrowing immediately after sowing gave the largest emergence in autumn under moist soil conditions. A few volunteers were detected in the fields 1 or 2 years afterwards. Seeds may also have been lost by germination without emergence, predation or attack of microorganisms. Four field trials were made at two sites in 2008 and 2009 with mechanical control of volunteer spring turnip rape in spring barley. The effect of early (blind harrowing, cereals 0-1 leaf) and late (cereals 3-4 leaves) weed harrowing, hoeing 2 times (cereals 3-4 leaves + flag leaf visible), and false seedbed preparation, eventually combined with blind harrowing varied between fields. Weed harrowing was done with an Einböck flexible tine harrow at 2-2.5 cm depth. Hoeing was made with a hand held equipment with a 20 cm wide goose foot share at 25 cm row spacing. Hoeing reduced the coverage of turnip rape usually by 50% or more, but not always the plant density. Blind harrowing resulted in some decrease of plant density at dry conditions. Otherwise the efficacy on spring turnip rape was poor. Other organic crops may have other opportunities for weed control. To support the field trials, the effect of moisture (moist, dry), constant temperatures (6, 12 or 20°C), light conditions (dark or light) and seed sources (newly harvested seeds of spring turnip rape: cv. Valo, Petita, Kulta, and winter oilseed rape: cv. Banjo, in addition to seeds shed before harvest (Petita), and one year old seeds (Valo or Petita)) on germination and dormancy were investigated in the laboratory in 2006-2009. The treatments were repeated twice in time (two years). At dark and moist conditions most seeds germinated. At dark and dry conditions, but also at 12°C at light and moist conditions, some dormancy developed. The dormancy development varied between cultivars and years. Fresh seeds of cv. Petita developed less dormancy than Valo in both years. Dormancy of shed seeds did not differ from newly harvested seeds. Seeds stored for one year developed very little dormancy. To get rid of seeds in autumn by germination, we conclude that harrowing should be performed immediately after harvest of spring turnip rape under moist conditions which usually occur at harvest of spring turnip rape. At dry conditions harrowing should be avoided.

Spring turnip rape cultivars with low dormancy potential should be preferred in organic farming. Spring turnip rape in spring cereals should preferably be controlled by hoeing. Blind harrowing at dry conditions in spring cereals caused some reduction of spring turnip rape, but the effect was probably too poor to be recommended as a weed control measure.

Control of docks (*Rumex spp.*) – experiments on optimizing soil tillage when renewing highly infested organic grassland

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Docks are among the most important perennial weeds in grasslands throughout the world and the need for more effective control methods is especially crucial in organic forage production. To find more effective control methods, field trials over 2 years at 4 Norwegian locations, were carried out mainly as a full-factorial design, including factors expected to reduce docks significantly. (i) Date of grassland establishment: may be important for preventing/decreasing the flush of seedlings from seeds as well as shoots from root fragments. (ii) False seedbed preparation: to decrease soil seed bank. (iii) Use of nurse crop (cover crop) to increase competitiveness against *Rumex* seedlings. (iv) Cutting the taproot, using a rotary tiller before ploughing, or the “dock-plough” (a skimmer modified to cut roots in the entire furrow width at ca 7 cm depth): as new shoots mostly come from the neck and the upper 5 cm of the taproot. (v) Ploughing depth and skimming: to decrease shoots from root fragments. Weed development was assessed as the number of emerging *Rumex* seedlings and plants sprouting from root fragments. Results indicated that frequently more plants emerged from seeds than from root fragments. Neither renewing the grassland in summer, nor the use of the rotary tiller or the “dock plough” reduced the number of docks in the renewed grasslands. The use of the false seedbed and nurse crop, at some locations and years, reduced the number of docks in the renewed grasslands. Deep ploughing (24cm) reduced the number of *Rumex* plants from roots by 65% percent compared to shallow ploughing (16cm). Furthermore, the use of a skimmer reduced the number of docks sprouting from roots by 28%. Among the investigated factors, competitiveness, false seedbed and ploughing depth, as well as ploughing quality, seems to be the most promising factors for reducing the number of docks in renewed grassland.

Allelopathic potential of different cover crops tested under field conditions

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In times where more and more herbicides are withdrawn due to environmental concerns it is important to find alternative methods for weed control. We are screening 16 different cover crops from several families (brassicaceae, fabaceae, poaceae, asteraceae) under three different cultivation methods (autumn and spring incorporation (at two different times) of cover crop residues) for *their competitive and allelopathic potential* against field weeds.

Under field conditions we are observing the effect of incorporation of cover crop residues on the germination and the growth of weeds in dependence of the time of incorporation. We are also studying the competitive ability of the different cover crops as a method of weed management.

Experiments under field conditions *are supplemented by* studying the effect of aqueous foliar extracts of dried leaf samples from cover crops grown in the field essay on seed germination and growth of in vitro plants. Additionally we are testing the effect of the incorporation of plant residues in the green house to confirm the observations in the field.

Our short term goal is to identify 3 to 5 cover crops with allelopathic potential, which we will then study in more detail in the coming years. We want to identify phytotoxic molecules, determine the *species* showing the *greatest allelopathic potential*, *selecting* the appropriate cultivation method, determining the right moment of incorporation of plant residues for maximum effect, etc.

Results will demonstrate whether certain cover crops can facilitate weed control. Our aim is to develop applicable solutions to reduce dependence on herbicides.

The poster will display the project and summarize results of the field trial accompanied by laboratory data from the first year.

Weed and celeriac response to mulch from cover crops

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The weeds and celeriac [*Apium graveolens* L. var. *rapaceum* (Mill.) Gaud] response to different cultivation methods based on the usage of mulch from cover crops was determined. In the studies carried out during the growing seasons of 2006-2008, the weed infestation and composition of weed flora and the growth and yield of transplanted celeriac were evaluated. Celeriac was cultivated as: - without cover crops, - in mulch with cover crops residues left on the soil surface - with cover crops residues cut and incorporated 10-12 cm deep into the soil. In all cultivation methods celeriac was a) not weeded, b) weeded by hand or c) sprayed with linuron in one treatment (675 g a.i. ha⁻¹) and with split application method (3x169 and 169+225 g a.i. ha⁻¹). Winter rye and hairy vetch mixture used as cover crops was sown in late summer after harvesting of previous crop. Overwintering cover crops, before transplanting of celeriac at the end of May, were desiccated with glyphosate and crumbling or cut and incorporated with the soil. Winter rye and hairy vetch mixture produces a high amount of biomass and are well adapted to Poland's growing conditions. Some authors indicate that weed biomass and density decrease as biomass of cover crops residues increases. During the studies, the primary and secondary weed infestation, density and biomass of weeds per m², the yield of celeriac and some ecophysiological factors were evaluated. Leaf area index (LAI) was determined by Sun Scan Canopy Analyzer, chlorophyll content in the leaves of celeriac by chlorophyll meter SPAD-501 and relative variable chlorophyll fluorescence was measured by Mini Pam fluorometer. Chlorophyll content in the leaves and relative variable chlorophyll fluorescence were measured six times: five during the vegetation period and the last one before harvest. Celeriac was harvested between 9 and 15 of October. Winter rye and hairy vetch mixture produced a high amount of biomass. Before desiccation the biomass of mixture exceeded 52 tons and before cutting 55 tons ha⁻¹. The weed infestation was dependent on cultivation methods. Cover crops left on the soil surface reduced primary and secondary weed infestation. The number of broadleaved weeds ranged from 3.1-16.9 m² in celeriac cultivated in mulch from cover crops residues left on the soil surface, without herbicide, and from 30.6-53.8 m² with cover crops cut and incorporated with the soil. In celeriac grown without cover crops, the weed density was higher than in cover crop residues left on the soil surface. The lowest weed biomass (fresh weight) was determined 56-63 days from transplanting celeriac in the system with cover crops left on the soil surface. Herbicide linuron was more effective without cover crops and with cover crops incorporated with the soil than in cover crops left on the soil surface. Lower activity of herbicide was caused by higher adsorption by the mulch. It was proved that cultivation system influenced celeriac yield. The highest yield was obtained when celeriac was grown in a mulch obtained from cover crops left on the soil surface. The maximum values of Leaf Area Index were observed in celeriac grown without cover crops and in cover crops incorporated with the soil. In cultivation methods with cover crops cut and incorporated with the soil and without mulch, a systematic increase of chlorophyll content in the leaves of celeriac and relative variable chlorophyll fluorescence until harvest were obtained. In celeriac cultivated with cover crops left on the soil surface, a decrease of both eco-physiological factors was noticed before harvest.

Direct weed suppression by cover crops and residual effects on grain maize and sunflower

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The aim of this study was to investigate the weed suppression potential of different winter cover crops during the cover crop growing cycle and in subsequent grain maize and sunflower.

A plot trial was carried out in 2005-06 and 2006-07 at the Interdepartmental Centre for Agri-Environmental Research "E. Avanzi" (CIRAA) of the University of Pisa (Italy) within the framework of a long-term experiment (MASCOT, i.e. Mediterranean Arable Systems Comparison Trial).

The cover crops experiment was laid out as a randomised complete block design with eight replications, with plot size of 10 x 12 m. A weedy control and 8 different cover crops (*Avena sativa*, *Brassica juncea*, *Phacelia tanacetifolia*, *Secale cereale*, *Trifolium incarnatum*, *Trifolium squarrosum*, *Vicia faba minor*, *Vicia villosa*) were compared in pure stands. In 2007 *S. cereale* was replaced by *Hordeum vulgare*. Two mixtures in 2006 (*A. sativa* + *T. incarnatum*, *S. cereale* + *V. villosa*) and three in 2007 (*A. sativa* + *T. incarnatum*, *A. sativa* + *T. squarrosum*, *H. vulgare* + *V. villosa*) were also included. Cover crops, that did not receive any fertilisation, crop protection or direct weeding measures, were broadcast seeded in early autumn and ploughed under in early April by means of a disc harrow. Maize and sunflower were sown on April 2006 and on May 2007 according to a randomised complete block design with four replications. Data were subjected to ANOVA and then tested with LSD test at $P \leq 0.05$ for mean separation.

In both years there were significant differences between treatments in terms for all the examined parameters. Leguminous cover crops showed the highest biomass production in both years. In 2006 we observed the highest value for *V. villosa* with 4.69 t ha⁻¹ respect to an overall mean of 2.67 t ha⁻¹. In 2007 the better results were achieved by the mixtures, with a mean biomass of 7 t ha⁻¹, followed by *Trifolium incarnatum* and *Trifolium squarrosum*, with 6.31 and 6.71 t ha⁻¹, respectively.

Mixtures were the most weed suppressive cover crops in both years, yielding on average 0.6 and 0.3 t ha⁻¹ of total weed biomass compared to an overall mean of 1.8 and 1.1 t ha⁻¹ in 2006 and 2007, respectively. The highest main crop yield was recorded when maize or sunflower followed *V. villosa* in 2006 (5.87 and 2.26 t ha⁻¹ respectively), the mixture between *V. villosa* + *H. vulgare* in 2007 (2.97 and 3.23 t ha⁻¹ for maize and sunflower, respectively). Weed biomass in the subsequent main crops significantly differed among treatments only in 2006 ($P < 0.001$) but not in 2007. The lowest final weed biomass was observed after *A. sativa* cover crop (0.4 t ha⁻¹) in sunflower, after *V. villosa* (0.3 t ha⁻¹) in maize.

Effect of planting time and tomato varieties on broomrape emergence (*Phelipanche* spp.) and tomato yield in western Turkey

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Turkey is one of the foremost tomato producing countries. Tomato and tomato products are important exporting goods as well as tomato is the most produced vegetable in Turkey. Tomato production for processing provides good income for farmers in the Marmara and Aegean Regions. However, pests limit tomato yield. One of the pests in tomato production is broomrapes (*Phelipanche* spp. (syn. *Orobanch*e spp.)). Varying methods such as chemicals, organic amendments, planting time, pulling etc. have been recommended to control broomrapes; but there has not been a single method that effectively controls broomrapes in tomato fields. In addition to economic losses, lack of very efficient control methods in tomato to control broomrapes has caused the problem to expand. There are already varying variety choices for farmers. Also, a longer period is available for tomato transplanting. The aim of current paper was to identify a better variety, which is less affected by broomrape and transplanting time, which helps decreasing broomrape infestation. Experiments were established at different places in the South Marmara Region each year in 2007, 2008, and 2009. Fields were infested with a mixed population of *Phelipanche aegyptiaca* (syn. *Orobanch*e *aegyptiaca*) and *P. ramosa* (syn. *O. ramosa*) in 2007, 2008, and 2009. Data from the three years were pooled and statistically analysed. Number of emerged broomrapes and tomato yield were not affected by transplanting time (early, medium and late). However, cv SACHTA caused more broomrape emergence than two other varieties (ALTA and H.2710), although it was not reflected in tomato yield.

Effect of organic farming on weed composition in maize in Hungary

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The different farming systems are diverse in their cultivation structures. The conventional and organic farming systems can develop different weed flora. The most challenging aspect of chemical-free crop production is to prevent weed infestation. The primary aim of our research was to investigate the weed flora of an area which had been cultivated according to organic farming practices for more than 10 years. In addition to that, we also examined the effect of the different conventional and organic farming systems on the weed flora of a given area. Our aims were to answer the following questions: (a) Which are the typical weed species of maize grown organically, and what is the extent of their coverage? (b) Which are the most problematic species of this farming system? Our study was carried out on one of the agricultural fields of the Körös-Maros Biofarm Ltd located in Gyula on the south-eastern part of the Great Hungarian Plain. Our survey also included the neighbouring maize fields which were cropped conventionally. The weed surveys were made between 2007 and 2009, and samples were taken four times during each growing season. During the survey, field margins – which meant the area within a distance of 2 meters from the edges of the field – and the inner areas were both investigated. Two assessments were done on the margins, and four in the inner areas of the field. In each survey, an examination area of 1 m² was used randomly, and the weed coverage was determined by estimation. Coverage of each weed species was expressed as percentage coverage. The statistical analysis of data was made by SPSS programs. During our weed surveys, there was a difference between organic and conventional maize fields regarding weed coverage and number of weed species. This difference was significant both in the inner and on the marginal areas for both parameters. The average coverage was low in April and in May, but later a higher level of coverage was found in organic maize. After some years of keeping the principles of organic farming and applying the available weed control methods in a professional way, organic farming can maintain weed coverage at an acceptable level in maize, but at the end of the growing season weed coverage can be substantial.

Examination of the effect of stubble-tillage methods on the number and cover of common ragweed (*Ambrosia artemisiifolia*)

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In field experiments were examined the effect of different stubble-tillage methods on the survival and re-germination of common ragweed in stubble field of winter wheat and spring barley in 2008. Number and coverage of common ragweed was very variable on the experimental fields before the stubble-tillage. The height of *Ambrosia artemisiifolia* plants was 25-37cm, the average cover was 45% and the density was 35 plants m⁻² at the time of treatments. The treatments were as follows:

1. untreated control
2. deep ploughing (25-30 cm)
3. shallow ploughing (18-25 cm)
4. heavy disking (12-15 cm)
5. shallow disking (8-10 cm)

Soil samples were collected before stubble-tillage to determine the seed content of the soil. The results showed that deep ploughing was most efficient in suppressing common ragweed followed by shallow ploughing and heavy disking. The efficiency of shallow disking was not satisfactory, because 30-40% of the plants survived. The stubble-tillage methods did not affect re-germination of common ragweed noteworthy. It was about 1% in all treatments, but ploughing caused some seedlings to occur. The cover of ragweed reached almost 100% on the control plots at the end of the growing season.

Innovative strategies and machine for physical weed control in urban area on the hard surface

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In Italy, weed control in urban areas is mainly performed by means of mowing, cutting and herbicide application. While trimmers are not effective in reducing weed density and are also potentially injurious for hard surfaces and the safety of citizens and operators, chemical control induces resistance to active compounds in spontaneous plants and it is surely a source of environmental pollution and a risk factor for the health of human beings and animals. For this reason, the use of herbicides in urban areas is strictly regulated by laws. As an alternative to ordinary devices, thermal equipments can be used successfully for weed control on hard surfaces. Flaming machines are the most efficient among thermal devices and they are suitable for treatments in many urban contexts. Research was carried out in 2006-2008 by the University of Pisa in two towns of Central Italy (Pisa and Livorno), with the aim of comparing different strategies (thermal and conventional based on the application of mowing or herbicides) on their effectiveness in weed suppression and costs of operations. Moreover, some flaming machines were projected, built and tested for this purpose. Flame weeding at low (LF) and high frequency (HF) was compared to an untreated control and mowing in Pisa and chemical and integrated management in Livorno. Weed canopy was determined according to Braun-Blanquet method. Afterwards, data were transformed into percentage of weed cover. For each treatment, working time and LPG consumption were determined. At the end of the research, total working times and costs of the compared treatments were assessed. Moreover, specific indexes were defined in order to evaluate manpower use and costs related to average weed cover. Experimental design was a randomized block with four replicates. Data were statistically treated by ANOVA using the CoHort Software. Means were separated by Fisher LSD test at $P \leq 0.05$. The results showed that physical strategies reduced weed canopy more effectively than the other methods: high frequency flaming allowed to maintain weed cover quite constant around an average of 5 % in Pisa and 11% in Livorno, while low frequency resulted in a mean weed canopy of 14% in Pisa and 10% in Livorno. Perennial species, especially belonging to the *Asteraceae* and *Poaceae* families, are typical of the urban flora in Central Italy. Climatic conditions of coastal Tuscany (moderately cold and rainy winter and warm summer) determine constant rate of weed development, so that the control of the weed flora can be hard and expensive. However, high frequency flame weeding suppressed both perennial and annual species in a rational way. Moreover, manpower and economic indices were much lower for Flaming HF followed by Flaming LF with respect to conventional (mowing and chemical) and integrated weed management, because working times and total costs of alternative and conventional methods were comparable, but weed suppression was always better with both flame treatments. In conclusion, the obtained results stressed that thermal strategies could become a relevant alternative to conventional weed management in both towns studied. Moreover, the flaming machines were effective, versatile and operator friendly.

SESSION 7
CHEMICAL WEED MANAGEMENT

Oral presentations

Session organizers:

Per Kudsk & Jens Streibig

Hormesis – an option for the portfolio of herbicides?

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The yield-enhancing effects of some pesticides are changing the focus in their use in crop production, from crop protection to crop enhancement. While such beneficial uses of pesticides are specifically en vogue for fungicides and seed treatments, the use of herbicides for crop enhancement has not been realized. The potential for improving crop production by low-dose, stimulatory effects of herbicides has been proposed and reports of 10-25% efficiency of improving certain plant traits under field conditions seem promising. However, the practical use of such herbicide hormesis has been hampered by insufficient predictability of the effects. The reasons for this lack of adequate predictability may be manifold, and knowledge of the possible causes of variations is needed if herbicide hormesis is to have practical implications in the field.

With the objective of determining the causes of variability of hormesis, experiments were conducted under controlled conditions to investigate the impact of environmental factors (*e.g.* temperature, light, CO₂ and nutrient availability), time, and preconditioning on plant growth stimulation by phytotoxins. Small scale test systems using *Lactuca sativa* or *Lemna minor* as test species were applied to study natural and synthetic phytotoxins (*e.g.* parthenin, auxins, glyphosate) under various conditions.

Results showed that hormesis is constrained by manipulations of experimental conditions, and that the impact varied, depending on test species, endpoint, time, and phytotoxin. Variation was mainly in the amplitude of hormesis, ranging from zero to maximum stimulation, rather than in the dose range of hormetic effects. Furthermore, the inhibitory action of some phytotoxins proved less susceptible to modifications in experimental conditions than the stimulatory effects. This suggests that applications of compounds inducing hormesis may be more susceptible to environmental stresses than conventional herbicide applications. Hence, despite a real growth increase potential under some conditions, this study points to fundamental constraints challenging the commercial use of herbicide hormesis under field conditions.

Is the production of winter cereals in the EU doomed, because of inability to control grass weeds?

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The availability of effective herbicides for grass weed control in winter cereals is declining, because of more restrictive EU pesticide regulations, the accelerating occurrence of resistance to existing products and the lack of new products with new modes of action. Within the next 5 years farmers will have access to few products and those that are available are likely to be less effective due to resistance. What should be done? Current practices in the UK and elsewhere in Europe, of minimal tillage, early sowing and continuous autumn cropping, all favour grass weeds. There is a need to adapt cropping practices to disadvantage these weeds and thus reduce the control needed from those herbicides that remain.

In our recent UK review of the effects of cultural practices on annual grass weeds in winter cereal-dominated rotations, based on published data over the last 30 years, we came to the following conclusions.

- In 36 experiments, ploughing prior to sowing winter wheat reduced populations of *Alopecurus myosuroides* by a mean of 67% compared to populations present on fields where the crop was established with non-inversion cultivation (tine, discs). Conversely, direct drilling increased the population by 35%.
- Delayed drilling from September to November, reduced *A. myosuroides* populations by 25% but delaying drilling into October only reduced populations by 14% (mean of 16 experiments).
- Increasing crop seed rates from 150 to 350 plants/m² decreased *A. myosuroides* populations by up to 40%.
- Adoption of competitive cultivars with more planophile leaves and greater height, decreased weed numbers by about 27%.
- Introducing a spring crop into the rotation reduced *A. myosuroides* populations by 80%.

Similar response patterns to these cultural changes were apparent with other grass weeds (*Avena fatua*, *Anisantha sterilis* and *Poa annua*), though there were differences, depending on their biology. However, overall, all non-chemical methods showed very variable levels of control.

Adoption of ploughing, delayed drilling, increased crop seed rates, more competitive cultivars and the inclusion of spring crops in the rotation will all reduce grass weed populations. None of these practices, alone, give levels of control that are comparable with herbicides but using combinations of several non-chemical methods can lead to significantly better weed control. However, all the suggested cultural changes have an economic and sometimes an environmental cost to the farmer. Despite these negative effects, adoption of more integrated weed management may be the only way forward for arable farmers, as the number of herbicides declines. The challenge is to get farmers to accept this approach, as there is no evidence that the chemical industry will produce a new 'silver bullet' to control annual grass weeds in cereals in the foreseeable future.

Herbicide Research in a Changing Landscape

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Innovation is essential for agriculture as the human world population is constantly increasing and the available agricultural area for food production is shrinking. It is estimated that around nine billion people have to be fed from an average arable area of 0.16 hectares in 2050 whereas today around 6 billion people are living from 0.25 hectares. About 50 percent of yield losses today are caused by weeds and diseases.

Herbicides represent a landmark in modernisation of global crop production. Rationalisation and consolidation of farming structures in major broad acre crops could only be achieved through introduction of chemical weed control thereby substituting mechanical as well as handweeding technologies.

Modern herbicides have been available over the last 60 years, but major innovations were only introduced beginning in the 1960s with the Triazines and have been improved dramatically through the last decade. Selective and efficient herbicides have been developed for weed management in all major crops e.g. cereals, corn soybeans etc. The discoveries of flexible, post applicable, non-selective herbicides were further revolutionary milestones shaping weed management in plantations, trees, nuts, and vines.

However the situation in herbicide technology has changed dramatically within the last 5 – 10 years. Several factors have contributed to these changes:

- The commercial success of herbicide tolerant crops, specifically the Round up Ready system
- The consolidation of the agrochemical industry
- Increased regulatory hurdles
- Generic herbicide production
- Further monolithisation of the cropping systems / crop rotations
- Drastic increase of herbicide resistance gaining significant economic relevance.

The first four factors resulted in reduced investments into herbicide research, in the loss of herbicide active ingredients and to increased competition triggering price reductions in the markets. The diversity of weed management solutions has thereby decreased considerably.

Monolithisation and weed resistance have created new challenges for agriculture and are continuing to seriously impact efficiency of weed control technologies at a global scale.

The need for new herbicides with alternative modes of action and/or resistance breaking capabilities as well as other superior agronomic features is more urgent than ever before.

New compounds must be complementary with GMO technologies, cost competitive, environmentally safe and offer unique “one pass” solutions. AgChem companies will have

to develop more effective resistance management strategies to ensure the sustainability of herbicides and they must provide research support to monitor the development of newly arising resistant weed biotypes. Respective consulting strategies have to be developed to support the farming community.

Bayer CropScience has established a state of the art herbicide discovery platform utilizing target based technologies, predictive chemistry approaches integrating very recent achievements in CAMD and molecular modelling with high throughput screening technologies. This presentation will demonstrate the necessity of continued innovation in herbicide technology and outline, how successful companies can contribute to provide valuable weed control solutions for the grower. Without herbicide innovation today's crop production technology will be seriously endangered within the upcoming decades.

Algorithms for site specific weed control; results of four projects on innovative control strategies

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Precision agriculture technology offers opportunities to optimize weed control site specifically. The optimization of weed control takes place at the level of grids within the crop or field, or at the level of individual plants in the crop. The size of grids in site specific weed control strategies is roughly between 1 and 100 m². Individual plant treatment takes place at a smaller scale and higher resolution, at the level of several cm². Though important steps have been made with R&D of site specific weed control strategies during the past two decades, the use of these strategies in current agriculture is still limited.

Every site specific weed control strategy consists of (1) a sensing unit for detection of site-specific variation in weed, soil and/or crop conditions, (2) a decision making unit that translate sensor readings into need and intensity of treatment, and (3) an actuator or implement unit that carries out the weed control. To be successful in practice, the strategy must be competitive with current methods and strategies in terms of costs, efficacy and ease of use. Several projects at Wageningen University & Research Centre are aimed to further develop site-specific weed control methods and strategies, focusing on sensor optimization, decision algorithms, actuators and integration of the different units. In this paper, we address decision algorithm development in four projects: (1) plant detection in crop rows and plant specific mechanical control, (2) plant specific mechanical control of *Rumex obtusifolius* in grassland, (3) site specific dosing of soil herbicides and (4) site specific dosing of potato haulm killing herbicides. Most attention will be given to project 3 and 4

In project 3 doses are adjusted to site specific conditions to a scale of ca 30 m². Soil maps with spatial variation in soil organic matter are the basis for site specific dosing of soil herbicides. Dosing algorithms that relate soil organic matter to dose were determined in greenhouse experiments. Adjusted doses are applied with injection sprayers or conventional sprayers carrying spray booms wider then 24 m. Efficacy data under field conditions are not yet available. Potential reductions are 10 – 20 %.

In project 4 doses are also adjusted to a scale ca 30 m². Nearby sensing of crop biomass is used to determine spatial variation within the crop, and is the basis for site specific dosing of the potato haulm killing herbicides. Dosing algorithms that relate crop biomass to minimum lethal doses were determined under field conditions. The strategy has been tested in more than 20 potato fields over four years. On average, a reduction of nearly 50 % was obtained while efficacy remained good.

In projects 1 and 2, algorithms for detection of specific plants were developed. Highlights of these projects will be briefly addressed in the presentation.

Multi-criteria evaluation of cropping system prototypes based on Integrated Weed management

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Integrated Weed Management (IWM) is based on the combination of management techniques used to reduce weed infestations during crop cycles in order to reduce the need for herbicides, both for environmental reasons and for avoiding selecting weed populations resistant to herbicides. A long term experiment was initiated in year 2000 in Dijon, France, to assess the performances of 4 variations of IWM cropping system prototypes with different management options. Roughly, the main principles used for weed management were (1) diversified crop rotations allowing diversified sowing dates to avoid selecting species with marked seasonality of emergence, (2) modified soil tillage, possibly including occasional mouldboard ploughing to bury seeds in deep soil layers, and repeated shallow tillage with such timing as to promote seedling emergence and destruction before crop drilling (the so-called false-seed bed technique, (3) delayed autumn sowing to escape the emergence peak of a range of autumn-emerging species, (4) competitive cultivars and competitive crop species, sown at high densities and reduced row distance to maximize the competitive ability of the crop canopy, (5) in-crop mechanical weeding, using weed harrows, simple hoes, rotary hoes, finger hoes, according to the crop and inter-row distances.

The results from the first six years showed that IWM allows satisfying weed management with a low reliance on herbicides. In spite of the low use of herbicide, no trend for any increase in the level of weed infestation was observed on the various fields of the experiment. Weed seed bank data were also consistent, confirming the efficiency of the combination of weed management techniques.

However, shifting to IWM implies heavy modifications at the cropping system level, so a comprehensive assessment required further analyses. Life Cycle Assessment at the system level (Swiss SALCA method) showed that the increase in energy input for soil tillage and mechanical weeding was more than compensated by the decrease in the level of nitrogen fertilization, so both the energy consumption and the greenhouse-gas emission per unit of cultivated area were reduced as compared to the standard system reference. The decrease in N fertilization was favored by the diversification of crop rotations with legume crops, and by reduced yield targets in cereal crops. IWM tended to increase the system complexity, introducing supplementary field operations such as false-seed bed preparation and mechanical weeding. However, farming system models demonstrated that the diversification of crop productions also tended to improve the distribution of field operations all over the year, hence reducing labor bottlenecks. The main IWM rule that could impair the technical feasibility was the delay in cereal sowing for escaping autumn weed emergence, as the number of days with climatic favorable conditions for sowing tends to decrease dramatically at the end of October. Regarding economic profitability, calculations were done using the economic context of year 2006. The saving of input costs (mainly pesticides) did not offset the low yields of spring crops introduced in the crop sequence for diversifying sowing dates, hence affecting the

overall profitability of the cropping system by about 100 Euros.ha⁻¹.year⁻¹. The multi-criteria evaluation thus provided evidences for trade-offs between the various issues considered, showing that IWM could be technically efficient, but that the adoption by farmers could be limited by real impediments at the farm level.

Allelopathy Phenomenon and its Application in Agriculture: 2. The Potential Uses of Sorghum and Sunflower Residues and Extracts for Controlling Weeds and Enhancing Lentil Productivity in Newly Reclaimed Sandy Soil

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Winter lentil (*Lens culinaris* Medik.) is one of the least competitive crops grown in Egypt; therefore weed control is critical for good production of lentils. Allelopathy has been explored as a substitute for chemical herbicides to reduce environmental pollution. Response of lentil and its associated weeds for foliar application of sorghum and sunflower water extracts at 30 and 45 days after sowing in comparison with hand weeding treatment were tested under field conditions. This study was carried out at the Agricultural Research Station of The National Research Centre at Al Emam Malek Village, El-Nobaria District, El-Behera Governorate, Egypt during winter of 2007/08 and 2008/09 seasons. Also, pot experiments were conducted to determine the allelopathic effect of sorghum (cv Dorado) and sunflower (cv Vedok) residues on some lentil varieties (Giza-1, Giza-9, Giza-51, Giza-370 and Sena-1) and two weeds (bureclover and canary grass). Results of the pot experiment revealed that lentil varieties differed in their responses to incorporation of sorghum and sunflower shoot residues where application of sunflower decreased seedling growth of lentil varieties at both rate (12 and 24 g/pot) more than sorghum residue. Amongst the tested lentil varieties, Giza-9 seemed to be tolerant to incorporation of sunflower residue. Also, residue of both crops exhibited selectivity in their effects on tested weed species, where sorghum residue inhibited germination, fresh and dry weight of grassy weeds (canary grassy) more than sunflower. While broad-leave weed (bureclover) was greatly depressed by adding sunflower more than sorghum residue. Under field condition, dry weight of weed decreased by 62.57 and 59.78% at 60 DAS and grain yield of lentil at harvest increased by 61.34 and 56.18% (average both seasons), for spraying of sorghum and sunflower extracts, respectively as compared to unweeded treatment. It may suggest that using farm residues of sorghum and sunflower serve as a new method for safe and less costly weed control as well as increase quantity and quality of lentil crop.

Keywords: Lentil-Allelopathy-Weed control-Sorghum extracts-Sunflower extracts

SESSION 7
CHEMICAL WEED MANAGEMENT

Poster presentations

Session organizers:
Per Kudsk & Jens Streibig

Efficiency and selectivity of herbicides in the regeneration of common oak forests

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Beside the harmful insects and diseases, weed vegetation presents a huge problem in the regeneration of common oak forests. The presence of weeds and large number of shrubby species per unit area represent the main limiting factor in the development of common oak. Due to the impossibility of preserving the seedlings and the formation of high-quality young plants and because of deterioration and slow development is necessary to perform weed control vegetation in the regeneration of common oak forests. Efficacy and selectivity of herbicides were tested during 2007-2009. Polish trials were set up in a randomized block design in four repetitions at two locations on the area of Ravni Srem. The following herbicides were tested: nicosulfuron, imazamox, bentazone and metsulfuron-methyl. The application of selected herbicides was performed after the germination of weeds and common oak. Analysis of the efficiency of herbicides was done 15 and 30 days after the application of herbicides and the evaluation of phytotoxicity were carried out every 15 days from the moment of treatment until the end of the vegetation. Of the total amount of herbicide that is applied both in agriculture and in forestry, a large part is deposited on the soil and may impact the activity of soil microorganisms. Microorganisms play an important role in the transformation of herbicides and other toxic substances in the soil. Herbicides not only affect the activity of microorganisms, but the activity of microorganisms influences the fate of herbicides in soil. For this reason investigations on the microbial activity of soil following herbicide application were carried out. Samples of soil for microbiological analyses were taken 7, 14 and 60 days after the application of herbicides. Laboratory analysis determined the total number of bacteria, number of azotobacter, aminoheterotrophs, actinomycetes, fungi and dehydrogenase activity. The results of the investigation indicate the presence of a large number of weed species. An abundant presence of broadleaf weeds species indicated that in the regeneration forests broadleaf weed species were a bigger problem than grass weeds, which were present in smaller number. The most effective weed control was achieved with metsulfuron-methyl however, this herbicide and herbicide bentazone were phytotoxic to the common oak plants. Nicosulfuron and imazamox showed minor effects on oak plants. However, one month after the application of herbicides the phytotoxic symptoms disappeared and plants developed without visible changes. The herbicides reduced the total number of bacteria and aminoheterotrophs at both localities but herbicide application increased the number of fungi and actinomycetes in the soil. Herbicides from the group of the sulfonylureas (nicosulfuron and metsulfuron-methyl) had a stimulating effect on azotobacters while the herbicides imazamox and bentazone had an inhibitory effect during the entire period of the study. Effects on dehydrogenase activity depended on the herbicide as well as the physical-chemical properties of soil in the investigated localities.

Results of precision weed management in small annual grains, sugar-beet, oil-seed rape and maize using real-time image analysis for weed identification and decision algorithms for patch spraying

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Spatial and temporal variations in weed distribution had been analysed in winter wheat, winter barley, sugar beet and maize over the past ten years to investigate the potential for herbicide savings using site-specific weed management practices. In former studies, a map-based approach was applied for site-specific weed control resulting in herbicide savings of 40-50 %. Herbicides were only applied at locations where the economic weed threshold had been exceeded. The objective of this study was to develop a real-time system for precision weed control. Bi-spectral cameras and image analysis algorithms have been developed to automatically identify weed species in digital images. A training data set of 17 very abundant weed species in German winter annual crops, such as winter wheat, winter barley and oil-seed rape and 16 very abundant weed species in summer annual crops, such as maize, sugar beet and spring barley was created. Approximately 60 plants of each species were photographed in the cotyledon growth stage, 2- and 4-leaves growth stage. More than 100 features were calculated for each plant. Half of the images were taken to create classifiers for automatic plant species identification. Another set of image was used to test the accuracy of automatic classification. The best classifiers and classification algorithms varied within species and growth stages so that a compromise of several features including geometric shape features, skeleton based features and hue moments was made. The average accuracy of classification was between 80 and 95 % for each crop. Images were georeferenced to create weed distribution maps and to verify and document real-time weed control decisions. The decision algorithm for patch spraying takes into account variability of weed density, -coverage and yield loss effects of weed species, growth stages and costs of weed control. Grass-weeds, broad-leaved weeds and perennials were selectively controlled using a GPS-controlled multiple tank sprayer. Several field studies in winter wheat, winter barley, maize, oil-seed rape and sugar beet were conducted to evaluate precision weed control methods based on herbicide savings, efficacy of control and yield effects due to weed competition and herbicide application. It was found that real-time patch spraying was the most economic treatment followed map-based site-specific weed control. Uniform herbicide applications and uncontrolled treatments gave the lowest economic return. Efficacy of precision weed control was equal to uniform applications. Herbicide savings using precision weed control varied from 20 to 70%. *Alopecurus myosuroides*, *Echinochloa crus-galli*, *Galium aparine*, *Chenopodium album* and *Cirsium arvense* were the dominant weed species in the field studies. The camera system is currently tested on a commercial farm in East Germany in combination with different sprayers. It allows image classification using an integrated processor on the bi-spectral camera. It transfers classification results to a board-computer that contains the decision algorithms for patch spraying.

Herbicide efficacy evaluation using sap flow method

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In 2009, the evaluation of herbicide efficacy using direct measurement of water flow through the stems was verified under the field conditions. The measurement was applied to 9 individual plants of *Helianthus annuus* L. in the period from 7.7. to 22.7.2009. The water flow was continually monitored by Sap Flow Systems T 4.2 (EMS Brno, CZ). The comparative measurement was done by photosynthesis intensity evaluation (CIRAS 2- PP Systems, UK). Herbicide treatment was carried out on 13.7. 2009. Three plants were untreated, three plants were treated with the herbicide Pardner 22.5 EC (225 g a.i. bromoxynil/l) at 1.5 l/ha while the three remaining plants were treated with Lontrel 300 (300 g a.i. clopyralid/l) at 0.4 l/ha. Growth stage of *H. annuus* was BBCH 56 at the beginning of the experiment. Influence of herbicide treatment on water flow decline was proved by computing correlation coefficients comparing transpiration average daily values (Q , kg of water/day) – in the period from 8.7. to 13.7. with the calculated values of sap flow (Q_{cal} , kg of water/day). Mean values of Q in untreated plants exceeded the values of Q_{cal} . This can be explained with unlimited growth of control plants. Average daily Q values in plants treated with herbicide Lontrel 300 was in sunny days (14.7.-21.7.) lower than Q_{cal} before herbicide treatment. This illustrates that plants transpired less than before herbicide treatment and their growth was reduced, perhaps even stopped. Clopyralid caused the stem to lean over and become slightly yellow in colour. Strong herbicide effect on Q decrease was evident following application of Pardner 22.5 EC. Average daily values of sap flow determined on untreated plants were 0.37 kg of water/day from 14.7. to 21.7. Pardner 22.5 EC reduced water flow to 0.12 kg water/day and Lontrel 300 to 0.22 kg water/day. Influence of herbicides on transpiration rate (Tr) in plants measured with sap-flow confirmed the results determined with CIRAS. The lowest values of transpiration were recorded in plants treated with Pardner 22.5 EC. Tr values in plants treated with Lontrel 300 were also statistically lower than the non-treated ones. Clopyralid significantly decreased the transpiration values; while a decline in photosynthesis intensity was detected later. This study showed that measurement of transpiration will be more suitable for assessing herbicides which have no direct effect on photosynthesis.

Supported by Projects MSM 6046070901 and NAZV - QH 82096.

Enhanced efficacy and cost-effective herbicide usage in maize

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Weed control in maize with a single herbicide treatment is often not adequate and economically justified. The objective of this research was to develop an efficacious and cost-effective weed control program using a mixture of herbicides at low rates plus effective oil adjuvants applied sequentially.

Two field experiments were conducted in 2008 and 2009. In Experiment 1, single herbicide treatments applied at recommended timing and rates were commercial formulations: terbuthylazine at 750 g ha⁻¹, nicosulfuron at 60 g ha⁻¹, and dicamba + tritosulfuron at 100 + 50 g ha⁻¹. In Experiment 2, mesotrione at 150 g ha⁻¹, foramsulfuron + iodosulfuron at 45 + 1.5 g ha⁻¹ + methylated seed oil (MSO) adjuvant at 1.5 L ha⁻¹, and dicamba at 240 g ha⁻¹. The standard herbicides in each experiment also were applied as reduced-rate mixtures, sequentially at 7- to 10-day intervals. Rates for herbicides in mixtures were reduced two- to four-fold and applied with a basic (high pH) MSO adjuvant in combination with or without liquid urea-ammonium nitrate fertilizer (28% N). Treatments were applied using a bicycle plot sprayer delivering 200 L ha⁻¹. Weed control was evaluated visually 4 weeks after the second sequential herbicide application. Net return was calculated based on maize grain income minus herbicide and application costs.

Maize was infested mostly with *Chenopodium album*, *Polygonum convolvulus* and *Echinochloa crus-galli*. Broadleaf plus grass weed control with standard herbicide treatments was low and varied from 6 to 28% in Experiment 1 and from 26 to 83% in Experiment 2. Herbicide mixtures at reduced rates (terbuthylazine + nicosulfuron + dicamba + tritosulfuron at 375 + 15 + 25 + 12.5 g ha⁻¹, respectively and mesotrione + foramsulfuron + iodosulfuron + dicamba at 25 + 7.5 + 0.25 + 120 g ha⁻¹, respectively) with MSO adjuvant split-applied at 7- to 10-day intervals greatly increased weed control and weed control consistency that ranged between 92 and 99% control in Experiment 1 and between 92 and 97% control in Experiment 2. Addition of liquid urea-ammonium nitrate fertilizer along with MSO adjuvant to herbicide mixtures in most cases increased weed control without visible phytotoxicity on maize. Sequentially applied herbicide treatments with adjuvant or adjuvant mixtures also provided much higher increase of maize grain yield than the standard herbicides applied once. The cost of herbicide mixtures and MSO adjuvant applied twice plus cost of applications were similar or slightly higher than the cost of a single treatment of standard herbicides at recommended rates. However, increased maize grain yield when treated with herbicides applied sequentially compensated for the cost of weed control and provided two to four times higher net return.

Integrated weed management in corn using herbicide, cultivation and variety

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In order to reduce herbicide use an experiment was conducted in Fars province in Iran in 2008. The effect of different concentrations of pre-emergence herbicide acetochlore in combination with inter-row cultivation was examined in two corn cultivars (early and late maturity). The experiment was conducted as a randomized blocks design with four replications. Treatments consisted of three levels of acetochlore (0, 1.5 and 3 l ha⁻¹) and three levels of inter-row cultivation (without cultivator, using cultivator once and twice) in 4th and 10th leaf stages. The results showed that the two corn cultivars responded differently to treatments. The highest grain yield (11.1 t ha⁻¹) and seed number per ear was obtained in late maturity cultivar (704) using 1.5 l ha⁻¹ acetochlore and two cultivations reducing weed infestation by 88.7%. This showed that Maxima (early maturity cultivar) was less competitive against weeds and yielded lower than 704. Also, maximum dry matter in both cultivars was in the treatment with 1.5 ha⁻¹ herbicide using two inter-row cultivations, although dry matter of 704 was by 12.9%, cultivation and herbicide treatments significantly reduced dry matter of the dominant weeds species (*Amaranthus retroflexus*, *Physalis* sp., *Echinochloa crusgalli*, and *Abutilon theophrasti*). In conclusion 704 was more competitive and using two cultivations decreases herbicide usage and increases crop yields.

Keywords: Competitiveness, Corn, Cultivation, Herbicide

Effective weed control in spring turnip rape (*Brassica rapa* subsp. *oleifera*) using the CLEARFIELD® Production System

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Spring turnip rape, *Brassica rapa* subsp. *oleifera*, is the main oilseed crop cultivated in Finland. Effective weed control is one of the key factors in profitable turnip rape production. The weeds reduce the crop yield, lessen its quality and thus also lower its value. The lack of suitable and effective herbicides represents a threat to profitable turnip rape production especially now that trifluralin is no longer available.

Imidazolinone herbicides are proved to be very effective against many weed species. Turnip and oilseed rape are naturally not tolerant of these herbicides but tolerance has been bred into them using conventional breeding methods. The use of tolerant varieties and IMI herbicides is known worldwide as the CLEARFIELD® Production System developed by BASF. Breeding work and research with IMI tolerance in Finnish turnip and oilseed rape lines has been carried out since 2002 at the University of Helsinki.

In summer 2009, five small-plot field trials were carried out in turnip rape to study the efficacy and the selectivity of two herbicide products containing imazamox. The trials were conducted in co-operation of BASF SE, the University of Helsinki, MTT Agrifood Research Finland and Berner Ltd. In addition, the CLEARFIELD® Production System for *B. rapa* was tested in farm-scale demo fields. The seed material in all trials was a Finnish IMI tolerant spring turnip rape line 'IMI4003'.

The five field trials were carried out in four localities in southern Finland according to a trial protocol with 7 treatments. The herbicide products BAS 797 00 H (imazamox 17.5 g/l + metazachlor 375 g/l) and BAS 720 06 H (imazamox 40 g/l) were compared with the local standard Butisan S (metazachlor 500 g/l). Herbicides were applied as a single post-emergence application at crop stage BBCH 10-22 on weeds with 2-4 leaves.

The herbicides did not cause any clear phytotoxic symptoms on turnip rape. Both imazamox herbicides were more effective on almost all weed species than the standard Butisan S. The efficacy of the imazamox herbicides was excellent on *Chenopodium album*, *Galium spurium* and *Erysimum cheiranthoides*, providing good control of *Stellaria media*, *Lapsana communis*, *Fallopia convolvulus*, *Galeopsis* spp. and *Spergula arvensis*, and satisfactory control of *Lamium purpureum*, *Viola arvensis* and *Fumaria officinalis*. The mixture of imazamox and metazachlor was more effective than the pure imazamox on *Galium spurium* and *Lamium purpureum*. In a field trial with the highest weed pressure, the herbicide treatments increased the turnip rape yield by 15-24%. In the same trial the imazamox containing treatments lowered

the content of weed seeds in the harvested crop significantly, also when compared with the Butisan S treatment. Most growers of the demo fields were also satisfied with the imazamox herbicides, which appeared moderately effective also on *Elymus repens*, *Avena fatua* and *Cirsium arvense*. In conclusion, the CLEARFIELD® Production System can become an effective weed control method in Finnish turnip rape fields.

Chlorophyll fluorescence *in vivo* as the indicator of sunflower susceptibility to ALS-inhibiting herbicides

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The aim was to test the effect of imazamox and tribenuron-methyl on chlorophyll fluorescence of sunflower hybrids with varying susceptibility to ALS-inhibiting herbicides in order to determine whether chlorophyll fluorescence parameters can be used as indicators of plant susceptibility to this group of herbicides. Three sunflower hybrids were tested: Rimi (tolerant to imazamox), Sumo-1-pr (tolerant to tribenuron-methyl) and Kazanova (susceptible to both herbicides). Plants were grown in pots to the four-leaf stage and then exposed to the herbicides. The following treatments were applied: 48 g of imazamox/ha to Rimi and Kazanova, 22.5 g of tribenuron-methyl/ha + 0.1% of Trend 90 to Sumo-1-pr and Kazanova. The experiment was replicated twice and treatments were replicated 4 times. The chlorophyll fluorescence parameters were evaluated at 24 hr intervals for seven days starting on the day of herbicide application. Plants were kept for 2 hrs in the dark prior to evaluation. Fluorimeter PAM-2100 was used to assess the following parameters: fluorescence of the leaf adapted to darkness (F_o); maximal fluorescence of the leaf adapted to light (F_m) and chlorophyll fluorescence yield (Yield). Based on the data obtained the following parameters were computed: fluorescence intensity ($IF = F_t/F_o$ where F_t = fluorescence value for a given time interval) and variable fluorescence ($F_v = F_m - F_o$).

Based on the analysis of the data it can be concluded that F_o , F_v/F_m , Yield and F_v were the most suitable parameters for testing sunflower hybrid susceptibility to ALS-inhibiting herbicides.

Effect of an ethoxylated soybean oil adjuvant on the efficacy of different herbicides

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This study evaluated the effect of Agnique SBO 10[®], an ethoxylated soybean oil adjuvant, on the efficacy of four different post-emergence herbicides (tritosulfuron + dicamba, bromoxynil octanoat, iodosulfuron + foramsulfuron, fluroxypyr + florasulam), using *Abutilon theophrasti* as test species. Agnique SBO 10[®] belongs to the group of non-ionic surfactants and contains on average 10 units of ethylene oxide (EO). Previous experiments confirmed that the adjuvant was not phytotoxic against *Solanum nigrum*, *Zea mays* or *Triticum aestivum* in concentrations up to 4 % (v/v). Single-dose experiments (25 % of recommended field rates) and complete dose-response experiments (100 to 0.0078 % of recommended field rates) were conducted under greenhouse conditions for all herbicides in single application or in combination with either Agnique SBO 10[®] or two other adjuvants as standards (rapeseed oil methyl-ester and a mixture of fatty acid methyl-ester, fatty alcohol alkoxylat and oleic acid). Efficacy was measured four weeks after application by comparing dry weights of treated and untreated *A. theophrasti* plants. Results of the single-dose experiment showed a clear trend towards an improvement of the efficacy of all herbicides by Agnique SBO 10[®], apart from bromoxynil octanoat. Furthermore, Agnique SBO 10[®] performed better than the two standard adjuvants (on average 14 % higher efficacy). Without addition of adjuvants, treatments with iodosulfuron + foramsulfuron and fluroxypyr + florasulam even tended to increase dry weight in comparison to control plants at 25 % of recommended field rates. Results of complete dose-response experiments showed that the efficacy of two of the four herbicides could be improved on average by 67 % by adding an adjuvant. The ED₉₀ for tritosulfuron + dicamba with Agnique SBO 10[®] was 2.6-fold lower than the ED₉₀ achieved without adjuvant and hence, Agnique SBO 10[®] was 40.7 % more effective compared to the fatty acid methyl-ester adjuvant. Agnique SBO 10[®] reduced the ED₉₀ for iodosulfuron + foramsulfuron by 6.2-fold and consequently was not as effective as the rapeseed oil methyl-ester which reduced the ED₉₀ 8-fold. Bromoxynil octanoat in combination with Agnique SBO 10[®] resulted in 20.7 % less biomass reduction compared to the treatment without adjuvant.

Finding a way of reducing herbicide input rates while still maintaining an adequate efficacy against weeds has a great importance in agricultural sciences to decrease costs and environmental impacts of chemical plant protection. This study shows that the application of a suitable adjuvant in combination with several herbicides is an efficient option to reach this aim.

Allelopathic effect of creeping woodsorrel (*Oxalis Corniculata* L.) under laboratory conditions

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Invasive spreading of *Oxalis corniculata* L. has been observed in the latest decades mainly in urban surroundings. This adventive weed species has a high content of oxalic acid but the effects of plant extract of *O. corniculata* on other plant species has not been investigated. In this study the allelopathic effect of *O. corniculata* was examined in the laboratory. Wheat (*Triticum aestivum* L.), white mustard (*Sinapis alba* L.), garden cress (*Lepidium sativum* L.) and meadow fescue (*Festuca pratensis* L.) were used as test plants.

For the laboratory germination trials water and alcoholic extracts of roots and shoots of plants collected South-Eastern Hungary was prepared using 10 g of plant material and 100 ml of distilled water or dehydrated ethyl alcohol. The germination test was carried out at 20 °C temperature in alternating light conditions (12 hours of darkness and 12 hours of illumination).

The allelopathic effect was assessed by recording the number of germinated seeds and measuring the lengths of plants. The results revealed that the extracts of shoots and roots of *O. corniculata* L. influenced the germination of test plants. Both the ethyl alcohol, and the water extracts decreased the lengths of shoots of some of the test plants.

The ethyl alcohol root extract and the water shoot extract had a strong inhibiting effect on the growth of wheat.

The treatments made with alcohol extracts of roots and leaves of *O. corniculata* and the water shoot extract on the germination and length of white mustard plants indicated significant negative effects.

The tests with alcoholic extract and water shoot extract showed the same effect on garden cress and white mustard.

The alcoholic and water extract have a strong inhibiting effect on meadow fescue.

Generally, root extracts did not influence growth and germination of test plants as much as shoot extracts but in some cases (garden cress, wheat) effects were the opposite.

Effect of herbicide treatments on the quality parameters of maize in different years

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Investigations were made in 2006, 2007 and 2009 on the tolerance of three maize hybrids grown on chernozem soil (Calciustoll) in Martonvásár to herbicides applied post-emergence. In all three years rainfall was below normal for the location, with 66 mm less than the 30-year mean in 2006, 47 mm less in 2007 and 187 mm less in 2009. The experiment was set up as a two-factor split-plot design with two replications, with an untreated control plot for each treatment. The herbicides were as follows: mesotrione, mesotrione + terbutylazine, tembotrione, foramsulfuron + isoxadifen ethyl + iodosulfuron-methyl Na, foramsulfuron + isoxadifen ethyl, rimsulfuron in 2006 and 2007 and sulcotrione mesotrione + terbutylazine, tembotrione, foramsulfuron + isoxadifen ethyl in 2009. The herbicides were applied post-emergence, in the 5–7-leaf stage, using the maximum recommended dose and double this dose. During the course of the growing period, visible phytotoxicity was scored 22, 17 and 22 days after treatment in 2006, 2007 and 2009, respectively, using a 0–100 scale, with 0 indicating no damage and 100 complete kill. The phytotoxicity score combined the number of killed plants and the extent of leaf scorching in a single parameter. A near infrared (NIR) spectroscope was used to determine the protein, starch and oil contents of the grain yield samples. In plots treated with twice the normal dose, phytotoxicity did not exceed 20% in 2006, while it was less than 15% in 2007 and 13% in 2009. The herbicide treatments caused changes in the protein and starch content but had no effect on the oil content. Extreme weather conditions aggravated the effect on quality.

Herbicide efficacy influenced by spray carrier pH and hardness

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Herbicides come in contact with several salts and other compounds in spray carrier water, which may influence their biological activity. Understanding the interaction between herbicides and these factors may lead to higher herbicide efficacy. The interactions of herbicides, dissolved salts and pH of spray carrier depend on the chemical properties of herbicides, the amount and kind of salts which may determine the pH of spray carrier.

Field experiments were conducted to study the effects of water quality on the efficacy of herbicides in 2008 and 2009. The influence of water hardness and pH on the efficacy of three herbicides (mesotrione, nicosulfuron, terbuthylazine) was examined. Various pH adjusters and other adjuvants were added to the spray carrier to determine if they could eliminate the antagonisms of dissolved salts and optimise pH. Herbicidal activity was evaluated on important weeds of maize (*Panicum miliaceum*, *Echinochloa crus-galli*, *Setaria glauca*, *Datura stramonium*, *Amaranthus retroflexus*, *Chenopodium album*).

Water samples were collected from 8 spray water sources. pH ranged from 7.06 to 9.04 and conductivity ranged from 400 to 1823 μS . The effects of spray carrier on efficacy was examined using 5 pH adjusters with or without surfactants in plot experiments using a Europulvet plot sprayer. Percentage weed control was assessed.

The susceptibility of the three herbicides to pH and water hardness differed significantly. Mesotrione did not respond to water hardness and was only slightly affected by pH. The efficacy of nicosulfuron was influenced moderately by pH and water hardness, and terbuthylazine responded significantly to both pH and water hardness. Significant loss of herbicide efficacy was observed in hard water (about 40%), and surfactants were not able to eliminate this harmful effect. However, biological activity was the same as in soft water with a pH adjuster (ammonium nitrate) which can overcome the antagonism of salts. The effect of pH adjusters were generally more significant than that of the surfactants.

Choosing the adequate adjuvants may be very important especially under unfavourable conditions (large weeds, unfavourable weather conditions and poor water quality).

Surfactants improve herbicide penetration, but they are not suitable for eliminating the harmful effects of dissolved salts in spray water and sub-optimum pH values. Optimum spray carrier pH can be achieved with pH adjusters and adding adjuvants with adequate HLB (hydrophilic-lipophilic balance) value enhances the biological activity of herbicides.

Sustainability of maize-based cropping systems with different weed management in Italy as evaluated with DEXiPM model

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There is strong social and political pressure to reduce pesticide use in European crop production systems. Evaluating the overall sustainability of cropping systems is a complex task due to the conflicting objectives underlying the economic, social and environmental dimensions of sustainability. The development and use of models that assess different Integrated Pest Management (IPM) scenarios and evaluate the most sustainable practical options at regional, national and European level is essential. With this aim, an expert-based survey was conducted in 2009 within the EU Network of Excellence ENDURE to provide information on current maize-based systems in the Po valley and to identify possible pest management practices that could be implemented in advanced maize-based systems aiming at pesticide reduction. The survey identified two main current systems (CSs): rotated grain/silage maize with winter wheat and continuous grain/silage maize-based systems, both irrigated. Weed management practices include pre- and post-emergence herbicide applications and one inter-row cultivation in continuous maize plus one post-emergence herbicide in the maize/winter wheat rotation. Considering experts' opinions/suggestions on alternative pest management practices, an advanced system (AS) was designed based on an irrigated grain/silage maize-winter wheat-soybean rotation. The herbicide input in this system is lower, with only post-emergence application for maize and winter wheat thanks to the use of prediction models for efficient timing, as well as one glyphosate application at soybean sowing. Narrow spacing, lower nitrogen inputs and one or two inter-row cultivations are proposed for maize, whereas false seedbed technique and narrow spacing with one inter-row cultivation are recommended for the winter wheat and soybean crops, respectively.

The DEXiPM® model for arable crops, a qualitative and multi-attribute model developed within ENDURE and based on DEXi software, was used to evaluate and compare the sustainability of the systems. Results of the assessment show that by reducing the herbicide Treatment Frequency Index (TFI), choosing herbicides with lower eco-toxicity and introducing alternative practices into the AS will result in improved environmental sustainability compared to the CSs in terms of higher water quality and lower air emissions. The model output shows no differences in weed abundance between systems, whereas higher weed diversity is obtained in the systems using rotation.

Although there is no overall difference between the economic sustainability of the systems, the AS has a higher gross margin due to the lower production costs (lower TFI and less fertiliser) and the absence of yield reduction linked to weed abundance. The higher energy consumption due to the increased inter-row cultivation in the AS has no direct consequences on the production costs because of compensation between basic attributes of the model. Overall, the DEXiPM evaluation suggests that, in comparison to CSs, the proposed AS is economically and environmentally acceptable for testing under "real" field conditions.

The effect of weed control on pasture improvement

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The renovation of deteriorated, weedy, fallow pastures starts with weed control. The aim of our research was to improve the productivity of the pasture and increase the amount of grass species in the plant stand through different weed control methods. Based on the botanical composition of the grass species, we concluded that the productivity of the grassland could be re-established following proper weed-control and cultivation technologies.

The herbicides applied were: MCPA (MECEFAR) at 2 l ha⁻¹, clopyralid (LONTREL 300): at 0.5 l ha⁻¹ and fluroxypyr (STARANE 250EC): at 0.5 l ha⁻¹ applied alone and in combination at the beginning of the improvement process, followed by yearly mechanical weed control (cutting).

To help the propagation of grass species, after weed-control, we applied a fertiliser containing 34% ammonium-nitrate at 50, 100 and 150 kg ha⁻¹, and added phosphorous and potassium at a NPK ratio of 1: 0.4 : 0.4.

The duration of the experiment was 5 years.

During the experiment, diversity changes, changes in plant cover, and yield and carrying capacity were measured.

The reinfestation of weeds was higher on non-fertilized plots (number of weed species of the deteriorated sward were 18 at the first year, and 19 at the end of the experiment) /

The ratio of weed species was influenced by the dosages of nitrogen applied. (the mean weed cover values across plots for the 50, 100 and 150 kg N ha⁻¹ were 30, 15, and 5% respectively)

The yearly cutting of weeds did not decrease the botanical diversity of the plant stand.

The yield was determined by the nutrient supply.

In pasture renovation, the ratio of weeds in the plant stand can be controlled by a single initial use of herbicides.

Weed control and fertilisation increased the yield and the carrying capacity. At 50 kg/ha N, the yield was 9.3 t/ha, with a carrying capacity of 0.8 heads/ha; at 100 kg/ha N, it was 15.1 t/ha and 1.3 heads/ha; at 150 kg/ha N it was 20.1 t/ha and 1.7 heads/ha.

The coverage of weeds did not increase to the extent that it caused a decrease in yield that would have required repeated use of herbicides.

Herbicide phytotoxicity to maize inbred lines

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The inbred lines usually require many cropping practices including weed control. They can be very susceptible to herbicides, causing visual damage and yield losses and their response to herbicides has to be checked. The present study report the results of an investigation of the effects of new pre-emergence herbicides on physiological and productive parameters of maize inbreds, parental components of ZP hybrids.

Field experiments were conducted in 2006 and 2007 at the Maize Research Institute, on a slightly calcareous chernozem. An experiment with three replicates was set up using a split-split plot design. The main plots encompassed 10-m rows of each inbred line (11), while subplots included post-emergence application of five herbicides and an untreated control. The following herbicides were applied at the 4-6-leaf stage of maize: H_1 : nicosulfuron (50.0 g a.i. ha⁻¹), H_2 : foramsulfuron (50.0 g a.i. ha⁻¹), H_3 : rimsulfuron + dicamba (9.78+182.4 g a.i. ha⁻¹), H_4 : foramsulfuron+iodosulfuron-methyl-sodium (45.0+1.5 g a.i. ha⁻¹) and H_5 : rimsulfuron+thifensulfuron-methyl (10.0+5.0 g a.i. ha⁻¹). Bound water (plant material dried at 105 °C) and phenolics (Simic et al., 2004) were determined 48 hours after herbicide application, while the visual evaluation using the EWRS scale was done three weeks later. The grain yield was measured at maturity and calculated with 14% moisture content. The data were analysed using an analysis of variance (ANOVA), and means were compared with a LSD test at the 0.05 probability level.

The average monthly air temperatures during the maize growing season differed over experimental years. In 2007 average monthly temperature was higher (20.7 °C) than in 2006 (18.1°C). Precipitation was optimum in 2007 (364.5 mm), while it was sufficient in 2006 (229.4 mm).

Table 1: Average values of investigated parameters in dependence on herbicide treatments

	Bound water (%)		Phenolics (mg g DM ⁻¹)		EWRC		Grain yield (t ha ⁻¹)	
	2006	2007	2006	2007	2006	2007	2006	2007
Control	39.00	5.86	80.17	354.92	-	-	7.66	3.93
H_1	32.13	6.42	87.26	330.26	2.16	1.72	6.87	4.22
H_2	34.98	6.33	65.88	306.75	2.42	1.92	7.00	4.09
H_3	31.24	6.06	65.81	282.28	2.55	2.14	7.67	3.95
H_4	40.18	5.99	77.50	274.60	2.48	2.83	7.51	4.00
H_5	28.63	6.12	87.29	284.00	3.16	2.64	7.58	4.07

The results showed that the measured parameters varied between years (Table 1). Herbicide H_4 caused a negative response in the majority of the inbred lines in 2006. The susceptible inbreds were characterised by a lower content of bound water and a higher phenol content, especially in 2007. A high positive correlation between bound water and grain yields of inbreds was observed for the H_1 , H_2 and H_3 treatments. On average for all inbred lines the most significant phytotoxic response to herbicide treatment were registered with H_5 in 2006 and H_4 in 2007. The herbicide application resulted in significantly lower yields, especially in the inbred line 2, particularly in the treatment with H_2 in 2007, where there was no yield at all.

Mesotrione-sulfonylurea herbicides antagonism observed in *Sorghum halepense* can be overcome by adjuvants and spraying timing

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Antagonism between mesotrione and sulfonylurea herbicides has been reported in *Sorghum* spp., caused by a decrease in sulfonylurea herbicide absorption due to the presence of mesotrione in the herbicide mixture. It is plausible that formulating these herbicide mixtures with adjuvants that increase sulfonylurea uptake and/or spraying *Sorghum* spp. at earlier growth stages (when leaf cuticle is not fully developed) may overcome this antagonism. *Sorghum halepense* plants at two different growth stages (two and four-five fully expanded leaves) were sprayed with different herbicide mixtures containing nicosulfuron, rimsulfuron, and mesotrione formulated with two surfactants (Trend90, an isodecyl alcohol ethoxylate; Surf 2000 a mixture of modified tallow amines plus a polysorbate spreader) and one paraffinic oil (Fixaoil). Two spraying volumes (20 and 300 L ha⁻¹) were tested as well. Maize plants were used as controls to check the putative phytotoxicity of these formulations on crops. Data from dose-response assays showed that none of the herbicide treatments sprayed on maize resulted in phytotoxicity values above 11%, which is within the agronomically acceptable damage levels. Regarding *S. halepense* control, single sulfonylurea rates (20 g a.i. ha⁻¹ nicosulfuron + 5 g a.i. ha⁻¹ rimsulfuron) showed the same degree of control as double rates. Antagonism between mesotrione and sulfonylurea herbicides was present in *S. halepense* as in other *Sorghum* species, although it was less at the early growth stage. In addition, the surfactant containing the modified tallow amines reversed the negative effect of mesotrione rendering good *S. halepense* control (phytotoxicity values over 90%) irrespectively of the mesotrione and sulfonylurea rate tested. Consequently, early *S. halepense* treatments using an adjuvant such as Surf 2000 are advised to overcome antagonism in mesotrione plus sulfonylurea herbicide mixtures.

Integrated weed management to reduce herbicide use in spring cereal production

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The aim of this study was to investigate if the amount of herbicides can be reduced using spring tillage, increasing crop competitiveness or reducing glyphosate doses. Preliminary results from the study are presented here.

In one of the experimental series control of *Cirsium arvense*, *Sonchus arvensis* and *Elymus repens* were studied in a factorial experiment with timing (autumn versus spring) and tillage (black fallow (harrowing) and ploughing) as factors. The experiments were carried out with four replicates at two sites started in the autumn of 2007 and 2008, respectively. Results from the first year at one site showed that time of ploughing did not significantly influence the growth of *E. repens*. On the other hand fallow in autumn suppressed this species more efficiently than fallow in spring. In general, *C. arvense* and *S. arvensis* showed the opposite behaviour regarding both time of ploughing and black fallow. Spring ploughing, as well as spring fallow, suppressed both these species more than treatments in autumn. These results need to be confirmed by new experiments.

In another experimental series *E. repens*, *Poa annua* or *Tripleurospermum inodorum* were treated with reduced doses of glyphosate in the stubble in the autumn at two sites. The experiments used a randomized block design with four replicates and were initiated in 2007 or 2008 and lasted for two years. Spring harrowing was the only tillage conducted. As expected, the results indicated that *P. annua* can be controlled with a low dose rate, while *T. inodorum* require higher dose, and *E. repens* the highest dose to be controlled. The temperature after spraying in autumn seems to influence the results and very late spraying resulted in poor control of *E. repens* and *P. annua*. In one of the trials with *P. annua*, cross – sowing (+ 100 kg ha⁻¹ sown, in addition to normal sowing rate) at two of the replicates was included in the second year to increase crop competitiveness. Cross-sowing caused a slight reduction of density and coverage of *P. annua*, but did not influence the efficacy of glyphosate.

Preliminary results indicate that there are possibilities to reduce the amount of herbicides by using non-chemical methods and reduced doses of glyphosate adjusted to the prevailing weather conditions and the weed species present. The effect of spring ploughing on perennial weeds is promising also from an environmental point of view with regard to soil erosion and nutrient leaching. Based on the results from these studies and environmental studies, best management practices in spring cereals will be developed.

Absorption, translocation and metabolism of metamiltron in *Chenopodium album* L.

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The *as*-triazinone herbicide metamiltron, an inhibitor of electron transfer in photosystem II, is used for the control of dicotyledonous weeds, including *Chenopodium album* L., in sugar beet (*Beta vulgaris* subsp. *vulgaris* L.). *C. album* populations from different sugar beet fields responded as resistant to metamiltron. They were found to have the same D1 point mutation as known for atrazine resistant biotypes. However, the results are not as clear-cut as observed with triazine resistance in the past. After treatment with metamiltron, susceptible reference populations reacted less susceptible than expected whereas metamiltron resistant populations reacted more resistant than the atrazine resistant reference population. Also, there were remarkable differences between soil treatments and post emergence treatments with metamiltron. These results suggest that *C. album* might dispose of yet another mechanism to survive metamiltron treatments. ¹⁴C-metamiltron uptake, distribution and metabolism studies were conducted to elucidate the herbicide fate in *C. album* populations. In addition, fluorescence measurements tested the presence of target site resistance and the recovery of *C. album* populations after a metamiltron treatment. Root and foliar uptake of the herbicide were compared for a metamiltron resistant, an atrazine resistant and a susceptible *C. album* population. Sugar beet was also included as a highly tolerant reference species. Separation of the extraction products by TLC allowed to visualize and quantify the degradation products. Our results suggest that differences in root and foliar absorption and metabolism in *C. album* have an important impact on the efficacy of metamiltron treatments.

Effect of herbicides on weed plants growing under different soil nitrogen levels

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In order to reduce leaching of nitrogen to surface and groundwater use of nitrogen fertilizer has been regulated by legislation in Denmark for several years and consequently the use of nitrogen fertilizer has been significantly reduced during the last 20 years. Farmers and advisors have raised the question whether a reduced input of nitrogen will affect herbicide performance. The objective of this study was to investigate if reduced nitrogen availability affects the efficiency of selected herbicides.

Three different weed species, *Chenopodium album* (L.), *Tripleurospermum inodorum* (L.) Sch. Bip. and *Anagallis arvensis* (L.), were grown outdoors in pots supplied with four levels of nitrogen. Plants were sprayed with a range of herbicide dosages of the ALS-inhibitor, tribenuron-methyl or oxynil+bromoxynil, a photosystem II inhibitor, at the 2-4 leaf-stage and harvested 3 weeks after spraying. Field experiments with tribenuron-methyl were conducted in spring barley in 2008 and 2009 on natural populations of *C. album* supplied with different fertilizer rates. Plants were sampled 4 or 3 weeks after spraying in 2008 and 2009, respectively. ED₅₀ and ED₉₀ values (dose required to achieve 50% or 90 % control) were calculated for dry weights.

Both *C. album* and *T. inodorum*, grew vigorously to increasing nitrogen rates in the pot experiment and were controlled effectively by very low herbicide doses. *A. arvensis* grew equally well on low and high nitrogen rates and was controlled effectively by tribenuron methyl. Growth of *C. album* in the field experiment increased with increasing soil nitrogen levels and was controlled effectively by tribenuron methyl.

In the pot experiments the efficacy of tribenuron methyl and oxynil+bromoxynil towards *C. album* and *A. arvensis* did not differ among soil nitrogen levels. For *T. inodorum*, however, ED₅₀ and ED₉₀ values were lower for high soil nitrogen levels. Results from the field experiment on *C. album* did not reveal differences in herbicide efficiency among nitrogen levels.

The results from this study suggest that the interaction of soil nitrogen with herbicide activity was dependent upon the weed species and the herbicide. Previously published research has also suggested that soil nitrogen levels can influence the herbicide dose required to give commercially acceptable weed control. A reduction in fertiliser recommendations may lead to greater variation in soil nutrient content and thereby influence both crop and weed development. Low nitrogen areas may need higher herbicides doses to achieve the same degree of control than nutrient rich areas. In time, this interaction of soil nitrogen and herbicide efficacy may contribute to changes in weed population dynamics. Further studies on the interaction of soil nitrogen and herbicide efficacy, including herbicides with different modes of action and contrasting environmental conditions, are required before general conclusions can be drawn and disseminated to farmers and advisors.

Chemical weed control of *Apera spica-venti* in winter wheat

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Loose-silky bent (*Apera spica-venti*) is considered to be the third most important weed in cereals in Hungary based on the results of the Fifth National Weed Survey.

The aim of our study was to draw farmer's attention to the *A. spica-venti* problem and to introduce chemical weed control opportunities including the risks of non-professional technologies.

The trial was set up as large field plots in 2008 and repeated in 2009. Registered herbicides with known effects against grass weeds were used. Herbicide application was done using a field sprayer (Haflinger) mounted with TeeJet11004 nozzles and operated at a pressure of 3 bar resulting in a volume rate of 300 L/ha.

Chlorsulfuron, pendimethalin, triasulfuron were applied pre- and post-emergence in the autumn, chlortoluron, isoproturon, isoproturon + beflubutamid, metsulfuron-methyl were applied post-emergence in the autumn, sulfosulfuron, iodosulfuron + mefenpyr-diethyl, aminopirialid + pyroxsulam + florasulam + cloquintocet-mexil were applied early post-emergence in the spring and fenoxaprop + mefenpyr-diethyl, aminopirialid + pyroxsulam + florasulam + cloquintocet-methyl were applied late post-emergence in the spring. Efficacy of the treatments were done using according to EPPO guidelines.

All the products used in the trial were effective against *A. spica-venti*. If farmers follow the label recommendations all the products will be effective against *A. spica-venti*.

It is concluded that the spreading of *A. spica-venti* can be prevented by applying the registered products, but the treatment should be repeated in the following years. One treatment will not be effective for years.

Phosphate influence on glyphosate desorption after repeated applications in four contrasting Greek agricultural soils

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Although glyphosate is a foliage applied herbicide, a significant amount reaches the soil where it is strongly adsorbed. Glyphosate has a similar sorption mechanism to phosphate and may therefore compete with it for binding sites in the soil. The extensive use of glyphosate in modern agricultural systems where phosphate fertilization is a common practice requires that special attention should be paid to the effect of phosphate competition on glyphosate sorption and its availability in the soil-water. The present work investigated how glyphosate desorption is affected by the combination of repeated glyphosate applications and addition of phosphate in the soil. The study included four Greek soils with contrasting properties, from agricultural areas. Soil properties ranged from sandy-clay, heavy-clay, loamy and silt. Samples of each soil type placed in centrifuge tubes were treated with glyphosate, for three consecutive days. After each glyphosate application, samples were left overnight to equilibrate. The following day soils were 'rinsed' with water or phosphate solution for two hours, with continuous shaking. After rinsing, samples were centrifuged and the supernatant was analyzed for the determination of glyphosate, using high performance liquid chromatography with post-column derivatization and fluorescence detection. The amount of glyphosate that remained adsorbed by each soil sample was calculated by extrapolation from the amount applied and the amount detected in the supernatant. According to the results, the studied soils had distinctly different sorption capacities during the repeated glyphosate applications, which were further accentuated when phosphate was added. The highest sorption capacity was demonstrated by the heavy-clay and loamy soils, whereas the lowest by the sandy-clay and silt soils. Sorption capacity of the sandy-clay and silt soils was further hindered by the phosphate addition (through the soil 'rinsing' procedure) compared to the control (i.e. rinse with water) whereas the heavy-clay soil was not affected. These differences were more prominent during the third application of glyphosate. Especially in the case of the sandy-clay and silt soils, the phosphate addition resulted in about 25% reduction in the amount of adsorbed glyphosate compared to the corresponding controls and up to 42% when compared to the heavy-clay soil. The results indicate that in conventional agricultural systems where repeated applications of glyphosate are common, it is possible to have an increase in glyphosate desorption, depending on the soil type. Some soil types may be more vulnerable to glyphosate desorption by the addition of phosphate fertilizer, which could lead to higher availability of glyphosate in the soil-water, thus increasing the risk of glyphosate leaching or potentially causing problems in crop plants through root absorption.

Influence of additives on efficacy of tribenuron-methyl and iodosulfuron- methyl sodium at hard water conditions

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Tribenuron-methyl and iodosulfuron - methyl sodium are ALS - inhibitor herbicides and provided efficacious control of weeds. Quality of water used in the spray tanks can reduce herbicide efficacy. Water is the primary carrier for herbicide applications. Increasing pH can increase the solubility of sulfonylurea herbicides, and theoretically increase their activity. For example, nicosulfuron solubility at water pH of 5 is 360 mg/L, at 7 is 12,200 mg/L, and at 8 is 39,200 mg/L.

An objective of this research was to determine the influence of different additives on the efficacy of two sulfonylureas herbicides applied with hard water (350 mg/l CaCO_3). The greenhouse experiments were conducted using tribenuron-methyl and iodosulfuron-methylsodium applied postemergence at reduced rate (50% of recommended rate e.g. 7,5 g/ha and 3,75 g/ha respectively) to oilseed rape as tested plants with ammonium nitrate 2% v/v, ammonium sulphate 2%v/v, citric acids 0,2% v/v and potassium phosphate 0,1% v/v. Two additional treatments were also sprayed: recommended rate alone and recommended rate with distilled water as well as untreated control. Treatments were sprayed in a 305-L/ha volume and applied with a flat fan nozzles with spray pressure set at 350 kPa. Visual assessment and reduction of biomass of tested plants were determined as herbicide efficacy. Plant shoots were weighed 3 weeks after treatment and fresh weight reduction was converted to percent control.

Results indicated significant efficacy and reduction of oilseed rape biomass as tribenuron-methyl was applied with ammonium nitrate or ammonium sulphate. When oilseed rape was sprayed with iodosulfuron-methyl sodium the best results was obtained with ammonium nitrate or ammonium sulphate as well as when citric acid was added to tested herbicide. Fertilizers containing ammonium nitrogen increased the effectiveness enhance herbicide formulated as a salt (e.q. tribenuron-methyl and iodosulfuron- methyl sodium).

Broomrape control with herbicides or organic amendments in tomato fields in western Turkey

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Tomato is the most produced and consumed vegetable in Turkey. Tomato and tomato products are important exporting goods as well. One of the main problems in tomato production is broomrapes (*Phelipanche* spp. (syn. *Orobanch*e spp.)). There have been methods already applied to control broomrape such as chemicals, organic amendments, pulling etc. However, none of the methods assure broomrape control satisfactorily. Lack of very efficient control methods in tomato to control broomrapes has caused increases in broomrape problems as well as economical losses. The broomrape problem in tomato fields in Turkey, especially processed tomato production in the Marmara and Aegean Regions, has expanded and become severe. Separate experiments with herbicides and organic amendments were conducted to find out the most efficient materials to use in further research with combined control methods. Experiments were set in tomato fields naturally infested with broomrape in Çanakkale Province where is located in South Marmara Part of Turkey in 2008 and 2009. Herbicides experiment included chlorsulfuron, glyphosate, imazapic, imazethapyr, and rimsulfuron, which were registered active ingredients in Turkey when experiments were planned. Herbicides were applied twice (Rimsulfuron, 12.5+12.5 g ha⁻¹; Imazapic, 0.5+0.5 g ha⁻¹; Chlorsulfuron, 1.8+1.8 or 3.6+3.6 g ha⁻¹; Glyphosate 24+24 g ha⁻¹ a.i.) in the fourth and sixth week after transplanting except imazethapyr (20 g ha⁻¹), which was applied once. Organic materials experiment included manures such as chicken manure (20 t ha⁻¹), and cow manure (30 t ha⁻¹), processed materials such as humic acid (50 g in 10 l water), chicken manure pellets(2.5 t ha⁻¹), cow manure pellets(2.5 t ha⁻¹), and humic acid pellets(2.5 t ha⁻¹), cover crops such as oat (360 kg ha⁻¹ seed), vetch (240 kg ha⁻¹ seed), and wheat (360 kg ha⁻¹ seed), and olive processing waste. Treatments were applied at different times. Cover crops were seeded in mid January and incorporated into soil in mid April. All other organic materials except humic acid applied and incorporated into soil in mid April too. Humic acid was applied at transplanting. Roots of tomato seedlings were dipped into humic acid solution. *Phelipanche aegyptiaca* (syn. *Orobanch*e aegyptiaca) and *P. ramosa* (syn. *O. ramosa*), were detected in the field. The experimental design was a randomized complete block design with four replications.

The data of two years were pooled and underwent statistical analysis. Except rimsulfuron, all other herbicides significantly decreased the number of broomrape shoots as compared to no-herbicide-check. Phytotoxic effect of imazethapyr was reflected in yield. The other herbicides gave similar yield along with the control. In organic materials experiment, the number of broomrape shoots was significantly different between treatments and check in the early counting; but, it was not statistically different at later stages. Tomato yield was significantly different and it was affected by year. Chicken manure caused the highest yield.

Response of wild barley (*Hordeum spontaneum*) and wheat (*Triticum aestivum*) to different herbicides in greenhouse

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In order to study the response of wheat (*Triticum aestivum*) and wild barley (*Hordeum spontaneum*) to different herbicides, a greenhouse dose response experiment was conducted in 2009 at Ferdowsi University of Mashhad using completely randomized design with three replications. Clodinafop propargyl, pinoxaden, sulfosulfuron, metsulfuron-methyl+sulfosulfuron, and metribuzin were applied postemergence at the 2-3 leaf stage of wheat and wild barley. Plant dry weight was determined three weeks after herbicide application, and ED₅₀, ED₂₅, and herbicide selectivity indices ($ED10_{crop}/ED90_{weed}$) were determined for each herbicide. No herbicide provided complete control of wild barley in wheat without injuring wheat. Clodinafop propargyl and pinoxaden, even at higher than recommended doses didn't reduce wild barley biomass (ED50 value of >400 and >500 g ai ha⁻¹, respectively) and are not recommended for wild barley control in wheat. Sulfosulfuron had a minor effect on wild barley at the recommended dose (20% biomass reduction) with an ED50 value of 90.5 g ai ha⁻¹, but at higher doses both wild barley and wheat biomass was reduced significantly (SI value of 0.012). Tolerance of wild barley to metribuzin was higher than of wheat (ED50 value of 712.4 and 173 g ai ha⁻¹ for wild barley and wheat, respectively). Since wild barley was tolerant to all the herbicides, none had a favorable selectivity index. Assuming 50% biomass reduction of wild barley, the selectivity index of metsulfuron-methyl+sulfosulfuron was 0.85. Among the herbicides, metsulfuron-methyl+sulfosulfuron was the most selective reducing wild barley biomass by 32% at the recommended dose. The ED50 and ED25 of sulfuron-methyl+sulfosulfuron for wheat was >80 g ai ha⁻¹ and for wild barley was 83.0 and 20.6 g ai ha⁻¹, respectively. In conclusion, wild barley tolerated the wheat selective herbicide at the recommended doses, and further studies are required to find the effective herbicides for controlling wild barley in wheat.

Keywords: Grass weeds, chemical control, herbicide tolerance, dose response, selectivity index.

The efficacy of sulfonylurea herbicides depends on winter wheat cultivars and crop density

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One of the main factors that affects herbicide activity is weed density per unit area, which can be strongly determined by cultivar and sowing rate. Cultivars differ in ability to weeds suppression. This property mainly depends on emergence rate, earliness and morphological features that determine ground shading and plants height. Sowing rate influences tillering ability and lodging resistance. Dense stand of crop limits weed emergence and prevents weeds biomass production. The objective of this study was the evaluation of two sulfonylurea herbicides efficacy in relation to winter wheat cultivars and sowing rate.

The field experiments were carried out in the area of Wrocław (South-West of Poland) during years 2006-2008. Experimental plots were set up on black soil. Individual plot size was 2 m x 8 m. The experiment followed a split-split-plot pattern with four replications. Two winter wheat cultivars – Kobra and Tonacja, currently registered in Poland were sown at two densities: recommended (400 plants/m²) and reduced (200 plants/m²). The efficacy of two sulfonylurea herbicides was investigated two sulfonylurea herbicides: chlorsulfuron (15 g/ha) and iodosulfuron methylsodium (1 g/ha). Herbicides treatments were carried out in the autumn, at the stage 2-4 leaves of wheat and in the spring, at the stage of wheat tillering. The effectiveness of herbicides was recorded by visual method four weeks after herbicides treatment. Wheat was harvested at maturity stage and at the time of harvest the grain yield was determined.

Fifteen weed species were recorded on experimental field, but the dominant was *Viola arvensis*, that occurred at 74-84 plants/m², depending on wheat cultivar. Moreover, other species of importance were: *Descurainia sophia*, *Polygonum convolvulus*, *Brassica napus*, *Thlaspi arvense*. The examined varieties had different weed infestation depending on sowing rate. In Kobra cultivar, weed density was similar at both sowing rate, whilst in Tonacja cultivar was significantly diversified. Total weed infestation at sparse sowing was 210 plants/m² and at standard 131 plants/m².

The examined herbicides achieved satisfactorily weed control, irrespective of cultivar and sowing rate. The spring application of both herbicides gave a similar weed control independently on cultivar, while the autumn treatment resulted in slightly reduced effect when it was used in Kobra cultivar. Iodosulfuron methylsodium applied in the autumn as well as in the spring reduced weeds effectively (93-95% in average from three years), but chlorsulfuron tended to be less efficient when it was used in the autumn compare to the spring treatment. The density of winter wheat cultivars did not differentiated herbicides effect markedly. Tested herbicides did not affect grain yield, regardless of sowing rate and wheat cultivars.

Testing image-based site-specific weed control in cereals

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Automatic weed detection and valid thresholds are required for operational patch spraying (PS). The aim of present work was to test a first version of Weed_class.exe, which automatically estimates ground covers of broadleaved weeds and cereal in RGB images. Both real-time and map-based trials (imaging and spraying in one or two operations, respectively) were conducted in spring cereals and winter wheat in SE Norway in 2009.

The version of Weed_class.exe tested estimates relative weed cover (RWC) and relative Tripleurospermum inodorum (mayweed) cover (RMC). RWC is the cover of all broadleaved weeds divided by the total plant cover. RMC is the cover of T. inodorum divided by the total plant cover. Nadir view images (appr. 0.06 m²) were acquired with a field robot (1.8 km h⁻¹) in grids 0.5-1m × 3-3.5m during spring, the normal time for broadleaf herbicide application in Norwegian cereals. The biological threshold (BT) is the weed infestation level giving indifferent mean yields between sprayed and unsprayed units.

In the three map-based trials, the mean RWC or RMC pr management unit (12m × 12.5m) was tested as a threshold. One to five days after imaging, iodosulfuron-methyl-sodium was sprayed with farmers' equipment. In the 1st trial (winter wheat), RMC was a better predictor of yield loss than RWC. Data of this trial indicated that a BT based on mean RMC should be < 0.015. In the 2nd trial (winter wheat), a BT of mean RWC = 0.027 was indicated (27% herbicide savings). In the 3rd trial (spring barley), a BT of mean RWC=0.057 was indicated (43% herbicide savings).

The three real-time trials were conducted with the robot. The sprayed units were 3.5m × 3m and the unsprayed units 3.5m × 0.5m. There was no difference in mean yield between PS and broadcast application in any of these trials. In the two spring barley trials, the mean PS weed density at harvest was ≤ than the weed density after broadcast application (herbicide savings were 22% and 97%). The tested threshold, a weighted moving average of RWC image⁻¹ = 0.042, thus seemed appropriate for spring barley. The threshold for spring wheat should probably be smaller, as indicated by the weed density at harvest.

A set of thresholds for patch spraying broadleaved weeds based on RWC (RMC where high mayweed infestation occurred) and Weed_class.exe were estimated. These threshold parameters- and values need further testing. Weed_class.exe appeared useful, but with further weed species discrimination it will be even more successful.

Problem of *Alopecurus myosuroides* Huds. and its control in South-West Poland

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One of the consequences of globalisation is also a spatial expansion of weeds to new areas and new habitats. One of weed species which has expanded the rangeland is *Alopecurus myosuroides* Huds. This is one of problematic annual grass weeds in the arable fields of many countries of Europe. **As grass weeds it is difficult to control in cereal crops.** *A. myosuroides* is most common in regions with climates influenced by the Atlantic, such as the U.K., Belgium, the Netherlands, and some parts of France and Germany. Locally it is also found in Italy, in Switzerland and in Scandinavia and rare is observed in the Mediterranean and central parts of Europe. Since the 80's *A. myosuroides* increase the area of occurrence in Poland but this is problematic weed only in some regions.

The aim of conducted trials was evaluation of occurrence and harmfulness of *A. myosuroides* in winter wheat in the south-west part of Poland and possibilities of its control.

The field experiments were conducted in the years 2007-2009 in winter wheat. They were conducted in randomized blocks with four replications, and plot size of 20 m². All of them were placed in farmers fields of winter wheat in the area of Lower Silesia region (south-west part of Poland). In the experiments 6 herbicides contain propoxycarbazone sodium, fenoxaprop-P-ethyl, pinoxaden and mixtures of iodosulfuron + mesosulfuron and flufenacet + diflufenican and isoproturon + diflufenican were selected. The herbicides efficacy was defined on the basis of the fresh weight reduction in comparison to untreated.

The field observation were confirmed that there are several local infestations by *A. myosuroides* in south-west part of Poland.

The trials results were showed that *A. myosuroides* is a very competitive weed species for cereals. In the case of winter wheat with high potential of yielding (above 6.50 t·ha⁻¹) the economical threshold of harmfulness will be overstep when the intensity of *A. myosuroides* is above 25 panicles per sq. meter.

Possibilities and efficacy of *A. myosuroides* control was dependent on the kind of herbicide and time of its application. The best results of *A. myosuroides* control were observed after autumnal treatments at 13-14 GS. The autumn application of pinoxaden with adjuvant and mixtures iodosulfuron + mesosulfuron or isoproturon + diflufenican assured the level of control between 92 and 98%. The lowest efficacy (only 81%) was obtain with flufenacet +diflufenican mixture.

The highest yield was measured for the treatment of iodosulfuron + mesosulfuron mixture (8.25 t·ha⁻¹). The plots treated in the autumn with pinoxaden and isoproturon + diflufenican mixture provided the grain yield on the level of 7.98-8.13 t·ha⁻¹, whereas application mixture of flufenacet + diflufenican assured only 6.39 t·ha⁻¹.

In the spring at the moment of herbicide treatment, *A. myosuroides* was at the growth stage

23-25 and therefore not all of tested herbicides were fully efficient. The best results of control in the case of pinoxaden, fenoxaprop-P-ethyl and propoxycarbason sodium were observed. This herbicide have controlled *A. myosuroides* infestation in the range from 92% to 98%. The spring treatment of iodosulfuron + mesosulfuron mixture provided some less efficacy (89% of panicles number reduction). The lowest efficacy of control (only 74%) was obtained with isoproturon + diflufenican mixture.

The longest period of competitive influence of *A. myosuroides* for winter wheat has caused that the level of grain yield was lower in comparison with spring treatment. The highest yield (7.48-7.53 t ha⁻¹), which was measured with the spring treatment of pinoxaden and fenoxaprop-P-ethyl. The application with propoxycarbason sodium and iodosulfuron + mesosulfuron mixture provided a yield level of 6.95-7.09 t ha⁻¹. The lowest yield (6.02 t ha⁻¹) after application isoproturon + diflufenican mixture was measured. The yield from untreated plots was 3.90 t ha⁻¹. The significance differences of winter wheat yielding by statistical analisys were confirmed ($LSD_{(0,05)} = 0,487$).

Fenoxaprop-P-ethyl enhances the activity of chlormequat chloride and prohexadione-calcium in winter wheat

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The aim of the study was to evaluate biological activity of fenoxaprop-P-ethyl, chlormequat chloride (CCC) and prohexadione-calcium applied in mixtures in winter wheat.

The characteristic of spray solution such as surface tension and contact angle were measured using TRACKER drop profile contactometer/tensiometer. The resistance of crop to lodging and bentgrass (*Apera spica venti*) control were examined in field experiments conducted in 2003-2005 in central Poland. Plot size was 12 m². The experimental design was a randomised block with four replications. Treatments were applied at BBCH 31 growth stage of wheat using a small plot spraying equipment with TeeJet 110 02 VP flat-fan nozzle with a water volume of 270 L*ha⁻¹ and an operating pressure of 0,3 MPa. The doses used were: fenoxaprop-P-ethyl - 69 g*ha⁻¹, CCC - 675 g*ha⁻¹, prohexadione-Ca - 50 g*ha⁻¹.

The surface tension of spray solution with CCC or prohexadione-Ca was significantly higher compared with the mixtures of these retardants with fenoxaprop-P-ethyl. The values were 70.4, 44.3 and 28.1, 27.4 mN*m⁻¹ respectively. The contact angle of droplets was measured at hydrophobic surface (paraffin wax). This parameter was significantly lower in spray solution with the mixture of growth retardant and herbicide compared to the solutions with these products used alone. The contact angle of CCC was 83.3°, while in mixture of CCC + fenoxaprop-P ethyl – 44.6°. In case of prohexadione-Ca the results were 88.6° and 48.9° respectively.

Both CCC and prohexadione-Ca were more effective when they were used in mixture with fenoxaprop-P-ethyl and protected crop against lodging much more than the growth retardants used alone. The length of wheat stems on untreated plots was 83.9 cm. CCC and prohexadione-Ca shortened stems to 73.3 and 78.5 cm respectively. However, the effect of crop shortening was bigger on plots treated with tank mixture of retardants and fenoxaprop-P-ethyl (70.6 and 74.2 cm respectively). The reduction of wheat stems length by fenoxaprop-P-ethyl also was found. It was 5,5% compared with untreated plants. Crop lodging on plots with CCC was 4.7% while on plots with CCC + fenoxaprop-P-ethyl no lodging was found. As regards of prohexadione-Ca the results were 11.5 and 1.3% respectively. As regards weed control no significant differences between fenoxaprop-P-ethyl applied with and without PGRs were noticed. All treatments were very effective against bentgrass. The mixture of retardants with fenoxaprop-P-ethyl were selective to winter wheat.

Harmfulness of *Ambrosia artemisifolia* L. and herbicides of its control in soybean under condition of the Ukraine

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In recent years phytosanitary situation in agroecosystem has worsened considerably. *Ambrosia artemisifolia* L. is one of the most harmfulness and the fastest spreading weeds in the Ukraine. In comparison to 1973 the area of its spread has increased 25 times and in August 1, 2008 it was 2,2 mill. ha. *A. artemisifolia* L. is mainly spread in the southern regions of Ukraine, but it becomes more widely spread on the territory of the left-bank and right-bank Forest Steppe. The aim of this research was to investigate the harmfulness of *A. artemisifolia* L. in soybean and chemical measures to control it. Field trials were conducted in 2006-2008 at the Feed Research Institute of UAAS. The soil was a grey wooded type with 2.2-2.4 % organic matter content and pH 5.2-5.5. After germination, *A. artemisifolia* L. was found to infest from 0 to 40 plants.m⁻². Herbicides efficacy was assessed 30 days after treatment (DAT) and at crop harvest by measuring the above-ground weed fresh weight.

The results on yield showed profound harmful effect of *A. artemisifolia* L. Even 2 plants.m⁻² of *A. artemisifolia* L. reduced the yield by 15,2 % in comparison to control. Maximum reduction of soybean yield was 53-63 % with 30-40 plants.m⁻² of *A. artemisifolia*.

Soybean plants have low competitive ability against *A. artemisifolia* L. and therefore herbicide use is a necessity. In soybean agroecosystem a mixed type of weed infestation with annual grass, dicotyledonous weeds and *A. artemisifolia* L. was found. Under such conditions substantial intensification of herbicide use is required for example herbicide mixtures with different mechanism of action herbicides.

These experiments showed a good efficiency of imazetapyr 50 g.ha⁻¹ and bentazone 720 g.ha⁻¹ + thifensulfuron methyl 4.5 g.ha⁻¹. Control of all weed species was 82-85%, while *A. artemisifolia* L. was controlled by 85-90 %. The compositions of herbicides provided the increase seed yield for 0,73-0,75 t. ha⁻¹ of soybean in comparison to untreated control and did not reveal negative effect on yield quality.

Environmental fate of oxadiazon in paddy fields

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Oxadiazon is a post-emergence herbicide widely used to control several grasses and broad leaved weeds in rice, soybean, sunflower, cotton, orchards and turf. In rice it is mainly used to control *Heteranthera* spp.

The study was carried out over 2007-2009 at Vercelli (45° 17' 47.99'' N – 8° 25' 53.82'' E), north-west of Italy, in a series of 3 paddy fields of about 2000 m² each. The aim was to evaluate oxadiazon fate in surface water and top soil in paddy fields under three management systems: A) straw and liquid manure incorporated in autumn and rice seeded in flooded field, B) straw incorporated in autumn and rice seeded in flooded field, C) straw incorporated in autumn and rice seeded in dry field and conventionally flooded starting from rice tillering stage. Oxadiazon was applied in rice pre-seeding at a rate of 380 g ha⁻¹ using a conventional 12-m wide boom sprayer.

Water and soil samples were collected at different intervals from herbicide application up to about 3 (water) or 10 months (soil) after the treatment. Water samples were collected both in the flooded fields and from the inlet and outlet floodgates by directly filling 0.5-L flasks. Soil samples were taken using a stainless steel shovel shaped to take the top 1.5 cm layer of soil. Herbicide extraction from water samples was carried out using SPE extraction cartridges. Herbicide extraction from soil was performed by using a cyclohexane/ethyl acetate solution (90/10 V/V). Analytical-grade oxadiazon was used as analytical standard. The analysis of the water or soils extracts was performed by using a Perkin Elmer 8500 GC, split injector, equipped with a 30m x 0.25µm df SPB 5 column. The injector and detector temperature was set to 250°C and 315 °C, respectively.

The trend of oxadiazon presence in flooding water showed remarkable differences between years, even though maximum concentration did not exceed 28.0 µg L⁻¹. Over the three years, the concentration in inlet water ranged between 1.24 µg L⁻¹ and 2.25 µg L⁻¹, while in outlet water, it was on the whole similar to that of flooding water. In all systems, starting from 47 days after treatment, concentration of oxadiazon in flooding water dropped below 3 µg L⁻¹. One year after herbicide application, oxadiazon concentration in soil always exceeded 18 µg kg⁻¹ and system C) showed concentrations two-folds higher than those found in systems A) and B).

Oxadiazon seemed to be quite persistent in the soil. The higher presence in system C) could be attributed to the shorter duration of flooding condition that led to a lower occurrence of leaching and dilution phenomena. Among the cultural practices adopted, water management seems to have the strongest effect on oxadiazon dissipation pattern.

EcoPest: Developing sustainable weed management and herbicide application systems in a pilot area in Greece

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Sustainable weed management and herbicide application systems were developed in a pilot (900 ha with cotton, maize, and plum tomato) area in Greece, as part of an EU LIFE+ project (EcoPest; www.ecopest.gr). The aim of the project was to develop, apply and demonstrate an economically viable Strategic Plan for the sustainable use of herbicides via its minimization and the effective management of the related risks in line with all the latest EU policy reforms. Minimization of herbicide use will be achieved through integration of a decision support system (WebHadss) applied to local conditions with band-application of all pre-emergent herbicides, mechanical cultivation in-between rows, and application of shield-directed post-emergent herbicides in cotton using a system with sensors (WeedSeeker®). Preliminary field experiments were conducted to measure the reduction of herbicide use since preliminary field testing (in 15 ha cotton, 2009) have shown a 50% reduction in pre-emergent herbicide (fluometuron) through band-application, and 30-80% reduction (depending on weed coverage) on post-emergent directed applications (glyphosate) using the sensor technology. Developing sustainable weed management systems aims mainly to control the most noxious weed in the pilot area that is purple nutsedge (*Cyperus rotundus*). Nutsedge coverage ranged from 10-75% and number of tubers ranged from 3.2 to 0.2 millions/ha. In addition, field experiments will be conducted to measure the efficacy of sustainable weed management systems with particular emphasis to control purple nutsedge.

Evaluation of the effectiveness of different doses of bentazone on redroot pigweed (*Amaranthus retroflexus*)

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The effectiveness of different doses of bentazone (480 - 720 - 960 g a. i. ha⁻¹) was assessed on redroot pigweed (*Amaranthus retroflexus*) plants at three leaves growth stage (BBCH 13) in small plot field experiments on the experimental station of Mendel university in Žabčice 49°01' N; 16°16' E) in the years 2005-2008.

The device PS1-meter was used to predict the effectiveness of bentazone. PS-1meter is based on the measurement of light-induced changes in absorbance and is able to capture the degree of damage of photosynthetic apparatus caused by herbicide before appearance of visible symptoms. Oxidation and reduction processes are measured by changes in absorbance at a wavelength of 820 nm (wavelength specific for reactions that take place in photosystem I and which are influenced by processes in PS II). The scale of device has range from 0 (no damage) to 100 (plant death). This early detection may allow the timely implementation of corrective application in cases when the first application failed.

Small plot field experiment had four treatments with four replications (the size of a plot was 21 m², 3x7 m). The application was done in the growth stage of four leave of maize (redroot pigweed BBCH 13) by a backpack sprayer Solo 432 set for the application pressure 0.3 MPa and a dose of 300 water l.ha⁻¹. The level of damage to photosynthetic apparatus was measured 1, 2, 3 and 4 days after treatment (DAT). The results of the effectiveness of different doses of bentazone on redroot pigweed predicted by PS1-meter device from the time of 4 DAT were compared with results of visual assessment carried out in term 14 DAT.

Analyses of variance showed significant effect of year, treatment, day of measurement (in DAT) and all interactions on the measured values of PS1. Analyses of components of relative variance made by percentage evaluation of individual factors showed 92.8% influence of treatment on PS1 values. Influence of other factors (assessed in analysis of variance) and their interactions were almost insignificant. High values of PS1 were found already 1 DAT for all doses of bentazone. Other days of measurement showed values in the range of 73-100. Values of PS1 (numbers without unit, the higher value means more damaged) grew slower for the dose of 480 g a. i. ha⁻¹ in 2008, but in term 4 DAT achieved the level of other tested doses. High efficiency on weeds (at least 90%) in term 4 DAT occurred in all years for all tested doses. This efficiency is similar to 65 points of PS1 values from device manual. Thus predicted efficacy was subsequently confirmed by the results of visual assessment in 14 DAT, when the efficacy was in the range of 90-97.5%. The obtained results showed that using dose of 480 g a. i. ha⁻¹ is sufficient for high efficiency of bentazone on redroot pigweed (BBCH 13) and the device PS1 meter can be used for prediction of the herbicide effectiveness of active ingredient bentazone.

Acknowledgement

This paper was prepared with financial support of the Ministry of Education, Youth and Sports of Czech Republic, as part of the research project - 2B06124 "Reducing the impacts and risks to the environment and provide information for informed decision-making methods of precision farming and by the Research plan No. MSM6215648905 "Biological and technological aspects of sustainability of controlled ecosystems and their adaptability to climate change."

Efficacy and selectivity of selected herbicides in onions (*Allium cepa* L.)

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Onion belongs to common vegetables cultivated in the Czech Republic (approximately 3. 000 ha). In total, there are 8 active substances (fluroxypyr, pendimethalin, ethofumesate, oxadiazon, propachlor, oxyfluorfen, quizalofop-P-ethyl, prapaqizafop) in 13 registered herbicide products for use in onion in Czech Republic.

Efficacy and crop safety of the most important herbicides used in onions in the Czech Republic were assessed in this study. Field trials were carried out at the experimental field of CULS Prague in 2006 and 2007. Tested herbicides were pendimethalin (1.6 kg ha⁻¹) applied pre-emergence (PRE). Fluroxypyr (0.1 kg ha⁻¹) and oxyfluorfen (0.18 and 0.15 kg ha⁻¹) were applied post-emergence (POST) at the growth stage (BBCH) of one, two and three leaves of onion as a split applications with pendimethalin, and then both together as a split application or in tank-mix. Herbicide efficacy on *Mercurialis annua* (MERAN), *Amaranthus retroflexus* (AMARE), *Solanum nigrum* (SOLNI) and *Chenopodium album* (CHEAL) was assessed, as well as the crop safety.

PRE application of pendimethalin stand alone caused only slight crop injury showing excellent efficacy on CHEAL (over 99 %) but relatively low efficacy on AMARE (below 85 %) and SOLNI (81 %). Split application of pendimethalin (PRE) and oxyfluorfen (0.18 kg ha⁻¹ at BBCH 13) and tank-mix combination of oxyfluorfen (0.15 kg ha⁻¹) + fluroxypyr (0.1 kg ha⁻¹) applied at BBCH 13 slightly improved the efficacy level on AMARE (over 92 %) and especially on MERAN (over 98 %). The highest efficacy on AMARE, CHEAL, MERAN and SOLNI had the split application of oxyfluorfen (0.18 kg ha⁻¹ at BBCH 12 followed by rate of 0.15 kg ha⁻¹ at BBCH 13). Onion was significantly more sensitive to oxyfluorfen in early growth stages than for other tested herbicides, especially at BBCH 11. Mean crop injury caused by oxyfluorfen was 23 % but onions regenerated within 2 weeks after application. Fluroxypyr showed significantly higher selectivity to onion than oxyfluorfen at all tested growth stages, but its efficacy on weeds was the lowest of all tested herbicides.

In conclusion, suitable herbicide for weed control in onion seems to be oxyfluorfen, best in tank mix with fluroxypyr or as a split application with pendimethalin (PRE). Post-emergence application of oxyfluorfen should be used at the onion growth stage of BBCH13, at least three days after intensive rainfall to minimize crop injury and achieve high efficacy on majority of annual weeds.

Integration effect of split nitrogen application and herbicides on soil weed seed bank in a continuous wheat (*Triticum aestivum* L.)

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A field study was conducted to determine the integration of split N fertilization and herbicide applications on weed management and soil weed seed bank in wheat field in Shiraz, Iran, during 2005-6 and 2006-7 growing seasons. The experimental design was a split plot design with four replications. Main factors consisted of N timing and splitting: $[T_1N_0, T_2N_0, T_3N_0]$, $[T_1N_0, T_2N_1, T_3N_0]$, $[T_1N_0, T_2N_2, T_3N_0]$, $[T_1N_{1/2}, T_2N_{1/2}, T_3N_0]$. The sub plots consisted of two herbicides, mesomax+udosulfuron methyl sodium (Chevalier 6%WG), solfosulfuron (Apyros 75% WG). Two check treatments, weedy and weed free were used. Results showed that the best nitrogen treatment was $[T_1N_{1/2}, T_2N_{1/2}, T_3N_0]$. This treatment had maximum LAI (4.7A), seed yield (240.0A 2005-6, 486.6A gm^{-2} , 2006-7) biological yield (780.5A 2005-6, 1153.0 A gm^{-2} , 2006-7) in wheat. Integrating of split nitrogen application and herbicides had significant effect on soil weed seed bank. The lowest weed seed density observed in mesomax+udo sulfuron methyl sodium without nitrogen but the lowest weed seed density obtained in solfosulfuron with nitrogen split of $[T_1N_0, T_2N_1, T_3N_0]$, it might be shown that the weakness of solfosulfuron in the control of wild oat, as a dominant weed in the field. The soil weed seed bank increased annually during the tree years of experiment. By using the herbicides, the increase in soil weed seed bank became lower. In conclusion, integration of chemical weed control and fertilizer management caused significant reduction in weeds and their seed bank in the soil.

T_1 =sowing, T_2 =tillering and T_3 =stem elongation

N_0 =no N fertilization, N_1 = full N fertilization, $N_{1/2}$ = half of the N fertilization, N = one third of the N fertilization and N = two third of the N fertilization

Effect of different doses of Imazethapyr herbicide on *Xanthium stromarium* L. competition with soybean

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Introduction: Common cocklebur (*Xanthium stromarium* L.) is an annual with a short, stout, hairy stem. Leaves broadly triangular-ovate or sub orbicular; flower heads are terminal and auxiliary racemes; white or green; numerous; male upper most; female ovoid, covered with hooked bristles; Flowering time is August-September. It multiply by seeds. This weed is able to compete with summer annual crops such as soybean and reduce its yield seriously. Imazethapyr is an imidazole compound used as a selective herbicide. It is applied pre seeding, pre emergence and post emergence. The compound controls weeds by reducing the levels of three branched-chain aliphatic amino acids, isoleucine, leucine and valine, through the inhibition of aceto-hydroxyacid synthase (AHAS), an enzyme common in the biosynthetic pathway for these amino acids. In this experiment reduced doses of Imazethapyr with different densities of Common cocklebur was tested.

Materials and methods: A field experiment was conducted to study herbicide dose effect on common cocklebur competition against soybean in 2009 at Research field of the Islamic Azad University- Karaj branch near Tehran, Iran. The experimental design was a randomized complete block design in factorial arrangement with four replications. Four densities of common cocklebur including 0, 4, 8 and 12 plants/m² were the levels of factor A and five doses of herbicide Imazethapyr (0, 0.25, 0.5, 0.75 and 1 liter per hectare) were the levels of factor B.

Results: There was no significant decrease in weed biomass by applying herbicide at 0.25 of recommended dose. Common cocklebur biomass decreased significantly with half of recommended dose. The decrease in common cocklebur biomass was well-described by standard dose response function. There was no significant difference among 0.5, 0.75 and full rate of herbicide doses. Probably, half of full rate can be recommended as an effective reduced dose to control common cocklebur in soybean and results described that there was no difference between densities of 4, 8 and 12 plants/m² and also there was not any difference between 0.75 and full rate of herbicide in soybean yield. The interaction effect between herbicide doses and soybean densities was significant and highest yield was at full dose and 12 plants/m² treatment and the lowest yield was in treatment of no herbicide and 12 plant/ m².

Gradients of diversity and species composition of weed communities in North-east Croatian arable lands

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Weed communities on arable lands are widespread and highly dynamic components that have changed dramatically in the last decades. These increasing structural changes are to be observed as (i) decrease in number and abundance of weed species, and (ii) increase in the relative importance of some species which are difficult to control. Regular and sequential changes in the environment and agronomic practices have been the major forces influencing the species shift and adaptation in weed communities. In many areas these relationships result that some ecologically specialized species declined, whereas nitrophilous or herbicide-tolerant species spread, leading to the development of species-poor, often monodominant communities.

The study area corresponds to the province situated at the northeast corner of the Republic of Croatia and represents a flat and open region. A recent weed survey in North-East Croatian arable land were compared with past records of weed communities from the main row crops in the region (maize, sunflower and sugar beat). Species occurrence was estimated using the seven-grade scale of Braun-Blanquet. An ordinal transformation on the 1-7 scale was used for calculations. Dominance-diversity curves were generated by joining cumulative cover abundance values plotted in a cumulative fashion against species rank. The data were subjected to ordination analysis, using the CANOCO 4, 5 package (ter BRAAK & _milauer, 2002). A canonical correspondence analysis (CCA) was performed with forward selection using Monte Carlo permutation test. Explanatory variables were Crop (maize, sunflower and sugar beat) and Geographic position of relevés (West, East and North part of Slavonia and Baranja region) presumably associated with variation in weed species composition.

A total of 95 weed species were recorded in row crops during the recent survey, and 79 were found in past survey. Only 55 species were common to the both research. Weed community structure, as defined by dominance-diversity curves changed over time showing the trend of increasing cover abundance of few dominant weed species. Some species were disappeared, probably due to intensive herbicide use, and some newcomers – invasive species showed a remarkable cover-abundance value compare to past research (*Ambrosia artemisiifolia* L., *Abutilon theophrasti* Medik., *Conyza Canadensis* (L.) Cronquist). A total cover-abundance value from both surveys reflects the changes of weed vegetation over past decades. Type of the crop significantly affected weed species composition in recent survey, while in the past was less pronounced between sunflower and sugar beat. Although, the differences in floristic composition between East, compare to the West and North part of investigated territory are visible in both surveys ($P < 0,05$), today's floristic composition of weed vegetation in row crops in the West and North sample stands seems to be more similar.

Author's index

A			
Abd-El Lateef E.M.	289	Baudry J.	141
Abrahamsen U.	271	Beeldens A.	250, 267
Adamczewski A.	24	Belz R.G.	48, 282
Adamczewski K.	53	Ben-Ami G.	31
Ádamszki T.	46, 47	Benoit D.	74
Agarwal T.	215	Béres I.	8, 181, 208, 279
Agha Ali Khani M.	191, 194	Berestetskiy A.	234, 236, 238
Ahmed M.F.	113	Berge T. W.	317
Aksoy E.	115	Bernicot M. H.	287
Anbari S.	77	Berzenyi Z.	302
Andersson K. J.	269	Bienau M.	246
Andersson L.	78, 79, 89, 90	Bigongiali F.	276
Andolfi A.	234, 236	Bilat J.	197
Andreasen C.	247	Biondi M.	222
Andújar D.	131, 154	Blache G.	45
Angevin F.	304	Bleeker P.O.	68, 286
Antichi D.	276	Bochenek A.	67
Antunovic S.	329	Bohren C.	218, 219, 241, 274
Anyszka Z.	275	Bon M.C.	201, 211, 212, 224
Aper J.	36, 309	Bónis P.	302
Apollonova L.	234	Borbély M.	170
Árendás T.	302	Borona V.	321
Asadi G. A.	205	Borza J. K.	153
Asgarpour R.	259	Boström U.	89, 90
Asi D.	149	Botta-Dukát Z.	116, 240
Atanackovic V.	161	Boursault A.	185
Auškalniene O.	71, 173, 175	Božic D.	76, 299
Auškalnis A.	71, 173, 175	Brandsæter L. O.	273, 308
Azam A. T. M. A.	114	Brant V.	294
Azens J.	197	Brants I.	45
B		Bulcke R.	36, 250, 254, 267, 309
Babenschneider S.	183	Busset H.	85
Bahrani M. J.	260, 261	Buttenschon R.	241
Bailly G. C.	12	C	
Baraibar B.	172	Camacho D.	307
Bårberi P.	134, 276	Campetella G.	106
Barbieri G.	38	Caneill J.	246
Bartha S.	106	Cantero C.	257
Bastiaans L.	244	Carlesi S.	276
Bastida F.	307	Carpi G.	276
Batlla D.	65	Carreira A. M.	126
		Cedergreen N.	282

- | | | | |
|--------------------|--------------------|--------------------------|-------------------------|
| Cernák I. | 199 | Demirkan H. | 314 |
| Chachalis D. | 23, 323 | Deytieux V. | 287 |
| Chamani Asghari T. | 187 | Di Cristina F. | 222, 223, 224, 233 |
| Chauvel B. | 33, 110 | Díaz J. | 91, 92, 93 |
| Chelovechkova V. | 234 | Dixon P. M. | 153 |
| Chowdhury A. R. | 113 | Djedbour D. | 196, 197, 204 |
| Chowdhury M. A. M. | 114 | Djurovic S. | 216 |
| Chowdhury M. H. | 114 | Dmitriev A. | 236 |
| Cimmino A. | 236 | Dobrodumov A. | 234 |
| Claupain W. | 73 | Dobrzanski A. | 275 |
| Clément J. | 33 | Dolgovskaya M. Y. | 201 |
| Colbach N. | 85, 157, 179 | Domaradzki K. | 316, 318 |
| Collavo A. | 38, 39 | Dorado J. | 131 |
| Colonnelli E. | 224 | Dorner Z. | 143, 278 |
| Conn J. S. | 107 | Dragicevic V. | 306 |
| Cordeau S. | 110 | Dürr C. | 85 |
| Cortat G. | 196 | Dvorák J. | 147 |
| Coruh I. | 184 | | |
| Covarelli G. | 87 | E | |
| Cristofaro M. | 222, 223, 224, 233 | Eckersten H. | 79 |
| Crivellari A. | 100, 144, 192 | Economou G. | 23, 52, 99, 146, 262 |
| Cussans J. W. | 155 | Edalat M. | 163, 167, 168 |
| Csecserits A. | 240 | Edwards J. | 108 |
| Csöndes I. | 208 | Einhorn G. | 22 |
| | | Elezovic I. | 299 |
| D | | Ellison C. | 207 |
| Daedlow D. | 169 | Ellmer F. | 22 |
| Dale R. P. | 12 | Eschen R. | 196 |
| Daly E. | 225 | Evidente A. | 210, 234, 236 |
| Dancza I. | 8, 217 | | |
| Datta A. | 256, 270 | F | |
| Dávid I. | 170, 303 | Fadia Sh. A.A. | 289 |
| David-Harris K. | 176 | Fagot M. | 250, 267 |
| Davis A. | 74 | Farcy P. | 287 |
| De Biase A. | 222, 223 | Fernández-Quintanilla C. | 131, 154 |
| De Cauwer B. | 250, 254, 267 | Ferrero A. | 100, 144, 192, 232, 322 |
| de Joffrey J-P. | 274 | Finizio A. | 210 |
| de la Fuente E. B. | 65, 126, 186 | Fischer A. | 13 |
| de la Warr P. | 108 | Follis F. | 100, 144 |
| De Lillo E. | 223 | Fontanelli M. | 248, 280 |
| De Marez T. | 35, 36 | Forcella F. | 74 |
| de Mol F. | 169, 183 | Forghanipoor E. | 149 |
| De Prado R. | 38, 39 | Frasconi C. | 248, 280 |
| Dekker J. | 58 | Fratzeskakis L. | 52 |
| Delabays N. | 219, 274 | | |
| Délye C. | 16, 33 | | |

G			
Gajardo H.	91, 92, 93	Hanzlik K.	104
Galdames R.	91, 92, 93	Hao C.	118
Gamliel A.	15	Harcza M.	305
Garcia A. L.	257	Harizanova V.	223
Gardarin A.	85, 157	Hatcher P. E.	273
Garnett R.	45	Haugland E.	273
Gassmann A.	198	Hayat R.	233
Gauvrit C.	39	Heini J.	300
Gerber E.	197, 198, 233	Hejazi A.	168, 260, 261
Gerhards R.	26, 73, 118, 249, 293, 300	Hemming J.	286
Gerowitt B.	43, 57, 98, 104, 127, 145	Hermann O.	35
Ghadiri H.	70, 163, 166, 327	Hernández Plaza E.	124
Ghorbani R.	205, 258, 259	Hess M.	17
Giannopolitis C. N.	312	Heuer H.	197
Giannopolitis K. N.	14	Hinz H. L.	233
Gil A.	186	Hlavacs B.	301
Glanfield P.	12	Hochberg O.	34
Glemnitz M.	156	Hodi A. M.	301
Gołaszewski J.	67	Hodi L.	301
Goldberg S.	317	Hoffmann R.	44, 208, 209, 220
Goldwasser Y.	94	Holec J.	51, 227
Golebiowska H.	140	Holst N.	75, 241, 264
Gólya G.	8	Honek A.	83
Gonzalez Andujar J. L.	74, 124, 186	Hornyák A.	311
Gonzalez L.	101	Horváth J.	181
González-Torralva F.	38	Hoseyni A.	258
Gooding M. J.	176	Hosseini M.	80
Górecki R. J.	67	Hosseini S. A.	315
Granger S.	179	Houot S.	142
Granillo G.	210	Hozayn M.	289
Graziani F.	74	Höft A.	145
Greenspoon I.	15	Hufnagel J.	156
Groeneveld R. M. W.	68	Hull R.	28, 29
Grundy A. C.	74, 264	Hutchings S-J.	12
Guermache F.	211	Huth V.	183
Gutjahr C.	293	Hyvönen T.	105, 132
Gültekin L.	223, 224		
György A.	129, 305	I	
		Idziak R.	295
		Iftikhar Hussain M.	101
H		Isik D.	74, 115, 162
Hahn M.	228	Islam M. K.	112
Hamouz P.	138	Islam M. N.	113
Hamouzová K.	20, 21, 51, 138, 294	Islam M. R.	112
Hansen P. K.	241	Isselstein J.	122
Hansson D.	264		

J			
Jahan R.	112, 113, 114	Klimek S.	122
Jahani M.	258	Klimeš P.	164
Jami-Al-Ahmadi M.	188, 189	Knezevic S. Z.	256, 270
Jamnejad M.	149	Kocurek V.	324
Jarak M.	292	Koesling M.	273
Jeanneau M.	201, 212	Kohut M.	275
Jócsák I.	302	Kolárová M.	133, 139
John M.	127	Komives T.	25
Jones W.	201, 211	Konstantinovic B.	125, 292
Jönsson Å.	182	Koocheki A.	178, 258, 259
Jursik M.	227, 326	Koprdoва S.	83, 171
Jüttersonke B.	22	Korac M.	125
		Korotyaev B. A.	224
K		Kotoula-Syka E.	52
Kacan K.	277	Kozak M.	124
Kaiser J.	17	Krähmer H.	17, 56, 73, 128, 284,
Kaiser Y.	26	Krause B.	135
Kalivas D.	146	Krawczyk R.	121
Kalocsai R.	106	Kristoffersen P.	247
Kanatas P. J.	262	Kröel-Dulay Gy.	240
Karamán J.	8	Kucharski M.	40, 318
Karlsson L. M.	59, 74, 182	Kudsk P.	241, 269, 310, 315
Karpova E.	150	Kukorelli G.	25, 46, 47
Karrer G.	200, 213	Kulin B.	305
Kashani A.	194	Kurlenya A.	234, 238
Kashina S.	234		
Kaspersen K.	317	L	
Kati V.	312, 323	L. Lulli,	280
Kaundun S.S.	12	Laber B.	17
Kaya Altop E.	115	Labreuche J.	142
Kaya E.	61, 162	Lassi K.	297
Kazemeini S. A.	167, 168, 260, 261	Le Corre V.	33
Kazinczi G.	8, 44, 180, 181, 208, 209	Lecce F.	222, 223, 224
Kéki S.	72	Legrand G.	35
Kelemen A.	72	Lehoczyk É.	81, 279
Kempenaar C.	264, 265, 286	Lengyel A.	106
Kerekes B.	279	Leskovsek R.	229, 270
Kerekes G.	44	Lešnik M.	229, 270
Keszthelyi S.	177	Leuschner C.	135
Khanjani M.	97, 188, 189, 190	Li M.	231
Khorramdel S.	178	Liebman M.	153
Kieloch R.	316	Liew J.	89, 90
Kierzek R.	24, 53, 121,	Loddo D.	64, 117
Kiss B.	25	Lő-Pelzer E.	304
Kleinman Z.	31	Luijendijk C. D.	165
		Lulli L.	248

Lundkvist A.	77	Meseldzija M.	125
Lundon A. R.	308	Mészáros G.	44
Lunnan T.	273	Meunier D.	142
Lutman P. J. W.	108, 283	Meyer S.	135
Lyra D.	99	Mézière D.	179
Lyra S.	52	Michel S.	33
M		Michielsen J. M.	68
Machera K.	323	Micskei G.	302
Madarász J.	217	Migléczy T.	72
Magnuski E.	89, 90	Miklavc J.	229
Magri B.	108	Milakovic I.	200, 213
Magyar D.	25	Milan M.	322
Magyar L.	32	Milberg P.	74, 89, 90, 182
Mahmoodi S.	97, 187, 188, 189, 190	Milbrath L.	201, 211
Mainx H.-G.	300	Miller P. C. H.	108
Malidza G.	270	Miri H. R.	263, 296
Mandic N.	125	Misonne J.-F.	35
Mangerud K.	273	Mitina G.	236
Mannino M. R.	85	Miziniak W.	320
Marczewska-Kolasa K.	40, 318	Mohajeri F.	70, 263
Marisavljevic D.	216	Mohammad-Abadi A. A.	258, 259
Marshall R.	30	Mohazabieh S. Z.	168
Martin J-F.	212	Mollard F. P. O.	206, 230
Martínez-Ghersa M. A.	186	Mollik M. A. H.	112, 113, 114
Martinkova Z.	83	Molnár E.	240
Marton L. C.	302	Mondani F.	178
Mas M. T.	120	Moonen A. C.	134
Masin R.	64	Mortensen D.	214
Massa D.	26	Mortezapour H.	328
Máté E.	303	Morton S.	108
Máté S.	208, 209	Morvillo C. M.	186
Mathiassen S. K.	28, 29, 241, 269, 315	Moss S. R.	28, 29, 30, 155, 283
Matus G.	72	Mráz P.	228
Matzrafi M.	34	Muelleder N.	39, 45
Mátyás K. K.	199	Mueller-Harvey I.	266
McCarthy N.	225	Munier-Jolain N. M.	157, 179, 246, 287
Mechant E.	35, 36, 309	Murdoch A. J.	74, 108, 176, 266
Médiène S.	246	Müller-Schärer H.	198, 205, 228
Meiss H.	246	N	
Melander B.	264	Nádasy E.	32, 95, 279
Menegat A.	118	Naderi R.	166
Menendez J.	307	Nagy S.	46
Mennan H.	61, 162	Nagy V.	95
Menne H.	17	Najafi H.	193
Mermillod G.	219, 274	Nassiri Mahallati M.	178

-
- | | | | |
|---------------------|--------------------|-----------------------|---------------------|
| Navarrete L. | 124 | Pfaf-Dolovac E. | 216 |
| Négre M. | 322 | Pfenning M. | 297 |
| Nejat J. | 296 | Piano S. | 322 |
| Nemecek T. | 287 | Pilgrim R. A. | 108 |
| Nemli Y. | 314 | Pinke G. | 106, 116 |
| Netland J. | 317 | Pivec J. | 294 |
| Neve P. | 74, 152 | Plancke M-P. | 45 |
| Ni H. | 118 | Poczaï P. | 199 |
| Nicholls R. A. | 74 | Poggio S. L. | 126, 141, 206, 230 |
| Nicolardot B. | 142 | Pokorný M. | 326 |
| Nieuwenhuizen A. T. | 286 | Porembski S. | 98 |
| Novák R. | 8 | Pozsgai J. | 177 |
| | | Praczyk T. | 320 |
| O | | Pšibišauskiene G. | 71, 173, 175 |
| Oreja F. H. | 65 | Punzo B. | 234 |
| Orlovic S. | 292 | | |
| Osca J. M. | 137 | R | |
| Otto S. | 64, 117, 304 | Raffaelli M. | 248, 280 |
| Oveisi M. | 328 | Rahimian Mashhadi H. | 194 |
| Overskeid D. | 317 | Rahmatullah M. | 112, 113, 114 |
| | | Ramula S. | 132 |
| P | | Rasekhi M. | 263 |
| Padovani L. M. | 210 | Rashed Mohassel M. H. | 187, 315 |
| Pál R. | 106, 116 | Rasic S. | 329 |
| Pál-Fám F. | 177, 208, 209, 220 | Rask A.M. | 247 |
| Pálfay G. | 180 | Rasmussen I. A. | 74 |
| Pallutt B. | 160 | Rauschert E. | 214 |
| Pandey S. | 134 | Ravn H. P. | 241 |
| Pannacci E. | 87 | Reboud X. | 110 |
| Panozzo S. | 41 | Recasens J. | 257 |
| Paolini A. | 222, 223, 224 | Redwitz C. | 183 |
| Papp M. | 72 | Reheul D. | 250, 254, 267, 309 |
| Pardo G. | 287 | Reigosa M. J. | 101 |
| Partosfalvi P. | 217 | Reinhardt C. | 49 |
| Paspatis E. | 14 | Reisinger P. | 25, 46, 47 |
| Pavlovic D. | 49, 216 | Rendtorff J. | 241 |
| Pavlu V. | 171 | Ribeiro A. | 131, 154 |
| Pekkeriet E.J. | 286 | Riemens M.M. | 68, 264 |
| Pelt M.-P. | 197 | Robinson T. | 108 |
| Pernin F. | 33 | Rocklin R. | 197 |
| Peruzzi A. | 248, 280 | Rola H. | 140 |
| Peters K. | 98 | Rometsch S. | 218 |
| Petit C. | 16, 33 | Rostami L. | 178 |
| Petit S. | 110, 185 | Royo A. | 161, 257 |
| Petrychenko V. | 321 | Rubin B. | 15, 31, 34, 94, 309 |
| Pettorossi D. | 87 | Rueda-Ayala V. | 249 |

Ruiz D.	154	Stefanic E.	329
Ruiz-Santaella J.P.	17	Stefanovic L.	76, 306
Ruuttunen P.	297	Steinmann H.	122
S		Stoeva A.	223
Sahin M.	162	Stølan T.	317
Salava J.	20	Storkey J.	155
Salerno C. M. B.	230	Strek H. J.	17, 284
Salonen J.	74, 105	Struck C.	57
Saric M.	76, 299	Strzalek A.	155
Saska P.	83, 164	Stuebler H.	284
Satrapová J.	51, 294	Sutay S.	184
Sattin M.	37, 38, 39, 41, 304	Swanton C.	310
Scarabel L.	37	Szabó R.	240
Scarpellini L.	210	Szemán L.	129, 305
Schaffner U.	197, 198	Szentey L.	8
Schulte W.	17	Szitár K.	240
Schulz A.	43, 284	T	
Schwalm M.	169	Taab A.	78, 79
Schwarz J.	160	Taller J.	199
Seier M. K.	198, 225	Tanner R.	196, 207
Sera B.	74	Tarbush E.	228
Seraj S.	112	Tatár B.	72
Sforza R.	201, 211	Tei F.	74
Shariff Moghaddasi M.	149	Tesio F.	100, 144, 192
Shaw R.	196, 207	Thevenot M.	197
Sheibani S.	327	Torma M.	180, 181
Shekoofa A.	70	Torra J.	161, 172, 257
Shrif M.A.A.	266	Tørresen K. S.	74, 271, 308
Sibony M.	31, 34, 94	Tóth T.	72
Simic M.	306	Tóth-Dobszai V.	81
Simoncic A.	229, 241, 270	Török P.	72
Skoczowski A.	40	Travlos I. S.	14, 23, 262, 323
Skrzypczak G. A.	313	Tschudy C.	142
Skuhrovec J.	171	Tumová P.	20, 21
Smith L.	223, 224	Türkseven S.	314
Smutný V.	147, 148, 324	Tyšer L.	133, 139
Sobiech L.	313	U	
Soekefeld M.	293	Ughy P.	32, 116
Sønderskov M.	310	Ulber L.	22, 122
Sorelli F.	248, 280	Ulloa S. M.	256, 270
Soukup J.	20, 51, 138, 139, 227, 326	Uludag A.	184, 277, 314
Sousa E.	74	Urbano J. M.	74
Söchting H.-P.	174		
Sredojevic S.	306		
Starfinger U.	241		

V		X	
Vahedi A.	194	Xamani Montserrat P.	57
Vajs S.	229		
Valkó O.	72	Y	
van de Zande J. C.	286	Yadav A. S.	215
van der Weide R. Y.	68, 286	Yakovleva O.	236
van der Werf W.	165	Yaqoubi S. R.	191
van Dijk C.J.	265	Yarmahmoodi Z.	296
van Evert F.K.	286	Yasuor H.	13
van Zeeland M. G.	68	Yativ M.	34
Varia S.	207	Yusofirad M.	149
Vasic V.	292	Yuzikhin O.	234, 236
Vasileiadis V. P.	117, 304		
Vazan S.	193, 194, 328	Z	
Venclová V.	326	Zábranský P.	227
Verdú A. M. C.	120	Zadorozhnyi V.	321
Verschwele A.	241, 264	Zalai M.	143, 278
Verwijst T.	77	Zamani G. R.	80, 187
Vida E.	72	Zan Q.	231
Vidotto F.	100, 144, 192, 232, 322	Zand E.	328
Vigh T.	44	Zanin G.	64, 117
Vitalos M.	200	Zeidler L.	73
Vlachos C.	146	Zengin H.	184
Vondra M.	324	Žveplan S.	229
Vrbnicanin S.	49, 76, 299	Zwerger P.	174
Vroman G.	35		
Virro M.	210		
W			
Wagner J.	24, 48		
Waldhardt R.	246		
Waldispühl S.	241		
Walker F.	26		
Walters N.	108		
Wang H.	231		
Wang Y.	231		
Waßmuth B.	241		
Wei P.	231		
Weis M.	249, 293		
Wesche K.	135		
Westerman P. R.	57, 153, 161, 165, 169, 172,		
	165		
Wevers J. D. A.	147, 148		
Winkler J.	274		
Wirth J.	295		
Woznica Z.			

ISBN: 978-963-9821-24-8