Book of Abstracts

19th EUROPEAN WEED RESEARCH SOCIETY SYMPOSIUM

Lighting the Future of Weed Science

20–23 June 2022 Athens, Greece

EWRS
2022
Athens

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19th EWRS Symposium 2022
Lighting the Future of Weed Science

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Welcoming by the organizers

Dear Colleagues and friends,

It is a great pleasure to welcome you to 19th EWRS Symposium, 20-23th June 2022, in Athens, Greece!

The Symposium will present the trends in Weed Science in areas such as weed biology/ecology, management of herbicide resistance, precision weed/herbicide technologies, biological control, innovative cropping systems, and biotechnology discoveries.

The Symposium organizers welcome weed scientists from academia, research, public/private sector, and industry to actively participate and make the best of this unique opportunity to meet colleagues from all over the world.

On behalf of the Organizing Committee, we have made every effort to provide an excellent environment for a stimulating and enjoyable scientific congress. The scientific program provides valuable information and networking opportunities for attendees with an interest in any basic or applied aspect related to weed science.

Welcome to Athens and enjoy the Symposium.

Dr Demosthenis Chachalis

Chairman of the Local Organizing Committee

19th EWRS Symposium 2022
"Lighting the Future of Weed Science"
20-23 June 2022 - Athens, Greece

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Matthias Schumacher **& Jonathan Storkey:** Weed Ecology

Therese With Berge: Site-specific Weed Management

Ilias Travlos & Milena Simic: Integrated Weed Management, Agricultural University of Athens

Lena Ulber & Björn Ringselle: Agricultural, Economic and Societal Aspects of Weed Management

Francesco Vidotto & Nedim Doğan: Herbicides and Application Technology

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INVITED
SPEAKERS

Food safety including pesticide residues in the broader perspective of public health

Antonis Zampelas

University of Athens, Greece

keynote

The Hellenic Food Authority (EFET) is the central competent authority responsible for the safety of foods after primary production in Greece. EFET is the focal point of EFSA, Codex Alimentarius, INFOSAN and the Food Fraud Network in Greece. This presentation will highlight the whole spectrum of EFET responsibilities that include the setting of food quality standards and good practices of food hygiene, the approval and implementation of training programs in food safety, the maintenance of food businesses register, the coordination/implementation of the food control programs carried out by its services or other authorities (including food control programs in the field of food contact materials), the development and implementation of research programs in the field of nutrition and food safety, the participation in the relevant EU bodies and international organizations for the development of the relevant directives, regulations, decisions and recommendations issued by these institutions, the proposals for national legislative acts and other measures related to food safety and nutrition, and the continuous information and education of the consumers. The audits carried out, relate to regular inspections, complaints, food incidents / RASFF as well as re-inspections for food safety, quality, authenticity and labeling. Data will be presented related to the monitoring of pesticide residues in foods indicating that food is safe and pesticides residues should not be of concern for the consumer. In addition to the chemical and microbiological risks, EFET has taken actions to reduce nutritional risks such as increased salt consumption and trans fatty acids. Specifically, it has developed the Salt Reduction Strategy which has been adopted by the Ministry of Health and includes 4 main pillars, while it has undertaken actions at both national and European level with the aim of eliminating industrially produced trans fatty acids. Other nutrition actions relate to the setting of maximum levels of vitamins and minerals in fortified foods as well as front of pack nutrition labeling in foods, as part of the EU Farm-to-Fork strategy. Regarding the actions in the field of fraudulent practices and food fraud, EFET systematically carries out inspections on products of national importance such as olive oil, feta cheese and honey.

Global Herbicide Resistance Action Committee: how the Ag Industry collaborate to tackle the weed resistance challenge

Gael Le Goupil

Sygenta

Weed control has become increasingly problematic due to the evolution of resistance to herbicides. The ambition of the Global Herbicide Resistance Action Committee (HRAC) is to support farmers protect crop yields and quality by sustainably fighting against herbicide-resistant weeds. Our mission is to provide comprehensive information about weed resistance and best control practices to regional and local weed science practitioners. Here, I will exemplify the current challenge of farmers when it comes to controlling weeds. It all starts with the ever-increasing spread of herbicide resistant weed populations worldwide. In trying to manage resistance, farmers intensify herbicide use while, at the same time, their herbicide options decrease. This has led to a series of downstream consequences that only serve to exacerbate the problem of weed resistance in a never-ending cycle of cause and effect. In addition, there are other external factors that increase the challenges faced by farmers. These include climate change, innovation decline and increasing societal and environmental pressure. More than ever, it is critical to sustain the usefulness of current and future herbicides, to secure food production and farmers profitability, by implementing good agricultural practices.

The current status of the IWGC as well as applications of weed genomics

Eric Patterson [1]; Dana MacGregor [2]; Todd Gaines [3]

[1] Michigan State University, East Lansing, United States
[2] Rothamsted Research, Unknown
[3] Colorado State University, Unknown

Oral

The International Weed Genomics Consortium (IWGC) was formed in 2021 with the mission to sequence, assemble, and annotate reference genomes for the most globally problematic weeds. It is a multi-institutional collaboration between four industry partners (BASF, Bayer Crop Science, Corteva Agriscience, and Syngenta), the US-based Foundation for Food and Agricultural Research, and academic researchers from dozens of universities around the world. Initially, the IWGC planned on 10 species, however, this mission has greatly expanded and now encompasses more than forty species with more being added as researchers learn of the IWGC's mission. The IWGC also offers training, educational, and networking opportunities to contributing members in utilizing IWGC resources as well as working with plant genomes in general. We are developing these resources to make them freely available to any who are interested. We have recently finished several of our prioritized de novo genomes. We are particularly proud of the genomes for two hexaploids: Chenopodium album and Conyza sumetrensis, as well as the very large genome of hexaploid Avena fatua. We have also developed novel annotation pipelines that give the most up-to-date functional genetic information possible. The presentation will cover the history of weed genomics, the structure and mission of the IWGC, recent success stories from the IWGC, and present some examples of how these new genomes can be utilized to answer basic and applied questions in weed science.

INDUSTRY SESSION

Automated Precise Weed Control in Cotton

George N. Zanakis, Georgios Valais

National Rd Thessaloniki Polygyrou

57001 Thermi, Thessaloniki, Greece

george.zanakis@corteva.com

Cotton is the largest spring row crop and one of the biggest revenue creators among crops in Greece.

The crop is vulnerable to weed competition and production faces significant challenges which result in yield and quality loss. Monoculture, limited registered herbicides and unstable weather in spring make weed control a challenging and critical risk factor. Mechanical cultivation is required (on average twice per season). The issue is so harsh at times, in regions and fields that oblige the farmer to hire labor for hoeing. In addition the availability of labor is shrinking year after year. In two years period (2020 – 2021) cotton fields pictures were collected to train the ecoRobotix machine learning algorthyms on cotton crop. A specific cart with two cameras (one RGB and one multispectrum) was used for this purpose. Software has been developed by ecorobotix which analyses the raw data to detect, identify, and treat weed species. ARA robot (hardware) is ready to perform autonomous weeding operations in cotton in the current season. Using cutting-edge machine learning, the robot detects with spot analysis and selectively sprays the weeds with the proper dose of herbicide and a micro-volume of spraying material. The centimeter-precise detection and spraying reduces the volume of the herbicide used by 75 - 90% with minimum or no contact with the crop depending on the set up. This innovative way to control weeds in cotton is to be validated in a commercial scale in 2022.

Keywords: *Cotton Image collection on spot analysis weed detection selective spray*

Benzobicyclon: A new herbicide for rice in Europe

M. Martin-Andres, L. Cornette

Gowan Crop Protection Ltd

Daniel Hall Building, Rothamsted Research, West Common,

Harpenden, Herts, AL5 2JQ, UK

mmartin@gowanco.com

Benzobicyclon is a Japanese origin herbicide used in Asian rice cultivation for which Gowan Crop Protection Ltd performed the development work in Europe in agreement with the supplier SDS Biotech K.K. The present article summarizes the properties of Benzobicyclon and its performances in field trials carried out in Europe between 2012 and 2020. Benzobicyclon is a HPPD inhibitor, a new mode of action for European rice, and will add a useful tool for weed management, especially those weeds that developed resistance to ALS and AACase inhibitors. It is selective to rice and will be positioned in preemergence of the crop, in flooded paddy rice. It shows a particularly high control of Heteranthera reniformis, Leptochloa fusca and all sedges while contributing to the control of Echinochloa spp.

Keywords: *rice, herbicide, HPPD, Benzobicyclon, sedge*

Environmental Impact Reduction of Crop Protection – How to model, how to measure, how to achieve?

Anja Gladbach1, Yuyue Zhang[2], Peter Fantke[2], Luke Settles[1] and Daniel Glas[1]

[1]Bayer AG, Crop Science Division, Alfred-Nobel-Str.50, 40789 Monheim/Rhein, Germany

[2]Quantitative Sustainability Assessment, Department of Technology, Management and Engineering, Technical University of Denmark, 2800, Kgs, Lyngby, Denmark
E-mail contact: daniel.glas@bayer.com

Agricultural activity has always had an impact on the environment. Efforts to make fields more productive and increase the efficient use of land and resources include tools like the use of pesticides to protect crops from (yield) losses due to weeds, diseases, and insect damage. Each tool that a farmer applies has benefits and drawbacks, and this is generally true for crop protection. And while crop protection products are not only developed to achieve efficacy, but as well rigorously tested to be safe for people and to pose no unacceptable impact on the environment, they still have an effect. Bayer thus in 2019 committed to reduce the environmental impact of our agrochemical uses by 30% by 2030. Reducing the environmental impacts of agrochemicals requires a coherent and efficient metrics system that allows a standardized quantification of the level of sustainable measures implemented and the extent of the associated impact. Therefore, impact indicators within a shared framework of regulation, practice, verification, and certification are needed to drive change. Based on a comprehensive and spatially resolved application dataset for >90% of the global crop protection market we quantified pesticide emissions and ecotoxicity impact, building on PestLCI and USEtox as state-of-the-art, consensus-based models for application in life cycle assessment (LCA) and environmental footprinting. After initial identification of global hotspots and drivers, we will assess the effects of reduction levers (e.g., emission management and mitigation, precision application, combination of chemical and biological crop protection, substituting high-impact chemicals by functionally equivalent more sustainable alternatives). We will use the results to achieve impact reduction ambitions and to guide company efforts within the safe and sustainable-by-design framework for crop protection. In this talk, we not only want to share how we approached this commitment (eg. identification and selection criteria of suitable models, setting of a reliable baseline scenario, associated data needed and the evaluation of the suitability of related impact reduction options), but as well the limitations, challenges, and learnings so far. With the proposed assessment framework, we aim to contribute to the discussion on how to achieve environmental impact reduction for agricultural production as well as to outline current limitations like data availability or incentivization systems for farmers.

Keywords: *Environmental Impact Reduction, Agrochemicals, Life-Cycle-Assessment, Sustainability*

UPL reimagines sustainability

Ms. Emilie Seguret

UPL is a global leader in sustainable agricultural solutions designed to secure our food future. UPL places collaboration at the heart of innovation and sustainability through its OpenAg commitment. OpenAg aims to power new levels of sustainable growth – for farmers, for producers, for customers, for partner and for societies everywhere. It is a fundamentally optimistic view of the future of agriculture; one with no borders, no limits that feeds sustainable growth for all. With OpenAg, we're working with innovative entrepreneurs and partners to rapidly characterize and evaluate new technologies. Working together, we're breaking down traditional barriers and significantly speeding up the process of getting new technologies tested, approved, and out in the field. Our agility and ability to drive change underpin our strong performance and business resilience. We are building a network that redefines the way an entire industry thinks and works – open to fresh ideas, innovative techniques and new answers, as we strive to make every single food product more sustainable. As a part of UPL's position as a market leader in sustainable ag solutions, we have launched **NPP – Natural Plant Protection**, housing UPL's portfolio of natural and biologically derived agricultural inputs and technologies. NPP's global offering will continue to benefit from UPL's extensive global distribution footprint. At UPL, reimagining sustainability has long been our goal and over the last decade we have been working to deliver this. It is the basis for every project we start, every process we design and every business we launch, as we work to secure our food future whilst safeguarding our environment.

SESSION I

WEED ECOLOGY

Effect of early and late mechanical treatments in autumn on bud growth and long-term control of Sonchus arvensis in spring cereals

Øystein Skagestad [1];

Kirsten S. Tørresen [2]; Lars Olav Brandsæter [1]

[1] Norwegian University of Life Sciences (NMBU), Ås, Norway

[2] Norwegian Institute of Bioeconomy Research (NIBIO), Ås, Norway

Oral

Sonchus arvensis is a perennial weed species that cause problems especially in organic farming in Northern Europe. It propagates by seeds and creeping roots. In the present study, the effect on biomass of below-ground separation and disturbance in autumn on S. arvensis were studied. Two experiments were conducted in SE Norway with treatments at two times (August and September) studying (1) complete separation of roots at 10 cm depth by horizontal root cutter on sprouting from root fragments, and (2) effect of four treatments at two sites on abundance of S. arvensis in spring cereals the subsequent year. In the first experiment, root fragments below the area of separation were collected 0, 2 and 4 weeks after separation and planted in a growth chamber (18°C, 18h daylength). Above-ground dry matter was measured after 3 weeks. In the second experiment, the treatments were 1) mowing at 5-6 cm height, 2) horizontal root cutting at 10 cm soil depth, 3) harrowing (rotavator) and 4) harrowing + increased competition (cross-sowing spring cereals), in addition to untreated control. Fields were ploughed in spring before sowing spring cereals. Percentage ground cover, shoot density and above-ground dry matter of S. arvensis were assessed in summer at final assessment. Preliminary results showed in the first experiment a significant increase in above-ground biomass from separated roots when compared to control, with both control and separated treatments showing a decreasing level of biomass later in autumn. There was significant difference between pairs of separated and control treatments in roots collected 4 weeks after the early treatment. For the second experiment early harrowing reduced the ground cover, density and biomass at both sites (significant for one site). Increased competition had no additional effect. Early root cutting more than halved S. arvensis abundance in one site, but not the other. The late treatments did not affect S. arvensis. Differences between separated and control treatments could indicate an effect of separation on the induction of seasonal restriction in roots of S. arvensis. The reduced plant abundance observed with early field treatments may be caused by the effect of seasonal restriction in roots observed in the first experiment, with early disturbance resulting in increased sprouting in S. arvensis compared to late disturbance, thus decreasing autumn root reserves.

Keywords: *Perennial sow-thistle, sprouting ability, mechanical control, Norway*

Management of Phelipanche aegyptiaca in cabbage (Brassica oleracea var. capitata)

Amit Wallach; Guy Achdary; Hanan Eizenberg

Department of Plant Pathology and Weed Research, Agricultural Research Organization, Newe-Ya'ar Research Center, Ramat-Yishay, Israel

Oral

Phelipanche aegyptiaca, a member of the Orobanchaceae family, is a root parasitic plant that causes severe yield losses and is considered as one of the main weeds in vegetable and field crops worldwide. After seed germination, and once established the vascular connections to the host plant roots, *P. aegyptiaca* becomes a major sink that draws nutrients, and water from the host resulting in crucial damage to the host plant. One of the most effective ways to manage *P. aegyptiaca* in the field is via herbicide application and previously was demonstrated for crops such as red clover, tomato, carrot, and more. The main objective of this research was to develop a protocol for the management of *P. aegyptiaca* in cabbage. In this work, two herbicides (glyphosate and ethametsulfuron-methyl) were examined via two application methods (foliage and to the root rhizosphere) in laboratory and field conditions. The herbicides were tested for *P. aegyptiaca* control as well as for crop safety. In the laboratory *P. aegyptiaca* control was evaluated using polyethylene bags (PEB) system at pre- and post-attachments stages of parasitism. In the field, each herbicide was applied at three sequential applications at 21, 35, and 49 days after transplanting with six different rates. Non-treated plots served as control. Additionally, growing degree days (GDD) models were developed to describe the *P. aegyptiaca*-cabbage dynamics based on minirhzothron sub-surface camera and soil temperatures. Our results show that under laboratory conditions, glyphosate and ethametsulfuron-methyl can control *P. aegyptiaca* when applied at both different stages of parasitism. Furthermore, the field experiments (seven different field trials throughout two years), revealed that glyphosate foliage application was found to be effective for the control of *P. aegyptiaca* at a rate of 72 g ai ha^{-1} with both application methods. However, *P. aegyptiaca* control with ethametsulfuron-methyl was achieved at a rate of 18 g ai ha^{-1} only when overhead irrigation was applied. The linear GDD model was computed (T_{base}=5˚C) and a log-logistic equation was used to predict the parasitism dynamics of *P. aegyptiaca* in cabbage fields. Based on the results from this study, a decision support system protocol was developed to control *P. aegyptiaca* in cabbage under field conditions. The protocol suggests that *P. aegyptiaca* control can be achieved by three sequential herbicide applications, at 150, 300, and 600 GDD. Applications of ethametsulfuron-methyl must be followed with overhead irrigation while glyphosate at a rate of 72 g ai ha^{-1} can be applied on cabbage foliage.

Benefits of a more functionally diverse weed flora and opportunities/barriers to manipulating weed diversity through integrated weed management

Stéphane Cordeau

Agroécologie, AgroSup Dijon, INRAE, Univ. Bourgogne,

Univ. Bourgogne-Franche-Comté, F-21000 Dijon, France

Keynote

Reconciling crop productivity and biodiversity is one of the main challenges of agriculture worldwide. The over-simplification of cropping systems (low crop diversity coupled with intensive use of tillage, herbicides and nitrogen fertilizers) has led to a drastic decline in weed diversity. This loss of within field weed diversity is part of the erosion of the natural capital on which sustainable crop production is founded. Indeed, weeds represent the base of food chains in agroecosystems, and therefore support higher trophic levels (e.g. beneficial insects and birds), responsible for a wide set of agroecosystem services, such as pollination and biological control. On the other hand, weeds can generate severe yield losses at high levels of abundance, which has justified their control. However, the intensive use of 'sledgehammers' such as tillage and herbicide in simplified crop rotation often leads to weed communities dominated by very few and highly competitive weeds. Consequently, the importance of weed diversity in mitigating yield losses has been identified as one of the top five research priorities in weed science Recent studies advocate that not all weed communities are detrimental to the crop production and that diversified weed communities limit the negative effect of competitive and dominant species on crop productivity while potentially promoting ecosystem services provided by subordinate species. To reduce reliance on herbicides/tillage and maintain crop productivity and weed diversity, integrated weed management (IWM) seeks to optimize synergies between diverse sets of weed management practices combined at the cropping system scale. Recent studies conducted in France investigated the legacy of long-term IWM management systems implemented on experimental and farmers' fields. They showed that IWM systems harbored higher weed diversity than the reference in the experimental farm but weed diversity did not increase with crop diversification in the farmer's network. Cropping system diversification does not always beget weed diversity but different options of cropping system diversification could promote weed diversity. Finally, when it comes to assessing diversity, whether it is weed diversity or the diversity of farming tools, the scale matters. Three common scales include the quadrat scale, the plot scale or the crop sequence scale. In addition, weed communities can be described by their density or biomass. Results showed that density indicators appear relevant for species centered analysis (i.e. the diversity of successful reproductive strategies) whereas biomass indicators appear more suitable for agroecosystem centered analysis (i.e. the diversity of species which contributed to agroecosystem functioning, weed-crop competitive relationships).

Keywords: *agroecology, cropping system, biodiversity-based management, weed diversity, mitigating yield loss, functional diversity*

What ecological traits and functions are important in a crop mixtures for effective weed management?

Malick Sidiki OUATTARA [1]; Raphaël PAUT [2]; Muriel MORISON [1]; Safia MEDIENE [1]

[1] INRAE, Thiverval-Grignon, France

[2] INRAE, Thiverval-grignon, France

Oral

Weed management in agricultural fields is mainly based on tillage and the use of herbicides, which have allowed the increase and maintenance of high agricultural production. However, the use of agrochemicals and fossil fuels has a negative impact on the environment and on the sustainability of agroecosystems. One lever that can be used is to promote ecosystem services through the mixing of crop species to promote the biological regulation of weeds. However, little is known about how to mix species for effective weed management. Furthermore, many combinations between species are possible to design crop mixtures. We aimed to use a functional ecology approach to generically identify important traits and functions that contribute to regulate weeds in a crop mixture. To do so, we organized workshops with scientists, farmers and advisors with expertise on the functioning of crop mixtures in order to identify the functions, plant traits and agronomic and environmental characteristics important for weed management in a crop mixture. The functional ecology trait-function-services approach was mobilized in order to have a general approach of crop mixtures. Indeed, this functional approach has made it possible to establish the links between functional traits and biological processes involved in weed regulation. Our results showed that the main functions that were important for weed management were essentially threefold: (i) reduction of weed establishment in the field through rapid spatial and temporal occupation of crop (ii) competition for nutrients, water and light in favour of the crop mixture of interest and finally (iii) reduction of weed emergence through seed stock reduction by suicide germination or allelopathy effects. We showed that traits in crop mixture such as root system, growth rate, height, biomass production capacity, leaf area and orientation were important for the realization of the above functions. We also showed that fertilization, initial nitrogen level in soil and soil type mainly impacted traits and functions related to weed reduction, establishment, development and competition between weeds and the crop mixture. The identification of important functions and traits will allow us to assess the level of service provided by a crop mixture and to identify the crop mixtures most likely to provide weed control in a given agri-environmental context. Ongoing work takes into account other ecosystem services as well as the identification of assembly rules of plant traits in a crop mixture, which will allow the choice of species in the mixture according to the services sought.

Keywords: *Functional ecology, ecosystem services, weed control, crop mixture*

Effect of irrigation on weed occurrence in Oregano crop

Georgia Nikolakopoulou; Dimitra Doulfi; Alexandros Fournarakos; Alexandros Assariotakis; Garyfalia Economou

Agricultural University of Athens, Athens, Greece

Oral

One of serious problems of Aromatic Crops is the unavailability of registered herbicides in order to manage effectively the weeds. Thus, weed management depends on cultivated measures which increase the final cost. This study aims to: a) record and rank the most important weeds and b) investigate the shifts in weed flora between the application of irrigation and non-irrigation treatments. In an established oregano crop (hybrid *Origanum x intercedes)* an irrigation experiment was carried during 2019-20 in the experimental field of the Agricultural University of Athens. Two treatments were applied, i) irrigation according the needs of the crop (20 mm) and ii) not irrigated with three replications. Measurements were taken in two periods (vegetative and flowering). The estimation of weed emergence in each treatment was based on their Abundance Index (AI) (AIk= Fk + Uk+ MFCk, where Fk, Uk, and MFCk represent the frequency, uniformity, and mean field coverage of a weed specie k, respectively). A quadrat of $1 m^2$ was established at the center of each plot in order to estimate weeds' Abundance Index. During the vegetative stage of oregano crop, before the application of irrigation the most important weeds were ranked based on AI: *Marticaria chamomilla* (152.8), *Cardarium draba* (109.95), *Malva sylvestis* (104.95), *Calendula arvensis* (71.63) and *Avena sterilis* (44.98). At the second period of measurements, at the pre flowering stage and before the application of irrigation, the following weeds were recorded at the ranking based on AI : *Scolymus hispanicus* (169.93), *A. sterilis* (139.45), *C. arvensis* (108.28) and *Phalaris arundinacea- picta* (78.3). However, the application of irrigation showed a significant effect on weed abundance compared to non-irrigation system based on analysis of Variance at 0.05 level. Particularly, the AI values of the most important weeds *S. hispanicus* and *P. arundinacea-picta* were statistically higher between the irrigated and the non-irrigated plots, at values (680 and 309.9) and (364.8 and 259.9), respectively. Data showed weed shifts in weed population during the cultivation period meaning that certain weeds are less competitive for the crop, while on the other hand some species remained in high populations, issue that we may take in consideration planning the weed control. Noticeably, no irrigation did not favored the weed emergence compared to irrigation treatment, while at the same time did not affect the final yields in terms the essential oil content with values 4.9% and 4.7% for the no irrigated and irrigated system.

Keywords: *oregano crop, weeds, irrigation, Abundance Index*

Weed communities in conservation agriculture: what really changes?

Bruno Chauvel [1]; Damien Derrouch [2]

[1] INRAE, DIJON CEDEX, France
[2] INRAE, Dijon cedex, France

Oral

Conservation agriculture (CA) has been identified as one of the farming systems likely to deliver sustainable agriculture but its effects over time on the diversity and composition of weed communities are still discussed. For ten years, different studies were carried out in in East of France in cropping system with short rotations essentially composed with winter crops. The objective of these different studies was to identify, focusing on the transition period, the changes in the composition of communities and the consequences in terms of agronomic risk in CA systems. Using networks of 100 winter wheat fields selected to encompass a gradient of years in CA (1 to 20 years), the changes that occurred in the diversity of weed communities were analysed over several years. For each field, weed communities were surveyed on a 50 × 40 m area. Weed data were collected at three periods: in early March, in mid-June and in early September during the intercropping period. All the observed weed communities were rich (average species richness of 23.9 species), diverse (average Shannon diversity of 2.15) and equitably composed of low-density species. The results showed an increase in species richness, total weed abundance and α-functional diversity but no change in species diversity and species evenness over time. Heterogeneity and average values of β-taxonomic and β-functional diversity between communities were high in the early years following the adoption of conservation agriculture. Nevertheless, heterogeneity decreased over time, leading to a homogenization of weed community assemblages. Furthermore, ten response traits were selected to highlight changes in the functional composition of communities. Out of the ten traits, four were impacted by the time following the adoption of CA significantly, whereas two only showed trends. Phanerophyte and geophyte life forms, summer-germinating and spring-and summer-flowering species increased with time. Some functional shifts occurred quicker than others, as for example summer-germinating species which increased after at least 10 years of continuous application of CA principles. Changes in weed community functional composition could potentially worsen current weed management efficacy. These results could therefore provide knowledge to farmers moving towards CA to redesign the management strategy to avoid to lost the control of the weed community.

Keywords: *No-tillage, assemblage of weed communities, life forms, heterogeneity, diversity*

Weed distribution in the Italian rice area in relation to agronomic practices and soil characteristics

Silvia Fogliatto; Marco Milan; Francesco Vidotto

Università degli Studi di Torino, DISAFA, Grugliasco, Italy

Oral

The Italian rice area is mainly concentrated in the North-West part of the country, in a relatively small territory, characterized by quite homogeneous pedo-climatic traits, which can influence weed composition of rice fields. In the last decade the increase in dry-seeded area compared to traditional water seeding has favored the weeds most adaptable to non-flooding conditions. The objective of the study was to monitor the distribution and the abundance of the main rice weeds through a series of farmer interviews and field surveys, considering almost 1,500 rice fields. Correlations of weed species presence with soil characteristics, geographical area and agronomic practices adopted by the farmers (i.e. soil tillage, crop rotation, seeding method) were explored through descriptive analyses, ANOVAs, PCA, and two-step cluster analysis. The study highlighted that the species of the genus *Echinochloa* were the most common weeds, found on almost 90% of the surveyed sites. Other weeds found on at least one third of the sites were: *Cyperus difformis*, *Heteranthera reniformis*, *Oryza sativa* (weedy rice), and *Alisma plantago-aquatica*. The main factors affecting weed species composition were seeding method and soil texture. The increase of dry seeding caused a shift of the weed community favoring a higher presence of weeds most typical of dry fields, such as *Persicaria maculosa, Digitaria sanguinalis* and *Panicum dichotomiflorum*. The PCA highlighted that weed density was negatively correlated with sand content of the soil, in particular for species found in flooded conditions; in fact, in these areas the seeding in flooded fields was the most common method. It was also found that weeds typical of dry conditions were found in sandy or loamy sand soil where dry seeding was the most common practice. The cluster analysis highlighted that the seeding method was the most important predictor for the cluster formation. Three clusters were created, one characterized by 93% of the sites with seeding in flooded fields and with high presence of weeds typical of flooded conditions (i.e. *H. reniformis, Echinochloa* spp., *C. difformis)*. Cluster 2 included 74% of the sites with dry seeding and with weeds both of flooded and dry seeding, while cluster 3 comprised 92% of the sites with dry seeding having weeds typical of this environment. The study permitted to have an updated picture of the infestations of rice fields and highlighted that some agronomic practices, i.e. type of seeding, can strongly influence the presence of certain weed species.

Keywords: *weed community, rice weeds, dry seeding, water seeding*

Arable Weeds and Management in Europe (AWME): A database of weed survey data from across Europe

Helen Metcalfe [1]; Jana Bürger [2]; Guillaume Fried [3]; Christoph von Redwitz [4]; Alicia Cirujeda [5]; Silvia Fogliatto [6]; Denise Dostatny [7]

[1] *Rothamsted Research, Harpenden, United Kingdom*
[2] *University of Rostock, , Unknown*
[3] *Plant Health Laboratory, , Unknown*
4 *Julius Kuehn-Institut, , Unknown*
[5] *Agrifood Research and Technology Centre of Aragón, , Unknown*
[6] *University of Torino, , Unknown*
[7] *Plant Breeding and Acclimatization Institute, , Unknown*

Oral

In 2019, the working group Weeds and Biodiversity of the European Weed Research Society set out to form a data collection of primary arable weed vegetation records. The resulting Arable Weeds and Management in Europe (AWME) data collection contained >40,000 observations of weed vegetation. The unifying feature of these records was that each comprised of a list of species found on a plot of a specific size from an arable field. Most observations are complemented by additional metadata including the survey date and geographic coordinates. Since the conception of AWME, the members of the group have gone on to develop the database to improve capabilities and have done further research to determine the novelty and utility of this data collection. They first compared the data within AWME with those within the European Vegetation Archive (EVA). The distinguishing feature of the AWME collection is that observations are supplemented with information on the agricultural management of the fields where the observations were done, making the data more useful to agronomists and weed scientists seeking to understand the impact of agricultural practices on weed communities. These agricultural management data include information on crop, previous crops and rotations, tillage or weed control treatments. Many studies were explicitly designed to answer research questions about the relationship between weed management and weed community composition or diversity, rather than describing or classifying plant communities. To determine the utility of the data collection the group reviewed the literature to determine several key challenges when analysing data collections of this kind. Through a series of case studies, they demonstrated several methods to address these challenges and demonstrated the robustness of analysis using the AWME data collection. This study demonstrated that a Europe-wide data collection such as AWME presents many opportunities for analysis of questions about the effects of climate change, or macro-ecological and biogeographical issues related to weed diversity as well as the dominance and rareness of specific weeds over Europe that could not be addressed in smaller datasets.

The AWME database is a growing collection and we welcome new data contributions and requests for data for analysis.

Keywords: *Weed Surveys*

A Weed Survey in Winter Sown Rapeseed Fields

Alireza Taab[1]*, Sedighe Nazari[1], Michaela Kolářová[2] and Somayeh Hajinia[1]

1Dept. of Agronomy and Plant Breeding, Faculty of Agriculture, Ilam University, 69315-516, Ilam, Iran. E-mail*: a.taab@ilam.ac.ir
2Dept. of Agroecology and Crop Production, Czech University of Life Sciences Prague, Faculty of Agrobiology, Food and Natural Resources, Prague, Czech Republic.

Oral

Information on weed flora composition in agricultural fields is of important value in weed management decisions. The rapeseed (*Brassica napus L.*) was introduced in the cultivations in west of Iran recently. Subsequently, some weeds such as Phelipanche aegyptiaca are becoming increasing problem. Therefore, the study was conducted to study weed flora and determine the relationship between weeds and climatic, soil and agronomic factors in rapeseed fields in Mehran and Dehloran counties of Ilam province in Iran during 2019-2020. The weeds survey was done in 83 randomly selected rapeseed fields from five areas. Weed abundance and coverage were determined based on the Braun-Blanquet scale. Canonical correspondence analysis (CCA) was used to analyze the relationships between weed species coverage data and regions, production area, altitude, last year crop, soil texture, mean yearly precipitation, total rain current year, total rain current month, mean yearly temperature, mean temperature current year, mean temperature current month and sources of irrigation water. Totally, 14 weed species were found including 78.6% dicot and 21.4% monocot species. In addition, 71% and 29% of the weeds were annual and perennial, respectively. *Malva sylvestris* showed the highest frequency (100 %) and mean coverage (2.05%). The most important variables affecting weed coverage based on direct gradient analysis CCA were the last year crop, mean temperature current month, mean yearly precipitation, regions, total rain current year, mean yearly temperature, altitude, mean temperature current year, and sources of irrigation water. The first axis of CCA showed the highest correlation with the last year crop, altitude and mean temperature current month and had a positive and consistent correlation with the distribution of a weed *Phelipanche aegyptiaca*. In the negative part of the first axis and the positive part of the second axis, mean yearly precipitation, total rain current month and mean yearly temperature had the greatest effect and had a positive correlation with the distribution of *Sorghum halepense*, *Alhagi maurorum*, *Hordeumsp.* and *Portulaca oleracea*. In the negative part of the first and second axes total rain current year, mean temperature current year, region and source of irrigation water had the greatest impact. *Malva sylvestris* and *Gundelia tuornefortii* were placed in this section. In overall, the results showed that there is a significant correlation between the relative cover of weeds in rapeseed fields and climatic, soil and agronomic factors. Thus the results can be used to adapt weed management strategies in the cultivation.

Vascular Plant Biodiversity Change in Central European Fields over 70 years – Winners and Losers of the Great Transition

Michael Glaser *,[1], AgriWeedClim-partners, Stefan Dullinger[2] & Franz Essl[1]

[1] Bioinvasions. Global Change. Macroecology Group, Department of Botany and Biodiversity Research, University of Vienna, Austria

[2] Department of Botany and Biodiversity Research, University of Vienna, Austria

*corresponding author Michael Glaser, T: +436603688188 e-mail: michael.glaser@univie.ac.at

Oral

Fields, i.e. agricultural sites planted with crops, have been a key feature of Central European landscapes for thousands of years. They provide food and fiber to society and are a habitat for a unique aspect of biodiversity. However, in recent decades, they have been affected by drastic changes such as changes in land use, and, more recently, climate. Studying these past changes provides important insights into ongoing dynamics, e.g. the emergence of new weeds or the decline of species. Analysing historic changes in weed vegetation also provides insights into potential future changes in weed vegetation. Here, we present the results of occupancy modelling of over 300 vascular plant species found in fields across Central Europe (Germany, the Czech Republic, Slovakia, Switzerland, Liechtenstein, Austria, Hungary, Northern Italy, Slovenia, Croatia, Switzerland, Liechtenstein) over the past 70 years using data from ca. 21,000 vegetation plots of the AgriWeedClim database (Glaser et. al. in prep.). Occupancy modelling (sensu Outhwaite et al., 2018) allows for calculating individual species' trends while overcoming spatiotemporal biases common in vegetation plot data by hierarchically combining an occurrence and a detection model. Insights into long-term trends in weed species occurrence was then gained by grouping species according to important attributes, e.g. biogeographic origin (native, archaeophytes, neophytes) and Ellenberg Indicator Values. Here, we present and discuss the changes in weed vegetation in Central Europe during the last 70 years. Outhwaite, C. L., Chandler, R. E., Powney, G. D., Collen, B., Gregory, R. D., and Isaac, N. J. B. (2018). Prior specification in Bayesian occupancy modelling improves analysis of species occurrence data. *Ecol. Indic.* 93, 333–343. doi:10.1016/j.ecolind.2018.05.010.

First comparative results after 45 years of weed surveys in winter cereals in northeastern Spain

A. Cirujeda [1]**;** Teresa Segarra [2]; Gabriel Pardo [3]; Joaquín Aibar [4]; Ana Isabel Marí [3]; Jorge Pueyo [3]; Carlos Zaragoza [3]

[1] *CITA, Plant Protection Unit, ZARAGOZA, Spain*
[2] *CITA, Plant Protection Unit, Zaragoza, Spain*
[3] *CITA, Plant Protecion Unit, Zaragoza, Spain*
[4] *Zaragoza University, Zaragoza, Spain*

Oral

Biodiversity decline in agricultural landscapes is a worldwide concern. The decrease of non-productive areas between agricultural plots serving as habitats for vegetation and associated animal life is one of the reasons for this decline. Inside the fields, crop simplification and generalized herbicide use also contribute to this biodiversity reduction. Weed species with attractive flowers are the most visible part of the ecological services that these plants offer, but very probably also other less eye-catching species contribute offering food and other services making biodiversity possible. Weed surveys in cereal fields have been conducted in the Zaragoza province of the Aragon region (northeastern Spain) in 1976-78 (125 fields). In years 2005-13 the same fields or, if sampling was not possible, plots were chosen as near as possible to those visited in the first survey series and weed species were recorded (142 fields). A third series of surveys has been initiated in spring 2021 surveying 91 fields. The fields were classified into 8 different production areas, some were intensive irrigated production areas, others were dryland and less intensive in their management. The aim of this work is to describe the weed species diversity in the three survey periods according to the different areas in order to detect the trends of weed diversity through this 45 year period. In all three surveys vegetation was described in zigzag transects by three trained persons during atleast 30 min until no more new species were found and covering the whole plot or at least 1 ha if the plots were bigger. One general abundance value per field was assigned to each species according to the visual CEB scale, which relates plant density with weed soil cover, allowing a better estimation in the lower abundance categories. Weed species diversity gradually decreased in all nine survey areas in the three datasets. Highest and lowest mean richness for an area in was 19.0 and 14.8 in 1976-78, 15.1 and 8.0 in 2005-13 and 14.5 and 8.8 in 2021, respectively. Overall mean richness was 16.1 for 1976-78 and 12.0 in the other two datasets. There was a tendency of higher weed species richness in rainfed fields compared to the irrigated lands but the differences tended to diminish in 2021. Barley fields had a slightly higher richness compared to wheat but with very little difference in all three datasets. The conclusions of this study is that weed species richness continues decreasing in the Zaragoza province in all the surveyed areas; intensive agronomic practices in irrigated fields tended to decrease species richness in all three datasets while the crop had little effect on weed richness.

Keywords: Weed species richness decline, rainfed, irrigation

Weed flora diversification through patch cropping

Michael Glemnitz [1]; Kathrin Grahmann [1]; Gina Geittner [2]

Research, Müncheberg, Germany 2 Eberswalde University of Sustainable Development, Eberswalde, German

Oral

Agricultural uniformization is considered as a major driver of the decline in weed flora diversity. Conversely the diversification in cropping is one of the main strategies to reverse negative environmental impacts of cropping and sinking level of social acceptance of modern agriculture. The "patchCrop" approach aims at a small-scale crop diversification and the integration of landscape elements in order to enhance weed flora diversity, related ecosystem services and reducing chemical plant protection . Within an agricultural system trial at the landscape level, where patches of various crops in distinct crop roatationas are combined, we have analysed the impact of field level patchiness against neighbouring monocrop fields, the impacts af various crops on the diversification, the crop effects versus edge effects and the impacts of reduced plant protection regimes on weed flora diversity, coverage and weed flora functional composition. Here we present the first results of the on-farm trials with respect of the above mentioned test factors.

Keywords: biodiversity, diversification, edge effects, weed management

Fighting neobiota with neobiota: do it more rigorously and more often

Heinz Müller-Schärer [1]; Yan Sun [2]; Urs Schaffner [3]

[1] *Université de Fribourg/PérollesDépartement de Biologie/Ecologie, FRIBOURG, Switzerland*
[2] *Huazhong Agricultural University, College of Resource & Environment, Wuhan· 430070, China*
[3] *CABI, Delemont, Switzerland*

Oral

Biological invasions are among the most pervasive drivers of global change and arise from accidental or, notably for plants, from deliberate introductions in areas outside their native range, with subsequent establishment and spread. Invasion science has developed into a rapidly expanding discipline within general ecology over the past decades, yet little progress has been made to understanding causes of impact and to developing sustainable and integrated management approaches, particularly against invasive non-native plants (INNPs).INNPs cause severe impacts on nature and human well-being and these are predicted to increase further under climate change. While management tools have been developed to control early-stage invasions orto clear or reduce weed cover on a piece of land,they are only rarely available to manage the invasion process at the landscape scale. Importation biological weed control (IBWC) offers a potentially effective tool, especially when combined with other management interventions.We will first present a decision tree to identifyneeds andconditions under which IBWC is particularly likely to lead to cost-effective and sustainable INNP management.Building on the three-tiered management tactic prevention, early detection and rapid response, and control,we propose a spatially explicitintegratedmanagement strategyto achieve different management objectives. We then explore why IBWC, either alone or in combination with other management measures, is not used more often.In reply to concerns raised against IBWC as lacking efficacy and being too risky, and that it takes ages and is too expensive, wecontrast historical approaches with recently suggested improvements, and then outline a path forward to increase efficacy and safety in future IBWC projects. The introduction and deliberate release of specialist natural enemies, mostly insects and pathogens, from the weed's native range, also has a policy implication, as it needs authorization by national authorities. Many new world countries have widely adopted IBWC since decades, while regulations are only now underway in countries in Asia, Africa and Europe.With two case studies, we furtherillustrate that IBWC is more than just reducing weed densities, as it also significantly contributes to environmental health and human well-being by affecting various sectors. Concerns raised against IBWC should be taken up jointly by the scientific community and the IBWC practitioners to continuously improve this crucial tool in INNP management, not to forbear in doing it, as the threats imposed by INNPs are urgently awaiting a sustainable and affordable solution.

Effect of ground cover management on beneficial ground-dwelling arthropods in organic and conventional apple orchards

Myrto Barda [1]; Vaya Kati [2]; Filitsa Karamaouna [3]; Theodoros Stathakis [3]; Leonidas Oikonomou [3]; Thomas Tscheulin [4]; Dionysios Perdikis [1]

[1] *Laboratory of Agricultural Zoology and Entomology, Faculty of Crop Science, Agricultural University of Athens, Athens, Greece*

[2] *Laboratory of Weed Science, Scientific Directorate of Pesticides Control and Phytopharmacy, Benaki Phytopathological Institute, Kifissia, Greece*

[3] *Laboratory of Efficacy Control of Pesticides, Scientific Directorate of Pesticides Control and Phytopharmacy, Benaki Phytopathological Institute, Kifissia, Greece*

[4] *Laboratory of Biogeography and Ecology, Department of Geography, University of the Aegean, Mytilene, Greece*

Oral

Intensification of agriculture has led to degradation of plant habitats for natural enemies of crop pests, including ground-dwelling arthropods. Actions to reverse this situation became a priority in recent EU agricultural policy. However, necessary data on the presence, diversity and populations of terrestrial beneficial arthropods in relation to plant biodiversity and cover crops in rural areas in Greece are scarce. The aim of our work was to assess the effect of sown cover crop mixtures vs weed vegetation, on the diversity and abundance of ground-dwelling arthropods, including key predators (e.g., Carabidae beetles) of pests in apple orchards (e.g., Cydia pomonella). The trial was conducted in 3 orchards (1 conventional and 2 organic) of Delicious Pilafa apples in Tegea-Tripolis, Greece, during spring of 2020 and 2021. Each orchard had two cover crop treatments, a) a sown mixture of selected plants and b) weed vegetation cover after tillage (control), with 6 plots (replications) each. The sown species in the mixtures were Anethum graveolens, Coriandrum sativum, Eruca sativa, Lathyrus sativus, Triticum sp., Vicia faba, Vicia sativa in 2020, with Foeniculum vulgare replacing L. sativus in 2021. Ground-dwelling arthropods were sampled using pitfall traps at weekly intervals. At the same time, plant cover and flower cover per species were estimated visually. Weed communities in the control plots differed between conventional and organic orchards. Main flowering weed species in the conventional orchard included Calepina irregularis, Capsella bursa-pastoris, Cardaria draba, Ranunculus sp., while in the organic orchards Lamium spp., Veronica spp., C. irregularis. The type of ground cover treatment in organic and conventional orchards had a significant impact on the abundance of arthropods, which included spiders and several beetle families. The beneficial arthropods found in the treatments include species that could potentially contribute to biological control of apple pests. These are known ground predators (e.g. Carabidae, spiders), some could commute from the ground to the apple trees (e.g. spiders), and other are weed seed predators (some Carabidae). Overall, the results of our study provide important information that will help to assess the interaction of plants and beneficial arthropods in apple orchards and facilitate the selection of suitable plant species for effective cover crop planning.

Keywords: *ground cover management; weed communities; beneficial ground-dwelling arthropods; apple orchard; biological control; integrated management*

Management of Phelipanche aegyptiaca in cabbage (Brassica oleracea var. capitata)

Amit Wallach; Guy Achdary; Hanan Eizenberg

Department of Plant Pathology and Weed Research, Agricultural Research Organization, Newe-Ya'ar Research Center, Ramat-Yishay, Israel

Oral

Phelipanche aegyptiaca, a member of the Orobanchaceae family, is a root parasitic plant that causes severe yield losses and is considered as one of the main weeds in vegetable and field crops worldwide. After seed germination, and once established the vascular connections to the host plant roots, *P. aegyptiaca* becomes a major sink that draws nutrients, and water from the host resulting in crucial damage to the host plant. One of the most effective ways to manage *P. aegyptiaca* in the field is via herbicide application and previously was demonstrated for crops such as red clover, tomato, carrot, and more. The main objective of this research was to develop a protocol for the management of *P. aegyptiaca* in cabbage. In this work, two herbicides (glyphosate and ethametsulfuron-methyl) were examined via two application methods (foliage and to the root rhizosphere) in laboratory and field conditions. The herbicides were tested for *P. aegyptiaca* control as well as for crop safety. In the laboratory *P. aegyptiaca* control was evaluated using polyethylene bags (PEB) system at pre- and post-attachments stages of parasitism. In the field, each herbicide was applied at three sequential applications at 21, 35, and 49 days after transplanting with six different rates. Non-treated plots served as control. Additionally, growing degree days (GDD) models were developed to describe the *P. aegyptiaca*-cabbage dynamics based on minirhzothron sub-surface camera and soil temperatures. Our results show that under laboratory conditions, glyphosate and ethametsulfuron-methyl can control *P. aegyptiaca* when applied at both different stages of parasitism. Furthermore, the field experiments (seven different field trials throughout two years), revealed that glyphosate foliage application was found to be effective for the control of *P. aegyptiaca* at a rate of 72 g ai ha^{-1} with both application methods. However, *P. aegyptiaca* control with ethametsulfuron-methyl was achieved at a rate of 18 g ai ha^{-1} only when overhead irrigation was applied. The linear GDD model was computed ($T_{base}=5°C$) and a log-logistic equation was used to predict the parasitism dynamics of *P. aegyptiaca* in cabbage fields. Based on the results from this study, a decision support system protocol was developed to control *P. aegyptiaca* in cabbage under field conditions. The protocol suggests that *P. aegyptiaca* control can be achieved by three sequential herbicide applications, at 150, 300, and 600 GDD. Applications of ethametsulfuron-methyl must be followed with overhead irrigation while glyphosate at a rate of 72 g ai ha^{-1} can be applied on cabbage foliage.

Impact of the competitive hierarchy of Ambrosia artemisiifolia and Ambrosia trifida on their generative production

Aleksandra Savic

Institute for Plant Protection and Environment, Belgrade, Serbia

Poster

Reproductive traits of alien plant species represent as important traits involved in their invasive success. Fecundity presents a biological mechanism that ensures survival in fickle and unfavourable environmental conditions and enables efficient expansion in new areas. In many European countries, *Ambrosia artemisiifolia* L. (AMBEL). is characterized as an invasive weed species with a large seed production, which retains germination for many years. Unlike AMBEL, *Ambrosia trifida* L. (AMBTR) is less widespread and investigated, but its biological and ecological properties attract the attention of many scientists. Both species are strong competitors for natural resources and space and very often in the ecosystem influence on the repression of other plant species, and changing structures of plant communities. Although the spread of AMBTR observed in recent years, it has not yet become the dominant species in comparison to AMBEL. The aim of the research was to examine the generative production of AMBEL and AMBTR in co-association and does it this competition could restrict the spread rate. Field experiments were carried out at a farm near Dobrić, Republic of Serbia (44°41´N, 19°34´E) using a replacement design model, where the competitive interaction between AMBEL and AMBTR was assessed. The experiment involves treatments were the proportion of AMBEL to AMBTR of 10:0; 8:2; 4:6; 6:4; 2:8 and 0:10), and 10 plants per m2 arranged in a randomized block design (four replication). During the two different climatic conditions year, seed production of AMBTR and AMBEL were measured in 2016 and 2017. Data analysis were performed in R-studio. During two seasons, AMBEL produced more seeds than AMBTR, with no significant statistical differences between treatments. Although AMBTR achieved higher seed production in a more favourable climate year (2017), in both seasons, the highest numbers of seeds were achieved in treatments with its highest number/m^2 in relation to AMBEL. Interspecific competition reduced seed production of AMBTR, while intraspecific competition did the opposite. Analysis of variance showed statistically significant differences between treatments. Unlike AMBTR, the obtained results could indicate the more successful invasiveness of AMBEL, since in unfavourable environmental conditions (reduced living space and stressful climatic conditions) it produces richer offspring, which is a precondition for its further spread and colonization to new habitats.

Keywords: *Ambrosia artemisiifolia L., Ambrosia trifida L., replacement design, competition, generative parameters*

A study on determination of Echinochloa P. Beauv. spp. in rice fields in the Edirne Province of Turkey

Onur GÖKTEPE [1]; Necmi AKSOY [2]; Ahmet ULUDAĞ [3]

1 Trakya Agricultural Research Institute, Edirne, Turkey
2 Düzce University, Faculty of Forestry, Düzce, Turkey
3 Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Plant Protection, Çanakkale, Turkey

Poster

Some *Echincohloa* P. Beauv. spp. have been among important agricultural weed species in many crops worldwide. Especially they are main problem in rice cultivation in many countries such as Turkey. Herbicide resistance and identification problems as well as biological features of *Echinochloa* spp. make the problem complex. Five Species of *Echinochloa* have been mentioned in rice fields of Turkey, namely *E. colona* (L.) Link, *E. crus-galli* (L.) P. Beauv., *E. oryzoides* (Ard.) Fritsch, *E. erecta* (Pollacci) Pignatt and *E. oryzicola* Vasinger although only former three were mentioned in Flora of Turkey which are *E. colona, E. crus-galli* and *E. oryzoides, others are given synonym in. In rice fields of the Edirne Province, so far E. oryzoides and E. crus-galli have been recorded.* The aim of the study was to identify *Echinochloa* species in rice fields of Edirne in the context of time of seed maturation. Fields in mainly centre district and four other districts were visited between July and October 2021 and 70 individuals were collected in maturation. Morphology of plant whole and seeds were investigated, seed features analysed, and species were identified using different identification keys worldwide although Flora of Turkey was main one. Seven plants were *E. oryzoides* and 57 *E. crus-galli*. Six individuals were identified as *E. colona,* which was not mentioned before from Edirne rice fields. These three species have also recorded in the same field in the same visiting date. It is concluded that biology of species in the context of herbicide efficiency and resistance as well as their share in the fields should be studied further.

Keywords: Echinochloa, identification, rice fields, Edirne, Flora of Turkey

Weeds found in Papaya plantation of Somalia

Mohamed Said Omar; Hüsrev Mennan

Ondokuz Mayız University, Samsun, Turkey

Poster

Fruit crops are among agricultural products which are mainly produced in Somalia. Papaya is one of the tropical crop plants that adapted widely in climatic conditions in the country. Due to research limitations in Somalia's agriculture at large and in Papaya particularly, weed species and their effect on yield are not known, so taking this in to consideration, we aimed to investigate weed species those are found in Papaya fields in Somalia's Puntland province. The survey was conducted between October and December, 2021 as this is one of the main farming systems in the region. In our research we visited 22 Papaya fields and identified existing weeds by recording their frequency and abundance. Randomly thrown 1 m2 quadrat was used and the weeds found inside the quadrat were counted to find the abundance and frequency of specific weeds. Twenty five Weed species from ten families were identified. The families of the observed weeds were *Poaceae*, *Asteraceae*, *Solanaceae*, *Euphorbiaceae*, *Amaranthaceae*, *Portulacaceae*, *Malvaceae*, *Cyperaceae*, *Convolvulacaea* and *Boragenaceae*. The most abundant and most widely distributed weed species belong to *Poaceae family*; particularly *Cynodon dactylon*. This weed has the abundance of 20 plant/ M^2 and its frequency was 80 %. Second to this weed in frequency, there were *Flaveria bidentis* (60%), *Convolvulus arvensis* (56%), Echinocloa colona (48%) and *Euphorbia prostate* (36%). Considering the abundance, most abundant weeds after *Cynodon dactylon* was recorded to be *Echinocloa colona* (7.5plant/M^2) and *Convolvulus arvensis* (5plant/M^2). All the identified weeds are believed to have effect on Papaya yield, but most probably *Cynodon dactylon* could cause the highest effect on the yield of the crop.

Keywords: *Somalia, Papaya, weeds*

Weed problem in oive orchards according to the farmers from the KÖPRÜBAŞI district, Turkey

Sevgi Uyar; Ahmet Uludağ

Çanakkale Onsekiz Mart Universty, Çanakkale, Turkey

Poster

Turkey is among foremost olive growing countries. The Manisa province ranks second with 21 million fruit-producing olive trees and ranks first in table olive production. Over 10% of lands of the Köprübaşı district of Manisa is covered with olive trees. A face-to-face survey was carried out to find out profile of olive producers, their farming technics and specifically their view on weeds in 2020 and 2021. There were 63 individual farmers' field belongs to 60 people and six for four companies. Age of farmers is 29-84 with average approximately 30 years' experience in olive farming. The size of fields was smaller except companies and average age of olive trees was around 20. Producers considered 48 different species as problematic weeds. Top weeds were *Cynodon dactylon*L. (57) *Sorghum halepense* (L.) Pers. (26), *Chenopodium* spp. (*Chenopodium album* L., *C. vulvaria*L.) (18), *Tribulus terrestris* L. (18), *Xanthium spp.* (*Xanthium orientale*L., *Xanthium strumarium L.*) (17),*Sisymbrium officinale* (L.) Scop. (12), Convolvulus spp. (*Convolvulus arvensis* L. and *C. Holosericeus M.*Bieb .) (12), and*Polygonum convolvulus* L. (11).They were mostly among the topmost common weeds which their number were higher than problematic ones, probably due to some of them considered easier to control. In addition, the number of less common weeds were the highest, which shows producers are careful about weeds and they are trying to know them. The total number of plant species in olive grows was over 100. Producers were mentioned 5.36 (min. 1 and max. 11) (median is 5) problematic weeds. One third of farmers think weeds enter their fields from neighboring fields, 11 different weeds were mentioned.Each farmer mostly gave more than one impact by weeds (average 2.32, median 2, min 1, max 5) and responds were grouped in 13 different impacts. The top negative impact was ˝moisture lost˝ with 46 responds followed by ˝difficulties in farming˝, ˝bothering tree development˝, ˝harvesting difficulties˝, ˝soil nutrition problems˝, ˝hosting oth-er pests˝, ˝decreasing yield˝ and some others impacts. The vast number of producers (51) said that weeds in orchards are problem from tree growth restarting to harvest. Half of the farmers apply herbicides, and glyphosate is the most preferred followed by some ACCase inhibitors and some others.The loss of efficiency for herbicides was mentioned more than half of the growers but it seems that they are not aware of the problem.

Reintroduction of rare arable plants and their influence on ecosystem services and yield under various farming practices

Rosa Witty; Matthias Schumacher; Roland Gerhards

University of Hohenheim - Department of Weed Science, Stuttgart, Germany

Poster

During the last decades we are facing a tremendous decline of biodiversity. In cultivated landscapes homogenisation and agricultural intensification led to losses of faunal and floral diversity. Counteracting these trends, we study the reintroduction of rare arable plant species and their influence on agroecosystems. Two experiments were established in spring barley in Southwestern Germany. The first one, established in 2019, focuses on various farming practices (e.g., fertilisation, weed control, row distance) and reintroduction efforts. Two different flowering mixtures containing rare plant species (*e.g., Bup*

leurum rotunidfolium L. and Consolida regalis Gray) were used for reintroduction efforts: one commercially available mixture and one site-adapted flowering mixture which is self-composed. The second experiment, established in spring 2021, investigates different reintroduction efforts: topsoil translocation and sowing of a self-composed site-adapted flowering mixture. In the first experiment, treatments containing rare arable plant species had on average twice the number of arable plant species (20 – 29 species) compared to treatments without any sown species in 2019 and 2020; only half of them were sown species. In 2021 the number of spontaneously growing plants was lower in treatments containing sown rare species (averagely 20.25) compared to treatments without any flowering mixture nor weed control or fertiliser use (averagely 30.5), though the alpha diversity was significantly higher. Moreover, up to 15 rare arable plant species (e.g., *Agrostemma githago L.*) spread to other treatments in three years. In 2020, treatments with sowing of rare arable plant species had a significantly lower yield (averagely 2.69 t/ha) than treatments with mechanical (6.72 t/ha) or chemical (7.43 t/ha) weed suppression. Furthermore, the two latter treatments did neither differ significantly in yield nor species richness. Rare arable plant species' reintroduction in the second experiment by sowing was successfully accompanied by an increasing floral alpha diversity (sowing: α = 15.56; control: α = 10.84), even though pollinators did not show any differences in 2021. In both experiments our reintroduction efforts led to higher floral diversity and have been successful. Finally, our results indicate a trade-off between yield and conservation within agricultural fields. Reintroduction is therefore probably more reasonable on fields with low yields combined with financial incentives.

Keywords: *arable plants, biodiversity, ecosystem services, reintroduction*

A survey on Amaranthus palmeri S. Watson in Cukurova Region of Turkey - A recent record for Turkish flora

MEHMET NEDIM DOGAN [1]; FILIZ ERBAS [2]; SULEYMAN GURDAL TURKSEVEN [3];
ALI RIZA ONGUN [4]; SAFIYE PINAR TUNALI [5]; CUNEYT ULGEN [6];
ANIL ALTUG PEK [6]; MAHMUT ERTEM [6]

[1] Adnan Menderes University, Faculty of Agriculture, Department of Plant Protection, Aydin, Turkey
[2] Adnan Menderes University, Faculty of Agriculture, Department of Plant Protection, Aydın, Turkey
[3] Ege University, Faculty of Agriculture, Department of Plant Protection, IZMIR, Turkey
[4] Ege University, Faculty of Agriculture, Department of Soil Science & Plant Nutrition, IZMIR, Turkey
[5] Adnan Menderes University, Faculty of Agriculture, Department of Biosystems Engineering, AYDIN, Turkey
[6] Agro Teknik Agricultural Consulting Limited Company, ADANA, Turkey

Poster

A. palmeri is a weed that causes significant damage to crops in many agricultural areas, and is considered an invasive species in many countries around the world due to its effects on agriculture. Rapid germination, rapid growth in the early period, high rate of photosynthesis and high biomass and giving a large number of seeds increase the success of the invasion. It has been first noticed in citrus groves and some field crops, as well as in non-agricultural areas in eastern Çukurova Regions of Turkey in 2014. It was identified definitively in 2016 and registered as a new species in the flora of Turkey. Therefore, a study was conducted to survey this weed at regional scale in Cukurova Region of Turkey. The survey studies were performed in Adana, Hatay, Mersin and Osmaniye provinces of Turkey by driving different directions from each city center. The coordinates were taken by stopping every ~5 km. At coordinate points firstly occurrence of *A. palmeri* was determined. In the case of presence the number of *A. palmeri* were recorded in 10 m^2 area in non-agricultural areas by centering the coordinate point. If there is infestation in adjacent agricultural areas, crop species and coverage of *A. palmeri* were recorded as a separate sampling point. The frequency, weed coverage (in agricultural areas) and density (in non-agricultural areas) were calculated. In evaluation of 456 coordinate points, frequency was calculated as 30%, although it is over in 70% in some counties. While the weed more common in agricultural areas in Adana and Osmaniye provinces, it has been found in agricultural areas as well as in non-agricultural areas in Hatay, and only in non-agricultural areas in Mersin. *A. palmeri* coverage in the agricultural areas was found averagely 16,6%, and the density in the non-agricultural areas was 6,8 plants m^{-2}. The agricultural areas where it has been observed mostly consist of citrus groves, corn, cotton and peanut fields. These results showed that *A. palmeri* became common in agricultural areas in Cukurova region and likely to extend to the neighboring provinces due to its high invasive capacity. Therefore, special attention should be paid to prevent spreading of this species to the other regions. Thus, effective management methods of this weed should be investigated in Turkey.

A New Alien Species and Weed Recorded in Banana Production in Turkey

Hilmi Torun [1]**;** Mine Özkil [1]; İlhan Üremiş [2]; Necmi Aksoy [3]; Ahmet Uludağ [4]

[1] *Biological Control Research Institute, Adana, Turkey*
[2] *Hatay Mustafa Kemal University, Hatay, Turkey*
[3] *Faculty of Forestry, Düzce University, Düzce, Turkey*
[4] *Çanakkale Onsekiz Mart University, Çanakkale, Turkey*

Poster

Banana has produced in a limited area in Turkey for over a century; but has increased for the last two decades because of introduction of protected production in basic greenhouses to tackle with unsuitable weather conditions in open field production of banana. In order to determine weed problem in banana cultivation fields were surveyed in 2021 and 62 species from 24 families were detected. *Pilea microphylla* (L.) Liebm. (Urticaceae) and a *Cardamine* L. sp. (Brassicaceae) were detected. *P. microphylla*, native to America is the first recorded in the nature from Turkey; but we were not able to detect the species of *Cardamine* sp., but it is close to *Cardamine* cf. *flexusosa.* With., which is native to Europeand was first recorded in northwestern Turkey in 2006. There are 14 *Cardamine* L.spp. taxa in Turkey and some of them native wild edible plants that known as a name "bittercress" (acıtere in Turkish) such as *C. hirsuta* L., *C. amara* L., *C. pratensis* L. This is the first time *C.* cf. *flexusosa* was recorded as a weed in agricultural areas from southern Turkey. Pathways of both species have not been clear: *P. microphylla* either intentionally by ornamental trade, production, or use or unintentionally via agricultural propagation materials such as banana seedlings, peat, soil etc.; and *C. flexusosa* only unintentionally more probable. Both species are weeds in disturbed areas including banana plantations in some countries. In the Mediterranean Region of Turkey, *Cardamine* sp. was found at 52.21% and *P. microphylla* at 20.35% of banana greenhouses but none of them was seen in open banana fields surveyed. Spread of species were attributed to manure used in excessive amounts in banana cultivation as well. Their average special densities in greenhouses detected were 10.03 individual/m^2 (15.10% coverage) and 7.23 weed/m^2 (9.85% coverage) for *Cardamine* sp. and P. *microphylla* respectively. It is clear that warm, wet and muddy environment of banana greenhouses encourages both species. We suggest an intensive eradication program to prevent further spread of both species in other croplands and natural areas.

Comparing the efficiency of different weed sampling methods

Christoph von Redwitz; Lena Ulber

Julius Kühn-Institut (JKI) Federal Research Centre for Cultivated PlantsInstitutefor Plant Protection in Field Crops and Grassland, Braunschweig, Germany

Poster

In 2019/2020, we sampled five winter wheat fields three times during the vegetation period: in autumn after herbicide application as well as before and after herbicide application in spring. Herbicide-free plots of 100 m^2 were set up in the field centre and at the field edge. Different sampling methods were compared: a) determination of the present weed species and their individual density (number of individuals) and cover (Londo scale) in 10 x 0.1m² plots within the untreated area of the field; b) sampling of the weed species present and their cover along a 30m x 1m transect; and c) in 5 x 1m² plots every five meters along this transect. In 2020/2021, we sampled 24 herbicide-treated fields in spring using a 50m x 1m transect as well as a 50m x 2m transect. Furthermore, we sampled the present weed species and their individual density and cover in 10 x 0.1m² plots distributed over the 50m x 2m transect as well as weed species and their cover in 10 x 1m² every five meters along the same transect. We could show that sampling of herbicide-free plots is not useful for the aim of a German-wide weed monitoring. The differentiation between the sampling methods conducted on regularly managed fields was not so clear-cut. While the mean number of identified weed species was very similar among the different sampling methods, though a bit higher for the 50m x 2m transect, the approach of sampling 10 x 1m² plots provided the same level of accuracy with additional information on the weed distribution and stability of the weed patches. Still, this plot method is more time consuming compared to the transect assessment.

Keywords: *weed diversity; sampling; time; MonViA*

Which structure and composition of agricultural land-use mosaics to enhance multiple services provided by arable weeds?

Stéphane Cordeau; Séverin Yvoz; Sandrine Petit

Agroécologie, AgroSup Dijon, INRAE, Univ. Bourgogne, Univ. Bourgogne Franche-Comté, Dijon, France

Poster

The need for multifunctional agricultural landscapes which combine the delivery of production services and that of other ecosystem functions is now widely recognised. Arable weeds are an interesting component of agricultural landscapes as they can be potentially harmful to crop production but also provide floral and seed resources that support organisms delivering pest control and pollination services. Weed communities delivering limited harmfulness and high level of services, both at a stable level across years, would represent an interesting trade-off. Here, we assessed the dual contribution of some 700 weed communities recorded within a small arable landscape in Burgundy, France, through the estimation of nine (dis)service proxies. We found that crop management strategies (number and type of crops in rotation and associated practices) strongly affected the trade-off between harmfulness and services; our results also highlighted that weed communities located at the edge of fields delivered higher levels of services than those located in the core of arable fields. Modifying the relative proportional cover of different crop management strategies (composition) and the length of field edges (structure) within a landscape could thus represent an interesting lever to achieve optimal trade-offs between harmfulness and services provided by weeds. To evaluate this statement, we developed from the current land-mosaics 72000 scenarios combining one of three landscape structures (large, medium and small field size) and crop management strategies composition (one to eight coexisting strategies, with varying relative proportional cover). Using Pareto frontier analyses, we identified the landscape scenarios that delivered the most interesting trade-offs. We found that land-use mosaics composed of many cropping strategies equally represented fared better than more simple landscapes, suggesting the existence of complementarities between strategies. Conversely, increasing the length of field edges in the landscape only had a limited impact on trade-offs, although it often improved the temporal stability of services. These results highlight the positive effects of landscape diversification on the functioning of agroecosystems.

Keywords: *pollination, pest control, yield loss, indicators, landscape scenarios, pareto frontier*

Avenues for future research on tillage effects on weed communities and crop performance in fields previously conducted under conservation agriculture principles

Stéphane Cordeau; Auxence Baudron; Guillaume Adeux

Agroécologie, AgroSup Dijon, INRAE, Univ. Bourgogne, Univ. Bourgogne Franche-Comté, Dijon, France

Poster

In Europe, conservation agriculture (CA) is currently challenged by higher weed pressure, potential glyphosate ban and reduced crop yield. The introduction of occasional tillage could be a viable option to diversify selection pressures on weeds and increase crop yield in CA. Very few non-chemical alternatives to glyphosate, other than occasional tillage, are currently efficient and available. Rather than perpetuating the sterile debate between those considering CA through its means (i.e. the three pillars described above) and, therefore, banning the use of tillage, and those considering CA though its objectives (e.g. increasing soil heath), and therefore, willing to consider a wider set of weed management tools (including occasional and superficial tillage), we highlight that little is known on the influence of tillage in fields previously conducted under CA principles. Results shed light on the short-term effect of different types of tillage on weed communities, weed:crop interference and crop performance in fields conducted under CA principles for years. However, methods could be adapted to investigate hypotheses concerning the underlying mechanisms. Hence, we provide insights for future research, detailing hypotheses, methods and key references for the implementation of such studies. Tillage effects on subsequent crop productivity could be related to (i) changes in abiotic conditions (soil temperature, moisture, nitrogen content, bulk density) or (ii) changes in weed communities (abundance per species and relative time of emergence), measures which could be obtained through soil sensors and weed scoutings, repectively. Subsequent plant growth could be characterized by nitrogen contentand canopy coverage dynamics (visually, green cover sensors, NDVI) and differences between tillage treatments could be related to (i) or (ii).The indirect effect of tillage on crop productivity through changes in weed communities could be isolated by placing pairs of weeded and unweeded zones across the different tillage treatments. Analysis of weed seedbanks could help forecast weed communities potentially up-welled by occasional tillage practices in CA. We encourage future experiments to repeat measures in time (to potentially contrast short-term benefits with potential long-term disadvantages) and adopt a more systemic approach, to compare coherently integrated sets of weed management practices during the fallow period (e.g. ploughing vs repeated false seedbed operations).

IPSIM-Cirsium, a qualitative expert-based model to predict infestations of Cirsium arvense

Marie-Hélène ROBIN [1]; Octave LACROIX [2]; Anna DOIZY [3]; Jean-Noël AUBERTOT [1]

[1] INRAE, 31326 CASTANET-TOLOSAN, France
[2] INRAE, 84914 Avignon Cedex 9, France
[3] Association Reusit, 97410 Saint-Pierre, France

Poster

In a context of recall of glyphosate and questioning about the intensive use of ploughing, tools are needed to offer an alternative for perennial weed control. Perennial weeds are a major problem in production fields, organic or conventional farming. To control them, a system approach is required. This is the aim of the work package Modelling of the European project AC/DC-weeds. Multi-attribute qualitative modelling, performed thanks to IPSIM (Injury Profile SIMulator), enables the evaluation of weed infestation for three perennial weeds included one *Cirsium arvense.* The models consider andintegrate verticallythe effect of weather, soil and cropping practices, and their interactions on weed infestation. For the conception of the models, the DEX method was used implemented by the software DEXi. The principle of the method is to subdivide a large problem into smaller and less complex subproblems. This method is perfectly applicable on weed infestation modelling, by considering numerous subproblems such as the complexity of interactions between crop practices. The originality of the IPSIM modelling platform is to apprehend the whole agroecosystem and to produce a schematic representation of it. This approach is particularly relevant for perennial weeds which developments are impacted not only by weather and soil, but also by the cultural practices or disturbances that occur during previous, between and current crop production. IPSIM-Cirsium has 33 attributes (20 basic attributes and 13 aggregates).It is organised in an aggregative hierarchical tree of attributes: Terminal attributes also called basic attributes are the input variables that the user will specify while using the models and the final aggregated attribute is the output of the model, here the *Cirsium* infestation. The IPSIM *Cirsium* model outputs was confronted to independent field observations collected across 6 fields, over a 16-year period in 3 sites. IPSIM-Cirsium showed a satisfactory predictive quality (accuracy of 78.2%). This qualitative model has a user-friendly interface which is now freely available online, in two languages (French, English): https://shiny.biosp.inrae.fr/app_direct/ipsimcirsium/?lang=en-TheIPSIM *Cirsium*modeling platform can be used as adecision-makingtool for farmers andadvisers to assess ex-ante prototypes of cropping systemsand to simulate Cirsium infestations to their crops. This prediction tool can also be used as an ex-post diagnosis for crop advisors and researchers to assist the design of systems less reliant on herbicides. Finally,the model can be used for teachers and trainers as aneducational tool to exchange and share agroecological weed management knowledge.

Fifth follow-up survey on weeds in spring cereal fields in Finland during 2020-2022

J. Salonen; H. Jalli; A. Muotila; P. Ruuttunen; T. Hyvönen

Natural Resources Institute Finland (Luke), JOKIOINEN, Finland

Poster

The weed flora in spring cereals has been investigated in Finland since the early 1960's. Regular surveys are regarded as a valuable way of monitoring the responses of weed floras to changes in agricultural environment. Spring cereals cover about 50% of the cultivated area in Finland. By comparing data from different decades, we have demonstrated that changes in cropping measures and environmental conditions affect the species composition of the weed flora and the level of weed infestation. Changes in herbicide use and trend towards reduced tillage as well as annual and regional variations in weather conditions play key role. A special attention in the current survey is paid to the incidence of herbicide resistance, *Stellaria media* expected to be the most common indicator species. In earlier surveys, more than 150 weed species have been identified, of which almost 90% have been broad-leaved species. In organically cropped fields, the average species number per field has been around 20, whereas in conventional fields after herbicide treatment 10-12 weed species only. *Elymus repens* has been the most frequent and abundant grass species, corresponding the highest proportion, about 30%, of the total weed biomass in conventional and organic systems. Data over decades have been applied to develop a special index which emphasizes weeds' importance for biodiversity. It describes trends in the amount of food provided by the weed community to other farmland species like birds. The on-going fifth survey during 2020-2022 is conducted in 16 regions, around 250 farms and 550 fields. Both conventionally and organically cropped fields are included. In addition to observing weeds from 10 sample quadrats per field in mid-July, we have interviewed farmers to work out their cropping practices. Data sets are analysed to explore the main drivers behind the weed shifts. Preliminary results from the current survey indicate that *Poa annua* and *Veronica* spp. have become more abundant (plants m^{-2}) during the last 10 years. Dry growing seasons, like 2021, strongly hamper the growth of *S. media*. *Spergula arvensis* is representative of organic cropping whereas *Galium spurium* is more typical in conventional cropping. Weeds in conventional cropping are commonly and sufficiently controlled with available herbicides whereas weed management in organic cropping urgently calls for IWM measures. For instance, weed harrowing is not a common practice in cereals. Weed survey Team from Finland has actively shared in the work of the EWRS Working Group ˝European Weed Mapping˝, established in 2009.

Occurrence of *Phytolacca americana* in crop fields in Austria

Swen Follak [1]**;** Michael Schwarz [2]; Franz Essl [3]

[1] Institute for Sustainable Plant Production, Austrian Agency for Health and Food Safety, Vienna, Austria
[2] Data, Statistics and Risk Assessment, Austrian Agency for Health and Food Safety, Vienna, Austria
[3] BioInvasions, Global Change, Macroecology-Group, Department of Botany and Biodiversity Research, University of Vienna, Vienna, Austria

Poster

Phytolacca americana L. (common pokeweed) is a large perennial invasive alien plantindigenous to the eastern United States. In Europe, it usually infests forest edges open woodland and ruderal sites; however, it had also locally emerged as a weed in crop fields in some European countries. In this study, the occurrence of the species as a weed in crop fields in Austria was analyzed based on distribution data collected from different sources (floristic databases and literature, unpublished records). Moreover, *P. americana* was surveyed in selected areas in southern Austria (Styria) in 2021 and its behavior as weed was analyzed by phytosociological relevés. The occurrence of the species in Austrian neighboring countries (i.e. the Czech Republic, Germany, Hungary, Italy, Slovakia, Slovenia, and Switzerland) was also briefly investigated based on a narrative literature search and an expert consultation. The results show that *P. americana* is rare on arable land in Austria and its neighboring countries. The survey and distribution data collected, however, showed that *P. americana* occurred locally more abundant in crop fields. Crop infestations were confined to southern Austria (Styria), which is also the hotspot of the species' general distribution in Austria. The species infested predominately oil-pumpkin and maize, but also soybean and cereals. *Phytolacca americana* colonized mainly the narrow strip between two crop fields and field margins, but it sometimes also occurred inside the crop field. The invaded weed vegetation belongs to the association *Echinochloo-Setarietum pumilae* Felföldy 1942. Two factors may have contributed to this phenomenon: (1) high propagule pressure from large forest and ruderal populations, (2) and small-scale and less intensive cultivation practices of particularly low growing crops such as oil-pumpkin. Individuals and small populations can be controlled by mechanical means (e.g. digging, cutting). The use of herbicides is another option, but there is a lack of experience under Central European conditions. The study illustrates the need to further monitor the occurrence of *P. americana* in crop fields and its potential impact.

Keywords:

spread, distribution, invasive alien plant

The development of Convolvulus arvensis collected from different provinces under different temperature and CO_2 conditions

N.T. Tursun [1]**;** Yucel Karaman [2]; Ahmet Uludag [3]

[1] *University of Malatya Turgut Ozal, Agric. Faculty, Battalgazi, MALATYA, Turkey*
[2] *Malatya Turgut Ozal University, Agric. Faculty, Plant Protection Division, Malatya, Turkey*
[3] *Canakkale Onsekiz Mart University, Agricultural Faculty, Plant Protection Department,, Canakkale, Turkey*

Poster

Field bindweed (*Convolvulus arvensis*) is one of the worst weeds worldwide. This Euroasian plant is highly detrimental for agricultural areas within Turkey. Climate change, with increasing temperature and greenhouses rates and unpredictable extreme weather events, has been among foremost problems of world. Its effect on weeds and crops are becoming increasingly severe due to predicted changes and ask for taking measures to mitigate negative effects of climate change. The effect of rising temperature and CO_2 on different populations on *C. arvensis* was studied under greenhouse conditions in the Malatya Province of Turkey in 2018 and 2019. Two temperature regimes (day/night 16/26 °C and 19/29 °C) and two CO_2 levels (400 and 800 ppm) were used. *C. arvensis* populations were collected from 14 different provinces representing different climate and altitudes: Adana, Ankara, Istanbul, Izmir, Erzurum, Hatay, Karaman, Kayseri, Konya, Malatya, Samsun, Sanliurfa, Tekirdag and Usak. Measurements were taken two months after experiment setup. The length of vegetative parts of *C. arvensis* plants did not differ among populations under all four conditions while dry weight was significantly affected by populations under 800 ppm CO_2 in 26 °C and 400 ppm in 29 °C. Rising CO_2 mainly did not affect the length or dry weight under any temperatures for the populations. It is concluded that populations from different areas show similar respond to CO_2 rates and temperatures, which reveals why *C. arvensis* is among the worst weed worldwide, i.e., its adaptation power in different environments is clear.

SESSION II

CROP-WEED INTERACTION

Plant-soil-microbe interactions – new perspectives in crop-weed competition

Andrea Cavalieri; Paul Neve

University of Copenhagen Department of Plant and Environmental Science, Taastrup, Denmark

Oral

Plants compete with neighbouring individuals for limited resources. The process of competition can occur among individuals belonging to the same or different species, generating intra- and interspecific competition, respectively. So far, to assess plant competition, researchers have mostly focussed on the relative reduction of above- and belowground biomass of competing plants as a measure of competition abilities, intensities and outcomes. Plants also respond to the presence of neighbours physiologically and biochemically via, for example, changes in root exudate composition. The ability of a single plant species to inhibit or stimulate the germination and growth of neighbours can be measured in the context of plant-soil feedbacks and allelopathy and will be impacted by the soil microbiome. Another emerging area of interest considers the impacts of the plant microbiome and plant growth-promoting bacteria on plant health, fitness, and plant-plant interactions. Indeed, there has been a notable increase in interest in the development of 'biologicals' and 'biostimulants' for enhancing crop growth and defence. In this context, it is timely to consider how plant competitive interactions might change the rhizosphere microbial community of plants growing in communities. Studies have shown that when two plant species are interacting, the resulting soil bacterial community matches that of the most competitive one. However, in a more comprehensive study assessing five different plant species grown in monoculture and in mixed cultures over densities, we observed that the bacterial rhizosphere community of the weakest competitor did not become more similar to that of the dominant species. Furthermore, it was shown that for the dominant competitor neither intra- nor interspecific competition had major effects on the composition of its rhizosphere bacterial communities. However, for the weakest competitor increasing intraspecific competition maintained a highly specialized bacterial community, and during interspecific competition led to the loss of specialized microbes followed by an increase of unique taxa. These taxa may offer a broader assortment of beneficial functions needed by the weakest competitor species suffering from interspecific competition, to survive. In conclusion, plant competitive interactions and the identity of competing species strongly influence the composition of the rhizosphere bacterial community. These effects mediated through plant-soil-microbe feedbacks may have important impacts on the outcomes of crop-weed competition particularly in a future where plant-microbe interactions are artificially manipulated through the use of plant biologicals.

Increased weed diversity mitigates weed competition with Romaine lettuce (Lactuca sativa L., var. Romana).

AV Virili; Anna-Camilla Moonen

Scuola Superiore Sant'Anna, Pisa, Italy

Oral

Recent studies have shown that species-rich communities are less competitive with the crop than species-poor ones (Adeux et al., 2019). Low abundance of weeds within the field may also support early colonization by antagonists of crop pests (Fonseca et al., 2017). Despite the increasing evidence in support of non-crop biodiversity, vegetables are managed with a low tolerance for weeds. However, crop losses due to competition likely depend on specific crop-weed interactions. Therefore, we propose a functional trait approach to vegetable-weed competition studies to determine systems that can tolerate weeds to optimize biological pest control. In this study we assessed the competitive ability of lettuce when grown with three Mediterranean weed species (*Sinapis alba*, *Lolium multiflorum*, *Malva moschata*) and their combinations, to establish whether crop-weed competition is reduced when the number of weed species increases and if this can be associated to species traits related to their competitiveness. For this reason, we selected a competitive dicot (known to compete early), a competitive monocot (known to compete later) and a perennial dicot which is not normally a competitive species in its first year. The crop (Lettuce) and weeds were grown in square plastic pots (0.32 x 0.32 x 0.36 m) with one lettuce plant and a total of 10 weed plants, in different ratios. The experiment had 7 replicates and was repeated three times. Crop performance was evaluated with the competitive balance index. The competitive index of lettuce was negative only when grown exclusively with *Sinapis alba*, while positive when grown in any of the other combinations. Orthogonal contrasts indicate that increasing weed diversity is beneficial in reducing the competitiveness of dominant weeds but is not able to completely counterbalance their effect, as demonstrated by the fact that lettuce performed better alone compared it is intercropped with *Sinapis*.The results of the study depend on the characteristics of the chosen weed species that affect their competitive ability such as the relative growth rate (which can be determined by leaf area index and net assimilation index; see Storkey 2004). A next step would be a screening of a much higher number of weed species to detect if certain weed traits are systematically resulting in a higher competitive ability to predict the competitive ability of different weed communities in field vegetable crops.

The competitiveness of the invasive weed Parthenium hysterophorus with field tomato (*Lycopersicum esculentus*) in Israel

Tuvia Yaacoby [1]; Gal Yaacobi [2]; Baruch Rubin [3]

[1] RH Smith Institute of Plant Sciences and Genetics in Agriculture, Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem, Rehovot, Israel

[2] Biobe, , Israel

[3] RH Smith Institute of Plant Sciences and Genetics in Agriculture, Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem, Rehohot, Israel

Oral

Parthenium hysterophorus is a worldwide noxious annual weed infesting field crops, orchards and roadsides in north-eastern Israel (Beit She'an and Jezreel valleys).The weedwas introduced to Israel during the late 70's most likely via importation of animal feed grains from abroad. The weed slowly dispersed for almost 25 years within these regions. During recent years the weed further invaded and was detected outside its original area infesting horticultural crops and pasture. In this study we examined the competition between *P. hysterophorus* and field tomato under screen house conditions in order to predict and evaluate its potential damage to commercially grown tomatoes. Seeds of *P. hysterophorus* collected from a highly infested chickpea field in the Jordan valley (Kibbutz Degania) were used. Weed and crop germination were carried out under controlled environment (28/22°C day/night and 12h photoperiod). Uniform seedlings of the weed and the crop at the 1 to 2 leaf stage were separately transplanted in a 90 L (60X50x30 cm) Styrofoam boxes filled with a 4:1 planting mix: loamy sandy soil (Typic Haploeralfs), pH 7.5. Plants were grown in the screen house under the prevailing summer climatic conditions, fertilized with a soluble 20-20-20 (N-P-K) fertilizer and irrigated as required. The seedlings were planted with a maximum number of four tomato seedlings per container (equal to 16 plants m^{-2}), and nine *P. hysterophorus* seedlings (equal to 36 plants m^{-2}). There were five densities: (a) 100% tomato; (b) 75% tomato - 25% *Parthenium*;(c) 50% tomato - 50% *Parthenium*; (d) 25% tomato - 75% *Parthenium;* (e) *100% Parthenium.*The experiment lasted 35 days after planting, with 4 replicates in a complete random design. At harvest time, the shoot fresh and dry weight were determined. We found that presence of *P. hysterophorus* at all planting ratios caused a significant reduction (~30%) of tomato shoot biomass/m^2, whereas *P. hysterophorus* plants gained ~25% increase in shoot biomass/m^2 at all combinations with tomato plants. We noted that intra-species competition of *P. hysterophorus* was stronger than its inter-species competition. Our results showed that the invasive weed *P. hysterophorus* is a real threat as competitor to field tomato crop.

Keywords: *Invasive weeds, Parthenium hysterophorus, Competition*

Rotational diversification and fertilization together explain the impacts of tropical weeds on rice yields through changes in plant communities and biomass

Ripoche A.[1,2], Allouch N.[2], Barkaoui K.[3,4]

[1] CIRAD UPR AIDA F - 97743 Saint-Denis Cedex 9 La Réunion
[2] AIDA, Univ Montpellier, CIRAD, Montpellier, France
[3] CIRAD, UMR ABSys, F-34398 Montpellier, France.
[4] ABSys, Univ Montpellier, CIHEAM-IAMM, CIRAD, INRAE, Institut Agro, Montpellier, France.

Oral

Under tropical conditions, weeds grow continuously and cause detrimental yield loss in annual cropping systems. In the rainfed rice-based agroecosystems of the mid-west region of Madagascar, weed pressure is extremely high and could decrease rice yield (until -30 kg.ha-1 rice per day of delay of weeding). The impacts of weeds are of greatest concern in such agroecosystems based exclusively on manual fieldwork and where the minimal use of external inputs confers very low soil fertility. To overcome these issues, diversification may be an option to promote yield while reducing weed pressure while fertilization may help the crop to be more competitive against weeds. Here, we tested the combined effects of plant diversification and fertilization on weed species biomass, composition and diversity in a 4-years field experiment carried out in Ivory, in the mid-west region of Madagascar, with a randomized block design and four replications. We compared three different rainfed rice-based rotations: Rice followed by Groundnut = RG, Rice followed by a mixture of Sorghum and Vigna unguiculata =RSV, Rice followed by a mixture of Mucuna cochinchinensis and Crotalaria spectabilis = RMC; under two levels of fertilization (F1 = manure vs. F2 = manure + fertilizer) using rainfed rice monoculture (RR) as control. We assessed weed biomass at each weeding (two per season), and weed composition and diversity at the second weeding only. Finally, we measured rice yields at harvest to evaluate the impact of weeds on rice productivity in the different rotational systems. We found that weed biomass, composition and diversity were affected by year, the type of rotation and the level of fertilization. Weed biomass was significantly higher in F2 than F1, and significantly lower in RMC than in RG, RSV or RR. Species richness, was higher in RR followed by RMC, RSV and ultimately in RG. In addition, the composition and structure of weed communities differed according to fertilization, year and rotation. Each year differed from the other and RMC differed from the other rotations and control due to the presence of cover crop regrowth and a higher species diversity during the growth of cover crops. Overall, rice yield was negatively correlated to weed biomass in F1. Diversification of rotations plays a key role in decreasing weed biomass, yet it did not increase weed diversity. Differences observed in terms of weed communities could lead to different degree of harmfulness considering rice and then partly explain the differences observed on rice yield.

Keywords: *tropical cropping systems, short rotation, weed communities, weed biomass*

Deciphering field-based evidences for crop allelopathy in weed regulation

Inès Mahé [1]; Bruno Chauvel [1]; Nathalie Colbach [1]; **Stéphane Cordeau** [1];
Aurélie Gfeller [2]; Antje Reiss [3]; Delphine Moreau [1]

[1] *INRAE, Dijon, France*
[2] *Agroscope, Nyon, Switzerland*
[3] *Chr. Hansen A/S, Hørsholm, Denmark*

Oral

It is now essential to reduce the negative impacts of weed management and especially herbicide use. Weed-suppressive crop species/varieties hold promise for integrated and sustainable weed regulation. Competition for resources and allelopathy are the two main underlying mechanisms of weed:crop interference. Unlike competition, which is well studied and established, allelopathy by living crops remains a contentious mechanism. A major difficulty to demonstrate the effects of allelopathy in the field is to dissociate them from those of competition. Here we systematically and quantitatively review the literature, searching for field-based evidence of the role of allelopathy (by root exudation of living crops) in weed regulation, independently of competition, focusing on studies comparing different varieties of a given crop species. Our critical literature analysis also aimed to identify weaknesses and strengths in methodology, providing insights on optimal experimental designs and avenues for future research. Our main conclusions are: (1) in most articles, the role of crop competition is disregarded or not exhaustively studied. Consequently, contrary to authors' conclusions, it cannot be determined whether weed regulation is due to allelopathy and/or competition. (2) Few articles provided convincing evidence of the presence/absence of allelopathy effects in the field. (3) To further investigate allelopathy in the field we recommend to (i) finely characterize crop competition by measuring traits in the field, (ii) assess crop allelopathic potential with complementary experiments in controlled conditions or by quantifying allelochemicals in the field, and (iii) quantify the contribution of each studied trait/mechanism in explaining weed regulation in the field with multiple regression models. In conclusion, the consistent use of the suggested guidelines, as well as alternative approaches (e.g. creation of varieties with altered allelopathic compounds production, development of process-based simulation models) may provide a basis for quantifying the role of allelopathy in the field and, subsequently, for designing weed management strategies promoting weed biological regulation.

Competition of Amaranthus palmeri S. Watson with corn and cotton at two different germination times

SERAP SUTAY [1]; FİLİZ ERBAS [2]; MEHMET NEDIM DOGAN [2]; ALI RIZA ONGUN [3]; SULEYMAN GURDAL TURKSEVEN [4]; SAFIYE PINAR TUNALI [5]; ZUHAL ERTÜRK [6]; CUNEYT ULGEN [7]; ANIL ALTUG PEK [7]

[1] International Agricultural Research and Training Center, İzmir, Turkey
[2] Adnan Menderes University, Faculty of Agriculture, Department of Plant Protection, Aydin
[3] Ege University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Izmir
[4] Ege University, Faculty of Agriculture, Department of Plant Protection, Izmir
[5] Adnan Menderes University, Faculty of Agriculture, Department of Biosystems Engineering, Aydin
[6] Adnan Menderes University, Graduate School of Natural and Applied Sciences, Aydın
[7] Agro Teknik Agricultural Consulting Company, Adana, Turkey

Oral

Amaranthus palmeri is an important weed occurring in some groves, non-agricultural areas as well as field crops in some regions of Turkey. Since it is newly introduced to Turkish flora, there is no information about the potential losses in crops due to competition. Therefore, these studies were carried out to investigate potential competitive ability of this weed with cotton and corn. In pot experiments conducted two seasons, crops (corn or cotton)-*A. palmeri* competition was investigated either at early timing (seeding weed along with crop seed) or later (~one month after crop sowing) at 3 different *A. palmeri* densities (1, 2 and 4 per pot). To evaluate competitiveness, single crop growing without *A. palmeri* and single *A. palmeri* growing without crop were included in to the experiments. Plant heights (weekly), fresh and dry weights (after 5-9 weeks) were recorded. Data were subjected to ANOVA and means were separated using Duncan Test. Depending on density, early competition caused significant reduction in cotton height (34.8-52.9%), fresh (80.7-94.8%) and dry (80.2-91.2%) weights in both years; while late competition decreased same parameters significantly only in first year by 10.1-22.3%, 37-44.3% and 36.6-40.2%, respectively. In the case of corn, decreases in height (20.0-33.6%), fresh (63.9-79.1%) and dry (46.1-77.2%) weights were significant at early competition only in first year. In late competition, except corn height in second year (with 3.2-8.1% reduction only in 2 and 4 *A. palmeri* densities) all parameters were insignificant. Mean height, fresh and dry weight of single *A. palmeri* was not significantly reduced under early interference in both years, but mean *A. palmeri* parameters were significantly reduced at 2 and 4 densities due to intraspesific competition. In the late competition all parameters were significantly reduced regardless of the *A.palmeri* density. Mean height, fresh and dry weights of an one *A. palmeri* was decreased by 0-78.2%, 5-97.2% and 3.3-89.2% in cotton and 2.7-89.5%, 21.2-96.2% and 26.6-95.8% in corn interference, respectively. Results showed that corn is more competitive than cotton against *A. palmeri*. Due to intraspecific competition, a significant reduction in heights, fresh and dry weights of crops were not observed as *A. palmeri* density increased. *A. palmeri* competition reduced the growth parameters of both crops significantly, especially at earlier stages. Therefore, an effective control strategy should be developed to prevent yield losses.

IF1 recognition from broomrapes triggers typical plant immune responses including ethylene and reactive oxygen species (ROS) production in tomato plants

Mouna Khalloufi[1], Isabell Albert[1], Markus Albert[1]

[1] *Friedrich-Alexander-Universität Erlangen-Nürnberg, Department of Biology, Molecular Plant Physiology (MPP), Staudtstr. 5, 91058 Erlangen, Germany*

Poster

Plants resist attacks by pathogens via innate immune responses, which are initiated by cell surface-localized pattern-recognition receptors (PRRs) and intracellular nucleotide-binding domain leucine-rich repeat containing receptors (NLRs) leading to pattern-triggered immunity (PTI) and effector-triggered immunity (ETI), respectively. PTI signalling is activated upon direct recognition of PAMPs (pathogen-associated molecular patterns) or DAMPs (damage-associated molecular patterns) by PRRs. To gain insights about the resistance mechanisms depending on *Phelipanche* derived PAMPs that can be perceived by tomato receptors, we obtained an IF1 (the translation initiation factor 1) homolog of *P. ramosa* mitochondria that can act as a *P. ramosa* PAMP. We cloned the gene with a c-terminal His-tag for protein purification and tested the *P. ramosa* IF1 protein on a collection of plants for the capability to trigger typical plant immune responses including the production of ethylene and reactive oxygen species (ROS); *S. pennellii*, *S. lycopersicum* and some introgression lines of *S. lycopersicum* x *S. pennellii* showed resistance responses when inoculated with *P. ramosa* or treated with extracts thereof. The results showed that *P. ramosa* IF1 triggers PAMP responses in *S. lycopersicum*, measurable as ROS- and ethylene responses but not in *S. pennellii*, and two tomato introgression lines (ILs). Therefore, a receptor should be present in *S. lycpersicum,* which gene has been mapped to a defined chromosome region. However, its identity is yet unknown and has to be clarified.

Keywords: IF1 homolog of P. ramosa, Phelipanche PAMP-perception, ethylene, reactive oxygen species (ROS), resistance mechanism.

Weed – crop competition is influenced by soil characteristics

Bàrbara Baraibar; Clàudia Canadell; Jordi Recasens

University of Lleida, Lleida, Spain

Poster

The resource pool diversity hypothesis (RPDH) posits that diversified agricultural systems that include crop rotations, green manure and organic fertilizers have a greater diversity of resource pools that can alleviate the competition between weeds and crops. Organic systems are usually more diversified than conventional ones but soil, crop and fertility management may ultimately determine the diversity of resource pools. In this experiment, maize (*Zea mays*) and palmer amaranth (*Amaranthus palmeri*)were grown in monoculture and in competition in soils from three organic and three conventional farms. A replacement series design with proportions of maize and *A. palmeri* of 0:1, 0.25: 0.75, 0.5:0.5, 0.75:0.25 and 1:0 were used. Four maize plants and 36 palmer amaranth plants were used in the monoculture treatments. Half of the pots received an organic-mineral fertilizer allowed in organic agriculture (F) and the other half did not (NF). Aerial biomass of all plants was collected after allowing the plants to grow for 8 weeks in pots and were dried and weighed. Relative yields (RY) for corn and *A. palmeri* as well as relative yield of the mixture (RYM) were calculated. RY equals one when competition is symmetric between the two species, when RY>1, one species is a better competitor than the other and RY <1, that species competes worse than expected. RYM>1 would be a sign of resource partitioning or overyielding. Corn in monoculture accumulated more biomass when grown in organic soils and weight of *A. palmeri* did not differ between systems but was significantly higher with fertilization. RY of corn and *A. palmeri* did not differ between systems. RY of corn equaled one in all systems while RY of *A. palmeri* was higher than one in F treatments and in organic NF fields. In NF conventional fields it was equal to one. RYM did not differ between systems or fertilizer treatments but it was higher than one in NF organic fields. There was a lot of variability in weed and crop growth across fields.Our results do not provide conclusive support for the RPDH buthighlight that soil can alter crop – weed competition. *A. palmeri* was more competitive than corn in two fields (one organic, one conventional), especially when fertilizer was applied. The availability of specific nutrients such as phosphor, could explain the better competitive ability of *A. palmeri* in those fields. A more specific definition of resource pools and its relation with edaphic fields characteristics is needed in order to better understand weed – crop competition.

Keywords: *Corn, Amaranthus palmeri, organic, conventional, Relative Yield*

Shade induced by weed interference hindered soybean growth and yield

D.S. Kim; J.A. Yoo; S.H. Lim; S.M. Han; J.E. Lee

Seoul National University, Seoul, Korea South

Poster

Weed interference affects crop growth and thus results in yield loss. Many efforts have been made to quantify the effects of weed interference on crop yield to establish an economic threshold, a key weed density for decision-making of weed control action. However, little effort has been made to understand ecologic and physiologic interaction between crops and weeds in their close vicinity. We conducted a field trial to understand the competition effects of velvetleaf (*Abutilon theophrasti*) and speen amaranth (*Amaranthus patulus*) on hindering soybean growth and yield with emphasis on light competition. Soybean and weed seeds were sown on June 10, 2021, and the weed plants were then thinned to 0, 2, 8, 32, and 128 plants/m^2. Plant growth of soybean and the weeds were assessed periodically until harvest in November. Photosynthetically active radiation (PAR) and the intensities of blue, red, and far red lights were measured along plant canopy during active vegetative growth stage. Decreased light transmittance into soybean canopy was observed with increasing weed density, resulting in lower PAR, blue and red light but greater far red light. The decreased light transmittance was greater in velvetleaf than speen amaranth. The number of soybean branches was decreased with increasing weed density and the decrease was greater in velvetleaf than speen amaranth. The close relationship between decreased number of soybean branches with decreased PAR, blue light and red/far red ratio in soybean canopy clearly demonstrate the effect of light competition of weeds on soybean growth, particularly stem elongation and branch formation. The greater light interception by velvetleaf canopy than speen amaranth canopy caused lower blue light and red/far red ratio, which induced stem elongation and hindered branch formation. Soybean yield was more significantly reduced with increased plant density of velvetleaf than speen amaranth. Non-linear regression analysis by fitting the rectangular hyperbolic model to soybean yields observed at a range of weed densities revealed greater competitiveness of velvetleaf (b=0.3625) than that of speen amaranth (b=0.019). Our findings suggest that faster weed canopy growth results in shading of the crop and thus affects crop growth, particularly stem and branch growth, and yield.

Camelina (*Camelina sativa* (L.) Crantz) as a tool for supressing winter weeds: corn poppy (Papaver rhoeas L.) as a weed model

Noemí Codina-Pascual; Aritz Royo-Esnal

Universitat de Lleida-Agrotecnio, Lleida, Spain

Poster

Camelina sativa (L.) Crantz is a useful oilseed crop, valuable for its agronomical and industrial characteristics. Its drought tolerance and its capacity to adapt to marginal areas make it with an interesting potential crop to be introduced in crop rotation in semiarid areas, such as the Ebro basin in North-Eastern Spain, where crop diversity is limited. As crop rotation is an essential tool for Integrated Weed Management (IWM), camelina would offer an alternative to diversify crop rotation in these areas. The objective of the present work was to study the capacity of camelina to reduce the growth and reproduction of corn poppy (*Papaver rhoeas* L.). An experiment was set at the University of Lleida during three seasons, 2018-19, 2019-20, 2020-21, in plots of 1.5 x 10 m^2, with three replicates. Camelina (*GP204, Sonny* and *Joelle*) and barley (*Meseta)* were sown in the second half of November each year, at 8 kg ha^{-1} (*GP204* and *Sonny*), 6 kg ha^{-1} (*Joelle*), and 200 kg/ha (barley). In each plot, three 0.5 x 0.5 m^2 quadrates were placed where only five corn poppy were allowed to grow. Controls without the crop were left nearby the plots. The previous day to harvest, weed individuals were removed, brought to the laboratory, and fitness parameters were measured: height, number of branches, vegetative and reproductive biomass, number of ripe and unripe capsules (including flowers), and number of seeds per capsule. Climatic conditions affected the crop's growth, hence, their competitiveness, being similar for camelina and barley in 2018-19, greater for barley in 2019-2020, and for camelina in 2020-21. Despite these results, the shorter life cycle of camelina permitted its harvest some weeks before barley, reducing the number of ripe capsules, and consequently, the number of seeds produced per plant and the seed rain. With camelina, the potential seed production of corn poppy was reduced by 34% in 2018-19, 52% in 2019-20 and 70% in 2020-21, while with barley this reduction was of 23% and of 56% in 2018-19 and 2020-21, respectively, while no seed rain reduction was observed in 2019-20. The reduction of the weed growth and of its reproductive capacity with camelina provide an interesting scenario for use its implementation in rotation with winter cereal to enhance IWM options against winter weeds.

Keywords: *corn poppy, crop-weed competition, crop rotation, Integrated Weed Management, oilseed crop*

The effect of extracts of different parts of waxy leaved mustard (*Boreava orientalis*) on wheat germination

Taiebeh Adeli; Iraj Tahmasebi; Sirwan Babaei

University of Kurdistan, Sanandaj, Iran

Poster

Waxy leaved mustard (Brassicaceae) in scientific name (*Boreava orientalis* Jaub&Spach) has recently been reported as an alien invasive crop weed in Kurdistan Province, Iran. In order to investigate the effect of allopathic substances of waxy leaved mustard on wheat germination, we conducted laboratory experiment in 2019-2020 in the Faculty of Agriculture, Department of Agronomy and plant breeding, in the laboratory in factorial format based on a completely randomized block design with four replications. Experimental factors included concentrations of extracts of 4 plants (inflorescences, stems, leaves and roots) at 5 levels (0% i.e. control, 1%, 2%, 3% and 4%) . The studied traits included the main germination traits which include germination percentage, germination rate and seed vigor index. Data were analyzed using SAS software (v.8) and LSD test (5%) and graphs were drawn using Sigma plot software (v.12). The highest germination percentage was related to the control treatment which was 73.5% and the lowest germination percentage was 7% which was related to the concentration of 4% plant extract from the inflorescence of the plant (α=0.05). The highest value of germination rate is 32.82 which is a control treatment and the lowest value of germination rate is 2.78 which was obtained with a concentration of 4% of inflorescence extract (α=0.05). The highest value of seedling vigor index was 16.68 which is the control treatment and the lowest value for the treatment of 4% inflorescence extract was 0.075(α=0.05). The results showed that with increasing the concentration of plant extracts, germination indices decrease. Allelopathic substances in waxy leaved mustard plant must be more in the inflorescence and leaf part of the plant than in other parts.

Keywords: *Allelopathy, germination, invasive weed, waxy leaved mustard*

Studies on crop-weed competition in spring fodder legumes in Greece.

M. Gerakari [1]; D. Chachalis [2]; E. Sarri [1]; G. Mohammadi [3]; E. Tani [1]; E. Abraham [4]

[1] *Laboratory of Plant Breeding and Biometry, Agricultural University of Athens, Athens, Greece*
[2] *Laboratory of Weed Science, Benaki Phytopathological Institute, Kifisia, Greece*
[3] *AGROLAND S.A. COMPANY, Karditsa, Greece*
[4] *Laboratory of Range Science, Department of Forestry & Natural Environment, Aristotle University of Thessaloniki, Thessaloniki, Greece*

Poster

Fodder legumes are important crops for animal's nutrition and would represent an important source of alternative to soybean proteins. Although a lot of research is done related to grain legumes for human consumption, a limited number of publications exist as forage crops, particularly in the Mediterranean conditions. One of the most critical aspects to determine their potential utilization and expansion is weed management. In order to understand, the crop: weed competition, data from specific field trials are needed. The three fodder legume species (pea, faba bean, vetch), were sown in spring (pea & faba beans: 22/04/2020; vetch: 03/04/2020), in Spata, near Athens, Greece. At three intervals (3, 6 and 9 weeks after sowing, WAS), the weeds were either removed mechanically or not from each plot and growth measurements (plants' dry weight) of both crop plants and weeds were done; final crop yields were also taken. The aim of the present study was to investigate at which particular period, the absence/presence of the weeds had the greatest effect on both growth and yields. In general, results indicated three major points: a) most of the differences (either growth or yields) were mostly related to the overall presence or absence of weeds in most of the intervals; b) differential response of the fodder legumes were measured, and c) the yields were more affected compared to the growth by the presence/absence of the weeds. For example, in vetch (the most competitive species for plant growth), at 9WAS, the continuous presence of the weeds had little effect compared to the continuous absence (0.95g vs. 2.3g, respectively). In contrast, pea was the least competitive species (8.5g vs. 31.1g), for the same treatments, as the presence of weeds, in the period from 3 to 6 WAS, reduced drastically the dry weight of the plants. Faba beans had similar trends with vetch in both growth and yields in the same treatments (8.4g vs. 13.3g), as mentioned above. Results from these studies, would provide needed data from field trials to enhance the spread of fodder grain legumes in Greece.

Keywords: *crop-weed competition; fodder legumes; weed flora; dry weight (d.wt); yield*

Winter wheat (Triticum aestivum L.) assessment of weed competitive ability using weed competitor and naturally weed-infested method

Aleš Kolmanic [1]; Andrej Zemljič [1]; Matej Knapič [2]; Andrej Vončina [2]; Uroš Žibrat [2]; Vladimir Meglič [1]

1 Agricultural Institute of Slovenia, Crop science department, Ljubljana, Slovenia
2 Agricultural Institute of Slovenia, Plant protection department, Ljubljana, Slovenia

Poster

Selection of wheat cultivars for competitive ability against weeds requires identification of relevant traits and development of procedures to measure/estimate them. Three separate trials, i.e. weed-free trial (weeds eliminated with the use of herbicides), weed competitor trial (barley used as the weed and weeds eliminated with the herbicide), and naturally weed-infested trial (no weed management applied) were established with 12 wheat cultivars in growing seasons 2019/2020 and 2020/2021 to study traits contributing to weed competitive ability. Traits were scored using classical phenotyping (field measurements) and multispectral sensing tools at different growing stages of wheat. Traits scored were wheat/weed soil cover, biomass, height, and number of plants; number, square surface, and dry weight of leaves, wheat growth type, grain yield, grain moisture, and thousand kernel weights. Field scorings and spectral signatures of cultivars were recorded at booting, heading, anthesis, and ripening growth stages. The results indicate correlations between the weed suppression ability of wheat cultivars and measured traits. Using classical phenotyping, cultivars with better weed suppression and traits that affected weed competitive ability could be identified. The weed competitor method was more reliable for evaluating the weed competitive ability of wheat and showed smaller variation compared to naturally weeded trials. The number of weed competitor plants correlated strongly and negatively with wheat height and wheat biomass, while the dry biomass of weed competitor correlated strongly and positively with the number of competitor plants and negatively with the wheat biomass and wheat height. On the contrary, only weak to moderate correlations were observed between soil cover and number of wheat leaves or LAI and weed number/biomass regardless of the wheat growth stage. Analysis of multispectral data by comparing weed biomass and Optimized Soil Adjusted Vegetation index (OSAVI) showed significant differences; however, $r2$ values show only weak relationships. Results indicate that the weed competitive ability of wheat cultivars differs. Rather than being attributed to a single trait, competitive ability encompasses a combination of different traits. Based on the dry biomass of weed competitor, tested varieties can be grouped into varieties with good weed competitive ability (Primorka, Marinka, Bernstein, and Vulkan); varieties with moderate weed competitive ability (Izalco CS, Savinja, Illico, Alixan, Gorolka, Reska); and varieties with low weed competitive ability (CCB Ingenio, Tata Mata).

Keywords: *winter wheat, weed competitiveness, traits, classical phenotyping, advance phenotyping, spectral signatures*

SESSION III

SITE SPECIFIC WEED MANAGEMENT

Hyperspectral imaging facilitates early recognition of Orobanche cumana below-ground parasitism on sunflower under field conditions

Guy Atsmon; Hanan Eizenberg; Ran Lati

Newe Ya'ar Research Center, Agricultural Research Center , Department of Phytopathology and Weed Research, Ramat Yishai, Israel, Ramat Yishai, Israel

Oral

Sunflower broomrape (Orobanche cumana) is a root parasitic weed that limits sunflower yield in large areas of Europe and Asia. Early detection of the parasite can facilitate site-specific control of this weed. However, most of its life-cycle takes place in the soil sub-surface and by the time that O. cumana shoots emerge, the damage to the crop is irreversible. The main aim of our study is to evaluate the potential use of hyperspectral imaging for the early detection of parasitism by monitoring changes in spectra of the host plants. A field experiment was conducted on infested and non-infested sunflower plants, imaged by a ground-based hyperspectral camera in two early parasitism stages that are relevant for herbicide application. A logistic regression model was used to classify infected and non-infected plants, at early sub-surface parasitism stages, 31 and 38 days after sunflower planting, with 76 and 89% accuracy, respectively. A partial dataset, containing only 10 spectral bands of the hyperspectral dataset gave 73 to 82% accuracy, suggesting the potential of multi-spectral sensors for the detection task. Sampling pixels from specific sunflower leaf segments improved the classification compared to non-specific sampling. This study thus contributes to establishing a basis for future development of site-specific weed management of O. cumana as well as of other broomrape species.

10 years of UAV technology for weed mapping: overview and future trends for site-specific weed management

Jose M. Peña [1]; Ana I. de Castro [2]; Gustavo A. Mesias-Ruiz [1]; Cesar Fernandez-Quintanilla [1]; Jose Dorado [1]

[1] *Institute of Agricultural Sciences - Spanish National Research Council (ICA-CSIC), Madrid, Spain*
[2] *National Agricultural and Food Research and Technology Institute – Spanish National Research Council (INIA-CSIC), Madrid, Spain*

Keynote

About 10 years ago, the first scientific papers on the use of Unmanned Aerial Vehicle (UAV), popularly known as drones, for weed detection and mapping in agricultural fields were published. Those papers focused mainly on arable crops such as soybean, maize, sunflower or barley, and on a single target class -weeds- without distinction of the weed species, pointing to the high potential of the UAVs to implement site-specific weed management (SSWM). Nowadays, the range of weed-crop situations studied with UAV technology also includes other arable crops (e.g. wheat, rice, sugar beet, tomato), woody crops (e.g. olive trees, vineyard, almond trees, citrus) and even grazed pastures. Moreover, the UAVs have already been applied to detect certain weed species, as in the case of *Alopecurus myosuroides, Amaranthus palmeri, Avena sterilis, Cirsium arvense, Cynodon dactylon, Pennisetum alopecuoides, Euphorbia esula, Lolium perenne, Papaver rhoeas, Silybum marianum, Sorghum halepense, Xanthium strumarium*, among others. In comparison to other conventional remote-sensing platforms (i.e. aircraft and satellites), the UAVs have several advantages to achieve successful weed detection in different scenarios: 1) they can flight at low altitude and provide ultra-high spatial resolution imagery (i.e. pixels of 1-3 cm, or even smaller), 2) they can be operated on demand according to critical vegetation stages, even on cloudy days, 3) they can use diverse sensors and perception systems (visible, infrared, thermal), and 4) their overlapping images can be used to generate crop digital surface models (DSMs) and compute 3D variables of the crop and weed plants. However, the large amount of data provided by the UAVs faces the bottleneck of the analyzing phase, i.e. obtaining the weed information by a proper, efficient and automatic process. Conventional methods are based on spectral discrimination and the application of pixel-based image analysis algorithms, although these methods are constrained by specific conditions (e.g. different phenology stage of the weed and crop plants). The up-to-date analysis alternatives are advanced procedures such as the object-based image analysis (OBIA) paradigm, computer vision techniques, and machine and deep learning (ML/DL) algorithms. These procedures are further exploiting the information on the UAV images, providing automatic extraction of the best features to identify the weed species in diverse crop scenarios, thus enabling to create weed classifiers, weed datasets and weed maps much more efficient and accurate than traditional analysis methods, which will allow UAV technology to add value for effective application of SSWM operations.

Keywords: *drone, machine learning, SSWM, weed maps, remote sensing*

Which interpolation method most accurately estimates weed distribution for site-specific weed control?

Mona Schatke [1]; Christoph von Redwitz [1]; Christoph Kämpfer [1]; Jana Wäldchen [2]; Lena Ulber [1]

[1] *Julius Kuehn-Institut (JKI), Institute for Crop Protection in Field Crops and Grassland, Braunschweig, Germany*
[2] *Max Planck Institute for Biogeochemistry, Department of Biogeochemical Integration, Jena, Germany*

Oral

Site-specific weed management has become increasingly popular in the recent years and has been shown to be a suitable method for reducing herbicide inputs in arable cropping systems. One challenge of precision herbicide application is to map the spatial distributions of weed species adequately without conducting a field-wide weed assessment. Potentially, this can be done by help of Unmanned Aircraft Systems (UAS)-based tools and geospatial information technology or by manually collected data on weed distribution. For both approaches, the first step in creating a spatial weed distribution map is to determine the percentage cover or number of individuals per weed species at pre-defined and georeferenced grid points. Yet, these methods leave a large part of the field uncovered. The second step therefore requires an automated interpolation procedure for estimating the weed distribution in the spaces between the spatially referenced sampling points. For an efficient site-specific weed management with maximized precision of herbicide application, the performance of the interpolation method is key for the generation of accurate weed maps. In this study, we compare the performances of three popular interpolation models in the area of weed mapping. The first interpolation method is based on distance weighting (Inverse Distance Weighted). Second is a geostatistical approach (Kriging) where the spatial variation of the measured values is expressed in a variogram and is based on the lowest estimation error. In the third method, the surface is divided into Voronoi diagrams and weights are assigned (natural neighborhood interpolation). For the comparison of the three methods, a dataset on the distribution of all species present in a winter wheat field was employed. The data set was based on weed occurrence data manually collected in early spring using a 12 x 12m grid and 78 sampling points. A cross-validation was used for the evaluation of the results, based on a random separation into 'test' and 'training' data. The interpolation procedure was performed using the 'training' data subset and the results were compared with the retained 'test' values. The results of this study demonstrate the required amount of point information needed to produce accurate weed distribution maps for individual weed species. Conventional interpolation methods appear to be sensitive enough to sufficiently map the exiting distribution of weeds on the study field. Furthermore, the results reveal which interpolation method best estimates the actual weed distribution.

Keywords: *Precision Farming, Site-specific weed control, interpolation, weed distribution*

Spatial-temporal aspects of weeds distribution within fields and orchards

Lior Blank [1]**;** Gal Rozenberg [2]; Nitzan Birger [3]

[1] Volcani Centet, Rishon LeZion, Israel
[2] Technion – Israel Institute of Technology, Haifa, Israel
[3] The Hebrew University of Jerusalem, Rehovot, Israel

Oral

Optimizing weed management can result from a better understanding of the spatial distribution and temporal dynamics of weed patches. Compared to the relatively well-studied spatial aspects of weeds in agricultural fields, temporal aspects, which require data collection in subsequent years, have got little attention. Information on the temporal dynamics of patches can be used to direct preemergence herbicide treatments when no visual information is available in the field. In this aspect, the spatial distribution of weeds from one year could serve as a basis for making spraying decisions in the following year. Based on a literature review we conducted recently, 62% of studies focusing on the spatiotemporal distribution of weeds, lasted only 1-2 years with most fields sampled once within a season. The study of weed distribution over time cannot be conducted within such a short timeframe. Only 8% of the studies exceeded five years. Despite the general tendency for species to aggregate, we found that a few species had contrasting spatial patterns between studies, highlighting the need to better understand the conditions affecting weed spatiotemporal dynamics. In this overview, we report findings from three studies. In a study of 11 commercial dry onion (*Allium cepa* L.) fields, we found that weed species communities (including both annuals and perennials) tended to cluster. In another study, we examined the temporal stability of *Ecballium elaterium* (a perennial) patches, in four commercial almond orchards. We found that the location of these patches remained constant throughout the three-years study period. The third study examined the spatial distribution and the temporal dynamics of weeds in ten no-till plots, and compared between winter cover crops and conventionally managed experimental plots of corn. We found that patch temporal stability was species-specific and varied across treatments. To maintain high yields, herbicides are essential, but their use should be optimized. Weed management can be improved by understanding the spatial interactions and feedbacks between weeds and their environment at the field scale.

Keywords: *SSWM*

Enhanced intra-row weed control using bi-directional camera-guided hoeing in maize

Georg-Peter Naruhn [1]; Kurt Möller [2]; Gerassimos Peteinatos [1]; Roland Gerhards [1]

1 University of Hohenheim/ Institute of Phytomedicine/ Department of Weed Science, Stuttgart, Germany; 2 Center for Agricultural Technology Augustenberg (LTZ)/ Department of Applied Crop Science, Karlsruhe, Germany

Oral

In the inter-row area mechanical weed control efficacy up to 90% and more can be achieved, which is comparable to herbicide efficacy. In the intra-row area only 65-75% is currently possible. To close this gap, a new cultivation methodology has been proposed and investigated, where mechanical weed control also can be applied in the intra-row area. A square crop pattern of 37.5 x 37.5 cm was established in maize by using a GPS-based pneumatic precision seeder, to enable mechanical weed control both lengthwise and transverse to the sowing direction. The experiment was carried out as a randomized split-plot design with three different hoeing treatments in South-Western Germany (Rheinstetten-Forchheim). For all three hoeing treatments, a camera-guided hoe equipped with goosefoot blades, down-cut side knives, and cutting protection discs was used at the 4-5 leaf growth stage of the maize plants. The camera-guided hoe was used in three different ways: (1) Bi-directional use (i. e. both along and transverse to sowing direction), (2) Lengthwise (i. e. the conventional way only along the sowing direction), (3) Transverse use (i. e. only across the sowing direction). As a reference, all treatments were compared to an untreated control. For the evaluation, the weed densities of the inter-row and the intra-row area, and the area of 5 x 5 cm around the maize plants were measured and the weed control efficacy (WCE) was calculated. Additionally, the crop density and the crop plant losses, the growth and vitality of the cultivated plants as well as the biomass development of crops and weeds were recorded. The average weed density in the untreated control plots three days after hoeing was 267 weeds·m^{-2} in the inter-row area, 283 weeds·m^{-2} in the intra-row area and 280 weeds·m^{-2} in total. In terms of total weed infestation, *Chenopodium album L.* (34%), *Echinochloa crus-galli L.* (31%) and *Amaranthus retroflexus L.* (15%) were the three most abundant species detected. Regarding the WCE, in total, the bi-directional hoeing treatment (91%) increased the performance compared to the lengthwise variant (87%) by 4 % and to the transverse treatment (73%) by 18%. While the WCE in the inter-row area for bi-directional hoeing (95%) was at a similar level to the lengthwise (100%), the WCE in the intra-row area could be more than doubled (bi-directional 86%, lengthwise 42%). Despite the fact that the plant losses in bi-directional treatments were much higher compared to lengthwise hoeing, the maize dry mass was not significantly affected (bi-directional 208 g·m^{-2}, lengthwise 193 g·m^{-2}). The results have shown, that the bi-directional hoeing technique offers a high potential to reduce the weed density especially in the intra-row area, and is simultaneously able to increase the maize dry mass compared to the ¨conventional¨ method of hoeing only in the sowing direction. It should be noted though that this bi-directional hoeing technique could be achieved with the appropriate seeder. To reduce the high plant losses caused by the bi-directional hoeing treatments, different types of implements and machine settings should be tested to improve the seeding procedure and to ensure stable crop yields.

A method for online separation of alfalfa seeds from weeds (*Cuscuta ssp.*)

C.N. Kasimatis [1]; G.G Peteinatos [2]; N Katsenios [1]; K Ferentinos [2]; D Leonidakis [3]; A Efthimiadou [1]

[1] *Department of Soil Science of Athens, Institute of Soil and Water Resources, Hellenic Agricultural Organization-Demeter, Sofokli Venizelou 1, Lycovrissi, 14123 Attica, Greece*

[2] *Hellenic Agricultural Organization "Demeter", Institute of Soil & Water Resources, Dept. of Agricultural Engineering, 61 Dimokratias Av., 13561 Athens, Greece*

[3] *Farmacon G.P., K. Therimioti 25, Giannouli, Larisa, 41500 Thessaly, Greece*

Oral

Alfalfa is a strategic widespread crop. In order to reduce the weed population in the field it is important to eliminate the weed infestation sources. Weed seeds, mixed with the crop seeds can be a source of such infestation. *Cuscuta* spp. are weeds harmful to alfalfa crops. Since the two seeds are similar, it is difficult for the farmer to separate the different seed types. Computer vision and Artificial intelligence can be used for such a task. In the current work, two different methods were examined for their capabilities of fast identifying and separating between the two plant seeds. Shape analysis and recognition along with Artificial Neural Networks (ANNs) were examined for their discrimination accuracy, and speed. Photographs of each seed type were taken with Canon EOS 90D (F=5.6, 0.01 sec and 34 mm total length) and a dataset of 500 photos from each seed type was created. Photos were taken in the laboratory but with various light conditions in order to improve the predicting accuracy of our model. During the procedure, an image with 100 seeds placed in a 10x10 grid, and a non reflective gray background were used, having 1 cm space between each. All different angles and placements of the seeds were considered, thought there was no seed overlapping. Three methods were evaluated. The first method was shape recognition and segmentation. The second method were Neural Networks, such as ResNet and Xception. The final method was YOLOv3, which is a single neural network applied to the whole image. This neural network predicts the bounding boxes and the classification probabilities of each one. All three methods were able to identify and separate between the two seed types. For each of these methods, we found the advantages and disadvantages. Shape recognition can be a powerful tool for recognizing and segmenting objects, with low needs on processing power, yet it lacks in accuracy and needs a high Signal to Noise Ratio. Neural Networks on the other hand can be more accurate and robust, but need higher processing power and resources. Furthermore, training these models can be a lengthy process. In addition, the slow processing speed still prevent them operational for fast real-time applications. YOLOv3 appeared to be three times faster than the previous methods with high accuracies. However, it presented higher positioning errors because of the low Average Precision scores. Therefore we can conclude that seeds from *Cuscuta* spp.and alfalfa could be separated in high resolution images with shape recognition being the fastest method, ANNs the more precise, while YOLOv3 being a good trade-off between speed and accuracy.

Monitoring patch size changes of the creeping perennial Cirsium arvense to evaluate the efficiency of control treatments

Marian Weigel [1]; Sabine Andert [2]; Bärbel Gerowitt [2]

[1] *University of Rostock, Faculty of Agricultural and Environmental Sciences, Crop Health, Rostock, Germany, Rostock, Germany*
[2] *University of Rostock, Faculty of Agricultural and Environmental Sciences, Crop Health, Rostock, Germany, , Unknown*

Oral

In arable fields, the creeping perennial weed species *Cirsium arvense* occurs in patches. Expanding creeping roots together with shoots arising from this clonal growth allow these patches to increase in size. Though well known, this characteristic of a creeping perennial has rarely been addressed when investigating the efficacy of control options. Common field experiments are designed with a fixed plot size for the treatments, which are systematically located but without accounting for existing patches. The drawback arising from this feature is that plots dividing patches allow creeping weeds to compensate easily between the plots. To overcome this, we designed a field experiment, accounting for existing patch patterns. Instead of using fixed plots with the same size, we used individual patches as individual plots. On the expense of an accurate, spatially arranged design, the spatial coordinates of the plots were defined by the species growth pattern. Consequently, initial plot size differed. The experiment took place on a conventional managed field close to Rostock in Northern-Germany from July 2019 – July 2021. In summer 2019, before the actual experiment started, each patch was determined via GPS (Pentax-GNSS, Getac-PocketPC, Spatial accuracy = 10 cm) on the ground and mapped using UAV in order to determine the initial aerial expansion. In the following two years of spring wheat cropping, we applied different control treatments: mouldboard ploughing in spring, white mustard as cover crop, and root cutting (prototype Kverneland) in autumn and spring. In addition to shoot density and height of the thistles, we monitored the aerial thistle patch expansion, hence, the response in the aerial patch expansion during the two-year experiment. The undisturbed control patches increased in size at the highest rate (plus ~180 %) whereas all treated patches decreased in size over the two-year experimental period. Significant differences of aerial expansion rates between 2019 and 2021 (treatment compared to control) appeared for all treatments. Combining all three methods (mouldboard ploughing with root cutting and cover crop) resulted in the greatest patch size reduction (minus ~93 %). Significant differences in patch size depending on the used treatments underline the importance of expansion measurements when creeping perennial weeds are in focus. This method offers the opportunity to analyse and rank different treatments while taking care of the biology of the species. Our future work focuses on merging changes in spatial expansion, shoot density and other relevant traits to one single parameter reflecting the efficacy of the treatment.

Effect of sprayer section control widths and spatial weed distribution on potential herbicide savings using aerial mapping at single plant level

Robin Mink [1]; Lukáš Kovařík [1]; Moritz Roth [1]; Michael Cramer [2]; Alexander ingo Linn [1]

[1] *SAM-DIMENSION UG, Stuttgart, Germany*
[2] *University of Stuttgart, Institute for Photogrammetry, Stuttgart, Germany*

Oral

The unspecific extensive use of herbicides for weed control has been outdated for years. Nowadays, new technical solutions such as unmanned aerial vehicle based mapping, on-line detection of weeds using field sprayer-based cameras, and increasingly smaller section control systems enable highly precise weed control at plant level. To save costs and time, a high-speed camera aerial mapping system has been developed for full-scale aerial mapping of entire field areas at the individual plant level. This enabled a complete overview of the weed distribution without interpolation between sampling points. A pre-trained convolutional neural network (CNN) was used to analyse the data, which classified the RGB aerial images into the categories of background/crop /weed. The aim of the study was to analyse the impact of different section control systems of current field sprayers on the savings potential depending on the spatial weed distribution. Therefore, field surveys were carried out in North Rhine-Westphalia, Lower Saxony, Saxony-Anhalt in Germany and in the Central Bohemian Region in the Czech Republic in sugar beet and maize from the first until up to four post-emergence weed control measures. The surveys were conducted in the vegetation seasons 2020 and 2021 at a Ground Sampling Distance (GSD) of 1 mm pixel, which allowed the CNN for a reliable plant identification starting from the cotyledon stage. The mapping was followed by precision weed control by field sprayers with single nozzle control (25 and 50 cm nozzle distance). The data set from the aerial survey was further used to perform a spraying simulation based on the geospatial weed positions. For this purpose, spraying passes were simulated with three sprayer section control widths of 25, 50 and 100 cm. The herbicide savings of the different sections differed by 4-9% if only the cell width was increased. If the cell sizes were additionally increased in their length (25x25, 50x50 and 100x100 cm cell size) due to varied travelling speed, herbicide savings were more than 10% lower. Over the course of the consecutive herbicide treatments, the herbicide savings were increased from 19% in the first post-emergence treatment to 82% at the third post-emergence treatment, calculated with a 25x25 cm section control width. Processing problems could be especially observed for field sizes >5 ha. In the course of the surveys, however, improvements were made to the processing software on the sprayers. The tests have shown the possibility of accurate weed control at single-plant level by aerial mapping. Small section control units can still enable high herbicide savings, at higher weed densities.

Keywords: *aerial weed mapping; AI weed detection; herbicide application maps; herbicide reduction; single-plant specific mapping; spot-spraying*

Implementing image vision for real-time weed management with the aid of ISOBUS

Gerassimos G Peteinatos [1]; Dionisio Andujar [1]; Manuel Perez - Ruiz [2];
Sara Esparza Sengáriz [3]; Roland Gerhards [4]

[1] *Centre for Automation and Robotics, CSIC-UPM, Madrid, Spain*
[2] *Universidad de Sevilla, Sevilla, Spain*
[3] *Grupo AN, Navara, Spain*
[4] *Institute of Phytomedicine, Department of Weed Science, University of Hohenheim, Stuttgart, Germany*

Oral

The European Union through the Green Deal and the Farm to Fork Strategy aims at reducing the pesticide inputs. The increasing public concern about food security has reduced the consumer acceptance of chemical plant protection. For herbicide applications, Site Specific Weed Management (SSWM) can be achieved by applying a treatment only on the weed patches. Agricultural sprayers are already separating the boom into sections (2 – 6 m), while per nozzle section control has already been demonstrated and starts to be commercialized. Current tractors with the aid of ISOBUS can already achieve a certain level of site-specificity. In DACWEED, a project funded by the EIT Food and co-funded by the EU, a combination of novel components (sensors, algorithms and implements) that already exist on the market was implemented. In cereals like wheat, and row crops like maize, herbicides were applied site-specificaly, utilizing the typical boom section control. Sensor data deriving from platform mounted - cameras provided the input to a Neural Network in order to i) separate the viewed plants into crop plants and weeds and ii) based on that information make decisions that could be iii) actuated into actions through the ISOBUS to the relevant implements, e.g. sprayer on/off, hoe/harrow intensity manipulation. The integration of perception systems for the detection and control of action devices will allow a more exhaustive, and therefore effective, herbicide treatment reducing for example herbicide usage between 30 – 60%. The herbicide input can be reduced, leading to safer agricultural products for the consumer and the environment, and ensuring a more sustainable agriculture.

Keywords: *herbicides, ISOBUS, site-specific weed control*

Laser Weeding with an Autonomous Vehicle

Mahin Saberi; Christian Andreasen

University of Copenhagen, Copenhagen, Denmark

Poster

Herbicide application and mechanical weeding are the most common weed control methods worldwide. The use of herbicides has led to unwanted contamination of the environment and increasing occurrence of herbicide-resistant weeds. Mechanical weed control increases the degradation of organic matter, may dry out the soil, stimulate new cohorts of weed seeds to germinate and harms beneficial organisms. Therefore, there is a need to develop more sustainable weed control means. WeLASER is a European research project that aims to merge current technologies to build, assess and push into the market a precision weeding system based on high-power laser sources and autonomous mobile systems with the main objective of eliminating the use of herbicides while improving productivity and competitiveness. Artificial intelligence can identify and locate crop and weed plants, and laser beams deliver high-density energy, which can warm up weed tissue and kill or harm the plants. Given the targeted nature of laser beams, the area exposed for weed control can be reduced substantially compared to other weed control methods. The risk of affecting non-target organisms is low. However, small autonomous vehicles may have limited weeding capacity, and precautions need to be taken as reflections from the laser beam can also be harmful to humans and animals. Based on experience from the project, we present consideration about advantages and disadvantages of using laser technology for weed control.

Using RetinaNet One-Step Neural Network to classify weed species and maize in RGB images

J López Correa [1]; J López Correa [2]; A Ribeiro [2]; J Bengochea-Guevara [2]; Dionisio Andujar [3]

[1] *Centre for Automation and Robotics CSIC, Arganda del Rey (Madrid), Spain*
[2] *Centre for Automation and Robotics CSIC, , Unknown*
[3] *Centre for Automation and Robotics CSIC, Arganda del Rey, Spain*

Poster

Weed distribution varies along the fields. The use of mapping systems allows site-specific treatments with great herbicide savings. However, weeds grow fast and the gap between mapping and treatment creates some failures on the treatment. The use of sensor systems allows real-time site-specific treatments. The use of deep learning techniques based on Object Detection Networks have shown their potential for weed recognition. The current study proposes a detection and classification system of the weed species *Cyperus rotundus* L., *Echinochloa crus-galli* L., and *Solanum nigrum* L. at different growth stages, combined with crop plants (*Zea Mays* L.). All the images were collected on commercial fields under real uncontrolled illumination conditions. RBG images were acquired as two series with different sowing dates were selected such that the crops corresponded with V1 and V3 growth stages. A total of 312 images, each one containing a high number of single weeds, were taken. The present plant species were identified and manually labelled using LabelImg. 70% of the images were randomly taken to form the Training Set, with the remaining 30% being the Validation Set. A set of 74 smaller sub-images was generated for each full-image. 4368 training sub-images, 2181 validation sub-images and 1310 test sub-images were obtained. The detection and classification of weed species and growth stages were done through a one-step procedure using RetinaNet Object Detection Network. The RetinaNet archives discriminate between two growth stages both for a broadleaf species (*Solanum nigrum* L.) as well as narrow-leaved species (*Cyperus rotundus* L.). The average precision values varies from 0.75 for *Cyperus rotundus* L. to the highest for the maize plants of 0.97. The use of Object detection method shows promising results for its usage under real field conditions for Site-Specific Weed Management at different weed growth stages.

Keywords: *Deep Learning, Object Detection Networks, RetinaNet, SSWM*

Testing the performance of Smartphone Apps for Weed Identification

Lena Ulber; Christoph von Redwitz

Julius Kuehn-Institut (JKI), Institute for Crop Protection in Field Crops and Grassland, Braunschweig, Germany

Poster

To design sustainable weed management strategies, farmers and advisors should be able to identify the weed species present in agricultural fields. Due to the high number of different weed species and their highly specialized and diverse taxonomic characteristics, the identification of weed species by conventional means is a scientific and technical challenge. In recent years, research on the development of artificial intelligence (AI), especially image processing and pattern recognition techniques, have been introduced into the field of plant taxonomy and identification. Today, various mobile apps for plant identification are available. These apps utilize computer algorithms, artificial intelligence and crowdsourcing to validate an image taken with the mobile device. In this study, we evaluate six plant identification apps regarding their reliability and accuracy in identifying weed species commonly found in Central Europe. We concentrated our study on mobile apps that (a) are freely available for an unlimited number of identification per day without any required payments, (b) cover the flora of Central Europe and (c) can be used on devices running both on iOS and Android. To evaluate the different mobile apps, we compiled a database of photographed images of weed species occurring predominantly in Central Europe. The database consisted of 150 images of 62 weed species (120 broadleaf, 30 grass) at different growth stages (BBCH stage). The majority of the utilized images were of plant specimen growing under field conditions. For species showing a low frequency in occurrence in Germany (e.g. rare weed species), images from plants grown in the greenhouse were used. Our study revealed that none of the tested mobile apps was able to correctly identify weeds at early growth stages. At later growth stages and especially at flowering, the performance of the apps increased and a higher number of species could be identified at least at the genus level. We also found that the quality of images had a minor impact on the rate of correct identification. Our study shows that identification of weeds at the species level at early growth stages by the tested apps is limited. For weed management decisions, an identification of weed species at an early plant growth stage is essential for ensuring that the plants can still be effectively managed. An increased ability of identifying weeds at young growth stages is therefore essential for the use of automated plant identification tools in an agricultural setting.

Keywords: *Automated weed identification, smartphone app*

Parameterization of the DSS for IWM named IPMwise for Greek conditions using dose-response curves

Alexandros Tataridas [1]; Per Rydahl [2]; Ole Bøjer [2]; Panagiotis Kanatas [3]; Ilias Travlos [1]

[1] *Department of Crop Science, Agricultural University of Athens, Greece, Athens, Greece*
[2] *IPM Consult ApS, Stenlille, Denmark, København, Denmark*
[3] *Department of Crop Science, University of Patras, Mesolonghi, Greece*

Poster

IPMwise is a 4th generation Decision Support System (DSS) for weed management. An economic potential of 20-40% reduction of herbicide input as compared to the common or best practice by farmers is considered one of the most important outputs of IPMwise. Field experiments were conducted in three fields in Greece during 2019-2020 in winter wheat to evaluate the efficacy of five herbicides against four grass and six broadleaf weeds. The tested herbicides were three mixtures of ALS inhibitors, pinoxaden, and a mixture of florasulam+clopyralid, and the surveyed weeds were the grasses *Alopecurus myosuroides, Avena sterilis, Lolium rigidum and Phalaris* sp., and the broadleaves *Gallium aparine, Matricaria chamomilla, Papaver rhoeas, Sinapis arvensis, Stellaria media* and *Veronica hederifolia.* The herbicide rates were 0, 0.125X, 0.25X, 0.50X, 1.0X, and 2.0X. The datasets underwent statistical analysis and were used to produce the efficacy profile of each herbicide. The results revealed that the effective dose to achieve 50% control of the weeds was below the recommended rate for all herbicides and ranged between 19.7% and 71.7% of the recommended rate for the most susceptible and the most resistant weed, respectively. Nonetheless, the effective dose for 90% control revealed that the herbicide input reduction depended on the weed biotype, the herbicide susceptibility status, and the field. The more susceptible weeds were highly controlled with only 29.2-50.3% of the recommended rate, in contrast to the more resistant, which required 46.3-175.3% higher dose than the recommended to achieve 90% control. IPMwise exploits a broad spectrum of efficacies against different weeds to recommend the optimum rate often resulting in herbicide reduction, without jeopardizing yield and reducing the risk of herbicide resistance. Field trials were conducted in one of the two regions, which validated the recommendations of the tool and significantly reduced the herbicide input. Further parameterization and validation are required to evaluate the efficacy of more herbicides on different weeds in different agricultural areas of Greece and release a commercial version of the DSS under Greek conditions. When IPMwise has included additional crops, weeds and herbicides, a next step forward may be the integration with machine learning/artificial intelligence, which upon suitable training for local conditions can determine weed infestation in fields on the species level, and thereby 1) replace manual weed scouting for uniform treatment of whole fields, and 2) deliver electronic spray maps for on/off site-specific treatments, and assist site-specific weed management through variation in herbicide doses within fields.

Keywords: *decision support system, herbicides, IWM*

Use of Multispectral Drone Images for Crop Growth and Health Monitoring, Phenotyping and Weed Detection at the Estonian Crop Research Institute

HJ Kennedy [1]; Reine Koppel [2]; Anti Konsep [2]

[1] *Estonian Crop Research Institute, Tallinn, Estonia*
[2] *Estonian Crop Research Institute, , Unknown*

Poster

Crop growth and health monitoring is time consuming, particularly for breeding trials, and recorded phenotypic data varies between observers. Weed detection and severity rating is also time consuming and may be inconsistent between observers. The Estonian Crop Research Institute (ETKI) is testing multispectral drone imagery for crop growth and health monitoring, phenotyping, and weed detection. A DJI Phantom4 RTK (P4) drone with built in RGB camera and a MicaSense RedEdge MX multispectral camera is used to image field plots. The goal of crop growth monitoring is to assist breeders in identifying varieties displaying desirable traits such as early heading in wheat. Crop health monitoring can also assist breeders in identification of crops with desirable traits such as disease resistance or drought tolerance. Vegetation indices, including NDVI, LAI, EVI, CWSI, etc., are calculated at the plot level. The vegetation indices will be evaluated by the breeders to determine which are most beneficial for detecting each trait for each crop. The goal of weed detection is to reduce herbicide use by accurate detection of weeds and the severity of the infestation. Multiple methods for weed detection are being tested including 1) color differentiation, 2) row pattern recognition, and 3) plant feature detection. The objective of this poster is to give an overview of ETKI's use of multispectral drone imagery for phenotyping breeding plots and detecting weeds in fields.

A sensor-based decision model for precision weed harrowing

T. W. Berge [1]; Frode Urdal [2]; Torfinn Torp [3]

[1] NIBIO - Norwegian Institute of Bioeconomy Research,
Invertebrate Pests and Weeds, Aas, Norway
[2] Adigo AS, Langhus, Norway
[3] NIBIO - Norwegian Institute of Bioeconomy Research, Aas, Norway

Poster

Weeds may reduce crop yields significantly if managed improperly. However, excessive herbicide use increases risk of unwanted effects on ecosystems, humans and herbicide resistance development. Weed harrowing is a traditional method to manage weeds mechanically in organic cereals but could also be used in conventional production. The weed control efficacy of weed harrowing can be adjusted by e.g. the angle of the tines. Due to its broadcast nature (both crop and weed plants are disturbed), weed harrowing may have relatively poor selectivity (i.e. small ratio between weed control and crop injury). To improve selectivity, a sensor-based model which takes into account the intra-field variation in weediness and "soil density" in the upper soil layer (draft force of tines), is proposed. The suggested model is a non-linear regression model with three parameters and was based on five field trials in spring barley in SE Norway. The model predicts the optimal weed harrowing intensity (in terms of the tine angle) from the estimated total weed cover and SD per sub-field management unit, as well as a pre-set biological weed threshold (defined as the acceptable total weed cover left untreated). Weed cover and SD were estimated with RGB images (analysed with custom-made machine vision) and an electronic load cell, respectively. With current parameter values, the model should be valid for precision weed harrowing in spring barley in SE Norway. The next step is to test the model, and if successful, adjust it to more cereal species.

Keywords: *Cereals, Mechanical weed control, Site-specific weed management*

SESSION IV

HERBICIDE RESISTANCE

How Australian Cereal Farmers Combat Multiple Resistant *Lolium rigidum*

P Boutsalis

Plant Science Consulting/ The University of Adelaide, Adelaide, Australia

Oral

The most challenging weed species for farmers in southern Australia is *Lolium rigidum*. It is widely distributed and problematic to control due to multiple resistance that has arisen after a long history of selection with diverse mode of action herbicides since the 1980's. Changing seeding practices minimum tillage have increased the reliance on herbicides for weed control. Random weed surveys involving weed seed collection and testing from thousands of fields have identified resistance to several mode of action herbicides. The incidence of resistance has been found to differ between regions based on the intensity of cropping. In recent random weed surveys in some of the higher rainfall regions in South Australia and Victoria, greater than 25% of ryegrass was identified as resistant to glyphosate with the incidence of resistance to Group 1 and 2 herbicides ranging between 50% and 100%. Such a prevalence indicates that in a significant number of cases there are no post-emergent options to control ryegrass in winter crops including in glyphosate-tolerant canola. Plant Science Consulting has been offering commercial herbicide resistance testing since 2004. The majority of samples tested are seed although live plants are also sent in during the growing season, mostly from situations where herbicides have failed in the field using a Quick-Test (Boutsalis, 2001). Providing herbicide resistance information on individual fields is considered a valuable tool in selecting effective and non-effective herbicides. Although managing multiple-resistant *L. rigidum* with diverse herbicides can be an effective strategy in the short term, the use of alternative techniques can further improve weed control. These include early sowing to maximise crop competition, growing competitive crops, the capture or destruction of weed seeds at harvest with implements such as the Seed Terminator, growing hay or silage crops and animal grazing. The use of multiple tactics in a single growing season has been shown to decrease weed numbers at each timing thereby reducing the seedbank. Common tactics include using a non-selective herbicide (s) such as paraquat and/or glyphosate if the growing season starts in early autumn followed by a combination of residual herbicides at sowing and early post-emergence followed by seed sterilisation techniques at the flowering stage of ryegrass followed by seed capture or destruction.

Keywords: *Lolium rigidum, herbicide resistance, Australia*

The new HRAC Mode of Action Classification System for Herbicides

Bernd Sievernich[1,3], Hubert Menne[2,3]

[1] BASF SE, Limburgerhof, [2] BAYER AG, Frankfurt, [3] ion behalf of European Herbicide Resistance Action Committee (EHRAC)

The sustainable and responsible use of herbicides requires that users and their advisors must consider information on the mode of action of the applied products. Only with this knowledge, resistance management measures, such as the alternation of mode of action can be successfully implemented. Therefore, the Global Herbicide Resistance Action Committee (GHRAC) developed a holistic system in the 1990's that allows a simple assignment of active substances to a letter code based on their mode of action, induced symptoms and chemical classes. Due to its simplicity and practicality, this system has successfully established itself in many countries worldwide, including Europe. At the same time, independent classification systems were developed and introduced in North America and Australia. However, such a classification system requires continuous adaptation to integrate new developments in science. New active substances, advances in elucidating the mode of action of active substances already on the market, as well as the successes achieved through intensive research in the discovery of novel herbicide mechanisms require continuous updating. In the last revision implemented in 2020, the additional task to create a uniform global classification system that meets scientific and practical requirements was added. In cooperation with the regional HRAC's, CropLife and Weed Societies such as WSSA, GHRAC developed a future-proof classification system for the coming decades, which (1) offers sufficient possibilities for the recording and coding of novel mode of action, (2) allows the application in a wide variety of cultural and linguistic areas in a globalized world and (3) enables a merger of the various applied classification systems. The introduced number-based classification system of the herbicidal mode of action covers all these requirements. However, the change from a letter-based to a number-based system does also affect agronomic advisors and growers. New codes must be learned and reconciled with previous knowledge. Moreover, new findings in the elucidation of various active substances or mode of action led to new- and re-classification within the system. The presentation covers the new HRAC classification system for herbicidal mode of action, specific changes that have been introduced since the last update in 2010 and the CropLife International MoA-Labelling Guidance, describing the parallel use of the letter- and number-based system within a transitional period. The European Herbicide Resistance Action Committee (EHRAC) is an association of agrochemical companies. The committee works closely with GHRAC, scientific institutions and the European regulatory authorities.

Actual status of herbicide resistance of species from Panicoideae sub-family in some European countries

Jan Petersen

University of Applied Sciences Bingen, Bingen, Germany

Oral

Herbicide resistance in summer grasses is quite common in the world but also in Europe. In some regions presence and spatial distribution of herbicide resistance *in Panicoideae* species is well known and described. Focus is on *Echinochloa crus-galli* (ECHCG)and the mediterranian region. However, due to increasing focus on chemical weed control, use of a limited number of active ingredients and extend growing of maize, problems are increasing in many countries. In a herbicide resistance monitoring program between 2016 and 2021, 396 populations from different *Panicoideae* species from 10 countries were tested for herbicide resistance in a greenhouse bioassay and resistance mechanisms were investigated (SNP-analysis). In 49 ECHCG, 7 *Setaria* sp. , 5 *Sorghum halepense* (SORHU) and one *Panicum* sp. population resistance to ALS-inhibitors were identified. Resistant ECHCG populations originated from Austria, Germany, Czech Republic and Poland. ALS-resistant *Setaria* species were found in Austria, Germany and Greece. One *Panicum* sp. was also resistant to ALS-inhibitors and originated from Austria. *Sorghum halepense* samples from Serbia obtained resistance to ALS-inhibitors as well to a large extent. Target-site resistance mechanisms in ECHCG were responsible for 47 out of 49 cases. Relevant amino acid substitutions in ECHCG were found at 6 different positions (122-Ala/Asp; 197-Pro/Thr; 205-Ala; 376-Asp/Glu; 574-Trp/Leu and 653-Ser/Tyr). In two ECHCG populations an ALS-inhibitor resistance was present, but no relevant exchange in ALS-gene could be identified which could explain reduced herbicide efficacy. This may indicate a NTSR mechanism. All populations tested were susceptible to ACCase- and to HPPD-inhibitors. Resistance in *Setaria* sp., *Panicum* sp. and *S. halepense* based on target-site resistance mechanisms. In *Setaria* sp. exchanges were identified at position 197 and 574. An Ala/Asp substitution at position 122 explained ALS-resistance in *Panicum* sp. from Austria. *S. halepense* populations from Serbia showed a 376-Asp/Glu or a 574-Trp/Leu substitution. Results indicate that reliance on ALS-herbicide for control of species from sub-family *Panicoideae,* only, can lead to resistance to different species. This is the case in many European countries. Different mutations on ALS-gene results in different herbicide responses depending on the active ingredients of herbicide group 2 (ALS-inhibitors) especially in ECHCG. However, herbicide diversification and widening of crop rotation, were ever possible, should be implemented to reduce speed of resistance evolution.

Keywords: *herbicide resistant weeds*

Irish black-grass (Alopecurus myosuroides) populations carrying target-site resistance to ACCase/ALS herbicides also impact glyphosate efficacy

A. V. Vijaya Bhaskar [1];

Dermot Forristal [1]; Sarah Cook [2]; Michael Hennessy [1]; Susanne Barth [1]

[1] *Teagasc, Carlow, Ireland*
[2] *ADAS, Cambridge, United Kingdom*

Oral

Ireland's evolving cropping systems from a historical mixed grassland-spring cropping systems, has resulted in much less proliferation and abundance of black-grass, compared to the UK or parts of Europe. Until now, there were no confirmed cases of herbicide-resistant black-grass in Ireland. Over-reliance on ACCase and ALS herbicides and associated resistance risk, makes herbicide-dependent cropping systems in these regions more vulnerable. In 2020, twelve black-grass populations were screened for resistance with two ACCase (propaquizafop, 100 g ha^{-1} and cycloxydim, 200 g ha^{-1}), one ALS (mesosulfuron + iodosulfuron, 15 + 5 g ha^{-1}) and glyphosate (540 g ha^{-1}) at recommended herbicide label rate. Populations, including the suspect ones, were collected from cereal production fields prior to 2020-harvest,as a part of a nationwide grass weed survey. Four of these populations (ALOMY-001 to ALOMY-004) exhibited resistance or variations in sensitivity, were subjected to detailed dose-response studies, where they were compared with known susceptible populations (S-006 and UKSD0827). Plants were sprayed at GS 12-13 (BBCH), with rates ranging from 0.25 to 8-times the label rate. Survival ED_{50} values were generally higher than the shoot dry weight GR_{50}. ALOMY-001 exhibited strong resistance, with GR_{50} values exceeded more than 3 times the label rate of both ACCase herbicides. However, it had similar sensitivity as susceptible populations to the ALS herbicide. ALOMY-002 to ALOMY-004 populations were resistant to both ACCase and ALS herbicides, with GR_{50} values either close to or above the label rate (0.7-1.4). For glyphosate, even though ED_{50} or GR_{50} values of ALOMY populations remained well below label rate (0.3-0.5), survival data revealed that 1.5 times the label rate was required to cause complete mortality. All ALOMY populations had the Ile-1781 mutation in the ACCase gene, and additionally, three of the ALOMY populations had the Pro-197 mutation in the ALS gene. Most of the analysed plants for these mutations were heterozygous, with few exceptions. These findings indicate the importance of adopting cultural and non-chemical integrated weed management, including drastic measures (whole cropping, grass leys or fallows) to eliminate the soil seedbank of these populations carrying stacked resistance. These were the first cases of herbicide-resistant black-grass in Ireland.

Keywords: *ACCase; ALS; black-grass; herbicide resistance; target-site resistance*

Rigid ryegrass (Lolium rigidum L.) occurrence and ACCase / ALS resistance in brewery barley belt in North Greece

Dimitra Doulfi [1];

Garifalia Economou [1]; Ilias Eleftherohorinos [2]; Panagiotis Madesis [3]

[1] *Agricultural University of Athens, Athens, Greece*
[2] *Aristotle University of Thessaloniki, Thessaloniki, Greece*
[3] *University of Thessaly, N. Ionia Magnisia, Greece*

Oral

Malt barley growers in the northern cultivation belt of Greece, complain about the insufficient control of *L. rigidum* L. after the application of pinoxaden (ACCase inhibitor). The primary goals were to investigate a) the degree of ryegrass infestation in Assiros (40.815877, 23.025570) and Nigrita (40.899558, 23.483114), b) the reasons of its unsatisfactory control and c) the occurrence of resistance to pinoxaden and mesosulfuron-methyl+ iodosulfuron-methyl (ALS inhibitor). Surveys were conducted during 2020 - 2021, in forty fields in the aforementioned sites where insufficient control has been recorded. According to methodology, *L. rigidum* seeds were collected before crop harvest from 15 sites and were sown in plastic pots to be tested for herbicide resistance. At the 4- 5 leaf stage seedlings were treated with pinoxaden and mesosulfuron-methyl+ iodosulfuron-methyl (22.5, 45, 90, 180, 270 g.ai/ha and 9, 18, 36, 72, 108 g.ai/ha, respectively). A pot experiment was established (2 experiments x 15 populations x 2 herbicides x 3 replications). Control of populations were assessed by measuring the above ground fresh weight of the surviving plants in each pot 6 weeks after treatment (fresh weight % of untreated control). Number of survived plants and tillers were also accessed for each population. Data were subjected to nonlinear regression analysis using Seefeld's (1995) log-logistic equation to compute the effective dose (GR50) required to give 50% control of ryegrass. From 20 fields in Assiros, *L. rigidum* occurred in all with an average mean coverage of 51% based on visual assessments. In Nigrita, *L. rigidum* occurred in 85% of the fields with an average mean coverage of 24%. Results of the pot experiment indicated that thirteen out of the fifteen populations were resistant to ALS, whereas nine were resistant to ACCase. Values of GR_{50} indicated that 9.12-29.04 g.ai/ha mesosulfuron-methyl+ iodosulfuron-methyl and 33.51-52.41 g.ai/ha pinoxaden were necessary for fresh weight to be reduced by 50%. Furthermore, application of molecular techniques via sequencing of *als* and *accase* fragments confirm the findings of the pot experiments. It is noticeable that occurrence of *L. rigidum* is higher in Assiros (100%) than in Nigrita (85%) whereas the studied populations were found to be resistant to both herbicides, with different modes of action. Taking these into consideration, it is essential to map ryegrass' distribution to take measures and thus to delay the evolution of new resistant populations.

Potential regulation of herbicide-resistant seeds by seed predator

HF Foffová

Crop Research Institute, Prague 6, Czech Republic

Oral

One inestimable opportunity with a large potential for weed regulation is an ecosystem service called seed predation. There are many taxonomical groups (bird, carabids, ants etc.) that consume and, by this, reduce seed abundance in soil. Nowadays, this phenomenon is investigated a lot. It was already explained that the seed predators can effectively reduce seed numbers from the seed bank (buried and also the seeds on the soil surface). Regrettably, there is no information about seed predation of the seeds from the herbicide-resistant populations. In our experiments, the predation of seeds produced by herbicide-resistant and herbicide-susceptible plants was tested. The seeds of *Solanum nigrum* and *Persicaria lapathifolia* came from populations either resistant or susceptible to triazines, and the seeds of *Amaranthus retroflexus* and *Chenopodium album* came from populations resistant or susceptible to atrazine. The predation was tested under laboratory and field conditions. In the laboratory, a one choice experiment was conducted, in which seeds were offered to the carabid *Pseudoophonus rufipes*. In the field conditions, seed predation of herbicide-resistant and herbicide-susceptible seeds was tested by seed cards. In each seed card, 50 seeds of one species of weed and herbicide resistance/susceptible were exhibited in the field of winter wheat. The first part of the experiments was realized in autumn 2021 and experiments will continue in spring 2022. The complete result will be presented at the conference. In the laboratory test, there is the effect of the seed species on the preferences of *P. rufipes*. The most prefered seeds were seeds of *A. retroflexus and Ch. album*. The first results suggest that in these two species there is an effect of the resistance/susceptible on the preferences of *P. rufipes*. The resistant seeds were preferred. This result suggests that seed predators may help to reduce herbicide-resistant weed seed in the soil seed bank.

Herbicide resistance mechanisms in *Bromus sterilis*

Madhab Kumar Sen [1]; Katerina Hamouzová [1]; Jakub Mikulka [1]; Rohit Bharati [2]; Pavlina Košnarová [1]; Pavel Hamouz [1]; Amit Roy [3]; Josef Soukup [1]

[1] *Czech University of Life Sciences Prague, Department of Agroecology and Plant Production, Prague 6 - Suchdol, Czech Republic*

[2] *Czech University of Life Sciences Prague, Department of Crop Sciences and Agroforestry, Prague 6 - Suchdol, Czech Republic*

[3] *Czech University of Life Sciences Prague, Excellent Team for Mitigation (ETM), aculty of Forestry and Wood Sciences, Prague 6 - Suchdol, Czech Republic*

Oral

Bromus sterilis L., a noxious weed, known to cause high yield losses in the productivity of winter wheat. Recently, in the Czech Republic, farmers have reported that the recommended doses of pyroxsulam have failed to control this weed species. The present study discovered the resistance mechanisms to ALS-inhibiting herbicides in a local *Bromus sterilis* biotype. The susceptible (S) and the resistant (R) biotypes were collected from the campus of the Czech University of Life Sciences Prague and a winter wheat field in the Ústecký (Louny) region of the Czech Republic, respectively. The pot experiments for the dose-response studies were conducted in an open-air vegetation hall. PCR-based sequencing with the degenerate primers were used for *ALS* sequencing. Flow cytometry was done using a Partec PAS flow cytometer (Partec GmbH, Germany). Chromosome counting was performed using α-bromonaphthalene pretreatment. With *Ubiquitin* as an internal standard, relative gene copy number and expression analysis were conducted. Dose response studies showed that the R biotype had low sensitivity to pyroxsulam (~288 times lower than the S biotype). Cross-resistant experiments showed that this biotype was also resistant to propoxycarbazone, iodosulfuron plus mesosulfuron and sulfosulfuron. Prior treatment with malathion lowered the resistance level to pyroxsulam, indicating the involvement of cytochrome P450s. Partial *ALS* gene sequencing detected no mutations. Flow cytometry excluded any ploidy level variation between the S and R biotypes. Relative copy number variation analysis of *ALS* gene ruled out the involvement of gene amplification. Relative gene expression analysis identified a significant difference in *ALS* gene expression between the S and R biotypes. *ALS* gene overexpression and enhanced metabolism are the resistance mechanisms to pyroxsulam in *Bromus sterilis*. The current study emphasises screening more brome populations for herbicide resistance in Europe. At present, alternative modes of action against this species are not available for cereals. Hence, we recommend using an integrated approach to delay the evolution of herbicide resistance in these species before they become a worldwide concern.

Keywords: *Bromus sterilis; herbicide resistance; ALS gene overexpression; CytP450s*

Herbicide efficacy patterns in sensitive and ALS-resistant Anthriscus caucalis populations and other weedy Apiaceae species

Rebecka Dücker [1]; Manja Landschreiber [2]; Johannes Herrmann [3]; Martin Heß [3]; Wagner Jean [1]

[1] Plant Pathology and Crop Protection, Georg-August University Göttingen, Göttingen, Germany
[2] Landwirtschaftskammer Schleswig-Holstein, Lübeck, Germany
[3] Agris42, Stuttgart, Germany

Oral

Weedy Apiaceae species are increasing significantly in importance in some regions of Germany. This is particularly the case for bur chervil (*Anthriscus caucalis*), which has become a noxious weed in some regions after being an endangered species in some states only a few decades ago. Bur chervil occurs primarily in winter crops where only limited chemical control options are available for this weed. This is especially true when resistance to acetolactate synthase (ALS) inhibitors is present. Therefore, 46 bur chervil populations from several German regions were evaluated for differences in their controllability with the ALS inhibitors metsulfuron and tribenuron, as well as the photosystem II inhibitor chlorotoluron, the synthetic auxin halauxifen, and the inhibitor of very long-chain fatty acid synthesis metazachlor. In addition to sensitive and ALS-resistant bur chervil, the most important weedy Apiaceae species in Germany - fool's parsley (*Aethusa cynapium*), hemlock (*Conium maculatum*), wild carrot (*Daucus carota*), and hedge chervil (*Torilis arvensis*) - were screened for different control options with herbicides of seven modes of action in a greenhouse bioassay. Finally, sequences of the ALS genes of the species were determined by RACE PCR and primers were designed to sequence the mutation sites. Using these methods, we detected a mutation at position 197 of the ALS gene in resistant bur chervil and linked it to the reduced efficacy of various ALS inhibitors. However, there was a partial effect by metsulfuron even in the resistant individuals. Notably, the synthetic auxins tested and chlortoluron also controlled the species well. Apart from the ALS inhibitors, there was little variation between the herbicidal effects on the different populations tested. However, there were major differences between the species tested, making the correct identification of the very similar looking species decidedly important.

Alterations in glutathione metabolism induced by ALS inhibition in Amaranthus palmeri in Spain

Mikel Vicente Eceiza; Miriam Gil-Monreal; Josu Encinas; María Barco-Antoñanzas; Ana Zabalza; Mercedes Royuela

Public University of Navarre, Pamplona/Iruña, Spain

Oral

Acetolactate synthase (ALS) inhibiting herbicides induce several physiological effects in affected plants. Changes in glutathione content and related enzymatic activities are included in such physiological effects and they have been observed in different species in response to ALS inhibiting herbicides. Nevertheless, the relationship between ALS inhibition and glutathione metabolism has yet to be clarified and it is also unknown whether this response also happens in ALS-resistant biotypes. The objective of this study was to get new insights of the role of glutathione metabolism in the mode of action of ALS inhibitors and in the physiology of resistant populations. To this purpose, *Amaranthus palmeri* sensitive and target-site resistant individuals (by a point mutation of *ALS* gene at position W574) originally from Spain were grown hydroponically and were treated with different doses of the ALS inhibitor nicosulfuron: untreated, field rate (FR) and three times FR (3FR). Glutathione content (reduced, oxidised and total) was quantified by capillary electrophoresis with laser-induced fluorescence and the in vitro activities of glutathione reductase (GR) and glutathione S-transferase (GST) were measured spectrophotometrically. FR and 3FR resulted lethal for sensitive individuals, whereas resistant individuals survived both herbicide doses. In sensitive individuals, glutathione content was not heavily altered in plants treated with FR, but was strongly increased in plants treated with 3FR. Both GR and GST activities increased in sensitive plants in response to herbicide treatment, especially in response to 3FR. However, glutathione content or enzymatic activities of resistant individuals did not change with any of the doses. In this way, nicosulfuron only induces changes in glutathione metabolism in sensitive plants. Probably, GR and GST activities increase because of glutathione accumulation. Although the physiological mechanisms that would explain the linkage between the herbicide treatment and glutathione production remain elusive, it can be established that it is related to ALS inhibition, as it is evidenced by the absence of alterations in glutathione metabolism in resistant plants due to target-site mechanisms.

Keywords: glutathione, nicosulfuron, Amaranthus palmeri

Multiple Herbicide-Resistant Amaranthus tuberculatus (Waterhemp) in Israel is an Alien Weed Species

B. Rubin [1]; I. Yadid [2]; A. Singer [2]; I. Roth [2]; Z. Peleg [2]; M. Sibony [2]

[1] The Hebrew University of Jerusalem, Faculty Agriculture, Food and Environment,
R H Smith Institute of Plant Science and Genetics in Agriculture, REHOVOT, Israel
[2] The Hebrew University of Jerusalem, Faculty Agriculture, Food and Environment,
R H Smith Institute of Plant Science and Genetics in Agriculture, Rehovot, Israel

Oral

Amaranthus tuberculatus var rudis (AT, waterhemp) is a summer annual, alien, dioecious weed, which is also known for its vigorous growth and prolific seed production. It causes severe yield loses to many crops, mostly in the USA. The weed was first detected in Israel approximately 20 years ago, mostly infesting roadsides, but now is also found in irrigated crops. The aims of this research were to determine the weed distribution in Israel and characterize its response to several herbicide modes of action. More than 40 AT populations were mapped and their seeds collected throughout the country, indicating three main invasion routs, infesting three main regions: The Hula Valley around a lake and fish ponds, in the Jezreel valley along the Kishon river and the Coastal Plain along the Sorek river. Herbicide-resistant populations were detected mainly in the Jezreel valley, while all populations collected along the Sorek river were mostly herbicide-sensitive. Molecular studies have shown that several populations were identified as cross-resistant to ALS-inhibiting herbicides as compared to the sensitive Tzora plants due to a Trp574Leu mutation. In addition, three PPO-resistant populations from the Jezreel Valley and Hula valley were identified resistant to carfentrazone-ethyl compared to the susceptible Tzora population. The PPX2 gene (the target site of PPO) was sequenced and, so far, no mutation was detected in the resistant populations. Glyphosate resistance was also detected in some AT populations along with ALS/EPSPS multiple-resistant populations. All herbicide-resistant AT populations detected, so far, were not exposed to high selection pressure or/ and frequent herbicide applications in Israel, hence we assume that the resistance traits were transferred, most likely from the USA, with imported food grains and animal feed.

Keywords: *Target site resistance; non-target site resistance; PPO, ALS, glyphosate*

Cyperus difformis cross-resistance among rice herbicides in South Portugal

João Santos [1]; Francisca Aguiar [2];

Isabel M. Calha [3]

[1] *ISA / University of Lisboa - School of Agriculture, Lisbon, Portugal*
[2] *CEF / ISA / University of Lisbon - Forest Research Centre, Lisbon, Portugal*
[3] *National Institute of Agronomic and Veterinary Research - INIAV, Oeiras, Portugal*

Poster

A population of *Cyperus difformis* L. (*Cyperaceae*) from a rice paddy field in Alentejo (South Portugal) was suspected of resistance after several years of application of penoxsulam (HRAC-2). Failure of control with bentazone (HRAC-6), an alternative mode of action (MoA), rose suspicion of cross-resistance between ALS – and PSII-inhibiting herbicides. In order to detect herbicide resistance to both active substances, a qualitative seedling-based quick-test was carried out using seeds of this population collected in 2020, and three susceptible populations. After seed germination, seedlings at the 1st leaf stage were transplanted to ELISA plates, 10 per well, in 5 mL of agar medium (1 %) under conditions of alternation of temperature and light in a growth chamber. A range of five concentrations was used for resistance screening. When 5 mg L^{-1} penoxsulam or bentazone were added, susceptible plant growth stopped and the 1st leaf turned chlorotic or necrotic while the resistant populations remained green and continued developing new leaves. The suspected population was compared with the susceptible populations. Plants of the former developed rapidly, with only about 14 days needed to finish the test. A non-parametric test allowed to significantly separate resistant from susceptible populations at a discriminant concentration of 5 mg L^{-1} for both herbicides. Further validation with pot experiments is ongoing. There is strong evidence that the studied population of *C. difformis* is resistant both to penoxsulam and bentazone. There are few cases of resistance to bentazone worldwide, therefore this would encompass a unique case of cross resistance to both MoA in *Sagittaria montevidensis* from Brasil. This is the first report of bentazone resistance in Europe.

Keywords: *herbicide resistance, quick test, smallflower umbrella sedge, bentazone, penoxsulam*

Different 574-ALS allelic variants in resistant Amaranthus hybridus biotypes widespread in north-eastern Italy

Andrea Milani [1];

Samuele Pinton [1]; Renato Antonio Danielis [2]; Silvia Panozzo [1]; Maurizio Sattin [1]; Laura Scarabel [1]

[1] *Istituto per la Protezione Sostenibile delle Piante, IPSP-CNR, Legnaro, Italy*
[2] *Agenzia regionale per lo sviluppo rurale - ERSA, Pozzuolo del Friuli, Italy*

Poster

The first *Amaranthus* spp biotype resistant to acetolactate synthase (ALS)-inhibitors in Italy was found in 2003 in a soybean field of the Friuli Venezia Giulia region. Until 2018, only one more case was confirmed in this region, although several farmers reported increasing control failures. During a monitoring carried out by the Regional Agency ERSA, 57 herbicide-treated soybean fields mainly infested by *Amaranthus* spp were found and seeds of putative resistant biotypes were collected. These *Amaranthus* spp accessions were studied to determine 1) the status of resistance to ALS-inhibiting herbicides 2) the *Amaranthus* species involved 3) the possible mutant *ALS* alleles 4) the susceptibility to non-ALS herbicides. Plants at the 2-4 leaf stage were treated with both imazamox and thifensulfuron-methyl at the recommended field dose by using a precision bench sprayer delivering 300 L ha^{-1}, at a pressure of 215 kPa and a speed of 0.75 ms^{-1}, with a boom equipped with three flat-fan hydraulic nozzles (Teejet 11002). Survivors to thifensulfuron-methyl were grown until flowering for species identification. Sanger sequencing was used to determine possible *ALS* mutations conferring resistance to thifensulfuron-methyl in six selected accessions. A PCR amplification of specific alleles (PASA) assay was developed to quickly genotype all accessions, by using DNA extracted from single seeds. The same six accessions previously selected, were used to determine the susceptibility to metribuzin, clomazone and metobromuron. Fifty-three out of the 57 accessions resulted cross-resistant to thifensulfuron-methyl and imazamox, and 50 of them had survival rates higher than 80% to both herbicides. Only *A. hybridus* was identified among all accessions. Two resistance-endowing allelic variants of codon 574 of *ALS* gene were detected by sequencing: leucine and methionine. The PASA genotyping revealed that the 574-leucine variant was more common in the accessions collected in the Northern part of the sampling area, while the 574-methionine was more common in the Southern accessions. In a few accessions, both resistance-endowing substitutions were detected. The six selected accessions resulted susceptible to metribuzin, clomazone e metobromuron applied in pre-emergence. This study reveals that most of the sampled accessions are highly cross-resistant to thifensulfuron-methyl and imazamox and the resistance is due to a point mutation at the 574 codon of *ALS* gene. Only *A. hybridus* was present and these ALS-resistant accessions can be adequately controlled by metribuzin, clomazone and metobromuron.

Crop production systems and the evolving status of herbicide-resistant grass weeds in Ireland

A. V. Vijaya Bhaskar [1]; Dermot Forristal [1]; Sarah Cook [2]; Susanne Barth [1]; Hennessy Michael [1]

[1] *Teagasc, Carlow, Ireland*
[2] *ADAS, Cambridge, United Kingdom*

Poster

Ireland's crop production has evolved from a mixed farming base, where spring crops were grown in rotation as a part of grassland system, to current cereal monoculture or part of an all-crop rotation. Spring-sown barley remains the most dominant cereal crop, and plough-based tillage systems dominate crop establishment. Irish cereal yields are among the highest in the world facilitated by an Atlantic climate coupled with a soil quality legacy from past mixed rotations. However, this same wet climate is conducive to the rapid development and proliferation of fungal diseases, grass weeds and to some extent, insect vector-borne diseases, making pesticides a critical tool in the achievement of these high yields. While fungicide efficacy and fungicide resistance research has been the main focus, the status of herbicide-resistant grass weeds were less well known until recently. The phasing out of herbicide classes and over-reliance on limited ACCase and ALS herbicides coupled with new weed introductions, has challenged conventional weed management, as evolving herbicide resistance and increases in difficult-to-control grass weeds combine. In response to growers reports of poor weed control, resistance testing was conducted from 2019 to 2020, in fields where herbicide control was inadequate, as a part of the Enable Conservation Tillage (ECT) project, resulting in a list of resistance cases around the country: 8 out of 31 *Avena fatua* populations collected in Wexford, Kilkenny, Cork, Tipperary and Kildare counties were resistant to ACCase herbicides. Mutations at Ile-1781 or Asp-2078 were frequently associated with this resistance. 8 out of 18 *Alopecurus myosuroides* populations collected in Meath, Cork and Waterford counties were resistant to ACCase and/or ALS herbicides. ACCase Ile-1781 or ALS Pro-197 mutations were frequently associated with this resistance. All 4 *Lolium multiflorum* populations collected in Cork, Meath and Tipperary counties were resistant to ACCase and/or ALS herbicides where the ALS Pro-197 mutation predominates. In addition to target-site mutations, ACCase/ALS non-target-site resistance is also likely. Resistance has been documented in all arable regions, and those analyzed likely only represent a part of the total number of resistance cases. The complex *A. myosuroides* situation in Ireland, with either unintentionally imported UK resistant strains, or evolved resistance in native strains, poses a significant threat to weed control. These results stress the need for resistance monitoring to detect evolving cases, and to develop intervention strategies to prevent the spread and build-up of resistance.

Geographical distribution of Lolium rigidum resistance in Greece

Thomas Gitsopoulos [1];

Ilias Travlos [2]; Demosthenis Chachalis [3]; Eleni Tani [4]; Ioannis Georgoulas [5]

[1] *Hellenic Agricultural Organization-Dimitra, Institute of Plant Breedind & Genetic Resources, Thes/ki, Greece*

[2] *Agricultural University of Athens, Laboratory of Agronomy, Athens, Greece*

[3] *Benaki Phytopathological Institute, Laboratory of Weed Science, Athens, Greece*

[4] *Agricultural University of Athens, Laboratory of Plant Breeding and Biometry, Athens, Greece*

[5] *Hellenic Agricultural Organization-Dimitra, Institute of Plant Breedind & Genetic Resources, , Greece*

Poster

The widespread continuous use of ALS- and ACCase-inhibitors in winter crops and of glyphosate in orchards has contributed to the evolution of resistance in annual ryegrass (*Lolium rigidum*) in Greece. However, mapping of its geographical distribution is lacking. In the frame of RELIUM project (ERA-NET C-IPM), field surveys were conducted in Greece, and during the last five years, ryegrass seeds were collected from plants that had survived the application of ALS-, ACCase-inhibitors and glyphosate. The survey was based on farmers' complaints for poor ryegrass control. Pot experiments were conducted during autumn periods of 2017-2021 to evaluate the efficacy of the maximum recommended rate of the most common ALS- and the ACCase-inhibitors used in cereals in Greece, mesosulfuron-methyl + iodosulfuron (15 + 3 g a.i.ha-1) and pinoxaden (45 g a.i.ha-1), and of glyphosate (720 g a.e. ha-1) widely used in orchards. Visual estimation of herbicide efficacy was performed, using a 0-100% scale, where 0%= no herbicide effect, 100%= dead plants, compared with the untreated control of each population. A herbicide-susceptible population was also included in each bioassay. Overall, resistance to ALS- was more frequent compared to the ACCase- inhibitor, and two cases of glyphosate resistance in orchards were found. Multiple resistance to ALS- and ACCase- inhibitors was revealed in most of the populations tested. No multiple resistance to glyphosate and to any of ALS- or ACCase- inhibitors tested was recorded, although recently a suspected population with multiple resistance to an ACCase-inhibitor (but not pinoxaden) and to glyphosate was collected. The majority of the resistance cases to ALS and ACCase-inhibitors were observed in northern Greece and especially in the administrative region of Central Macedonia in the municipalities of Thessaloniki, Chalkidiki and Kilkis. Also noteworthy to mention, similar multiple resistance cases were also detected in the municipalities of Drama, Florina and Kozani. Questionnaires on winter crop management highlighted that in almost all cases where winter cereal was grown in monoculture, herbicides were used intensively and without rotation. Resistance to glyphosate was found in orchards and in the western/southern Greece and in the municipality of Etoloakarnania and Achaea. Monitoring the evolution of annual ryegrass resistance in Greece contributes to improving awareness of farmers, researchers, industry and other stakeholders and to devising effective and shared resistance management strategies.

Keywords: *weed mapping, ryegrass*

Molecular methods for early detection of glyphosate resistant *Lolium* spp. populations

M Gerakari [1];

N. Cheimona [2]; E Tani [1]; E Sarri [1]; I Travlos [3]; D Chachalis [2]; D Loddo [4]; S.K Mathiassen [5]; T.K Gitsopoulos [6]; L Scarabel [4]; S Panozzo [4]; M Kristensen [5]; P. Kudsk [5]; M Sattin [4]

[1] *Laboratory of Plant Breeding and Biometry, Agricultural University of Athens, Athens, Greece*

[2] *Laboratory of Weed Science, Benaki Phytopathological Institute, Kifisia, Greece*

[3] *Laboratory of Agronomy, Agricultural University of Athens, Athens, Greece*

[4] *Institute for Sustainable Plant Protection (IPSP-CNR), , Italy*

[5] *Department of Agroecology, Aarhus University, , Denmark*

[6] *HAO-DEMETER, Institute of Plant Breeding and Genetic Resources, , Unknown*

Poster

Lolium spp. are annual weeds that cause serious problems mainly in winter cereal crops worldwide, including Europe. In recent years they have developed several resistant mechanisms to some important herbicides. In the present study, the possible resistance mechanisms to glyphosate in four *Lolium spp.* populations (*Lolium rigidum Gaud.* and *Lolium multiflorum-Lam.*), originated from Greece and Italy, was determined. To this perspective, a holistic approach was used for the four studied *Lolium spp.* populations, based on dose-response experiments, determination of shikimic acid concentration in plant leaf tissue, as well as molecular analysis. The 5-enolpyruvylshikimate-3 phosphate synthase (*EPSPS*) gene was studied to investigate the existence of a mutation in the Pro-106 codon. Furthermore, four *ABC-transporter* genes were also studied for their relative transcript levels at three different time points (3 , 6 and 12 hours) after glyphosate application. *ABC-transporter* genes probably play an important role in glyphosate resistance of *Lolium spp.* populations as their relative transcript levels were abundant at very early time points after glyphosate treatments. On the other hand, the analysis of target-site resistance did not reveal any important findings, as no mutation was observed in the Pro-106 codon of the *EPSPS* gene. Dose-response experiment and shikimate analysis were in accordance with the findings of the quantitative PCR (qPCR) analyses. According to these findings, we suggest that the relative expression ratio of ABC-transporter genes can be a useful tool to rapidly identify *Lolium spp.* populations resistant to glyphosate.

Keywords: *Lolium resistance mechanisms; dose-response; shikimic acid; EPSPS gene; ABCtransporters; TSR; NTSR*

Seek and you will find: characterization of Amaranthus palmeri ALS-resistant populations from Spain and Italy

Alfredo Manicardi [1]; Andrea Milani [2]; Joel Torra-Farré [1]; Laura Scarabel [3]

[1] *University of Lleida, Lleida, Spain*

[2] *Institute for Sustainable Plant Protection (IPSP-CNR), Legnaro (PD), Italy*

[3] *Institute for Sustainable Plant Protection (IPSP-CNR), Legnaro(PD), Italy*

Poster

Amaranthus palmeri S. Watson is spreading around Europe, undermining summer crops production and herbicides effectiveness. A. *palmeri* populations resistant to acetolactate synthase (ALS)-inhibiting herbicides have been recently documented in Spain and Italy and the presence of two resistance-endowing mutations in the ALS gene was described: the substitution Trp574Leu was found in both Spanish and Italian populations, while the Pro197Thr was found only in Spanish populations. Since then, new *A. palmeri* populations not adequately controlled have been identified and collected but the resistance pattern to ALS-inhibitors is unknown. The goals of this study were to (i) define the ALS-inhibiting herbicide resistance patterns, (ii) seek for point mutations in the *ALS* gene conferring resistance. A total of ten *A. palmeri* populations were studied, four Italian, five Spanish plus a wild type population. A greenhouse whole plant bioassay was performed and seedlings at 4 leaf stage were treated with imazamox (40 g a.i./ha) and thifensulfuron-methyl (6 g a.i./ha). Four weeks after treatment, the survival rate was evaluated and genomic DNA was extracted from fresh leaves of survived plants. The DNA from imazamox survivors was checked for the presence of the amino acid substitution Trp574Leu with a cleaved amplified polymorphic sequence (CAPS) assay. Instead, DNA from thifensulfuron-methyl survivors was checked for the presence of mutations from position Ala122 to Asp376 by Sanger-sequencing. The wild type was fully controlled by both herbicide applications.In six out of nine *A. palmeri* resistant populations, high cross-resistance to imazamox and thifensulfuron-methyl were registered, suggesting a common resistance mechanism. Indeed, in most plants of these populations, the CAPS method confirmed a point mutation at codon 574 of *ALS*, causing an amino acid shift from tryptophan to leucine. Three out of nine resistant populations showed higher survival rate to thifensulfuron-methyl. The Sanger sequencing revealed the presence of the point mutation Pro197Thr (CCC->ACC) in one population and the point mutation Asp376Glu (GAT-> GAA) in the other two. The results clearly indicate that *A. palmeri* populations have different resistance pattern and different *ALS* mutations conferring resistance. The Trp574Leu mutation was found in most of the A. palmeri populations conferring cross-resistance to both imazamox and thifensulfuron-methyl. Notably, the point mutation Asp376Glu is reported for the first time in this species in Europe. The number of *A. palmeripopulations* resistant to ALS inhibitors in Europe is increasing, making its management even more challenging and requiring harsher and costly control approaches.

Keywords: *Amaranthus palmeri, target site resistance, acetolactate synthase, cross resistance*

Five substitutions in Pro197 causing different levels of florasulam and tribernuron resistance in Tripleurospermum inodorum populations from several European countries

K. Hamouzova [1]; Pavlina Kosnarova [2]; Lena Ulber [3]; Wiktoria Kaczmarek-Derda [4]; Björn Ringselle [5]; Dagmar Rissel [3]

[1] , Prague, Czech Republic, [2] Czech University of Life Sciences Prague, Faculty of Agrobiology, Food and Natural Resources, Prague, Czech Republic; [3] Julius Kühn-Institut (JKI), Federal Research Centre for Cultivated Plants, Institute for Plant Protection in Field Crops and Grassland, Braunschweig, Germany; [4] Norwegian Institute of Bioeconomy Research, Department Invertebrate Pests and Weeds in Forestry, Agriculture and Horticulture, Division of Biotechnology and Plant Health, As, Norway; [5] Research Institutes of Sweden (RISE), Division of Bioeconomy and Health, Department of Agriculture and Food, Borås, Sweden

Poster

Tripleurospermum inodorumis a troublesome dicotyledonous weed in several cropping systems throughout Europe. Because of their frequent use, resistance to ALS inhibiting herbicides has been detected in *T. inodorum* in some European countries. The objective was to determine whether the phenotypic response of *T. inodorum t*o florasulam and tribenuron is due to differences in target site (TS) substitutions or/and in zygosity level. Thirteen populations from the Czech Republic, Germany, Norway and Sweden were examined. Seed samples were taken from fields with unsatisfactory control with ALS inhibiting herbicides. Greenhouse bioassays including a sensitive reference population from the Czech Republic were conducted to quantify the phenotypic responses to varying doses of florasulam and tribenuron. Resistance factors were obtained by comparing herbicide dose-response curves between the potentially resistant populations and the sensitive reference. Eight of the 13 populations were found to be resistant to both active ingredients and the molecular basis for resistance was determined by pyrosequencing 60 individuals from each population for substitutions at position 197. Overall, the eight populations showed a high level of resistance to ALS inhibitors. Most of the populations were phenotypically homogeneous and contained solely herbicide resistant individuals. However, differences in plant responses depending on the population and active ingredient tested were observed. For florasulam, the level of resistance was 2 to 13-fold, with the highest resistance factors observed in German and Czech populations and the lowest in Swedish populations. For tribenuron, resistance indices ranged from 2 to >30. All resistant populations had substitutions at the Pro197 position, but encoding for five amino acid substitutions: leucine, alanine, threonine, glutamine and tyrosine. Herbicide resistance was predominantly TS based, more than 50% of resistant individuals possessed an amino-acid substitution at position 197, most of them were heterozygous. The threonine substitution was detected most frequently and carriers of this substitution showed no or minor herbicide symptoms. Gene sequencing showed that all five substitutions in Pro197 were associated with resistance to both herbicides. However, the strength of the resistance differed both between the five substitutions and between populations carrying the same substitution. The later may be partially explained by differences in zygosity between populations and/or presence of other substitutions or resistance mechanisms, which was not tested for. This study provides understanding of the basis of resistance in *T. inodorum* populations and demonstrates that the level of resistance conferred by a TS substitution is not only determined by the type of substitution.

Role of Glutathione-S-transferases in reduced sensitivity to VLCFA inhibitors in a German population of Tripleurospermum perforatum

Dagmar Rissel [1]; Jeannette Lex [1]; David Riewe [2]; Christoph Böttcher [2]; Lena Ulber [1]

[1] *Julius-Kühn Institute Federal Research Centre for Cultivated Plants, Institute for Plant Protection in Field Crops and Grassland, Braunschweig, Germany*

[2] *Julius-Kühn Institute Federal Research Centre for Cultivated Plants, Institute for Ecological Chemistry, Plant Analytics and Stored Product Protection, Berlin, Germany*

Poster

Tripleurospermum perforatum (Mérat) Lainz (scentless mayweed) is an annual dicotyledonous weed species which infests crops such as winter cereals and spring crops in temperate regions around the world. So far, seven cases of herbicide resistance in scentless mayweed were reported; all of which were found in Europe (UK, Norway, Germany, Denmark, France, Poland and Sweden) and based upon resistance to ALS herbicides. Recently, we identified a *T. perforatum population* (M363) showing reduced sensitivity to the Very Long Chain Fatty Acid (VLCFA) inhibitor metazachlor (HRAC group 15) under field conditions. Two individual plants from the M363 population surviving the full dose metazachlor treatment in bioassays were crossed to generate an F1 progeny population (M363-1). Soil-based bioassays with both populations (M363 and M363-1) confirmed that reduced sensitivity to metazachlor is heritable. It is known that several factors such as seed germination, seeding depth, soil structure and moisture or growth stage at the transplanting time point impact on the response of soil-grown plants to pre-emergence herbicides such as metazachlor. Therefore, agar-based bioassays were conducted additionally to assess metazachlor sensitivity in the populations. The application of the pharmacological inhibitor NBD-Cl indicated the involvement of glutathione-S-transferases in the plant detoxification process of metazachlor. Analysis of metazachlor metabolites confirmed glutathione conjugation in response to metazachlor treatment. Currently, studies on the activity of glutathione-S-transferases and overall gene expression in response to metazachlor treatement are under way.

Keywords: *herbicide resistance, Tripleurospermum perforatum*

Resistance to (ALS)-inhibiting herbicides in white mustard (*Sinapis alba*) from Northern Tunisia

M. Chtourou [1]; J. Torra Farré [2]; G. Mora Marin [2]; Z. Hada 1; T. Souissi [1]

1 Department of Plant Health and Environment, National Institute of Agronomic of Tunisia, University of Carthage,, Tunis, Tunisia

2 Dept. Hortofructicultura, Botànica i Jardineria ETSEA, Universitat de Lleida,, Lleida, Spain

Poster

White mustard (*Sinapis alba*) is problematic in many Mediterranean countries in arable fields, and is common in agricultural zones in the north of Tunisia. This weed species was reported with a persistent seed bank, a high competitive ability in several cropping systems and a high fecundity. Tribenuron-methyl (TM) has been used widely to control white mustard in cereal crops and it became the dominant acetolactate synthase (ALS)-inhibiting herbicide used for post-emergence control of white mustard. The objectives of this research were: (1) to determine the resistance level to TM of two *S. alba* populations in comparison to two susceptible (S1, S2) populations collected from Tunisia and Spain respectively; and (2) to characterize the cross-resistance patterns to other classes of ALS-inhibiting herbicides. Two *S. alba* biotypes (R41, R29) were collected from Beja, North Tunisia, and cultivated under greenhouse conditions for screening tests. Dose-response results demonstrated that all populations were resistant to TM, imazamox, florasulam and flucarbazone. The TM dose required to reduce the fresh weight of the R populations by 50% were at least 60 times higher than those needed for S plants. Moreover, whole plant results also indicated significant differences in response to imazamox, florasulam and flucarbazone among S and R biotypes of white mustard. Reductions in fresh weight of the R populations by 50% needed at least 4 times the dose required for the S plant for these herbicides, providing evidences of cross-resistance among different ALS-inhibitor chemistries. This is the first ALS resistance case confirmed in this species in Tunisia.

Keywords: *ALS inhibitor, dose–response, cross-resistance*

Characterization of Amaranthus tuberculatus populations suspected as Glyphosate-resistant

I. Roth; M. Sibony; B. Rubin

The Hebrew University of Jerusalem, Faculty Agriculture, Food and Environment, R H Smith Institute of Plant Science and Genetics in Agriculture, Rehovot, Israel

Poster

Weeds are the main biotic cause for yield and quality loses, specifically, *Amaranthus tuberculatus* (waterhemp) is considered the 2nd most troublesome weed in corn in the USA. Populations of *A. tuberculatus* from different regions in Israel were collected and their response to glyphosate, applied postemergence, was evaluated. Two main populations were investigated: Newe Ya'ar (GR – glyphosate resistant) and Nahal Timnah (GS – glyphosate susceptible). Glyphosate dose response and shikimic acid accumulation assays were the main phenotyping methods used in this report. Plants at 3 to 5 leaf stage grown in pots were treated postemergence using a Chamber Sprayer equipped with a Tee Jet 110015E nuzzle delivering 200 L ha-1. Three dose response curves were conducted, in order to calculate the level of resistance. An average RI (resistance index) of 2.41 was obtained for the population from Newe Ya'ar (GR). Shikimic acid accumulation assay showed higher accumulation in the mature leaves of the GS population. DNA sequencing of the EPSPS gene did not reveal any mutations at the known reported sites, indicating the involvement of non-target site resistance mechanism. The results suggest that Newe Ya'ar population is glyphosate-resistant, most probably due to reduced availability of glyphosate to the target site in the chloroplast.

Keywords: *Herbicide resistance, shikimic acid, point mutation, EPSPS*

Resistance of Avena fatua and Avena sterilis to ALS and ACCase inhibitor herbicides

E Kaya Altop [1]; O Güzel [2]; H Mennan [3]

[1] *Ondokuz Mayıs University, Samsun, Turkey*

[2] *Republic of Türkiye Ministry Of Agriculture and Forestry Directorate of Plant Protection Central Research Institute, Ankara, Turkey*

[3] *Ondokuz Mayis University, Samsun, Turkey*

Poster

Avena species are problems in many different cropping systems, including winter cereals. The intensive use of herbicides has resulted in the evolution of herbicide-resistant weeds. This evolutionary process largely depends on the biology of the weed species, the biochemical properties of herbicides and management factors. This project aimed to find out the incidence of resistance in Avena fatua and Avena sterilis biotypes to ALS and ACCase inhibitory herbicides in wheat fields. A total of 288 populations, 200 Avena fatua and 88 Avena sterilis, collected from Samsun, Çorum and Amasya provinces of Turkey, were screened with both farmer complaints and random sampling. It was determined that approximately 31% with ALS and 11% with ACCase inhibitor herbicides of the total population could not be controlled when the licensed dose of herbicides was applied. In dose-response experiments in which eight different doses were applied, it was determined that four populations to ALS, six populations to ACCase, and one population showed multiple resistance of A. fatua. In dose-response tests of A. sterilis populations, the Resistance index (RI) was determined as ≤2. In the results of ALS and ACCase enzyme activation determined by spectrophotometrically obtained absorbances and inhibition values (I50), the amount of enzyme increased in resistant biotypes (R) compared to susceptibles (S). For the ALS and ACCase gene region, the nucleotide and amino acid sequences of R and S biotypes were examined as a comparison of the 1740 bp and 3200 bp base sequences, respectively. No mutations were found at nucleotide positions in the possible point mutation sites comprising amino acids. While these data indicating non-target resistance do not indicate large-scale resistance, the presence of a resistant biotype in the field is an important factor in the spread of resistance. It is essential to adopt integrated control approaches such as crop and herbicide rotation before the situation becomes irreversible due to selection pressure.

Keywords: *Avena, herbicide resistance, winter cereals, ALS, ACCase*

SESSION V

NON CHEMICAL
WEED CONTROL TOOLS

Advances in mechanical weed control technologies

Bo Melander; Margaret McCollough

Aarhus University, Department of Agroecology, Slagelse, Denmark

Keynote

This presentation reviews the latest advances in mechanical weed control technologies for agricultural and horticultural field crops. Mechanical weed control (MWC) can be grouped into three categories, full-width cultivation, inter-row cultivation, and intra-row cultivation. With full-width cultivation, both crop and weed plants are treated simultaneously. Therefore, successful implementation relies entirely on field conditions and tool settings for selective application, whether weeds can be removed without significant crop injuries. The fundamental problem of low selectivity still exists; however, new implements have emerged in recent years, making adjustment and operation more straightforward, for example weed harrowing and cultivation of potato ridges. Inter-row cultivation has benefitted markedly from the introduction of automatic guidance systems, which has eased the task of steering and erased the need for manual assistance. Inter-row cultivation is a standard treatment in traditional row crops like maize, soybean, and sugar beet; this strategy is now gaining popularity in organic cereals and pulses grown at increased inter-row spacings. Arguably, the greatest modern innovations made in MWC are those relating to automatic intra-row weeding in row crops, grown with enough space between individual plants to allow for the selective operation of an aggressive weeding device. Vision and GNSS (Global Navigation Satellite System) technologies can now detect individual crop plants and distinguish them from weeds, making the guidance of a mechanical tool for intra-row weed control possible. These technologies are currently most successful in transplanted crops, but it is foreseen that physical automatic intra-row weeding may soon revolutionize weed management in direct-sown row crops; the latest examples of that will be shown.

Decay dynamic of Avena fatua and Echinochloa crus-galli seeds from different populations in a seed burial experiment

Jevgenija Necajeva; Elvis Garais

Institute for Plant Protection Research, Latvia University of Life Sciences and Technologies, Jelgava, Latvia

Oral

Management of the weed soil seed bank is one of the key aspects of a successful long-term weed control strategy. To achieve it, understanding of the processes that govern seed decay in soil is required. Not only soil characteristics and pedoclimatic conditions, but also the intra-specific variation of seed characteristics, such as dormancy, resistance to ageing and defense traits, can influence the fate of the seeds in soil. A seed burial experiment was established in two sites in Latvia to follow the dynamic of seed decay in two commercially important weed species, Avena fatua and Echinochloa crus-galli. Seeds of each species that were used in the seed burial experiment were collected from three different populations in 2020 and collected again from the same populations in 2021. Seeds were buried at two depth levels in each sites at the end of August-September, and seed samples were recovered after two and eight months of burial. The seed mass collected in 2021 was lower than that collected in 2020 from the same populations in all E. crus-galli populations and in one A. fatua population. In 2021, the percentage of mass that represents the seed hull was significantly lower in one of the A. fatua populations. The initial germination of A. fatua seeds immediately after collection was significantly higher in 2021 than in 2020. After the first two months of burial, most of the E. crus-galli seeds remained intact. In both species, the proportion of seeds that germinated in soil differed between sites and burial depths, and both population and collection year had a significant effect. Germinability of intact E. crus-galli seeds after two months of burial was 83 to 100%, indicating that the primary dormancy was released, while germinability of the intact A. fatua seeds was 0-2%. The endosperm tissue of ungerminated A. fatua seeds softened and partly decayed, and visual signs of microbial infection were observed on the seed surface. However, tetrazolium test and germination of the seeds treated with gibberellic acid proved that these seeds were viable. The relation between seed characteristics and seed fate in the soil seed bank is further discussed.

Keywords: *wild oat, barnyard grass, soil seed bank*

The role of legume cover crops in the ecological intensification of winter wheat to manage weeds under different soil tillage regime

Alireza Taab ; Ekhlas Amini; Emanuele Radicetti; Lars Andersson

1 Ilam University, Faculty of Agriculture, Dept. of Agronomy and Plant Breeding, ILAM, Iran

2 Ilam University, Ilam, Iran

3 University of Ferrara, Ferrara, Italy

4 Swedish University and Agricultural Sciences, Uppsala, Sweden

Oral

Ecological intensification by means of legume cover crops undersown in winter wheat has the potential to control weeds and reduce the herbicides adoption in cereal cultivation. They may also provide high biomass to be used for feeding livestock in case of cash crop failure due to the climate changes consequences. Field experiments were conducted to investigate the effect of legume cover crops undersown in wheat (*Triticum aestivum* L. cv. Baharan)to suppress weedsunder different tillage systems at the research station of Ilam University (Iran) during 2018-2019 and 2019-2020. The treatments were three soil tillage systems (conventional tillage, minimum tillage and no-tillage); and four legume cover crop [Persian clover (*Trifolium resupinatum* L. var. Haftchin), vetch (Vicia villosacv. Maragheh), grass pea (*Lathyrus sativusL.*) and bitter vetch *(Vicia ervilia* (L.) Willd.)]. In addition, wheat monoculture with and without weeds, monoculture of each legume cover crop and a fallow plot were included. Legume cover crops were sown at 50% and wheat at 100% of the seed rate adopted by the farmers. In 2018-2019, weed aboveground biomass was reduced of 43.0, 86.5, 68.4 and 3.5% when Persian clover, vetch, bitter vetch and grass pea, respectively, were undersown in wheat under no tillage system. The reduction for the same treatments was of 54.0, 98.0, 85.0 and 84.9 %, respectively, under minimum tillage and 70.0, 95.8, 65.8 and 50.8%, respectively, under conventional tillage. In 2019-2020, the reduction in weed aboveground biomass under no-tillage system was significant only for vetch and bitter vetch (33.4 and 10.3%, respectively), while no reduction was observed in Parsian clover and grass pea. Under minimum tillage, the reduction was 28.2, 62.0, 58.5 and 55.5% in wheat undersown with Persian clover, vetch, bitter vetch and grass pea, respectively, and 43.9, 57.4, 44.3 and 46.3%, respectively, under conventional tillage. Vetch adopted for ecological intensification of wheat showed the greatest impact in reducing weed dry weight. As expected, the highest wheat grain yield (8422 kg ha-1) was obtained in wheat monoculture with weed control followed by wheat + bitter vetch intercropping (6267 kg ha-1) under minimum tillage. The forage quality in legume crops and soil factors were also improved under intercropping system. The land equality ratio was more than one in all intercropping patterns. We concluded that the intercropping of wheat with the legume cover crops present promising environmental-friendly approaches for managing weeds in a sustainable way while maintaining the crop production system.

Facilitation of weed seed predation by living mulch and cover crops

Matthias Schumacher;

Roland Gerhards

University of Hohenheim, Department of Weed Science, Stuttgart, Germany

Oral

Weed seed predation (WSP) is an important agro-ecosystem service that naturally controls weed populations. However, disturbances like harvesting and soil tillage directly interfere with the activity of the seed predators during a peak in weed seed availability around cereal harvest. Plant soil cover and reduced soil tillage are factors that might positively affect WSP. The aim of this study was to investigate cover crops (living mulch and cover crops) along with soil distur-bance (direct and conventional seeding) in comparison to a fallow and repeated stubble tillage in terms of WSP facilitation. A field experiment with a randomised complete block design and 4 repetitions was set up from 2017 - 2019. WSP rates were assessed monthly from July to November during a period of 8 days by using seed cards and exclosure cages. Living mulch exhibited the highest WSP rates of 72% and >95% right after cereal harvest in August and September of 2017 and 2019, while the rest of the treatments was between 2-5%. In October and November mustard showed on average twice as high WSP rates than the other treatments (50% vs. 10-25%). Disturbance did not significantly influence WSP, except for living mulch. Predator groups (invertebrates and vertebrates) were not influenced by the treatments, rather year and month determined the groups dominance. Living mulches, and to a certain extent also cover crops, are a potent tool, not only for preventive weed control, but also to facilitate weed seed predation after cereal harvest.

Keywords: *weed seeds, Carabid beetles, ecosystem services, cover crop, tillage*

Carry over effects of cover crop mixtures and management practices on subsequent crops and weeds in no-till

Alicia Rouge [1]; Guillaume Adeux [1]; Delphine Moreau [1]; Jean-Philippe Guillemin [2]; Stéphane Cordeau [1]

[1] INRAE, Dijon, France

[2] Agrosup Dijon, Dijon, France

Oral

Cover crops (CC) appear as a promising agroecological tool to suppress weeds and maintain crop productivity while reducing chemical inputs such as herbicides and nitrogen fertilizers. The weed suppressive effect of CC and CC nitrogen release have been related to CC composition, soil resource availability and CC termination methods but the relative effect of these factors and their interactions remain poorly documented, especially in the case of CC mixtures. Moreover, most studies have focused on the subsequent spring crop, and hence, lacked to investigate long-term carry over effects of CC. A two field:year experiment was conducted to investigate the effect of CC mixture (2 or 8 species including or not legume species, compared to a bare soil control), resource availability (water and nitrogen) at CC sowing and CC termination method (rolling and glyphosate, compared to a winterkill control) on weed biomass and productivity of two subsequent unweeded, unfertilized and direct seeded crops (spring barley and winter linseed in year 1 and 2, respectively). Weed biomass in the two subsequent crops was lower when CC were terminated by glyphosate whereas no difference was observed between rolling and winterkill. Nevertheless, few combinations of CC mixture and resource availability at CC sowing resulted in similar weed biomass whether terminated by rolling, winterkill, or glyphosate. In barley (year 1), weed suppression could be attributed to a higher CC mulch effect, resulting from higher total biomass at CC termination when CC were fertilized at CC sowing (inconsistent results across field:years). In linseed (year 2), weed suppression could be attributed to changes in weed community composition. Productivity of both crops was higher when CC were terminated by glyphosate than rolling or winterkill. However, few combinations of CC mixture and resource availability at CC sowing resulted in similar barley productivity whether terminated by rolling, winterkill, or glyphosate. This could be attributed to higher nitrogen release by legume-based CC mixtures or by fertilized non-legume based CC mixtures (but results were inconsistent across field:years, possibly due to contrasted nitrogen availability before CC sowing). Such an effect was not observed in linseed, probably due to reduced nitrogen availability after barley. Our results encourage further experiments to identify the best combination of CC mixture and management practices to both control weeds and improve the subsequent crop productivity, without using glyphosate.

Unravelling the success of weed control by relay intercropping with legumes in low-input cereal-based Mediterranean cropping systems

Federico Leoni [1]; Stefano Carlesi [1]; Per Kudsk [2]; Anna-Camilla Moonen [1]

[1] *Sant'Anna School of Advanced Studies, Institute of Life Sciences, Pisa, Italy*

[2] *Aarhus University, Department of Agroecology, Slagelse, Denmark*

Oral

This presentation shows the results of a study investigating the performance of three legumes (*Medicago sativa, Medicago polymorpha*, and *Trifolium subterraneum)* as a IWM tool in a relay intercropping system with durum wheat.The study was conducted near Pisa (Italy) in a low-input Mediterranean cropping system for two consecutive wheat-sorghum rotations to assess the effects of relay intercropping of legumes on weeds at crop rotation level. During the intercropping period legumes reduced weed biomass up to 90% compared with the control (wheat sole crop), without negative impact on yield.After wheat harvest, legumes persisted in the field and biomass production level determined their weed control capacity. *Medicago sativa* and *Trifolium subterraneum* established a suppressive mulch and reduced weed biomass up to 90 % compared with the control whereas no significant effect was observed for *Medicago polymorpha*. In the subsequent spring legumes were incorporated into the soil and sorghum was sown. Residual effects of *Medicago sativa* significantly reduced weeds biomass by the 50% in sorghum compared with the control. Results of this experiment confirmed that the biomass production is a good indicator of the weed control ability of legumes. However, biomass did not fully explain the variability in weed control capacity of the selected legumes. Allelochemical effects of legumes may also be involved. Studying the allelochemical properties of legumes can be difficult under field conditions and therefore two additional laboratory experiments were conducted to deepen the knowledge about the chemical interactions between wheat, legumes, and weeds during two critical phases for weed control: the intercropping period and the period after the incorporation of legume residues into the soil. An intercropping pattern was created in pots to explore the effect of the co-cultivation with wheat on the biosynthesis and root exudation of flavonoids in legumes. Flavonoids with potential allelochemical activity such as daidzein, genistein, medicarpin, formononetin and kaempferol significantly increased in plant tissues and root exudates of the legumes in response to co-cultivation with wheat. An additional pot experiment was carried out to investigate the allelopathic effect of the legume fresh biomass on the germinability of four weed species (*Alepecurus myosuroides, Lolium rigidum, Chenopodium album* and *Sinapis alba*). To simulate the incorporation of legumes before the sorghum sowing, legume fresh leaves were grinded and mixed with field soil at two concentrations: 25 and 50 g/l. Results of this experiment were consistent with what had been observed under field conditions and confirmed that Medicago sativa has the highest allelochemical potential compared with the *Trifolium subterraneum* and *Medicago polymorpha.*

Keywords: *Living mulch, crop diversification, Integrated Weed Management, root exudate; plant interactions, allelopathy*

Managing inactive weed propagules – key technologies in sustainable weed management

B. Gerowitt [1]; Barbara Baraibar [2]

1 University of RostockGroup Crop Health, ROSTOCK, Germany

2 University of Lleida – Agrotecnio, Spain, , Spain

Oral

The soil propagule bank is the reservoir from which weeds colonize arable fields. It is composed of weeds seeds and ramets, which arefragments from clonal growth of perennial weeds. Inactive propagules are those that are not germinated or sprouted. We present advances in managing inactive weed propagules. Historically, this part in management was very important for arable weeds but was put aside when herbicides became the dominant weed control option seven decades ago. However, herbicides require activated weed propagules, germinated or sprouted plants with at least a radicle or later roots and green tissue to be effective. Here, we exclusively looked at ways of managing inactive propagules. Based on the location of the targeted weed seeds and ramets, four processes were identified; namely: crop harvest (weed seed crushing and milling), weed seeds on the soil surface (weed seed predation), weed propagules in the soil matrix (weed seed decay and mechanical destruction of ramets) and theprocess chains around arable farming (manure or crop biomass transport and biogas plants). The revision of these processes renews the way we look at propagule bank management and circumvents dormancy as a protection strategy of weeds. However, we hypothesize ¨responses¨ from both annual and perennial weeds in terms of adaptations.

Keywords: *Weed seed crushing, seed predation, seed decay, mechanical control, inactive propagules*

Experiences in electrophysical vegetation control as substitution for non-selective herbicide-application

Benjamin Klauk [1]; Dr. Jan Petersen [2]

[1] *Technische Hoschule Bingen, Bingen am Rhein, Germany*

[2] *Technische Hochschule Bingen, Bingen am Rhein, Germany*

Oral

The omission of herbicidal active ingredients and the evolution of herbicide-resistant weeds require other methods to ensure the vegetation control in several indications. The aim of this investigation was to evaluate a non-selective electrophysical procedure for testing suitability in desiccation in early potatoes, control of perennial weeds (*Cirsium arvense, Elymus repens, Rumex obtusifolius*) and stale seedbed method in *Alopecurus myosuroides*-control. Therefore, the Electroherb™ technology of the Zasso® company, which is based on a non-selective, systemic, electrical flow through the vascular system of the plants, was tested at Bingen (Germany) in 2020 and 2021. All indications were tested in separate field trials due to different application times and treatments. In addition to different driving speeds (1, 3 and 6 km/h), combinations of chemical (60 g carfentrazone ha-1) and mechanical (haulm chopper) methods with 6 km/h (five days after chemical and mechanical treatment) were tested for desiccation of the leaf canopy in early potatoes. Testing this procedure for controlling *A. myosuroides* (BBCH 10-12 at application time) in October or the perennial weeds in June the driving speed was varied from 1 (except in stale seedbed trial), 3 and 6 km/h. In all experiments, only one-time electrical application was conducted. In 2020, additionally to driving speed the position of the electrodes was varied in stale seedbed trial resulting in a larger contact area between electrode and surface. In the trial year 2020, a 100% degree of leaf and stem dieback was recorded in all treated potato treatments. In 2021, efficacies between 80 and 90% were achieved in the electrophysical-only treatments, which was due to dense potato leaf canopy. Perennial weeds showed efficacy rates on the shoots of up to 100%, but all species re-sprouted four weeks after treatment in 2021. In 2020 only E. repens showed resprouting after treatment. Generally, efficacy increased with decreasing soil moisture in perennial weed control. *A. myosuroides* was reduced after application by 66 % in 6 km/h-treatment and 82 in 3 km/h-treatment in 2020. Due to late germination of A. myosuroides in 2021, density was only reduced 10 % (comparison: density in untreated control increased 200 %). Besides costs of the technology, for a comprehensive evaluation, there is still a lack of knowledge regarding risks for soil flora and fauna and the influence on efficacy by different soil parameter. However, electrophysical weed control may offer the opportunity to replace some of the herbicide indications in the near future.

Keywords: *non-chemical weed control, perrenial weeds, desiccation of early potato*

The Potential of Cover Crop (CC) Mixtures to Suppress Winter and Summer Weeds in Citrus Orchards

Nikolaos Antonopoulos [1]; **Ioannis Gazoulis** [1]; Katerina Zervopoulou [1]; Panagiotis Kanatas [2]; Ilias Travlos [1]

1 Agricultural University of Athens, Laboratory of Agronomy, Athens, Greece

2 University of Patras, Department of Crop Science, P.D. 407/80, Messolonghi-Greece, Messolonghi, Greece

Oral

A field trial was conducted (2020 to 2021) to evaluate cover crop (CC) mixtures and monocultures, mowing and glyphosate applications for weed management in a citrus orchard *(Citrus reticulata Blanco cv. Nova*) located in Pyrgos, Western Greece. A randomized complete block design (RCBD) was established with nine treatments replicated four times. Treatment list included: oat (*Avena sativa L.*), hairy vetch (Vicia villosa Roth.), and white mustard (*Sinapis alba L.*) CC monocultures, two-species CC mixtures of oat + hairy vetch and white mustard + hairy vetch, a three-species CC mixture of oat + white mustard + hairy vetch, two mowing passes, two glyphosate applications, and an untreated control. Glyphosate was applied at 720 g a.e. ha-1 with a pressurized Gloria® 405 T sprayer calibrated to deliver 300 L ha−1 of spray solution at 200 kPa pressure through five 8002 flat-fan spray nozzles. *Medicago lupulina L.* and *Avena sterilis L.* were the dominant species. CCs were established in autumn. After eight weeks, the first mowing pass was performed as well as the first glyphosate application. Winter weed biomass was evaluated before CC termination. At late flowering, CCs were flail-mowed and their residues were left on soil surface to suppress summer weeds. The second mowing pass and the second glyphosate application were performed four weeks after CC termination. *Echinochloa crus-galli* (L.) P.Beauv. and *Mercurialis annua L.* were the dominant species. Summer weed biomass was evaluated twelve weeks after CC termination. Oat + white mustard + hairy vetch mixture produced the highest amounts of biomass followed by white mustard + hairy vetch. Treatments affected winter weed biomass (***P ≤ 0.001). Glyphosate provided satisfactory control of winter weeds. A polynomial regression indicated that winter weed biomass decreased by increasing the number of species in the CC (***P ≤ 0.001). The three-species CC mixture suppressed weed growth by 87% compared to the untreated control. Mowing was among the least effective treatments. Glyphosate provided excellent control of summer weeds while the three-species CC mixture suppressed summer weed growth more than two-species CC mixtures and CC monocultures. A reciprocal linear regression was observed between CC biomass and summer weed biomass (***P ≤ 0.001). Our results suggest that diversified CC mixtures can potentially contribute to the development of Integrated Weed Management (IWM) practices in fruit orchards.

Keywords: *Avena sativa L.; Vicia villosa Roth; Sinapis alba L.; Citrus reticulata Blanco; mowing; glyphosate*

Two years multi-site field experiments to control perennial weed species without herbicides

Marian Weigel [1]; Lars Olav Brandsæter [2]; Therese W. Berge [3]; Jukka Salonen [4]; Timo Lötjönen [4]; Bärbel Gerowitt [5]

[1] *University of Rostock, Faculty of Agricultural and Environmental Sciences, Crop Health, Rostock, Germany, Rostock, Germany*
[2] *Norwegian University of Life Sciences (NMBU), Faculty of Biosciences, Department of Plant Sciences, Ås, Norway, Norwegian Institute of Bioeconomy Research (NIBIO), Division of Biotechnology and Plant Health, Department of Invertebrate Pests and Weed, , Unknown*
[3] *Norwegian Institute of Bioeconomy Research (NIBIO), Division of Biotechnology and Plant Health, Department of Invertebrate Pests and Weeds in Forestry, Agriculture and Horticulture, Ås, Norway, , Unknown*
[4] *Natural Resources Institute Finland (Luke), Finland, , Unknown*
[5] *University of Rostock, Faculty of Agricultural and Environmental Sciences, Crop Health, Rostock, Germany, , Unknown*

Oral

The perennial weeds *Cirsium arvense, Elymus repens* and *Sonchus arvensi*s, propagating by vegetative reproduction, are widespread in European arable farming systems. Prevalent control measures rely on an extensive use of herbicides in conventional farming whereas in organic farming intensive inversion tillage is common. We established a joint factorial field trial series at three different sites i.e., in Germany, Finland and Norway from July 2019 to September 2021. After experiment initiation and first tillage operations in autumn 2019, spring cereals were cropped for two years. The experiments included the factors: (i) Subsidiary crops (DE: mustard; FI/NO: ryegrass + clover), (ii) Mouldboard ploughing in spring (20-25 cm depth) and (iii) "Kverneland root cutter" (autumn: 10 cm depth; spring: 20-25 cm depth). This root cutter is a prototype machine cutting below ground without inverting the soil. The three experimental factors were implemented in two levels (with and without the treatment) and operations were repeated twice (2019 and 2020) in the same experimental plot. The species occurred differently: *C. arvense* dominated the site in Germany, *E. repens* and *S. arvensis* the one in Finland, while in Norway all three species were present. In terms of shoot biomass, in Germany mouldboard ploughing gave the best control of *C. arvense*, second best control was obtained by the root cutter, while subsidiary crops resulted in no reduction. The effect of the root cutter was equal to ploughing in Norway. The effects for *E. repens* for the three experimental factors followed the same tendencies in the same order as they did for *C. arvense*. For *S. arvensis* in Norway, the least weed biomass was found in the treatments in which subsidiary crops, root cutting and ploughing were all combined. In Finland, ploughing decreased the effect of root cutting against *S. arvensis*. We show that root cutting may have the potential to control *C. arvense* up to a similar extent as ploughing. For controlling *E. repens* and *S. arvensis*, root cutting can at least be an alternative to stubble treatment. The results indicate the possibility to combine root cutting and the establishment of subsidiary crops. This research was part of the project "AC/DC-weeds- Applying and Combining Disturbance and Competition for an agro-ecological management of creeping perennial weeds" funded within the ERA-Net Cofund SusCrop/EU Horizon 2020, Grant no. 771134.

Phytotoxic efficacy of phytocannabinoids on the germination and root growth of common problematic weeds in Zea mays (L.)

Michael Merkle [1]; Roland Gerhards [2]

[1] University of Hohenheim, Department of Weed Science 360b, Stuttgart, Germany

[2] University of Hohenheim, Department of Weed Science 360b, , Germany

Oral

In addition to the competition effects, the release of phytotoxic secondary plant metabolites plays an essential role in the weed suppressive properties of cover crops. We investigated the phytotoxic effects of various secondary plant metabolites of the group of phytocannabinoids and one aqueous cover crop extract (*Cannabis sativa L.*) on the germination rate and seedling root length of Zea mays and several weed species (*Alopecurus myosuroides*, *Stellaria media*, *Echinochloa crus-galli* and *Chenopodium album)* in laboratory experiments. Pure secondary metabolites belonging to the group of phytocannabinoids (*cannabidiol* (CBD), cannabigerol (CBG), cannabichromen (CBC), cannabinol (CBN), cannabidivarin (CBDV) and tetrahydrocannabivarin (THCV)) were tested in germination bioassays in a randomized block design in six different concentrations (6.125%-100%) including a control (0%) with deionized water (dH2O). The phytocannabinoids were dissolved in ultrapure ethanol and a stock solution (100%) of 2 mg phytocannabinoids per ml ethanol was prepared. The stock solution was diluted to the desired concentrations of 6.125 %, 12.5 %, 25 % and 50 % by adding ethanol, applied on the filter paper in the petri dish and placed under a vent to evaporate. *Aqueous C.* sativa extract was prepared using a stock solution of 500 mg fresh cover crop biomass per ml dH2O. 30 weed seeds (4 maize seeds) were added to each petri dish, 3 ml of dH20 (for the phytocannabinoids) or 3 ml of the aqueous cover crop extract was applied and sealed with parafilm. The germination rate (GR) was observed after 10 days. Additionally the root length were measured 10 days after treatment (DAT). To better classify the abiotic stress level on the investigated plants caused by the applied secondary plant metabolites, the Weed Tolerance Index (WTI) was calculated from the collected measurements. The WTI combines the germination rate with the root length and generates an index between 0 (stressed) and 1 (not stressed). First results showed that among the phytocannabinoids, only CBD and CBDV showed significant suppressing effects on the root length of all weeds but not on germination rate. On average, weed root length was reduced by 52% (CBD) and 81% (CBDV) by application of 0.1 mg and by 62% (CBD) and 59% (CBDV) by a concentration of 1 mg. In maize a concentration of 0.125 mg reduced the root length by 32% (CBDV). The results so far of the ongoing trials indicate a strong suppression of weed root length by the application of the phytocannabinoids CBD and CBDV.

Keywords: *Allelochemicals, germination test, phytotoxicity, plants extracts, root length, phytocannabinoids, Zea mays L.*

The potential for Harvest Weed Seed Control (HWSC) of Common Weed Species in Denmark

Christian Andreasen [1]; Zahra Bitarafan [2]

[1] University of CopenhagenDepartment of Plant and Environmental Sciences, Taastrup, Denmark

[2] Norwegian Institute of Bioeconomy Research, Ås, Norway

Oral

Harvest weed seed control takes advantage of seed retention at maturity by collecting weed seeds as they pass through the harvester. We assessed the seed production and shedding pattern of common weed species in two wheat and two oat fields in Denmark. The aim was to evaluate the possibility of harvesting retained seeds on weeds at crop harvest by a combine harvester based on estimation of weeds seed retention. Before flowering, ten plants of each weed species were selected and surrounded by a seed trap comprising of a porous net. When the plants started shedding seeds, the seeds were collected from the traps and counted weekly until crop harvest. Just before crop harvest, the retained seeds on the plants were counted and the ratio of harvestable seeds and shed seeds during the growing season were determined. The seed production and shedding patterns varied between the species. In *oat*, *Anagallis arvensis L.*, *Capsella bursa-pastoris (L.) Medik.*, *Chenopodium album L.*, *Fallopia convolvulus* (L.) *Á. Löve*, *Geranium molle L.*, *Persicaria maculosa Gray*, *Polygonum aviculare L.*, *Silene noctiflora L.*, *Sinapis arvensis L.*, *Sonchus arvensis L.*, *Spergula arvensis L.*, *Stellaria media* (L.) *Vill.*,*Veronica persica Poir.*, and *Viola arvensis Murray* retained on average 61, 52, 67, 44, 58, 32, 59, 95, 67, 23, 45, 56, 51, and 33%, respectively, of their produced seeds at crop harvest. In wheat, *Alopecurus myosuroides Huds.* and *Apera spica-venti* (L.) P. Beauv. retained on average 34 and 33%, respectively, of their seeds at harvest. *Silene noctiflora* was classified as a good target for harvest weed seed control; *A. myosuroides*, *A. spica-venti*, *C. bursa-pastoris*, *C. album*, *F. convolvulus*, *G. molle*, *P.maculosa*, *Sinapis arvensis*, *Sonchus arvensis*, *Spergula arvensis* and *V. arvensis* were classified as intermediate targets; and *A. arvensis*, *P. aviculare*, *S. media* and *V. persica* were classified as poor targets. The research shows that there is a great potential to reduce the input of weed seeds to the soil seed bank by harvest weed seed control.

Keywords: *Harvest weed seed control; Soil seed bank ; Weed seed retention*

A quest for herbicide-free viticulture

Matteo Mota [1]; Serena Fantasia [1]; Thierry Heger [1]; Florine Degrune [1]; Frédéric Lamy [1]; Dorothea Noll [1]; Markus Rienth [1]; David Marchand [2]; Robin Sonnard [2]; Vivian Zufferey [3]; Nicolas Delabays [4]

[1] Changins, Viticulture and Oenology / HES-SO University of Applied Sciences and Arts Western Switzerland, 1260 Nyon, Switzerland
[2] Institut de recherche de l'agriculture biologique (FiBL), 1001 Lausanne, Switzerland
[3] Agroscope, 1009 Pully, Switzerland
[4] HEPIA, HES-SO University of Applied Sciences and Arts Western Switzerland, 1254 Jussy (Geneva), Switzerland

Oral

In viticulture, mechanical weed control is commonly viewed as the best alternative to herbicide use. However, mechanical weeding is not well adapted to areas that are difficult to access (under the crop row, steep slopes) or prone to soil erosion. In these situations, weeds are still commonly treated with herbicides. The aim of the present research is to provide sustainable alternatives to chemical weeding in Switzerland through the development of beneficial vegetation covers, established from the selection and promotion of species which grow spontaneously in vineyards. Here, we present the key steps of the research, its progress, and perspectives. The first step consisted to inventory species present in the vineyard and their associated functional traits. We further interviewed producers to learn from their on-field experience with beneficial species. A set of plant candidateswas then selected based on their height, root depth, life strategy, phenology, and potential allelopathic properties, as well as their ability to promote ecosystem services. In the second step, the benefits provided by the selected species – alone and in mixtures – was evaluated in a simplified field system without vines. Several Swiss ecotypes of *Medicago lupulina*, *Bromus tectorum*, *Arenaria serpyllifolia*, *Origanum vulgare*, *Clinopodium vulgare*, and *Prunella vulgaris* were tested under different mowing intensities. For each treatment, we recorded the ability of the plants to regrow or resow,and their capacity to control unwanted weeds. This work allowed us to identify optimizedseedling mixtures and appropriate mowing intensity. Lastly, we implemented these mixtures in an on-farm network under various pedoclimatic conditions and agronomic contexts (mechanized plots and terraced vineyards). This vineyard network is part of a 4-year national project (CV-VigneSol; 2021-2024) and consists of 12 plots located across 4 counties. The objective is to determine the most efficient way to integrate these mixtures in an optimal technical itinerary, maximizing their benefits. Mixtures were sown in combination with other ground managements: tillage, spontaneous flora or sowing of winter cover crop. Several environmental and agronomic surveys will be conducted over the next three years. This will provide useful insights into the relevance of these innovative itineraries. Altogether, this project can lead to the development of a practical solution for winegrowersand will contribute to develop a more sustainable viticulture.

Keywords: *alternatives to herbicides; seedling development; functional traits; ecosystem services; Swiss viticulture.*

Managing Cynodon dactylon in organic vineyards with rolled cover crops

Carlos Cabrera; Bruna Català; Barbara Baraibar; Jordi Recasens

University of Lleida, Lleida 25198, Spain

Poster

One of the main problems in organic vineyards is to achieve an efficient weed control given the yield losses they can cause and the costs associated with their control. In this sense, the use of cover crops become an efficient strategy. Cover crops offer ecosystem services such as nitrogen retention, organic matter increase, erosion reduction and weed management, among others. However, the presence of noxious weeds such Bermuda grass (*Cynodon dactylon*) can make weed management by cover crops difficult. Mowing the cover crops when they finish the life cycle is not entirely efficient on *C. dactylon* control given the active summer development of the weed. An alternative is terminating the cover crops with a roller-crimper pass creating, a more durable mulch, that can limit the weed emergence because of the lack of light and the potential release of allelopathic compounds. With the aim to improve the control of *C. dactylon* in vineyards with the use of cover crops, a field trial was carried out in Raimat, Lleida (Spain). In November 2019, different cover crops were sown in the inter-rows: Triticale(210 kg/ha), *Hordeum vulgare*(150 kg/ha), *Avena strigosa*(70 kg/ha), *Lolium multiflorum*(40 kg/ha), *Sinapis alba* (20 kg/ha) and Phacelia tanacetifolia(10 kg/ha). The two management options were: a) a roller-crimper pass in spring (April 2020) creating a slowly decaying mulch, and b) the traditional mowing/shredding pass in early summer (June 2020). Except S. alba, all covers showed, in April 2020, a coverage greater than 80%. On average, the overall values of *C. dactylon* coverage were lower in the rolled covers than in the mowed covers, in both sampling dates: July (10.8% vs 14.3%) and September (16% vs 26.4%), respectively. The rolled covers where the coverage of *C. dactylon* was significantly lower than the mowed covers in September 2020 -five month after the roller crimper pass- were *A. strigosa* (7.2% vs 25.7%) and *Ph. tanacetifolia* (8.9% vs 34.4%), respectively. These results highlight the potential use of the roller crimper on cover crops in organic vineyards to contain the expansion of noxious species such as *C. dactylon.*

Keywords: *Vineyards, bermudagrass, cover crops, roller-crimper*

Cover crops in citrus orchards for weed management and support of natural enemies of insect pests

Philippos Mylonas [1]; Stathakis [2]; Leonidas Economou [1]; Myrto Barda 1; Filitsa Karamaouna 1; Konstantinos Kassiotis [3]; Vaya Kati [4]

[1] *Laboratory of Efficacy Control of Pesticides, Scientific Directorate of Pesticides Control and Phytopharmacy,* [2] *Laboratory of Efficacy Control of Pesticides; Laboratory of Weed Science, 3 Laboratory of Toxicological Control of Pesticides,* [4] *Laboratory of Weed Science, Benaki Phytopathological Institute, Kifissia, Greece*

Poster

Cover crops in orchards are increasingly adopted to support sustainable farming for the multitude of services they provide. The current study was performed in the context of the multidisciplinary project PLANT-B (PRIMA) and focused on the effect of several cover crop species on suppressing weeds and supporting populations of natural enemies (parasitoids and predators) of insect pests. A field experiment was conducted in a 15-year-oldcitrus orchard (0.5 ha) cv Merlin with clay soil and trees planted at 5*5m, in Argolida (Peloponnese, Greece). Five treatments were tested: three cover crop species including vetch (*Vicia sativa L.*),rye (*Secale cereale L.*), and tall fescue (*Festuca arundinacea Schreb.*), herbicide application (glyphosate at 3600 g a.i./ha) and untreated control, arranged in a RCBD with four replicates (60 m2/plot). After shallow soil cultivation of the entire orchard, cover crops were sown by hand between tree lines in December 2020. In mid-April 2021, during cover crop flowering, weeds and cover crops present in a 0.25 m2 quadrat/plot were cut to the ground level for dry weight measurement. At the same time, the presence of natural enemies was assessed with suction sampling. After these measurements, cover crops and the untreated control were terminated with mowing. Furthermore, weeds in separate plots were treated with herbicide using a hand-held battery-operated sprayer fitted with a 2 m boom with 3 flat-fan nozzles and calibrated to deliver 300 L/ha at 2 bar pressure. One month later, weed re-growth and presence of natural enemies were re-assessed, as before. The most dominant weed species in the citrus orchard (>10 plants/0.25 m2) were *Capsella bursa pastoris* (L.) *Medik.*, *Veronica sp. L.* and *Lolium rigidum Gaud.* Just before termination weed biomass was significantly suppressed in rye and vetch cover crops, compared to the untreated control. Weed re-growth in rye and vetch cover crops was comparable to the herbicide treatment, and significantly lower compared to tall fescue and mowed control. The incidence of natural enemies did not differ significantly between the cover crop treatments before termination. Their recovery one month later, was significantly higher in tall fescue compared to the other cover crops, while the mowed control and herbicide treatment had an intermediate effect. Our results showed that rye and vetch can suppress weeds efficiently while the perennial tall fescue that recovered after termination, probably favours conservation of natural enemies. Further research is necessary to elaborate on this interesting weed-insect interaction with cover crop species.

Weed suppression in cover crop mixtures under contrasted levels of resource availability

Alicia Rouge [1]; Guillaume Adeux [1]; Delphine Moreau [1];
Jean-Philippe Guillemin [2]; Stéphane Cordeau [1]

[1] INRAE, Dijon, France

[2] AgroSup Dijon, Dijon, France

Poster

Cover crop (CC) mixtures appear as a promising agroecological tool for weed management. Although CC supress weed growth by competing for resources, their suppressive effect under contrasting levels of soil resource availability remains poorly documented. A two field:year experiment was conducted to investigate the weed suppressive effect of four CC mixtures. They were composed of 2 or 8 species including or not legume species and compared to a bare soil control. The experiment included two levels of irrigation and nitrogen fertilisation at CC sowing. The objectives were to assess (i) weed and CC aboveground biomass response to CC mixtures and resource availability, (ii) the weed suppressive effect of CC mixtures across a gradient of CC biomass and (iii) weed community response to CC mixtures and resource availability. CC and weed biomass were mainly influenced by interactions between CC mixtures and fertilisation and between CC mixtures and irrigation, with contrasted effects between field:years. Nitrogen fertilisation increased biomass of non-legume based CC mixtures but this only resulted into a further reduction of weed biomass of little biological relevance. Legume-based CC mixtures better suppressed weeds without nitrogen fertilisation in year 2 but not in year 1, possibly due to contrasted initial soil nitrogen availability (lower in year 2). Weed biomass generally benefited more from irrigation than CC. Among the 33 weed species recorded, weed communities in each plot were dominated by wheat regrowth and two sown species each year (i.e. *Geranium dissectum* and *Veronica persica* and *Geranium dissectum* and *Echinochloa cru*s-*galliin* year 1 and 2, respectively), whose relative species biomass varied across the interaction between year, CC mixture and resource availability. Our results showed a complex effect of the interaction between the environment (e.g. resource availability) and CC and weed traits on weed:CC mixture relationship. Further experiments focusing on plant traits should improve our understanding of weed:CC competitive outcomes under various levels of resource availability.

Suitability of Alopecurus myosuroides Huds. for Harvest Weed Seed Control in Germany

Lena Ulber

Julius Kuehn-Institut (JKI), Institute for Crop Protection in Field Crops and Grassland, Braunschweig, Germany

Poster

Reducing the entry of weed seeds into the soil seed bank by collecting and destroying weed seeds during harvest (Harvest Weed Seed Control; HWSC) is a long-term strategy for reducing weed populations of competitive and resistant-prone weed species such as *Alopecurus myosuroides Huds.*. A high efficacy of HWSC for reducing weed populations primarily depends on the a) extent of seed retention at the time of crop harvest and b) height of produced seeds above the ground (> 15 cm) for the target species. Seed shedding and seed retention rate at harvest was therefore determined for *A. myosuroides* in three winter wheat fields in 2020. Two different winter wheat harvest dates (regular and two weeks earlier) were compared. To quantify the amount of shedded seeds over the growing season before harvest, strips of water-permeable fleece were laid out between the wheat rows and sheeded seeds were collected weekly from the time of seed ripening until harvest. At the two harvest dates, plots were harvested and the amount of retained seeds assessed. The three experimental sites showed considerable differences in seed shedding and seed retention arte. At the early harvest date, *A. myosuroides* showed a seed retention rate of52-73 %,whereas at the regular harvest date only 31-51% of the seeds were retained on the plants. In our trials, all *A. myosuroides* seed stands were above the usual harvest height of 15 cm, so that they could be completely captured by the combine. Our results confirm previous studies from Denmark which observed seed retention rates of 29-37% in *A. myosuroides* at harvest time of winter cereals. It can therefore be concluded that *A. myosuroides* shows a medium potential for efficient HWSC use. Nevertheless, on fields with high *A. myosuroides* densities, reducing the soil seedbank by using HWSC tactics can be a valuable additional IWM option not yet fully explored in Europe.

Keywords: *Harvest weed seed control, seed retention, seed shedding, integrated weed management*

Mechanical weed control evaluation in dry seeded rice in Italy

Eleonora Miniotti [1]; Marco Romani [1]; Simone Sgariboldi [1]; Elio Dinuccio [2];
Silvia Fogliatto [2]; Francesco Vidotto [2]

[1] *Ente Nazionale Risi, Castello d'Agogna, Italy*

[2] *Università degli Studi di Torino, DISAFA, Grugliasco, Italy*

Poster

In a field study carried out 2021 in Pavia (N-W, Italy) combinations of mechanical and chemical weed control methods where compared with the aim to reduce the use of chemical inputs in rice. In a split plot design with four replicates, an untreated treatment (M1) was compared to three inter-row hoeing weeders: weeder 1 with 15 cm row spacing (RS) (M2); weeder 2 with 30 cm RS (M3); weeder 3 with 36 cm RS (M4). Inter-row hoeing was complemented with two (in M4) or three passages of finger harrowing along the rows. Each mechanical treatment was evaluated under three herbicide programs: i. herbicide untreated plot (H1); ii. early post-emergence treatment (H2); iii. early and late post-emergence treatment (H3). "Caravaggio" rice variety was drill seeded on May 17 (140 kg/ha) at 15, 30 or 36 cm RS. Weeding interventions with the different weeder types were carried out on June 11 (M2) and 14 (M3 and M4), with rice at BBCH stage 13-20 and with a working depth of 5-7 cm. Cyhalofop-butyl, clomazone and pendimethalin were applied in treatment H2 (June 1) and profoxydim in treatment H3 (25 June). The use of weeder and finger harrowing resulted in a high *Echinochloa crus-galli* control in the intra-row space, with a reduction compared to control of about 78, 43 and 33% for M4, M3 and M2 treatment, respectively. No control was observed on the row. High control of *Cyperus esculentus* was obtained both in the intra-row space (96, 92 and 70% for M2, M4 and M3) and on the row (91, 71 and 69% for M4, M2 and M3). Yield was not statistically different among different weeders (8.7, 8.0, 7.5 and 7.2 t/ha in M2, M3, M1 and M4, respectively), while M2 showed a statistically higher panicle density (410 panicle/m2). Lower yield performance of M4 were primarily due to difficulties in the weeder setup. Herbicide application resulted in significantly higher yield (8.9 t/ha for both H2 and H3) respect to the untreated plot (5.7 t/ha). Number of herbicide applications did not affect yield, yield components and weed control, with similar results for H2 and H3 treatment. The results showed that hoeing and harrowing can reduce weed pressure in rice, while maintaining high yield performance.

Weed control in sweet maize (Zea mays var. succharata) eco-farming

Milena Simić; Milan Brankov; Vesna Dragičević

Maize Research Institute Zemun Polje, Zemun-Belgrade, Serbia

Poster

Sustainability in agricultural systems is largely based on increasing biodiversity and reducing the input of agrochemicals. Weed species occurrence and distribution in fields is driven by anthropogenic factor and cropping measures applied for high yield achievement. In sustainable cropping systems with cultivation of specific maize varieties such as sweet maize, special attention has been usually paid to weed control because these genotypes are additionally sensitive to herbicides. Sweet maize is mainly consumed directly by humans and its cultivation is supposed to be conducted without chemical control of weeds, giving advantage to cover crops. Cover crops influence weed infestation level through competition for space, light, water, and minerals. The aim of the investigation was to identify the most effective species or mixtures of cover crops in weed control of sweet maize in the present agro-ecological conditions. The experiment was conducted at the Maize Research Institute Zemun Polje, Belgrade, Serbia during 2014-2016. Sweet maize was grown after different cover crops: V1-common vetch (*Vicia sativa L.)*, V2-field pea (*Pisum sativum L.*), V3-winter oats (*Avena sativa L.*), V4-fodder kale (*Brassica oleracea convar. acephala L.*), V5-common vetch+oats and V6-field pea+oats, V7- straw and V8- bare soil as a control. The preceding crop was winter wheat and each treatment had three repetitions. Sowing of cover crops was done in autumn while incorporation by ploughing was performed in spring, one week before sweet maize sowing (hybrid ZP SC 421su)in a density of 65.000 plants ha-1. Six weeks after sowing, the weed association composition was analysed by weed species, number of individuals, and biomass determination per m2. After that, weeds were removed by hand hoeing and herbicides were not applied. The 19 weed species were determined during the investigation while seven species were present in each year and made a base of association: *Solanum nigrum L., Sorghum halepense* (Pers.) *L., Chenopodium album L., C. hybridum L., Amaranthus retroflexus L., A. hybridusL.* and *A. albus L.*. Number of weed species, weed individuals and their biomass were significantly affected by year, cover crop, and their interaction. The highest number of individuals was detected in 2016 which was favourable regarding sum and distribution of precipitation. V1, V2 and V3 were the most efficient cover crop treatments in weed control, with the lowest number of weed species and individuals. In average for three years, weed biomass was significantly reduced after cultivation of field pea, V2 (820.2 g m-2) and its mixture with oats, V6 (794.3 g m-2) in comparison to control, bare soil, V8 (1582.6 g m-2).

Hot water treatment: an alternative solution for vegetation control on railway tracks

Judith Wirth [1]; **Aurélie Gfeller [2];** Frédéric Tschuy [2]

1 Agroscope Plant Production Systems Herbology in Field Crops, uré, Switzerland

2 Agroscope Plant Production Systems Herbology in Field Crops, 1260 Nyon, Switzerland

Poster

Vegetation control on railway tracks is a safety issue: vegetation retains water and deforms the railway track. It can also interfere with the laser beams used to check the gauge of the rails or make the inspection rounds of the railway workers more complex. In addition, the effective control of line-side vegetation is imperative in order to allow agents to move quickly and evacuate passengers in the event of a problem. Currently railways are large users of glyphosate. Some countries like France will soon ban glyphosate for non-agricultural uses. Alternative solutions are urgently needed. The Swiss Federal Railways developed a hot water spray technology, which was tested over three years (2019 to 2021) at Muttenz, close to Basel, in Switzerland. Hot water (6 to 10 l/m2) was sprayed at 95 °C over a width of 4.6 meters through 116 nozzles with a speed of 15 km/h and botanical surveys were performed on line-side vegetation. In 2019 and 2020, three treatments were performed during the vegetation period whereas in 2021 the number of treatments during the vegetation period varied between 1 and 3 depending on the railway track. The effectiveness of the treatment was evaluated between 82% and 99% based on the Henderson-Tilton formula. In 2021, a unique treatment in spring was tested and provided good weed control for the whole season. Plants with a root system that can accumulate reserves, such as certain Asteraceae, can start to regrow after the treatment, but they rarely reach seed set. Nevertheless we ignore the long term effect of the hot water treatment and how the weed flora will adapt to this new weed management technique. Regardless of economic and energy considerations, which were not considered in this first evaluation, hot water treatment on railway tracks can be considered as an alternative to glyphosate.

Keywords: *non-chemical weed control, alternatives for glyphosate, non-agricultural land*

Mechanical intra-row control efficacy is affected by species specific anchoring force

Evyatar Asaf [1]; Hanan Eizenberg [2]; Ran Nisim Lati [3]

[1] Department of Phytopathology and Weed Research, Agricultural Research Organization, Newe Ya'ar Research Center. The Robert H. Smith Institute of Plant Sciences and Genetics in Agriculture, the Hebrew University of Jerusalem, Ramat-Yishay, Israel

[2] Department of Phytopathology and Weed Research, Agricultural Research Organization, Newe Ya'ar Research Center. The Robert H. Smith Institute of Plant Sciences and Genetics in Agriculture, the Hebrew University of Jerusalem, , Israel

[3] Department of Phytopathology and Weed Research, Agricultural Research Organization, Newe Ya'ar Research Center, , Israel

Poster

In recent year there is growing concern about environmental issues associate with herbicide usage, and much attention is put on the integration of mechanical weed control tools into the currently used managements. The finger weeder (FW) is a mechanical control tool that handle weeds in the crop row. One of the main control mechanism of the FW is uprooting, which affected by the root anchoring force. This force varied between species and growth stages, however, there is no data about the impact of this factors on the FW control efficacy. The objective of this study was to evaluate the anchoring force of various weed species, and to determine the impact of the main botanic groups (broadleaf vs cereal) and their growth stage on the FW control efficacy. For that purpose, *Triticum aestivum vr. Galil* and *Sinapis alba* were used as model weeds and sown in a 1.93 × 10 meter raised bed with two rows. Intra-row cultivation treatments were performed using the FW at three growth stages: cotyledons, 2nd and 4th leaf. One week after treatment the number of weeds and their biomass was determined. *T. aestivum* and *S. alba* were also seeded in a net house simultaneously with cultivation. Their root system morphology (length and volume) was analyzed using WinRHIZO software. Additionally, 10 weed species (5 broadleaf and 5 cereals) were grown in net house and their anchoring force was evaluated at the 2nd and 4th leaf stage. In the field, the FW affectively control the S. alba plants at the cotyledon and 2nd leaves stages, while the *T. aestivum* plants were not affected with 80% and 15% biomass reduction, respectively. At the 4th leaf stage, both species were not control with ~10% biomass reduction. The morphological analysis of the root system revealed that *T. aestivum* root length and volume were significantly higher than *S. alba* in the cotyledons and 2nd leaf stage, while in 4th leaf stage no differences were observed. These results can elucidate the variation between the control results of these species in the field. When the anchoring force of the 10 species was evaluated, large variability among the species was observed. However, cereal species had significantly higher anchoring force than broadleaf at both growth stages (P= 0.0045 and <0.001). Our results elucidate the impact of roots morphological traits and architecture on control efficacy of the FW and can be used to optimize its application.

Keywords: *finger weeder, root system morphology , anchoring force*

Steam Soil Disinfestation to Control Bromus sterilis and Echinochloa crus-galli

Z Bitarafan [1]; W Kaczmarek-Derda [1]; C E Øyri [1]; I S Fløistad [2]

[1] Norwegian Institute of Bioeconomy Research (NIBIO), Division of Biotechnology and Plant Health, Ås, Norway

[2] Norwegian Institute of Bioeconomy Research, Division of Forestry and Forest Resources, Ås, Norway

Poster

Soil disinfestation by steaming is being reconsidered for its efficiency in controlling or even eradicating pathogens, nematodes and weed seeds, particularly to avoid excess use of pesticides. Most weeds within a field result from seeds in the soil seedbank and therefore management of weed seeds in the soil seedbank offers practical long-term management of weeds, especially those difficult to control. We investigated the possibility of thermal control of seeds of grass weeds *Bromus sterilis* (barren brome) and *Echinochloa crus-galli* (barnyardgrass) using a prototype of a soil steaming device. Five different soil temperatures of 60, 70, 80, 90 and 99°C with an exposure duration of 3 min were tested. Four replications of 50 seeds of each species were placed in polypropylene-fleece bags. Bags in the same replicate of each target temperature were placed at the bottom of one plastic perforated basket container and covered by a 7-cm soil layer. Each basket was placed in the steaming container and steam was released from the top and vacuumed from the bottom of the container. Soil temperature was monitored by 10 thermocouples and steaming was stopped when 5 of the thermocouples had reached the target temperature. The basket was then removed from the steaming container after 3 min exposure time. Bags were taken out, opened, placed on soil surface in pots and covered by a thin layer of soil. Seed germination was followed for 8 weeks in the greenhouse. Non-steamed seeds were used as controls. It was shown that soil temperatures of 60, 70, 80, 90 and 99°C lasting for 3 min reduced the seed germination of barren brome by 83, 100, 100, 95 and 100% and seed germination of barnyardgrass by 74, 69, 83, 89 and 100% respectively, compared to the controls. Germination rate of control seeds were 94 and 71% for barren brome and barnyardgrass, respectively. These results show a promising seed mortality level of these two weed species by steaming and that steam is a potential method to control weed seeds, however further studies are needed to investigate the effect of other factors such as soil type and moisture content.

Keywords: *Non-chemical weed control, thermal soil disinfection, weed seedbank*

Control of *Heracleum mantegazzianum* (Sommier and Levier) by different mulches

Terho Hyvönen [1]; Marleena Hagner [2]; Bengt Lindgvist [2]; Hannu Ojanen 2

1 Natural Resources Institute Finland (Luke), Jokioinen, Finland

2 Natural Resources Institute Finland (Luke), , Unknown

Poster

Heracleum mantegazzianum is an invasive environmental weed causing reduction in local plant biodiversity, considerable economic damage and health hazard to humans. During recent decades it has spread widely throughout northern Europe with a continually increasing distribution. In the EU, *H. mantegazzianum* is included in the recently launched list of Invasive Alien Species of Union concern, which obliges EU countries to restrict the distribution or eradicate a species. This calls for new innovations for appropriate novel control methods. In this study, efficacy of a novel biodegradable mulch consisting of pyrolysis liquid and peat was compared with other types of mulches and glyphosate for the control of *H. mantegazzianum*. A four-year field experiment comprising nine experimental fields was established in southern Finland in August 2018. Experimental fields were established by cutting *H. mantegazzianum* stand, removing the cuttings and conducting the treatments. Each experimental field included one replicate of the following treatments in randomized order: 1) pyrolysis liquid + peat mulch (PLM1) (spread once), 2) pyrolysis liquid + peat mulch (PLM2) (mulch fixed annually), 3) plastic PE -mulch, 4) biodegradable Ökolys mulch, 5) glyphosate (Roundup Bio (0.36 g a.i. m-2)) and 6) untreated control. The size of the experimental plot for each treatment was 1 m × 2 m. Observations on the percentage coverage (0-100%) of H. mantegazzianum were conducted annually in 2018-2021. The results were analyzed by using Mann-Whitney U test. Experimental fields were regarded as independent replicates in the analyses (n=9). Biodegradable Ökolys and plastic PE -mulches controlled the growth *H. mantegazzianum* totally. Glyphosate treatment failed in the first year of the experiment (2018) and was repeated in 2019. After re-treatment, *H. mantegazzianum* was controlled effectively also by glyphosate. PLMs did not control *H. mantegazzianum* effectively in 2019 and 2020, when the coverage of *H. mantegazzianum* in PLM treatments did not differ from control treatment (P>0.05). However, in 2021 the coverage of *H. mantegazzianum* was 24% lower in PLMs than in control treatment (P<0.05). The coverage of *H. mantegazzianum* in different types of PLMs did not differ between each other (P>0.05). The results suggest that mulches made on pyrolysis liquids and peat do not control full-grown *H. mantegazzianum* effectively despite the decline in the plant coverage in the fourth year of the experiment. In contrast, biodegradable Ökolys and plastic mulches provided effective control by prohibiting the light and water supply. A combination of cutting and covering with these mulches can be recommended as an effective control treatment for *H. mantegazzianum*.

Removal/destruction of weed seeds during harvest (HWSC) in arable crops, a novel weed management approach in Israel

Y. Kashti [1]**;** M. Sibony [2]; O. Keisar [3]; I. Roth [2]; D. J. Bonfil [4]; B. Rubin [5]

[1] *Institute of Agricultural Engineering, ARO, The Volcani Center,, Rishon LeZion, Israel*

[2] *RH Smith Institute of Plant Science and Genetics in Agriculture, Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem, Rehovot, Israel*

[3] *Institute of Agricultural Engineering, ARO, The Volcani Center, Rishon LeZion, Israel*

[4] *Gilat Research Center, Vegetables and Field Crops, ARO, The Volcani Center, Gilat, Israel*

[5] *RH Smith Institute of Plant Science and Genetics in Agriculture, Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem,, Rehovot, Israel*

Poster

Intensive use of herbicides with limited crop and herbicide-rotations, combined with the adoption of reduced-tillage practices, resulted in a widely-spread evolution of herbicide-resistant weeds (HRW) in Israel. Grass weeds such as *Lolium spp.*, *Phalaris minor*, *P. paradoxa* and *Avena sterilis* as well as broadleaved weeds such as *Chrysanthemum coronarium*, *Diplotaxis erucoides* and *Erucaria hispanica* infest various winter-grown arable crops, causing a substantial increase in yield losses and weed control costs. Harvest weed seeds control (HWSC), is a system developed in Australia, primarily for the control of *L. rigidum* and other weeds seeds during harvest. Long-term application of HWSC integrated as component of the weed management, resulted in a significant reduction in *L. rigidum* infestation. Hence, the objective of our study was to examine the influence of HWSC technologies on the weed infestation and crop yields in arable crops grown in Israel. Three HWSC technologies were examined in two field trials located at the southern part of Israel. The first is a 'chaff removal', using a device that was constructed and installed on an old combine harvester for collection and removal of 'chaff' (weed seeds and small pieces of straw) from the field. Long term field experiments were conducted at Gilat Research Center. The second technology is a 'chaff on top' of windrow, based on directing the chaff to the top of windrow using a device that was constructed and installed on a commercial JD 9500 combine harvester. The third technology is a commercial 'bale-direct' device operated by a JD S690 combine harvester. The 'chaff on top' and the 'bale- direct' were chosen because of the high demand for baled straw in Israel (for livestock and mushroom production). The last two devices were tested in comparison to the commercial harvesting technique as a control at Kibbutz Bet Kama. The main results from the chaff removal experiment showed a significant reduction in weeds infestation following 5 years use of the chaff collection device. The initial results (2 years) from the 'chaff on top' trial showed a significant increase in the baled straw yield in comparison to control in both years. The research is still going on and in the coming harvesting season a fourth technology of an 'integrated impact mill' installed on a combine harvester for seed destruction during harvest will be examined as well.

Keywords: '*Weeds on top*'; *bale-direct; herbicide resistance; impact mill; chaff*

Processing Eucalyptus globulus foliage for allelopathic weed control

Carolina G. Puig [1]; María Pardo-Muras [2]; Nuria Pedrol [2]

[1] University of Vigo, Department of Plant Biology and Soil Science, Vigo, Spain

[2] University of Vigo, Department of Plant Biology and Soil Science, , Unknown

Poster

The use of allelopathic agroforestry biomass, through the release of a cocktail of phytotoxic compounds from the plant material, has been demonstrated as a tool for integrated weed management. Our previous works have pointed out the herbicidal efficacy of crushed eucalyptus foliage as green manure in agricultural systems (Puig et al. 2019, Crop Protection), where an agronomically feasible dose at 1% (dw/dw) was effective in controlling weeds but without damaging the crop. Another of the most labor-demanding agricultural job is weeding and removal of weeds that invade the paths, corridors, and borders of crop fields. In these cases, it would be desirable to obtain a greater and more lasting effect. Thus, it is necessary to process the plant material in a way to achieve this long-lasting effect and to facilitate its application at large doses. With these assumptions, we hypothesized that by densifying (Chen et al. 2015, Renewable and Sustainable Energy Reviews) the allelopathic eucalyptus biomass, a lower decomposition rate of the plant material would be achieved, resulting in a slower and longer-lasting release of allelochemical compounds into the environment. At the same time, the volume of the plant material would be reduced. The objective of this work was to evaluate the herbicidal activity and compare the long-term weeding effect of densified eucalyptus versus crushed eucalyptus foliage, regarding a control (no eucalyptus). A field experiment was carried out during the summer season. Crushed or densified eucalyptus foliage was incorporated into the soil at a dose of 4% (dw/dw). At 30 days after incorporation (DAI), the emergence of dicot and monocot weed species was recorded. At 90 DAI, the aerial weed biomass was harvested for botanical characterization and classification, obtaining the total weed biomass. The emergence and establishment of dicot weed species were reduced by both crushed and densified ecoherbicides (65% and 96%, respectively) compared to the control during the first month of the experiment. After 3 months, the biomass pretreated by densification was still controlling the density (96,9%) and biomass (92%) of dicot weed species, vs. the reduction by 65,6% and 64%, respectively, by the crushed foliage. In the latter case, there were no significant differences respect to the control. No ecoherbicide controlled monocot species, mainly composed of *Cyperus rotundus.* The eucalyptus foliage treated by densification not only retained the herbicidal efficacy but also achieved a greater and longer-lasting effect compared to the crushed plant material, making it a suitable tool for non-chemical weed control.

Keywords: *Allelopathy, ecoherbicide, biomass pretreatment, by-products, densification*

The effectiveness of Cytisus scoparius foliage added to the soil for weed control relies on complex multiple interactions among volatile and water-soluble allelochemicals

María Pardo-Muras; Carolina G. Puig; Nuria Pedrol

University of Vigo, Vigo, Spain

Poster

The use of residues from agroforestry allelopathic species incorporated into the soil, such as the foliage of *Cytisus scoparius* (L.) Link. (Scotch broom), could be a feasible practice in IWM. The foliage used as a soil amendment has been demonstrated to release cocktails of different allelochemicals, both volatile (VOCs) and water-soluble, capable of exerting effective weed control. So far, powerful paired synergistic interactions between VOCs were observed, resulting in enhanced phytotoxicity on certain weeds. However, knowing the low quantities of each allelochemical present in the *C. scoparius* tissues, as well as the weak phytotoxic effects of each of them at their natural concentrations, why are they so effective when acting together? What is their mode of action once released into the soil from the plant residues? We argued that the herbicidal potential of *C. scoparius* could be due to synergistic interactions among phytotoxic VOCs or phenolic compounds, or even between both classes of compounds. To test this hypothesis, the individual and concomitant phytotoxic effects of the volatiles naturally emitted by the flowering foliage of *C. scoparius* and its aqueous extract were tested in vitro, with and without soil, on the germination and early growth of *Amaranthus retroflexus*. Seeds or pre-germinated seedlings were incubated in the substrate wetted with the aqueous extract, in addition to fresh plant material hanging from the lid of the hermetic chamber. Studies dealing with interactions among compounds of different chemical classes are almost unpublished in Agriculture and Plant Sciences. In absence of soil, we found that the volatile and water-soluble natural compounds produced additive phytotoxic effects on *A. retroflexus* root growth, but only the emitted VOCs significantly inhibited germination and shoot growth. In contrast, when the soil factor was added, the joint action of both classes of compounds produced greater phytotoxicity with a 60% inhibition of germination and an 80% reduction in root and shoot length relative to the control. Therefore, multi-level synergistic allelochemical interactions among volatile and water-soluble compounds must underlie the bioherbicidal efficacy of *C. scoparius* foliage applied as a soil amendment.

Keywords: *allelopathy; Amaranthus retroflexus; phenolic compounds; Scotch broom; synergism; VOCs; weed control*

Hot water as an alternative method of weed control in apple orchards

Wiktoria Kaczmarek-Derda [1]; Therese With Berge [2]

[1] NIBIO, Norwegian Institute of Bioeconomy Research, Division Biotechnology and Plant Health, , Norway

[2] NIBIO, Norwegian Institute of Bioeconomy Research, Norway, Division Biotechnology and Plant Health, Ås, Norway

Poster

Weed-free zone underneath apple trees is important to maximize vegetative growth, fruit yield- and quality. Glyphosate applied twice is the usual strategy in apple orchards in Norway. Due to uncertain future of glyphosate there is a need for alternative strategies. A field trial was conducted during 2021 in an orchard (three-year-old trees). Five alternative strategies were tested: 1) Hot water at 3 L m-2 x 3 (spring, early summer, summer), 2) Hot water at 6 L m-2 x 3 (times as previous), 3) Pelargonic acid at full dose (10.9 kg a.s. ha-1) x 1 (early summer), 4) Pelargonic acid at half dose (5.44 kg a.s. ha-1) x 2 (spring, early summer), and 5) Rotary hoe x 3 (early spring, early summer, summer). Glyphosate at 1.08 kg a.s. ha-1x 2 (early summer, summer) was included as reference strategy. Hot water (about 80 C, 0.1 bar) was applied with a commercial machine (Heatweed Technologies, Norway). Visual assessments of percentage of ground covered by living vegetation were used to estimate weed control efficacy. Dominating species were *Taraxacum officinale, Tripleurospermum inodorum, Poa annua, Polygonum aviculare, Galium aparine, Viola arvensis* and *Senecio vulgaris.* Assessed mid-summer (June 24), hot water applied twice (both 3 L m-2 and 6 L m-2) showed very high efficacies, both about 90%. Pelargonic acid showed rather low efficacies, about 15% (10.9 kg a.s. ha-1 x 1) and 45% (5.44 kg a.s. ha-1 x 2). Rotary hoe twice had almost 60%. Efficacy of glyphosate once was 75%. The last assessment was conducted in mid-July, i.e. about 1-2 weeks after the last application of hot water, rotary hoe and glyphosate. The two hot water strategies resulted in very good weed control, i.e. < 1% total weed cover. This was in same order as the glyphosate strategy (about 4% total weed cover), but better than the rotary hoe strategy (9% total weed cover). The results of the first trial in study showed very good efficacy of hot water, especially against annual weeds. There seemed to be no benefit of doubling hot water from 3 to 6 L ha L ha-1. Repetition is needed to confirm this.

Keywords: *Non-chemical weed control, thermal weed control, alternatives to glyphosate, Integrated Weed Management*

Allelopathic potential of aqueous extracts of Cannabis sativa L. on the seed germination and seedling growth of barnyard grass

Angeliki Kousta; Panayiota Papastylianou; Ilias Travlos; Anastasia Karatza

Agricultural University of Athens, Athens, Greece

Poster

Industrial hemp (*Cannabis sativa L.*) is well known as an effective weed suppressing crop due to its rapid growth and canopy closure. However, weed management practices are needed especially when hemp is grown for seed and/or inflorescences, or at low plant densities. Apart from the dominant herbicide application, hemp could also be investigated as a natural herbicide thanks to its ability to release allelochemicals with stimulatory effects impeding seed germination and growth of several weed species. Laboratory trials were carried out to evaluate the allelopathic potential of aqueous extracts of different varieties of *Cannabis sativa L.* on the germination rate and the seedling growth of barnyard grass (*Echinochloa crus-galli*). The aqueous extracts bioassay was carried out through the filter paper method. The hemp extracts were made of root, stem, leave, and inflorescence of two monoecious varieties (Fedora 17, Uso 31). The crude extracts of 100% concentration were diluted to obtain different concentration i.e., 25% and 50% (v/v) solutions. Treatments were replicated three times in Randomized Complete Block Design for each of three concentration ranges (25, 50, 100%). Extracts of each variety were applied separately, while the control variant was seed-treated with distilled water. The effect of the extracts on seed germination, length of radical and plumule of the test plant was investigated. The obtained results suggest that the aqueous extracts delayed the seed germination of barnyard grass which varied among hemp varieties and the effect was concentration dependent. The highest concentration (100%) of extracts from root, leaf, stem, and inflorescence of both varieties provoked a significant reduction ($P<0.005$) to germination rate compared to control. The length of radical and plumule was inhibited the most by the root, stem, and inflorescence extracts of Fedora 17, and the leaf extracts of Uso 31. While the high concentrated root extract of Uso 31 promoted the seedling vigor increasing the length of radical and plumule at 4 and 34%, respectively. The results of this study revealed that hemp can be a useful bioherbicide against barnyard grass as the aqueous extracts of different plant parts present an allelopathic potential, therefore merits further research.

Keywords: *allelopathy, Cannabis sativa L., aqueous extracts, Echinochloa crus-galli, seed germination, seedling vigor*

Assessing the herbicidal activity of some Mediterranean plant species extracts

Mariano Fracchiolla [1]; Generosa Jenny Calabrese [2]; Saida Messgo Moumene [3]; Angela Boari [4]; Rym Boukhalfa [2]; **Maurizio Vurro** [4]

1 DEPARTMENT OF AGRICULTURAL AND ENVIRONMENTAL SCIENCE, Bari, Italy
2 International Center for Advanced Mediterranean Agronomic Studies, Mediterranean Agronomic Institute of Bari (CIHEAM Bari), Valenzano, Italy
3 University of Blida 1, Blida, Algeria
4 Institute of Sciences of Food Production, National Research Institute, Bari, Italy

Poster

Weeds are a major threat to crop production and their control is mostly based on the use of synthetic herbicides that pose environmental risks, result in herbicide-resistant weeds, and are forbidden in organic agriculture. Natural compounds with herbicidal activity could provide suitable solutions and the Mediterranean basin is a partially unexplored source of plants producing bioactive compounds. A screening was performed considering the leafy parts of eleven plant species, still scarcely studied for herbicidal properties: *Anacyclus clavatus* (Desf.) *Pers., Arisarum vulgare L., Artemisia absinthium L., Cynara cardunculus L., Dittrichia viscosa Greuter, Malva sylvestris L., Myrtus communis L., Oxalis pes-caprae L., Pinus halepensis Mill., Ruta graveolens L., Urtica dioica L.* Plants are known as sources of bioactive compounds and were harvested from natural environments in Center of Algeria (Blida - Wilaya of Tipasa). The dried samples of each plant were separately ground into a fine powder and then stored at room temperature. Aqueous and solvent extracts were prepared, using 40 grams of powder. For aqueous extracts, samples were soaked in 1L of distilled water and kept for 24 hours in a shaker, before to be filtered. For solvent extracts, 600 mL of ethanol and tricholomethane were used, using a Soxhlet apparatus. The extracts were filtered and evaporated to dryness. The effects were tested on the following indicator species, chosen because of their suitable characteristics (sensitive to chemical stress, easily available, high germination rate, fast growth): *Lens culinaris Medik., Solanum lycopersicum L., Hordeum vulgare L., Cucurbita pepo L., Papaver rhoeas L., Malva sylvestris L., Nicotiana tabacum L.* The effects were evaluated as inhibition of seed germination, reduction of root and stem elongation, induction of necrosis and/or chlorosis, appearance of wilting symptom. The latter were induced by plant uptake, by placing cut plantlets at the stage of three true leaves for one day in vials containing the test solutions, and then transferring them to distilled water for 2 days. The appearance of stem and leaf symptoms were evaluated using an empiric scale. *A. absinthium, C. cardunculus, D. viscosa, M. communis, M. sylvestris, O. pes-caprae, P. halepensis* and *R. graveolens* strongly inhibited the seed germination, seedling growth and cause severe symptoms with plantlet uptake. The most active extracts (*A. absinthium, C. cardunculus, D. viscosa* and *R. graveolens)* were also tested under conditions closer to practical use. The tests consisted of sowing the plants in pots and then applying the extracts to the soil or after the emergence of the plantlets (direct spraying). The results confirmed the potential herbicidal activity. This preliminary study opens the way to further research and applicative investigations on the selected species confirming the feasibility of the approach for organic weed management.

Keywords: *Allelopathy, bioherbicides, germination, growth parameters, plant extracts, phytochemical screening*

Development and Testing of a new Mechanical Weeding Hoe for Re-compacted Ridge Tillage culture in Maize

Oyebanji Alagbo [1]; Michael Spaeth [2]; Marcus Saile [2];
Matthias Schumacher [2]; Sebastian Hajek [2]; Roland Gerhards [2]

[1] *Universität Hohenheim, Stuttgart, Germany*

[2] *University of Hohenheim, Stuttgart, Germany*

Poster

Crop competitiveness against weeds at early growth stages can be enhanced by soil tillage systems. Common ridge tillage systems often provide higher soil temperature and better root penetration – both needed for crop take-off against early weed pressure. A new ridge tillage system was tested in this study. Different from previous ridging systems, dams are recompacted before seeding of the crop. In addition to the advantage of the common ridging technologies, it can also increase soil moisture content in the dams and facilitate post-emergence mechanical hoeing in the dam area. The objectives of this study are to investigate weed-maize interactions after re-compacted ridge tillage (RCRT) and to develop a suitable hoeing technology for the recompacted dams. In this current study, a manual steered mechanical hoeing implements capable of navigating the RCRT without disruption was assembled. This includes a pair of *no-till sweeps* positioned to fit parallel to the ridge surface with maximum 5 cm distance to the maize rows. A down-cut side knife bent to an angle of 130° parallel to the steep sides of the ridges and a *ridge re-builder* coupled behind to enable weed burial and restoration of disrupted ridges. To further minimize damage to maize roots and ridge compaction, implements were adjusted to a working deepth of 2 cm into the soil. An initial prototype without the ridge *re-builder* was developed and tested on the field between June and September 2021. The later hoe was tested and compared on the field within a completely randomized split plot design experiment with two tillage types (RCRT and flat tillage) and four different weed control treatments (herbicide, no weed control, mechanical weeding twice and mechanical weeding once plus living mulch). Data were collected on percentage weed cover, weed biomass, root and shoot biomass of maize separated into the ridge valley and on the top of the dams). Weed coverage and weed biomass was significantly reduced in the herbicide treatment and after two passes of mechanical weeding compared to the untreated control. One pass of hoeing combined with living mulch in the ridge valleys did not reduce weed pressure. Interestingly, mechanical weeding (one and two passes) amounted equal shoot and root biomass of maize as the herbicide irrespective of tillage systems. The above results show the potential of RCRT and flat mechanical weeding to reduce herbicide use in maize.

Perennial weed control capacity of liquid spray-on-mulches (hydromulch) based on crop residues following circular economy criteria

Alicia Cirujeda [1]; Gabriel Pardo [1]; Ana Isabel Marí [1];
Joaquín Aibar [2]; Maria Teresa Mas [3];
Antoni Maria Claret Verdú [3]

[1] CITA, Plant Protection Unit, ZARAGOZA, Spain,
[2] University of Zaragoza, Zaragoza, Spain
[3] Escola Superior d'Agricultura de Barcelona (ESAB),
Universitat Politècnica de Catalunya, 08860 Castelldefels
(Barcelona), Spain

Poster

Biodegradable mulches are a technically viable alternative to polyethylene mulches in vegetable crops but films are difficult to install in perennial crops such as vineyards, olive and fruit tree orchards. During the first years of tree establishment weeds are especially competitive and the most frequent options for weed control are mechanical weed control or using any of the limited number of registered herbicides. Liquid spray-on mulch (hydro-mulch) could be an alternative to these methods in the first years of perennial crop establishment. After testing different mixtures in field conditions without any crop in Zaragoza (Spain), those based on recycled paper pulp and containing wheat straw, rice husk or used mushroom substrate performed best than others showing a longer duration on the soil. Two trials are shown in this work to investigate the capacity of these mulches on perennial weed control: 1) In a field trial in a peach tree plantation it was verified that *Cyperus rotundus*L. was able to pierce all three mulches and to grow normally. Hydromulches were applied in 1 m2 around one year-old peach trees using an amount of 17 l/m2 of the mixture; five trees were considered one replicate, and there were three randomly distributed replicates per treatment. 2) A pot experiment in greenhouse was set-up and repeated four times during 2019 and 2020 (2 times in 2 different localities) with the purpose to confirm the results on C. rotundus and to quantify the capacity of weed control of the mulches in other perennial weed species. Four species were selected, which cause problems in different crops: *C. rotundus, Sorghum halepense*L. (Pers.), *Paspalum dilatatum Poiret* and *Cynodon dactylon*L. (Pers.). In the greenhouse trials, pots measured 39 cm diameter and 28 cm in height; each pot contained 10 propagules, and each of them was placed in an 8 cm x 8 cm x 8 cm black plastic pot (called box) to hinder tubers and rhizomes from sprouting without piercing the mulch, forcing them to grow vertically inside. A non-mulched control was included. Four replicates of each mulch-weed species combinations were randomly distributed. The three hydromulches were applied in the same proportion as in the peach tree experiment after planting the propagules. *C. rotundus* grew through the mulches in

the peach orchard, similarly in all three mulch treatments and also in the non-mulched control. In May 2019, 149 days after mulch installation, it was present in a mean of 85% of the sampling points on the three mulches covering as a mean 22% of the soil. These values increased in time reaching a mean of 100% frequency covering 56% of the soil in September (272 days after installation). In the pot experiment, *C. rotundus* was the species showing the most sprouted and emerged tubers: 96% of the sprouted tubers also emerged through the applied hydromulches 90 days after application. The mulches controlled better the emergence of the other three species: 88% of all the sprouted *P. dilatatum* tubers were trapped under the mulches; for *C. dactylon* and *S. halep*ensethere were more than 50% of the sprouted rhizomes. Results were similar for all three tested mulches. In the greenhouse experiments, the three tested hydromulches were able to partly reduce the emergence of *P. dilatatum, S. halepense* and *C. dactylon*but very little *C. rotundus.* The low control capacity on this latter species is coincident with the results obtained in the field experiments in a peach tree orchard where this species was present.

w- SEEDS Guide: Identification of major weed seeds in cereals in Greece

Stavroula Kiadimou, Paraskevi Yfanti, Dimitra Douma

University of Ioannina, Arta, Greece

Poster

The w-SEEDS is an easy-to-use guide of photographic material, collected from the literature and the internet with images of weeds (plants and their seeds) that compete with winter cereals in Greece. The purpose is to facilitate identification of major weed species through a guide that relates the plant with its seed. As such, the w-SEED guide aims to support the farming community and weed researchers in the successful identification of the weed species, in seed/soil seed bank samples. One of the major preventive measures to reduce the spread of weeds and to ensure the good quality of plant products is the use of certified seed that is pure of weed seeds. However, cereal producers often use farm saved seed with a presence of weed seeds in their seedlots. On the other hand, researchers in Universities or Institutes could find this guide useful when analyzing soil samples, in the characterization of soil seed bank. This guide is a comprehensive photographic gallery from 13 weed families found in winter cereal crops in Greece, with 33 of their most representative and important weed (6 narrow- and 27 broad-leaved) species. The 13 weed families are as follows: Apiaceae (3 species), Asteraceae (7 species), Boraginaceae (2 species), Brassicaceae (3 species), Caryophyllaceae (2 species), Fabaceae (1 species), Papaveraceae (2 species), Plantaginaceae (1 species), Polygonaceae (2 species), Ranunculaceae (2 species), Rubiaceae (1 species), Violaceae (1 species) and Gramineae (6 species). In each species, there is a full set of images, which relate the plant with its seed. This guide aims to provide a user-friendly and fully comprehensive material for identifying weed species in seed/soil seed samples.

HERBICIDES AND APPLICATION TECHNOLOGY

The Sustainable Use Of Herbicides Using Digital Agronomy And Precision Application Technologies

Joanna Davies

Syngenta, Bracknell, United Kingdom

Oral

The agrochemical industry remains dedicated to the discovery, development and registration of safe and efficacious herbicides that are cost-effective for growers around the world. Despite utilising novel sources of chemistry, deploying molecular technologies to identify new modes of action and implementing state-of-the art high-throughput screening systems, the discovery of new compounds has declined rapidly over recent years. Those compounds that exhibit the required selectivity, efficacy and are amenable to large scale manufacture, face a prohibitively complex series of regulatory challenges to demonstrate the human and environmental safety of both parent molecule and environmental metabolites. In addition, frequent regulatory guidance updates, especially in the EU, result in a never-ending cycle of data generation and re-registration processes. Meanwhile, the EU Green Deal (2020) has set the target of reducing the use of synthetic pesticides and fertilisers by 50% by 2030, whilst simultaneously maintaining food security and mitigating climate change. At the same time, proposed regulatory guidance updates affecting the registration of herbicides are predicted to severely limit herbicide use and force growers to adopt alternative forms of weed control. In 2020, a grower survey conducted on behalf of CropLife Europe showed that in the absence of conventional herbicides, growers of several crops in several EU countries are likely to resort to alternative methods of weed control, particularly mechanical methods [1]. While all forms of weed control are valuable in integrated weed management systems, mechanical weed control by deep ploughing or hoeing can be detrimental to soil health, promoting soil erosion, surface water run-off and carbon release, thereby contributing to surface water pollution and climate change. Therefore, growers in the EU will, in future, face the contradictory challenges of maintaining crop yield with reduced conventional inputs and preferably without promoting carbon release from soil. This presentation aims to raise awareness of how we can meet these contradictory challenges through integrated weed management strategies that include agronomic and conventional chemical approaches. Specifically, the use of precision application technologies alongside digital agronomy tools, will be explored as a means of optimising herbicide inputs in integrated systems. If European agriculture is to benefit from these innovations in the future, the EU needs to retain access to the necessary herbicide products by accommodating the use of these technologies into the regulatory processes for herbicides.

[1] Bremmer et al (2020) Impact Assessment Framework with Specific Protection Goals (SPGs) for Non-Target Terrestrial Plants (NTTPs). Wageningen Economic Research Report 2020-074 | Project code 28200408

Yellow nutsedge: what control strategies work in practice?

Max Fuchs; Judith Wirth

Agroscope

Oral

The invasive weed yellow nutsedge (*Cyperus esculentus* ssp. aurea Ten) leads to important yield quantity and quality losses in arable and vegetable farming in Switzerland. First infestations were reported in the 1990s and the plant has spread in the country since then. To tackle this issue, farmers and agronomists have jointly implemented and evaluated different control methods. We are presenting two research projects aiming to compare and validate different strategies for yellow nutsedge control in infested areas. To this aim, on-farm trials were carried out between 2016 and 2020. In a first project, 14 Swiss farmers implemented different control strategies over a four-year period (2016-2019). In a second project the effect of a 3-year fallow (2018-2020) combined with repeated soil cultivation with and without application of three different herbicides (S-metolachlor; foramsulfuron, thiencarbazone and iodosulfuron; sulfosulfuron), on the nutsedge infestation level was evaluated. To assess the effect of the different control strategies, the number of tubers per litre soil was determined at the beginning of the trial period and at the end of each year. This allowed following the infestation level of each field. In the on-farm trials, yellow nutsedge was most effectively managed in rotations including late drilled crops, allowing repeated soil cultivation in spring (up to over 90% reduction after four years). As an example, repeated soil cultivation in spring, followed by incorporation of S-metolachlor and late maize drilling (after May 20th) lead to significant reductions in tuber density. Cultivation of autumn cereals partly reduced tuber numbers or maintained tuber density on a constant level. Furthermore, a key parameter identified for successful control of yellow nutsedge was the determination and motivation of the farmers. Indeed, omitting control measures for several months in an infested field was sufficient to annihilate all previously made efforts. In the fallow trials, applying herbicides did not show any additional effects as compared to repeated soil cultivation only. On average, the reduction in tuber numbers after three years of fallow was 75%. To conclude, so far none of the investigated strategies was able to eradicate this weed completely on the farms, showing that controlling yellow nutsedge is a very complex, time-consuming and expensive undertaking. In spring 2022, we will start a follow-up project for further optimising the use of a fallow for several years, with the use of different cover crops and without herbicides. We also aim to gain a better understanding on tuber dormancy over time in controlled conditions.

Keywords: *yellow nutsedge, fallow, herbicide, S-metolachlor, soil tubers*

Amaranthus palmeri S. Wats. invasion in Greece, chemical control and insights for its successful management and prevention of further dispersal

Ilias Travlos[1]; Alexandros Tataridas[2]; Dimitra Petraki[2]; Panagiotis Kanatas[3]; Ioannis Gazoulis[4]

[1] *Agricultural University of AthensFaculty of Crop Science / Lab. of Agronomy, ATHENS, Greece*
[2] *Agricultural University of AthensFaculty of Crop Science / Lab. of Agronomy, Unknown*
[3] *Department of Crop Science, University of Patras, P.D. 407/80, 30200 Mesolonghi, Greece, Unknown*
[4] *Agricultural University of AthensFaculty of Crop Science / Lab. of Agronomy, Greece*

Oral

Amaranthus palmeri S. Wats. (Palmer amaranth) is an invasive weed that has recently invaded Central and Western Greece. It is a noxious annual weed that causes high yield losses to annual spring crops, often develops multiple herbicide resistance and presents high invasiveness dynamics. Palmer amaranth biotypes were detected in cotton fields in Central Greece and in maize and sorghum fields in Western Greece in 2020. The weed was present inside the plantations, in field margins, and in roadsides. The surveys repeated during the summer of 2021 revealed that new areas have been infested and farmers are expected to be concerned. Seed collection was carried out in both regions for two consecutive years for use in herbicide efficacy evaluations. Pot experiments were conducted at the Agricultural University of Athens in 2020 and 2021 to assess the efficacy of nicosulfuron (at a rate of 45 g ai ha[1]) on four Palmer amaranth biotypes. In 2021, dose-response assays were conducted in pots to assess the susceptibility of four biotypes on glyphosate (potassium salt, recommended rate 1440 g ai ha^{-1}). In the first experiment, all biotypes were susceptible to 2,4-D, while nicosulfuron did not provide adequate control. The dose-response screening revealed that three biotypes were susceptible and one resistant to glyphosate. Field trials should be conducted in the short-term to assess the efficacy of pre-emergence and post-emergence herbicides for the control of Palmer amaranth under real-field conditions. Several agricultural areas in Greece pose suitable habitats for the invasion and colonization by Palmer amaranth. Monitoring and integrated management actions are crucial to be undertaken in the short-term to prevent further dispersal of the weed.

Soybean response to micro-rates of dicamba and 2,4-D

Stevan Knezevic

University of Nebraska, Lincoln, United States

Oral

Off-target movement of dicamba and 2,4-D is a concern with introduction of dicamba-tolerant (DT) and 2,4-D-tolerant (Enlist) soybeans in North America (and elsewhere). Therefore, field studies were being conducted in Nebraska to evaluate glyphosate-tolerant (GT) soybean response to micro-rates (0, 1/1000th, 1/500th , 1/100th, 1/50th, 1/10th) of the label rates of dicamba (Xtendi-Max®@560 g ai ha^{-1}) and 2,4-D (Enlist-One®@ 2,240 g ai ha^{-1}) applied at V2, V7/R1, and R2 soybean growth stages. Each study was arranged in a split-plot design where main-plot was application time (V2, V7 or R2) and subplot was herbicide rate. There were 6 replications and each plot had four crop rows planted 76 cm apart with 4 m wide and 10 m long. Both herbicides negatively influenced the growth parameters of GT soybeans including: visual injury, plant height reduction, delayed physiological maturity as well as yield and yield components. Visual injuries from dicamba were significantly higher than those from 2,4-D for the same rate. For example, when sprayed at V7/R1 stage, the 1/10th rate of 2,4-D caused 19% compared to 82% injury by dicamba; the 1/100th rate of 2,4-D caused 5% compared to 79% by dicamba and the 1/500th rate of 2,4-D caused 4% compared to 58% by dicamba.In general, soybean yield losses from dicamba were significantly higher compared to 2,4-D. The highest yield losses from 1/10th of the label rate were about 90% for dicamba and 25% from 2,4-D. Unsprayed soybean yielded 4909 kg ha^{-1}. However, when sprayed at V7/R1 stage, the 1/10th rate of 2,4-D soybean yielded 3698 kg ha^{-1} compared to only 403 kg ha^{-1} from dicamba; the 1/100th rate of 2,4-D soybean yielded 3953 kg ha^{-1} compared to 3015 kg ha^{-1} from dicamba; the 1/1000th rate of 2,4-D soybean yielded 4556 kg ha^{-1} compared to 3819 kg ha^{-1} from dicamba. These results suggest that all possible measures must be taken to reduced drift of dicamba and 2,4-D to avoid risk to GT soybean, or any other types of soybean.

Characterization of the retention process of diuron and diclosulam in different types of straw

Gustavo Vinícios Munhoz-Garcia; V Takeshita; N G Moraes;
C W Pinácio; R F Pimpinato; V L Tornisielo

*Center of Nuclear Energy in Agricultural, Tropical Ecosystem Functioning Division,
University of São Paulo, Piracicaba, SP, Brazil., Piracicaba, Brazil*

Oral

Diuron and diclosulam are preemergence herbicides applied to straw/crop residues in tropical cropping systems. The straw acts as a barrier preventing the herbicide from reaching the soil seed bank, reducing the effectiveness of weed seed bank control. This straw-herbicide interaction is mentioned only as a physical barrier, but the possible chemical interaction between herbicides/straw has not yet been characterized. The objective of this work was to characterize the retention process of diuron and diclosulam in *Raphanus sativus* (RS), *Fagopyrum esculentum* (FE) and *Avena sativa* (AS) straw. Sorption-desorption and leaching experiments of the ^{14}C-herbicides were performed using radiometric techniques proposed by the Organisation for Economic Cooperation and Development. The sorption-desorption study was a 2x3 factorial with the two herbicides and the three straw types in amount equivalent to 2.5 t ha^{-1}. The leaching experiment followed a 2x3x2 factorial design, with the two herbicides, the three types of straw mulch in amounts equivalent to 2.5 and 5 t ha^{-1}, submitted to a 6 rainfalls (equivalent to 10 mm each) applied sequentially. Herbicides were used at 2150 g ai ha^{-1} and 35 g ai ha^{-1} for diuron and diclosulam, respectively, according to the recommended dose for crops like sugarcane and soybean in Brazil. Microscopic, spectroscopic, and bromatological analyses were performed to characterize the straw-herbicide interaction. Sorption-desorption data were submitted to ANOVA and when significant, to Tukey›s test (p<0.05). Leaching was analyzed by non-linear regression (Mitscherlich model, *p*<0.05). The retention of diuron and diclosulam was influenced by the type and amount of straw (*p*<0.05). High sorption rates of diuron (~45%) and diclosulam (~28%) were observed in AS straw. While lower amounts of diuron (~33%) and diclosulam (~22%) were sorbed in the RS straw. Higher sorption and lower desorption were observed in the AS straw, with higher lipophilicity. At 2.5 t ha^{-1} about 76-93% of diuron and 81-100% of diclosulam can pass through the straw. Increasing the amount of straw (from 2.5 to 5 t ha^{-1}), the leaching of diuron was reduced by 23-30% and diclosulam by 14-20%. Scanning electron microscopy analyses evidenced a destruction of the anatomical structures of the RS and FE straw after sorption. For AS straw, small pore spaces were present, increasing sorption and physical trapping of the molecules. Spectra obtained by FTIR showed changes in the peaks after sorption, indicating chemical changes in the straw-herbicide interaction. Herbicide retention in the straw can be characterized as physical and chemical process, influenced by chemical, physical and anatomical aspects of the straw and by herbicide chemical-physical properties.

The efficacy and off-target movement of mesotrione and rimsulfuron plus thifensulfuron-methyl

Milan Brankov[1]; Milena Simić[2]; Greg Kruger[3]

[1] Maize research Institute ˝Zemun Polje˝, Belgrade, Serbia
[2] Maize Research Institute «Zemun Polje», Belgrade, Serbia
[3] Xarvio Digital Farming Solutions, BASF, United States

Oral

Limitations on the available herbicide portfolio and concerns regarding environment protection have led to a need for optimizing application techniques. It means achieving the maximum efficacy of the applied herbicide and at the same time saving the environment by reducing an off-target movement. To this end, a herbicide tank-mixture of mesotrione (MES) with rimsulfuron plus thifensulfuron-methyl (RIMTHIF) was sprayed in a low speed wind tunnel simulating drift. Airspeed was set at 4.4 m s^{-1}, representing the labelled upper limit for applications, and sprayings were done through XR and TTI nozzles. Cantaloupe, cotton, green bean, pumpkin, soybean, sunflower, wheat, and watermelon were exposed to herbicide drift and biomass data were collected 28 DAT. Droplet size spectrum and tracer deposition were evaluated for each nozzle. Plants were positioned at the following distances from each nozzle: 0.5, 1, 2, 3, 4, 6, 9, and 12 m, where nozzles were integrated into the wind tunnel, including untreated check. In a second experiment, six weeds were treated with MES and RIMTHIF in tank-mixture with five adjuvants (ammonium sulfate – AMS, crop oil concentrate – COC, drift reducing adjuvant – DRA, methylated seed oil – MSO, and nonionic surfactant – NIS) sprayed with XR, AIXR, and TTI nozzles using a three-nozzle spray chamber, calibrated to deliver 94 L ha^{-1} at 276 kPa. Weeds were: *Chenopodium album*, *Abutilon theophrasti*, *Amaranthus tuberculatus*, *Amaranthus palmeri*, *Echinochloa crus-galli*, *Sorghum bicolor*. According to the first experiment, tracer deposition was higher at all downwind distances from the XR nozzle compared to the TTI. Accordingly, greater injuries were recorded for applications with the XR nozzle at all downwind distances. Soybean and wheat were the two most tolerant crops, while cantaloupe and green beans were the most susceptible ones. Because of possibility to injure crops, it is very important to mitigate drift in MES and RIMTHIF applications. Besides obtained results, the main question is does the nozzle selection influence herbicide efficacy. Selected nozzles had influence only on *A. theophrasti* and *Sorghum bicolor* control, indicating possibility to apply herbicides with coarser spray, avoiding an off-target movement. Our findings suggest adjuvants as an essential factor for improving weed control over the active ingredient alone up to 18.7% and 38.3% for MES and RIMTHIF, respectively. *E. crus-galli* biomass reduction was greater than 98% with RIMTHIF in tank-mixtures with COC and MSO adjuvants, compared to 65% when was applied alone. *C. album* had 52.1% biomass reduction when RIMTHIF was sprayed alone, while the addition of adjuvants to the tank-mixture resulted in biomass reduction ranging from 60.1% (COC) to 94.1% (AMS). These results indicate that the addition of adjuvants in herbicide solution can improve efficacy (COC and MSO for *E. crus-galli*; NIS, AMS, and MSO for *A. theophrasti*; and NIS, COC, and MSO for *C. album*).

The herbicidal potential of pelargonic acid to control Cirsium arvense in arable farming

Eliyeh Ganji; Sabine Andert

*University of Rostock, Faculty of Agricultural and Environmental Sciences,
Crop Health, Rostock, Germany*

Oral

Cirsium arvense (creeping thistle) is difficult to control in arable crops with reduced or no reliance on herbicides. Bio-based herbicides such as pelargonic acid are innovative alternatives to implement more environmental-friendly practices in weed management. Pelargonic acid is a non-selective and broad-spectrum contact herbicide. Its herbicidal activity results in a rapid membrane dysfunction that causes loss of membrane integrity and, eventually, cell death. Our study aimed at investigating the effects of pelargonic acid as a natural herbicide on *C. arvense* compared to other chemical non-selective herbicides. In 2020 and 2021, a randomized block design field experiment with four replicates was conducted in northeast Germany. The experimental setup compared an untreated control with the commercial products Beloukha® (10.9 kg ai ha^{-1} pelargonic acid and reduced dose 3.4 kg ai ha^{-1} pelargonic acid), Quickdown® (19.36 g ai ha^{-1} pyraflufen), a mixture of Beloukha® and Quickdown® (3.4 kg ai ha^{-1} pelargonic acid + 19.36 g ai ha^{-1} pyraflufen) and Roundup Powerflex® (1.44 kg ai ha^{-1} glyphosate). The herbicides were applied at the four- to eight-leaf-stage of *C. arvense* on the same plots (plot size 3 m^2) in autumn and spring at both experimental years. The shoot number per m^2 was assessed before application and 21 days after herbicide application. The herbicidal potential of pelargonic acid mainly differed between the two experimental years and the application seasons (spring or autumn). An early autumn application of pelargonic acid decreases more shoots and reduces the shoot number in subsequent spring. At the end of the experiment in the year 2021, the single treatment pelargonic acid (10.9 kg ai ha^{-1}) and the mixture of pelargonic acid and pyraflufen(3.4 kg ai ha^{-1} pelargonic acid + 19.36 g ai ha^{-1} pyraflufen) decreased the number of *C. arvense* shoots strongly compared to the untreated control. Indeed, no significant differences were found between the single treatment pelargonic acid and the mixture of pelargonic acid and pyraflufen in comparison with the treatments pyraflufen and glyphosate within each season in both years. After twice per year application, pelargonic acid and its mixture with pyraflufen could decrease the density of *C. arvense* under field conditions. Yet, the active ingredients glyphosate and single pyraflufen showed the significantly lowest shoot number at the end of the experiment in the year 2021. These treatments did not differ from each other. The final observed shoot number reductions of single treatment pelargonic acid/mixture of pelargonic acid and pyraflufen were much lower compared to glyphosate and the single pyraflufen treatment.

Keywords: *Perennial weed, Bioherbicide, Agro-ecological weed management, Creeping thistle, Glyphosate alternative*

Benefits and risks of Conviso® Smart technology for sugar beet growers in conditions of Central Europe

Miroslav Jursík; Josef Soukup; Michaela Kolářová; Luděk Procházka

Czech University of Life Sciences Prague, Prague, Czech Republic

Oral

The spectrum of herbicides used in conventional varieties of sugar beet in Europe is rather narrow and further restrictions are expected in the near future. The technology of sugar beet tolerant to acetolactate synthase (ALS) inhibitors foramsulfuron + thiencarbazonewas developed mainly for European farmers, who cannot use technologies with genetically modified varieties.The main aim of the study was to evaluate benefits and risks of the new herbicide-tolerant technology Conviso® Smart compared to conventional weed management strategies used in sugar beet. Plotfield trials were carried out in Prague (Czech Republic) in 2016-2020. *Chenopodium album, Amaranthus retroflexus, Echinochloa crus-galli, Abutilon theophrasti* and weed beet were monitored. Moreover, in growing season 2019-2021, field monitoring of Conviso® Smart sugar beet stands was performed in Bohemia region to detect the field efficacy and the creation of flowers of sugar beet varieties. Herbicide Conviso One (foramsulfuron + thiencarbazone) controlled all tested weeds very well (efficacy more than 97 %) in case of split application with an oil adjuvant. When only one application of herbicide Conviso One was performed in dry weather conditions, efficacy on *C. album* and *A. theophrasti* was insufficient (less than 90 %). Herbicide Conviso One fully controlled weed beet at all tested weed management strategies in all experimental years and the residual activity of this herbicide did not allow new emergences of this weed. The highest sugar beet yields (78 – 100 t ha^{-1}) were reached on plots where split application of Conviso One was used. Significantly lower yields (45-52 t ha^{-1}) were recorded with one application of Conviso One, mainly because *C. album* and *A. theophrasti* were not sufficiently controlled. On plots where weed beet was the only weed not controlled, sugar beet yield ranged from 23 to 61 t ha^{-1}. Field monitoring of Conviso® Smart sugar beet stands confirms the high efficacy of split application of herbicide Conviso One in different weather and soil conditions, including when soil conservation tillage practices were adopted. However, large differences were recorded in amount of bolting/flowering beet plants among Conviso® Smart varieties, especially in cold spring 2019, where a few plants of some varieties developed flowers. These bolting/flowering beet-plants need to be removed, which is the most important stewardship measure for this technology. Lack of this measure could lead to spread of new, ALS tolerant weed beets. For long-term sustainability of this technology, the reduced use of ALS inhibiting herbicides in subsequent crops (especially in maize and sunflower) is important anti-resistant strategy, also considering that a few populations of *Amaranthus* spp. resistant to ALS inhibiting herbicides have been already detected in South and South-East Europe.

Evaluation of persistence, efficacy and volatilization of a new dicamba based nanoformulation

Francesco Vidotto [1]; Giulia Papandrea [1]; Tiziana Tosco [2];
Monica Granetto [2]; Lorenzo Patrucco [1]; Marco Milan [1]; Silvia Fogliatto [1]

[1] Università degli Studi di Torino, DISAFA, Grugliasco, Italy
[2] Politecnico di Torino, DIATI, Torino, Italy

Oral

Nanoformulated pesticides can be a possible solution to reduce environmental contamination, as the use of nanomaterials can reduce leaching and volatilization. The objective of the study was to evaluate persistence, efficacy and volatilization of a clay-based dicamba nanoformulation, compared to a commercial product. Data collected were compared through descriptive analysis, one-way ANOVA and REGWF post-hoc test at $P<0.05$. The persistence of the nanoformulation was studied analyzing its dissipation in a standard soil for 40 days. Post-emergence efficacy was tested through greenhouse trials on sensitive broadleaf weeds (*Amaranthus retroflexus* and *Centaurea cyanus*) treated at 98, 195 and 293 g ha^{-1} of dicamba, corresponding to the minimum, medium and maximum label rate of refence commercial formulation, respectively. Because of its partial radical activity, the efficacy of the nanoformulation was also evaluated in pre-emergence trials, that were first conducted in Petri dishes kept in growth chamber on seed germination of *A. retroflexus* and *C. cyanus* and subsequently in greenhouse on seedlings *A. retroflexus* and *Portulaca oleracea*. Eventually, a preliminary test on volatilization was conducted in greenhouse, by visually evaluating phytotoxicity damage on sensitive soybean plants exposed to vapors arising from different treated surfaces (plastic, wet soil, dry soil, grass sod and other soybean plants). Degradation studies highlighted that the nanoformulation half-life (6.7 days) was shorter than the commercial product half-life (10.9 days). In post-emergence trials, visual evaluation of the damage on *A. retroflexus* showed that the nanoformulation average efficacy was 93%, not significantly different from the commercial product (97%). Moreover, adding an adjuvant to the nanoformulation helped enhancing its efficacy to 98%. On *A. retroflexus,* pre-emergence tests highlighted high efficacy of the nanoformulation in Petri dish, where average germination rate for seeds treated at medium and maximum doses was 1.5%, whereas in greenhouse conditions data showed high variability. However, medium and maximum doses of the nanoformulation significantly inhibited the emergence of *P. oleracea* in greenhouse conditions and visual efficacy rate was >90%. Preliminary volatilization tests highlighted possible lower volatilization of the nanoformulation from treated soybean leaf surface compared to the commercial product. Phytotoxicity damage rate was approximatively 10% with the nanoformulation, while the commercial product showed a significantly higher value (23%). While maintain a good efficacy, this nanoformulation may be a promising solution to reduce leaching and volatilization of dicamba.

Keywords: *nanoherbicide, dicamba, volatility*

Can new technologies overcome the work of advisors?

MONTULL JM[1], LLENES JM[2], RYDAHL P[3], BOEJER O[3], BÜCKMAN H[4], VERCHWELE A[4]

[1]Hortofructicultura, Botànica i Jardineria, Agrotecnio-CERCA Center, ETSEA- Universitat de Lleida, Lleida, Spain. josemaria.montull@udl.cat
[2]Unitat de Malherbologia del Servei de Sanitat Vegetal, DARP, Generalitat de Catalunya, Lleida, Spain.

[3] IPM Consult Ltd., Hovedgaden 32, 4295 Stenlille, Denmark
[4] Julius Kuhn-Institut, ,Messeweg 11/12, Braunschweig. Germany

Poster

New digital technologies in the field of agriculture have come to stay. In the case of chemical weed control, a possible workflow could be: weeds are detected, an application map is generated and the sprayer applies the herbicide at variable rates depending on weed species. IPMWise is a DSS developed in Denmark since the 80's and has also functional versions in Norway, Spain and Germany and has the potential to be the nexus between weed infestation maps and variable rates spraying maps. IPMWise proposes a wide list of solutions that ensure the control over the infestation reported on the plot ordered by price or environmental impact. Generally, residual herbicides have a higher environmental impact than foliar herbicides and for this reason they appear at the bottom of the list. Until now, IPMWise doesn't offer information about possible new weed flushes that justify the use of a residual herbicide. For this reason, decision-making process in the field of weed management is complex. The objective of this work is to know if the decisions can be taken automatically based on the environmental impact or if it is necessary the supervision of an advisor to select between all the possible options recommended by the DSS. For this reason, in this work we present the results of the use of the DSS IPMWise in Germany and Spain, with two criteria: to select the mixture based exclusively on the environmental impact or to select the mixture depending on possible new weed emergence flushes. For this, the results of 18 validation tests in Germany and 6 in Spain of the IPMWise system in maize crop sprayed in early stages are presented. These results are also compared with the standard practices in each area. In the case of treatments based on root action herbicides, selected by advisors based on the DSS suggestions andapplied at 11BBCH of the maize, the difference between obtained efficacies and predicted onesby the DSS are in average higher than 3%. However, if the criteria is only the environmental impact, foliar herbicides are applied and the differences at midterm are higher than -5% due to new germinations after the spraying unless the efficacies at short term are accurate. Thus, at this early phenological state, the DSS IPMWise predicts accurately the efficacies if possible new germination flushes are considered and the mixtures are selected properly within all the possible solutions showed by the DSS.

Evaluation of the selectivity of new winter cereal varieties to herbicides

Montull JM[1], Taberner A[3], Llop J[2], Llenes JM[2], Betbese, JA[4]

[1]Hortofructicultura, Botànica i Jardineria, Agrotecnio-CERCA Center,
ETSEA- Universitat de Lleida, Lleida, Spain.josemaria.montull@udl.cat
[2]Unitat de Malherbologia del Servei de Sanitat Vegetal, DARP,
Generalitat de Catalunya, Lleida, Spain.
[3] Agronomist, PhD. Lleida, Spain.
[4] Centro UdL-IRTA. Lleida, Spain.

Oral

Selectivity tests of new varieties of winter cereals to herbicides have been carried out for more than 20 years. The tests are carried out in the growing area of Lleida (NE of Spain) in two different fields, one under irrigated conditions and in a sub-humid rainfed one. The objectives of these field tests are two: To determine, of the most sown varieties, which are more sensitive to the herbicides applied and to know the selectivity of the new herbicides that appear on the market, or that are on the way to be commercialised soon. As an average, 20 herbicides and more than 60 different varieties are tested each year. To carry out the evaluations, the phytotoxicity scale proposed by the EWRS is used. This scale is very useful to determine the damage of the herbicides. However, from the crop point of view, it is difficult to compare between varieties using only this index. In addition, as some varieties and herbicides change from year to year, it is not easy to compare the effects between different years. For this reason, we propose the use of a new index, complementary to the EWRS Index, designed to evaluate the cumulative effect during the growing season, which allows to make these comparisons and to know the profile of each variety on a multiannual basis. Thus, we can calculate, for each trial, which varieties are in the upper, middle or lower tercile of sensitivity, which allows comparing between years and varieties in a simpler way. Taking into account the last 6 field tests, since 2019, most sensible barley varieties to the tested herbicides were RGT Planet, Albacete and Shuffle. The less sensible were Hispanic, Idra and Cometa. In the case of soft wheat, the most sensible varieties to herbicides where Arthur Nick, Nogal and RGT Tocayo and the less sensible varieties where Paledor, Chambo and Pistolo. The main conclusion is that this index allows comparing varieties in a multiannual basis, eliminating year-on-year variability.

Dose-response curves of pelargonic acid efficacy against summer and winter weeds in central Italy

Euro Pannacci [1]; Daniele Ottavini [1]; Andrea Onofri [2]; Francesco Tei [2]

[1] University of Perugia - Dept. of Agricultural, Food and Environmental Sciences, PERUGIA, Italy
[2] University of Perugia - Dept. of Agricultural, Food and Environmental Sciences, Perugia, Italy

Poster

Pelargonic acid is a non-selective post-emergence contact bio-herbicide which is registered both for cropping and non-cropping uses in several countries. In cropping systems it can be mainly used to control annual weeds on false seeding as alternative to nonselective synthetic herbicides whose use has been restricted or might become more restricted. Nevertheless, efficacy data of pelargonic acid against common weeds are not broadly available. The aim of this study was to determine dose-response curves of pelargonic acid efficacy against summer and winter annual weeds in central Italy. Two experiments were carried out in a field with a clay-loam soil and where a false seedbed preparation was carried out, either in winter (18 November 2019) or summer (29 May 2020) seasons, four weeks before pelargonic acid treatments. Experimental design was a randomized block with four replicates and plot size of 11.25 m^2 (2.25 m width). Pelargonic acid (Beloukha, 680 g ai L^{-1}, maximum recommended dose: 21.8 kg ai ha^{-1}) was applied at five doses (1.4, 2.7, 5.4, 10.9 and 21.8 kg ai ha^{-1}), with the weeds at 6-8 true leaves using a backpack plot sprayer calibrated to deliver 300 L ha^{-1} spray liquid at 200 kPa. Untreated plots were added as control. The efficacy of pelargonic acid towards each weed species was visually assessed on weed ground cover, 3 weeks after treatments, on a scale from 0 (no weed control in comparison with untreated control) to 100 (total weed control). Data of pelargonic acid efficacy was subjected to a non-linear regression analysis using the logistic dose-response model and the doses of pelargonic acid required to obtain 90% weed control against each species (effective dose, ED_{90}) were estimated. Weeds (their percentage ground cover in the untreated control and ED_{90} of pelargonic acid in kg ha^{-1} ± standard error are in parentheses) and the ranking among them based on their sensitivity to pelargonic acid are reported as following: *Kickxia spuria* (5%, 3.4 ± 0.2) > *Heliotropium europaeum* (5%, 4.1 ± 0.2) > *Echinochloa crus-galli* (18%, 7.1 ± 0.6) > *Solanum nigrum* (18%, 8.0 ± 0.6) > *Papaver rhoeas* (18%, 10.9 ± 0.5) > *Stachys annua* (5%; 16.8 ± 5.2) > *Matricaria chamomilla* (19%, > 21.8) = *Lolium multiflorum* (10%, > 21.8) = *Veronica hederifolia* (21%, > 21.8) = *Amaranthus retroflexus* (50%, > 21.8) = *Portulaca oleracea* (84%, > 21.8). Pelargonic acid, also at reduced doses, is an effective herbicide to control several annual weed species; however, a limit could be the presence of non-susceptible weeds.

The effects of biostimulant application, mechanical weed control and herbicide application on weed growth and maize (*Zea mays L.*) yield

Ioannis Gazoulis [1]; Nikolaos Antonopoulos [1]; Alexandros Tataridas [1]; Panagiotis Kanatas [2]; Ilias Travlos [1]

[1] *Agricultural University of Athens, Laboratory of Agronomy, Athens-Greece, Athens, Greece*
[2] *University of Patras, Department of Crop Science, P.D. 407/80, Messolonghi-Greece, Messolonghi, Greece*

Poster

In contrast to synthetic fertilizers, natural substances and microorganisms known as biostimulants provide an environmentally friendly way to favor crop growth and productivity. Our hypothesis was that their combination with mechanical weed control can reduce the use of fertilizers and herbicides in maize while achieving high yields. A field experiment was conducted (2020 to 2021) to evaluate different fertilization practices and weed control treatments in a maize field located in Agrinion, Western Greece. The experiment was laid out in a split-plot design with four replications. Two fertilization practices, conventional and alternative fertilization were assigned to main plots. Four weed control treatments were assigned to subplots. Conventional fertilization included fertilizer incorporation to supply the crop with 160 kg N ha^{-1}. The alternative fertilization practice included a foliar application of *NitroStim* biostimulant along with fertilizer incorporation at 50% lower rate (80 kg N ha^{-1}). *NitroStim* is a pre-package microbial solution containing nitrogen fixing bacteria at the concentration of 1×10^{12} CFU L^{-1} that claims to enhance crop growth. The biostimulant was applied at the 3-leaf growth stage of maize with an Elettra Venus 5 pressurised sprayer calibrated to deliver 5 L ha^{-1} of spray solution at 200 kPa pressure through a conical nozzle. Weed control treatments included: one interrow mechanical cultivation at the 4-leaf growth stage of maize, two interrow cultivations carried out at the 4- and 6-leaf growth stages of maize, tembotrione application at the 6-leaf growth stage of maize. Tembotrione was applied at 99 g ai ha^{-1} with a Gloria 405 T pressurized sprayer calibrated to deliver 300 L ha^{-1} of spray solution at 250 kPa pressure through five 8002 flat-fan spray nozzles. An untreated control was included. *Datura stramonium* L., *Amaranthus retroflexus* L., and *Setaria viridis* (L.) P. Beauv. were the dominant weeds. Fertilization practices and weed control treatments affected weed biomass and maize grain yield (P < 0.001). Biostimulant application along with herbicide application provided excellent weed control. A polynomial relationship indicated that weed biomass decreases and grain yield increases by increasing the number of mechanical interrow cultivations (P < 0.001). Biostimulant application improved crop's nitrogen partial factor productivity (PFP$_N$) by 56% compared to conventional fertilization. Further research is needed to optimize the use of biostimulants along with mechanical weed control methods to achieve higher yields in maize and other economically important crops.

Chemical control of ivy (Hedera helix L.) prior to reforestation of oak forests

Verica Vasic; Predrag Pap; Sasa Orlovic; Sreten Vasic

Institute of Lowland Forestry and Environment, Novi Sad, Serbia

Poster

The climbing plant ivy (*Hedera helix* L.) is an evergreen species which has beautiful, shiny leaves but it is a plant species that can cause serious damage in forest. On the areas where the restoration of oak forests is planned, the presence of ivy can hamper growth and development of young oak seedlings. Mechanically cutting ivy is not an easy job and such a control method is costly because it requires time, labour and perseverance, and the species is difficult to control once established. For that reason, the objective of this study was to examine the possibility of applying chemical measures. In the period 2019-2020, experiments were set up at the Forest Enterprise -Sremska Mitrovica, Management unit–Varadin (44058´5″N, 19016´08″E). The experiment was arranged as a randomized block design with four replicates and eight treatments. Each experimental subplot was 10 × 5 m in size, so each treatment covered an area of 200 m^2. The study included and control, which were not treated with herbicides. The herbicides used in the study were applied in two rates: glyphosate at 2.88 and 4.32 kg ai ha^{-1}; fluroxypyr at 0.37 and 0.50 kg ai ha^{-1}; dicamba at 0.72 and 0.96 kg ai ha^{-1} and metsulfuron-methyl at rates of 0.006 and 0.012 kg ai ha^{-1}. The herbicides were applied at 10 Jun 2019 and 22 Jun 2020, when the plants of ivy had fully developed leaves mass. Herbicide applications were performed with an air-pressurized hand-sprayer, with a boom fitted with one nozzle, calibrated to deliver 300 L ha^{-1} of water at 250 kPa pressure. The herbicide efficacy was rated visually 15, 30, 45 and 60 days after herbicide application where 0 % meant no efficacy and 100 % meant full ivy control. Results indicated that ivy had good tolerance to dicamba, as both applied rates were not effective. Fluroxypyr applied at rate 0.50 kg ai ha^{-1} generally was more effective than at 0.37 kg ai ha^{-1} but neither rate provided a level of control that could be deemed satisfactory. Metsulfuron-methyl provided excellent control of ivy, as rates of 0.006 and 0.012 kg ai ha^{-1} provided around 90% and 100% efficacy. Glyphosate provided 100% control of ivy at both applied rates. This study showed that ivy can be effectively managed with glyphosate and metsulfuron-methyl and that applying lower rates of 2.88 kg ai ha^{-1} glyphosate and 0.006 kg ai ha^{-1} metsulfuron-methyl can achieve excellent efficacy.

Keywords: *Ivy, herbicides, forest*

Preliminary results of herbicidal application with other plant protection products and biostimulants in winter wheat

Nesho Neshev; Mariyan Yanev; Anyo Mitkov; Maya Dimitrova

Agricultural University of Plovdiv, Plovdiv, Bulgaria

Poster

Winter wheat is the second most important crop in the world after maize. In Bulgaria, it is a major crop. To obtain stable yields, the control of weeds, diseases, and pests is of particular importance. The combined use of plant protection products together with plant biostimulants in a tank mixture may reduce investment in pest control and increase the crop competitiveness. In 2021 a field trial in the experimental field of the Department of Agriculture and Herbology at the Agricultural University – Plovdiv, Bulgaria was conducted. The Bulgarian winter wheat variety ˝Enola˝ was grown. Tribenuron-methyl (f.p. Granstar 75 DF; 750 g ai kg^{-1}) was applied alone at 11.25 g ai ha^{-1} (treatment 1) or adding the following products as tank mixing combinations: α-cypermethrin at 15 g ha^{-1} (insecticide, f.p. Mageos MD; 150 g ai kg^{-1}) (treatment 2); bixafen at 62.5 g ha^{-1} + tebuconazole at 207.5 g ai ha^{-1} (fungicide; f.p. Zantara 216 EC; bixafen 50 g ai L^{-1} + tebuconazole 166 g ai L^{-1}) (treatment 3); Amino Expert Impuls (biostimulant) at 3.0 L f.p. ha^{-1} (treatment 4); Fertileader Vital (biostimulant) at 3.0 L f.p. ha^{-1} (treatment 5); combination of 2, 3, and 4 (treatment 6); combination of 2, 3 and 5 (treatment 7), and combination of 1, 2 and 3 (treatment 8). An untreated control was also included (treatment 9). The application was performed in the growth stage end of tillering – beginning of spindling of the crop (BBCH 29-31). The treatment efficacy against economically important weed species such as *Anthemis arvensis* L., *Viola arvensis* Murray, and *Veronica hederifolia* L. was assessed by using the quantitative-weight method. At the application time, the growth stage of the weeds was 9 or more leafs unfolded (BBCH 19). The following crop measurements were performed: plant height, ear length, seed yield, absolute and hectoliter seed mass, seed gluten content. The efficacy against *A. arvensis* was 100% in all treatments. Against *V. arvensis*, the efficacy of application of tribenuron-methyl in tank mixture with insecticide and fungicide was influenced by the type of biostimulant, as the herbicide efficacy increased from 6.2% for treatment 6 to 76% for treatment 7. The efficacy against *V. hederifolia* was low. The highest values of plant height (0.91 cm), ear length (10.67 cm), seed yield (6.64 t ha^{-1}), hectoliter seed mass (77.67 kg), and gluten content (23.53%) were observed after the combined application of tribenuron-methyl, insecticide, fungicide and Amino Expert Impuls (treatment 6). The highest value of absolute seed mass (39.20 g) was recorded for the treatment with the combined application of tribenuron-methyl and Amino Expert Impuls (treatment 4).

Management of *Melilotus sulcatus* in *Allium* crops in Israel

Shaharit Ziv [1]; Daryl Gillett [2]; Abraham Gamliel [3]; Maor Matzrafi [4]

*[1] The Robert H. Smith Faculty of Agriculture, Food and Environment,
The Hebrew University of Jerusalem. Department of Plant Pathology and Weed Research,
Agricultural Research Organization, Newe-Ya'ar Research Center, Ramat- Yishai, Israel
[2] Southern Arava R&D, Yotvata, Israel
[3] Institution of Agricultural Engineering, Agricultural Research Organization,
The Volcani Institute, Rishon LeZion, Israel
[4] Department of Plant Pathology and Weed Research, Agricultural
Research Organization, Newe-Ya'ar Research Center, Ramat- Yishai, Israel*

Poster

Melilotus sulcatus is an annual weed, endemic to the Mediterranean basin and Asia. Farmers across Israel have reported its increased abundance during the past few years, mainly in fields cropped with *Allium* crops, such as garlic and onion. These are considered weak competitors with low tolerance to weed disturbance. Furthermore, the herbicides registered for weed control in *Allium* crops are limited. *M. sulcatus* seeds can germinate in several flushes during the season, which requires continuous interventions to control this weed and prevent its disturbance to crops. The objective of the current study was to develop an improved herbicide management practice for the control of *M. sulcatus* in *Allium* crops. Seeds of two *M. sulcatus* populations collected at Yifat (Jezreel valley) and Grofit (southern Arava) were used for assessing herbicide effect in greenhouse experiments. The efficacy of three post-emergence herbicides (oxyfluorfen 480 g ai ha^{-1}, f.p. Galigan®; fluroxypyr 288 g ai ha^{-1}, f.p. Tomahawk®; ethofumasate 600 g ai ha^{-1}, f.p. Nortron®) was tested at three rates (1/2X, X, and 2X; X=labeled field rate) and for two growth stages (2-4 and 6-8 leaf stage). Oxyfluorfen and fluroxypyr were more effective in controlling *M. sulcatus* plants in young (2-4 leaves) as compared with mature growth stages (6-8 leaves) for all the rates tested. Field experiments were conducted in the southern Arava region during the winter season of 2021. The experiment was set at a randomized complete block design, with 14 replicates for each treatment (plot size of 12 square meters). The efficacy of pre-emergence (chlorthal-dimethyl 7200 g ai ha^{-1}, f.p. Dacthal®), and post-emergence herbicide application (oxadiazon 500 g ai ha^{-1}, f.p. Ronstar®; oxyfluorfen; fluroxypyr; ethofumasate) was tested. Oxyfluorfen and oxadiazon resulted in mild phytotoxic symptoms on the onion leaves and the crop recovered over time. The total number of *M. sulcatus* plants was significantly lower following pre-emergence treatment of chlorthal-dimethyl, compared with untreated control plots. The post-emergence herbicide ethofumasate treatment showed leaf cupping and meristematic damage symptoms. Bleaching, necrotic spots, and leaf distortion were observed for both oxyfluorfen and oxadiazon. The most effective damage on the weeds was shown for the fluroxypyr treated plots, where *M. sulcatus* plants exhibited necrotic and blight symptoms. Our study provides insights that could be used to establish improved chemical control of *M. sulcatus* under various growth stages and growing conditions.

Keywords: *Weed control, Melilotus sulcatus, Onion, Herbicides, Post-emergence, Pre-emergence, Oxyfluorfen, Oxadiazon, Fluroxypyr*

Selectivity of pre- and post-emergence herbicides in castor bean (*Ricinus communis L.*)

Anestis Karkanis; Andromachi Sortikou; Georgia Christodoulou; Spyridon Souipas; Kyriakos Giannoulis

University of Thessaly, Department of Agriculture Crop Production and Rural Environment, Volos, Greece

Poster

Castor bean (*Ricinus communis L.*) is an important industrial crop that is cultivated for oil production. Its oil is used for biofuel production, while ricinoleic acid is the predominant fatty acid in seeds. Weeds are a main constraint in this crop since their competition can result in high yield losses. Thus, a field experiment was conducted in 2021 to assess the selectivity of five herbicides in castor bean. The crop was planted on 19 May and seven treatments were arranged in a randomized complete block design with three replicates, and plot size of 15 m^2. The compared treatments were: 1) weed-free control, 2) weedy control, 3) pendimethalin (1.32 kg ai ha^{-1}), 4) S-metolachlor (0.96 kg ai ha^{-1}), 5) fluometuron (1.25 kg ai ha^{-1}), 6) bentazon (1.44 kg ai ha^{-1}), and 7) fluazifop-p-butyl (0.25 kg ai ha^{-1}). Fluazifop-p-butyl and bentazon were applied when castor bean plants reached the 2 to 3-leaf stage, whereas the other herbicides were applied pre-emergence. In the weed-free plots four hand hoeing's were made. The application of herbicides was done using a field plot sprayer equipped with flat-fan nozzle delivering 300 L ha^{-1} at constant pressure of 250 kPa. The results showed that the crop density was reduced in fluometuron plots compared to weed-free treatment, while there were no significant differences among pendimethalin, S-metolachlor, and weed-free treatments for this parameter. Bentazon and fluometuron caused severe necrosis in leaves, while slight chlorosis in the upper part of leaves was observed on some plants in S-metolachlor plots. In the latter herbicide, the symptoms were transient and did not affect castor bean growth. In contrast, pendimethalin and fluazifop-p-butyl did not caused phytotoxicity on plants. Moreover, the lowest aboveground dry biomass and seed yield were recorded in weedy control, while there were no significant differences between pendimethalin and S-metolachlor for both parameters. In conclusion, the herbicides pendimethalin, S-metolachlor, and fluazifop-p-butyl could be used for weed control in castor bean, while their selectivity should be also examined under different application doses and soil conditions.

The combination of banded herbicide application and inter-row cultivation is an effective way to reduce herbicide use in soybean

Jovana Krstić[1]; Goran Malidža[1]; Miloš Rajković[1]; Maja Meseldžija[2]

[1] *Institute of Field and Vegetable Crops, Novi Sad, Serbia*
[2] *University of Novi Sad, Faculty of Agriculture, Novi Sad, Serbia*

Poster

According to the strategy of the European Commission, by 2030 the use of pesticides (herbicides) is expected to be reduced by 50%. The adoption of band application of herbicides, combined with mechanical measures, may contribute to achieve this goal. The aim of the study was to determine whether reducing application of herbicides by applying 50% of the recommended label rates in combination with an inter-row cultivation can result in satisfactory weed control in soybean and if this technique is economically sustainable. Field trials were conducted in 2020 and 2021, at the experimental fields of the Institute of Field and Vegetable Crops in Novi Sad and design was completely randomized block with four replications. The size of the plots were 30 m^2, with a row spacing of 50 cm. The following treatments were tested: 1) pre-emergence broadcast application of dimethenamid-P (864 g ai ha^{-1}) + metribuzin (240 g ai ha^{-1}) with and without inter-row cultivation, and 2) the same herbicides as in 1) applied on a 25 cm wide band across the crop row (thus allowing 50% reduction of herbicide applied per ha of crop) with inter-row cultivation; 3) post-emergence broadcast herbicide application of bentazone (864 g ai ha^{-1}) + imazamox (40 g a. ha^{-1}) with and without inter-row cultivation and 4) the same herbicides application as in 3) in band with inter-row cultivation; 5) a combination of pre-emergence and post-emergence treatments; 6) untreated weed-free and 7) weedy check. Untreated weed-free plots were obtained by manual weeding. Herbicides were applied with a backpack sprayer with compressed CO_2, nozzles TeeJet XR11002 (for broadcast application) and TP4002E (for band application), 200 L ha^{-1} of water and a pressure of 2 bar. Combination of pre-emergence and post-emergence herbicides band application with inter-row cultivation gave 99% efficacy in controlling *Abutilon theophrasti*, *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Chenopodium album*, *Datura stramonium*, *Solanum nigrum* in 2020, 2021 while the efficacy of herbicides in controlling *A. artemisiifolia* was 98% in 2021. These results were equal to or greater than control provided by broadcast applications. There is no significant statistical difference in soybean yield between the mentioned treatment and the treatment with the same combination only with the broadcast application. It can be concluded that this treatment can provide optimal weed control in soybean crops and at the same time allow a significant reduction of herbicide input which is important from the aspect of the sustainable concept of agricultural production and environmental protection. Properly applied treatment helps reduce production costs without affecting crop yield.

Keywords: *Weed control, herbicides, soybean, band application, inter-row cultivation*

Prickly sida (*Sida spinosa L.*) management in cotton with pre- and post-emergence herbicide combinations

Vaya Kati [1]; Ioannis Vasilakoglou [2]; Thomas Gitsopoulos [3]; Christos Vlachos [4]; Philippos Mylonas [5]

[1] *Laboratory of Weed Science, Scientific Directorate of Pesticides Control and Phytopharmacy, Benaki Phytopathological Institute, Kifissia, Greece*
[2] *Department of Agriculture—Agrotechnology, University of Thessaly, Larissa, Greece*
[3] *Hellenic Agricultural Organization-Dimitra, Institute of Plant Breeding and Genetic Resources, Thessaloniki, Greece*
[4] *Agronomist, Karditsa, Greece*
[5] *Laboratory of Efficacy Control of Pesticides, Scientific Directorate of Pesticides Control and Phytopharmacy, Benaki Phytopathological Institute, Kifissia, Greece*

Poster

Sida spinosa L. (Malvaceae), known as prickly sida, is an annual summer weed, native in the Americas. It was introduced in Greece about two decades ago and is now threatening crop production in irrigated spring crops. Herbicide control of prickly sida in cotton (*Gossypium hirsutum* L., Malvaceae) has proved to be particularly challenging. In order to find efficient solutions, an experiment was conducted during spring-summer 2021 in Karditsa (Thessaly), a major cotton-producing area in central Greece, in a field heavily infested with prickly sida. Ten treatments were tested, arranged in a RCBD (four replicates/treatment, 16 m^2/plot, comprising four cotton-rows 5m long). The treatments included an untreated control and nine pre-emergence (PRE) or post-emergence (POST) applications with the following herbicides (and applied field doses, g ai ha^{-1}): pyrithiobac PRE (68.9), tank-mixture pyrithiobac+s-metolachlor PRE (68.9+960), tank-mixture pyrithiobac+isoxaben PRE (68.9+150), tank-mixture flurochloridone+fluometuron PRE (375+2000), tank-mixture flumioxazin+s-metolachlor PRE (50+960), commercial mixture pendimethalin+terbuthylazine PRE (750+1500), tank-mixture pyrithiobac+s-metolachlor PRE (34.5+960) followed by pyrithiobac POST (34.5), pyrithiobac POST (68.9), and tank-mixture pyrithiobac+trifloxysulfuron POST (68.9+7.5). Cotton and the majority of prickly sida plants were at the first true-leaf stage (BBCH 10-11) during POST applications. Spraying was performed with an AZO hand-held boom sprayer, equipped with six twin flat-spray nozzles and operated with compressed air to deliver 300 L ha^{-1} at 210 kPa pressure. Assessments included visual estimation of prickly sida ground cover using a 0-100% scale, (0%=no ground cover, 100%=total ground cover by prickly sida), number of prickly sida plants m^{-2} and observation of any crop injury. Assessments were performed in the central inter-row area of each plot, at 3 and 8 weeks after treatment (WAT) for the PRE, and at 4 WAT for the POST and for the PRE followed by POST applications. Based on prickly sida plant numbers, the PRE applications and the PRE followed by POST application provided the highest reduction in weed density (from 88-100%), compared to the control (200 prickly sida plants m^{-2} on average) at 8 WAT. The most effective herbicides (99-100% reduction of prickly sida plants m^{-2}) were: pyrithiobac PRE, pyrithiobac+isoxaben PRE, pyrithiobac+s-metolachlor PRE, and pyrithiobac+s-metolachlor PRE followed by pyrithiobac POST. The POST applications were moderately effective (70% reduction by pyrithiobac and 74% by pyrithiobac+trifloxysulfuron, 4 WAT). No crop injury was observed in any of the treatments. These findings provide useful information for the successful management of prickly sida in cotton crop.

Keywords: *Sida spinosa, cotton, weed management, herbicides, pre-emergence, post-emergence*

Weed control and yield in cotton as affected by three different tillage systems

T.G. Gitsopoulos; Eleni Tsaliki; Apostolos Kalyvas; Ioannis Georgoulas; Ioannis Panoras; Ioannis Grigoriadis

Hellenic Agricultural Organization-Dimitra Institute of Plant Breedind and Genetic Resources, Thessaloniki, Greece

Poster

Cotton is the most important industrial crop for Greece, covering about 300,000 ha. Conservation Agriculture (CA) is widespread adopted in North and South America and its application in cotton has been reinforced by the widespread cultivation of herbicide-tolerant genetically modified cotton. However, CA in Greece is rarely applied in cotton, both as consequence of the ban on the cultivation of genetically-modified crops and the extremely limited number of herbicides available to control broadleaf weeds in post-emergence. Legumes as cover crops are suitable in low-input cropping systems associated with crop rotation sequences under CA, due to their great contribution to soil fertility, gas emissions mitigation, crop diversification and sustainability, although they may provide less effect on weed control compared to other cover crops. The objective of the present study was to compared the effect of conventional tillage (CT), strip-tillage (ST) and no-tillage (NT) systems in terms of weed control and cotton yield when Austrian winter pea (hereinafter ¨pea¨) (*Pisum sativum*) is used as cover crop. The study was carried out in north Greece by planting pea in the fall of 2014, followed by cotton in spring 2015 in the same field in a RCBD with 4 reps/treatment in plots of 12 m length including 4 cotton rows spaced 90 cm apart. Pea was terminated the same day either mechanically in CT or chemically with glyphosate in ST and NT plots. In ST, strips about 25cm wide were tilled prior to planting. A Greek cotton cultivar was hand-planted (15 April 2015) in all plots fifteen days after pea termination. One day after planting, pendimethalin (Stomp 330 EC) at 1820 g ai ha^{-1} was applied in all plots to control weeds; fluazifop-p-butyl (Fusilade 12.5 EC) at 312 g ai ha^{-1} was applied in the last week of June 2015 against grass weeds. Assessments performed 8 weeks after planting did not reveal any significant difference in weeds m^{-2} or total weed dry weight. Similarly, there was no significant difference in cotton height, boll number, boll height, boll dimensions, fiber content and seed cotton yield that was 3380, 3270 and 2940 kg ha^{-1} for CT, ST and NT, respectively. The results indicated no different effect of conventional compared to strip- or no-tillage on weed control nor yield.

Keywords: *Conservation tillage, Austrian winter pea, cover crops, Pisum sativum*

Novel sensor-based method for the in-season rapid evaluation of herbicide efficacy under real field conditions in maize (*Zea mays L.*)

Anastasia Tsekoura [1]; Ilias Travlos [2]; Ioannis Gazoulis [2];
Nikolaos Antonopoulos [2]; Panagiotis Kanatas [3]

[1] *Benaki Phytopathological Institute, Athens, Greece*
[2] *Agricultural University of Athens, Athens, Greece*
[3] *School of Agricultural Sciences at the University of Patras, Amaliada, Greece*

Poster

Herbicides are very effective method to prevent or interrupt weed growth in arable crops. Nevertheless, the need to reduce the use of agrochemicals is timely than ever since raise in environmental concerns and after the introduction of specific strategies, such as the European Green Deal 2020. Within this framework, in-season evaluation of herbicide performance and the rapid detection of herbicide resistance are essential tools of Integrated Weed Management (IWM). The objective of this study was to elaborate a sensor-based method for the *in situ* herbicide evaluation and detection of potential resistant weed biotypes in maize (*Zea mays L.*). Two field trials were conducted during the 2020 cropping season in Pyrgos and Agrinio (Greece), respectively. NDVI and total weed density were evaluated 1 and 2 weeks after the treatment (1 & 2 WAT). NDVI values were obtained using a Trimble® GreenSeeker® handheld crop sensor (Trimble Agriculture Division, Westminster, CO, USA). The direction of the device was parallel to the direction of the crop rows. The sensor was held stable at approximately 20 to 25 cm above the weed leaf area for 5 s, in the area delimited from the rows of the crop, and focused only on the weeds. The experiments were conducted in a RCBD with seven treatments and four replications. The treatments included six herbicides and one untreated control. More specifically, six post-emergence herbicides were applied consisting of 1: a mixture of nicosulfuron (39.6 g_{ai} ha⁻¹)+ rimsulfuron (9.9 gai ha⁻¹)+ mesotrione (118.8 g ai ha⁻¹), 2: a mixture of florasulam (7.515 g ai ha⁻¹)+ mesotrione (120.15 g ai ha⁻¹), 3: a mixture of nicosulfuron (40.48 g ai ha⁻¹)+ rimsulfuron (10,2 g ai ha⁻¹)+ dicamba (242 g ai ha⁻¹), 4: a mixture of nicosulfuron (38.61 g ai ha⁻¹)+ rimsulfuron (9.63 g ai ha⁻¹), 5: a mixture of mesotrione (112.5 g ai ha⁻¹)+ nicosulfuron (45 g ai ha⁻¹) and 6: 2,4 D-ester (600 g ai ha⁻¹). The applications were performed with a pressurized backpack Gloria® 405 T sprayer equipped with five flat spray nozzles (spray angle: 80°) delivering 300 L ha⁻¹ of spray solution at 300 kPa pressure when maize was at the stage of 3- to- 6 leaves. Both trials resulted in higher NDVI values and total weed density after being treated with herbicide 6 and mixture 5. For instance, for Pyrgos the recorded NDVI values reached 0.88 at 2 WAT with the mixture 5 while the control recorded 0.89. Low NDVI values (0.48-0.52) and total weed density (7-12 plants m⁻²) were recorded at 2 WAT with mixture 1. Moreover, the overall results for Pyrgos indicate a strong correlation between NDVI values and total weed density (R^2= 0.82). In Agrinio trial, lower NDVI values (0.62-0.68) were noted at 1 WAT with mixture 3 in comparison with the control (0.77-0.80). Thus, this mixture was suggested to be very effective for the specific weed flora. Furthermore, both the high-density *Echinochloa crus-galli* (18-20 plants m⁻²) and the high NDVI values (0.80-0.87) observed at 2 WAT with mixture 5 indicated the existence of a possible resistant population. The results suggest that NDVI measure could be included in IWM as a useful tool in evaluating herbicide efficacy and for early detection of herbicide resistance.

Keywords: *NDVI, herbicides efficacy, field trials, herbicide resistance*

Herbicidal activity of indaziflam in cow bonechar-amended soil

Kassio Mendes [1]; Rodrigo Sousa [2]; Kamila Mielke [1]

[1] Federal University of Viçosa, Viçosa, Brazil
[2] University of São Paulo, Piracicaba, Brazil

Poster

The addition of carbonaceous material such as cow bonechar to the soil can affect the bioavailability of applied pre-emergence herbicides such as indaziflam. However, how cow bonechar affects the bioavailability of indaziflam is not yet known. The aim of this study was to evaluate the effect of cow bonechar on herbicidal activity of indaziflam on weeds in a tropical soil. The study was completely randomized under a factorial arrangement of six doses of cow bonechar added to soil and herbicide application (with and without indaziflam). Four replications were considered and each experimental unit consisted of an aluminum tray. Cow bonechar was added homogeneously to top soil (0–10 cm depth), at 1, 2, 5, 10, and 20 t ha^{-1}; a treatment with unamended soil was also included. Subsequently, the addition of cow bonechar was applied indaziflam herbicide. The commercial product Alion® (Bayer Brazil) was used to prepare the herbicide solution, with a dose corresponding to 75 g ai ha^{-1}. The application was made using costal spray with pressurized CO_2 cylinder, equipped with 1.0 m bar and two spraying tips type range Teejet TT 110.02. Herbicide application was made at 50 cm in height of the trays, using a solution volume of 145 L ha^{-1} and an application pressure of 20 kPa. At 21 days after indaziflam application, treatment efficacy (visual score) and weed species were recorded. Already 1.4 t ha^{-1} (estimated value from the regression curve) cow bonechar added to soil was enough to reduce the treatment efficacy by 50%. Rates of cow bonechar higher than 2 t ha^{-1} greatly affected indaziflam efficacy, giving results similar to untreated application. Eight weed species (3 monocots and 5 dicots) were identified in all treatments. *Eleusine indica and Digitaria horizontalis* accounted for about 99.7% of the entire weed community. Cow bonechar decreases indaziflam pre-emergence herbicidal activity in tropical soil for weed control, most likely due to the high sorption and unavailability of the product in the soil solution.

Keywords: *Injury levels; efficacy; high sorption; top soil*

SESSION VII

AGRICULTURAL, ECONOMIC AND SOCIETAL ASPECTS OF WEED MANAGEMENT

The strategy of weed scientists for managing new or emerging weeds under global climate change

Ahmet Uludag [1]; Heinz Müller-Schärer [2]; Mark van Kleunen [3];
Sava Vrbničanin [4]; Alexandros Tataridas [5]; Christian Bohren [6];
Bojan Konstantinović [7]; Tijana Stojanović [7]; Mehmet Arslan [8];
Miloš Rajković [9]; İlhan Üremiş [10]; Necmi Aksoy [11]; Javid Kashefi [12];
Marie Claude Bon [12]; Vladimir Vladimirov [13]; Rumen Tomov [14];
Eyüp Gülbandılar [15]; Yasin Çiçek [15]; Mostafa Oveisi [16];
Ahmet Tansel Serim [17]; Khawar Jabran [18]; Giuseppe Brunda [19]

[1] Faculty of Agriculture, Canakkale onsekiz Mart University, canakkale, Turkey, [2] University of Fribourg, Fribourg, Switzerland, [3] Ecology, Department of Biology, University of Konstanz, Konstanz, Germany, [4] Faculty of Agriculture, University of Belgrade, Belgrade, Serbia, [5] Faculty of Crop Science, Agricultural University of Athens, Athens, Greece, [6] Former Chair of the EWRS IP WG, Freelance, Switzerland, [7] Faculty of Agriculture, University of Novi Sad, Novi Sad, Serbia, [8] Faculty of Agriculture, Erciyes University, Kayseri, Turkey, [9] Institute of Field and Vegetable Crops, Novi Sad, Serbia, [10] Faculty of Agriculture, Hatay Mustafa Kemal University, Hatay, Turkey, [11] Faculty of Forestry, Düzce University, Düzce, Turkey, [12] 12USDA ARS EBCL, Montferrier sur-Lez, France, [13] Sofia, Bulgaria, [14] University of Forestry, Sofia, Bulgaria, [15] Department of Computer Engineering, Osmangazi University, Eskişehir, Turkey, [16] Faculty of Agriculture and Natural Resources, University of Tehran, Tehran, Iran, [17] Faculty of Agriculture, Bilecik Şeyh Edebali University, Bilecik, Turkey, [18] Faculty of Agricultural Sciences and Technologies, Niğde Ömer Halisdemir University, Niğde, Turkey, [19] Department of Agricultural Sciences, University of Sassari, Italy

Oral

Many invasive alien plant species (IAP) often become weeds shortly after they have been introduced and naturalized in new habitats. These new or emerging weeds may have no natural enemies in their introduced regions and thus their top-down control is released. Weed scientists have mostly focused on their individual fields of expertise. However, a sustainable strategy for IAP management requires the consideration of the whole invasion process, and it should be linked to global climate change, as well as to the increased movement of people and goods. Quarantine measures have been the main tool in preventing the introduction of new pests, but there is a need to implement early detection and rapid response actions more generally. Stakeholders of the agricultural sector should cooperate with qualified international organizations dealing with IAP, such as IUCN, as well as with local NGOs, in order to inform farmers and citizens, and promote the opportunity to react early to the new alien plants invasion. Furthermore, the public should be encouraged to take an active role in detecting the newcomers in their early stages of invasion. One of the problems for a quick response to alien plants' introduction is the issue of reaching a decision whether this non-native species could potentially become an invasive or not. Available artificial intelligence-based systems might significantly contribute to this matter. However, the key strategic action for IAP is building a strong connec-

tion between qualified organizations and people, locally, regionally, and globally, to establish a continuous exchange of experiences and knowledge. Furthermore, terms and definitions need a more general agreement and common understanding. For instance, in forestry, the term understory flora can have an unclear meaning, including both native species and alien weeds without discrimination. Chemical and mechanical control of weeds increasingly have drawbacks, including herbicide resistant weeds and contributions to carbon emissions, which make them less efficient and sustainable. In addition, weeds in riparian areas and conservation areas need different control methods. Biological and biotechnological methods should be developed and implemented via new fast and reliable systems. Moreover, outreach activities should have priority, as well as education and training. It should be noted that the cause of the bigger problems, which will inevitably occur in the future, besides the new invaders, also lies in the species shifts of the current floras, as well as in the change of their ecophysiology.

Keywords: *citizen science, strategy, prevention, ecosystem services, biodiversity, artificial intelligence*

Joining efforts in the Mediterranean Europe to tackle the invasion of *Ailanthus altissima* (Tree of Heaven)

Javid Kashefi[1]; Vladimir Vladimirov[2]; Ahmet Uludag[3];
Francesca Marinini[4]; Elisavet Chatzivassiliou[5]; Vaya Kati[6];
Bojan Konstantinović[7]; Ilhan Uremis[8]; Guillaume Fried[9]; Sava Vrbničanin[10];
Nicos Seraphides[11]; Giuseppe Brundu[12]; Maria Ángeles Marcos García[13];
Tijana Stojanović[14]; Ahmet Tansel Serim[15]; Sonja Stutz[16]

[1] USDA ARS EBCL, Montferrier sur-Lez, France,[2] IBER, Bulgarian Academy of Sciences, Sofia, Bulgaria,[3] Faculty of Agriculture, Çanakkale Onsekizmart University, Çanakkale, Turkey [4] BBCA Onlus, Rome, Italy, [5] Plant Pathology Laboratory, Department of Crop Science, Agricultural University of Athens, Athens, Greece, [6] Laboratory of weed science, Benaki Plantpathological Institute, Athens, Greece, [7] Department of Environmental and Plant Protection, Faculty of Agriculture, University of Novi Sad, Novi Sad, Serbia,[8] Faculty of Agriculture, Hatay Mustafa Kemal University, Antakya/Hatay, Turkey, [9] Plant Health Laboratory, Anses, Montferrier-sur-Lez, France, [10] Faculty of Agriculture, University of Belgrade, Belgrade, Serbia, [11] Plant protection, Agricultural research institute, Nicosia, Cyprus,[12] Department of Agricultural Sciences, University of Sassari, Sassari, Italy, [13] Centro Iberoamericano de la Biodiversidad, University of Alicante, Alicante, Spain,[14] Department of Environmental and Plant Protection, Faculty of Agriculture, University of Novi Sad, Novi Sad, France, [15] Faculty of agricultural and natural sciences, Bilecik Seyh Edebali University, Bilecik, Turkey, [16] CABI, Delemont, Switzerland

Oral

Ailanthus altissima (Mill.) Swingle (*Simaroubaceae*) is a deciduous tree, native to East China and North Vietnam, known as Tree of Heaven. It has been intentionally introduced to Europe and in other parts of the world mainly as an ornamental and landscaping plant. This species adapted well, naturalised, and became invasive in all South-European countries. It inhabits a wide range of habitats, such as urban areas, transport and riparian corridors, forest margins, rocky slopes, agricultural areas, pastures and meadows, abandoned land, buildings, and cultural monuments. Numerous negative impacts have been documented, e.g., competition with native plants, change of plant communities' structure and composition, mechanical damages to roads, railways, buildings, and cultural monuments, harming endemic fauna, etc. Although the intentional introduction of *A. altissima* has been discontinued, this species has very efficient mechanisms for secondary spread without human assistance. It reproduces by winged seeds (samaras) which are distributed by wind to long distances, while its numerous root suckers form very large clonal dense stands. It was first added to the EPPO List of invasive alien plants in 2004. The highly competitive abilities of the species and its invasive behaviour in the warmer parts of Europe, supported the decision to include it in the List of invasive alien species of (European) Union concern, under the Regulation (EU) no. 1143/2014, in 2019. Therefore, EU-member states are committed to taking measures to prevent the entry, control the spread and contain this species whenever eradication is not feasible. The already wide invasion of *A. altissima* in the Mediterranean and partly in central Europe, its potential to adapt easily to a wide range of habitats and its very efficient mechanism of seed-dispersal, make the eradication or

containment of the species very challenging or even impossible if carried out only at individual country level. Climate change is predicted to stimulate the invasion of the species further north and higher-up in the mountains of Europe and within the Mediterranean islands. Therefore, the aim of the present study is to provide a baseline review of the distribution, habitats, impacts, and possible control measures in different European and Mediterranean countries. Particular attention is paid to low-intensity or abandoned agricultural areas and to the option of using biological control as a sustainable and environmentally friendly method. This project is expected to provide a solid basis for knowledge exchange to effectively contain the Tree of Heaven invasion and minimize its negative impacts.

Assessing the Economic Performance of Livestock Legume Farms: A Case Study from Thessaly, Greece

EFSTRATIOS MICHALIS[1]; ATHANASIOS RAGKOS[1]; ILIAS TRAVLOS[2]; CHRYSOVALANTIS MALESIOS[3]

[1] *HELLENIC AGRICULTURE ORGANIZATION, Agricultural Economics Research Institute, ATHENS, Greece*
[2] *AGRICULTURAL UNIVERSITY OF ATHENS, Faculty of Crop Science, ATHENS, Greece*
[3] *AGRICULTURAL UNIVERSITY OF ATHENS, Department of Agricultural Economics, ATHENS, Greece*

Oral

Economic effectiveness is always one of the most important key factors affecting farmers' decision-making process on issues related to the management of their farm, including weed control issues. Weeds constitute one of the most serious problems related to the global food system, as they are responsible for marked food losses. Weeds in agro-ecosystems threaten crop productivity and also food security for the rapidly growing world population. At the economic level, the reduction of crop yields caused by weeds impairs the market value of products, besides the environmental impact which is caused by the use of chemical herbicides. Weeding is generally considered the key hindering factor for sustainable farming and especially preventive interventions are constantly gaining attention. The aim of the present study is to examine the economic performance of farms, in relation to the expenses that they incur for plant protection and weed control. For this purpose, technical and economic data have been collected from a sample of 50 farms in the Region of Thessaly in Central Greece that cultivate annual arable crops with special emphasis on livestock legumes. Meaningful economic performance indicators have been calculated, based on all costs and benefits coming from the annual operation of the farms. A socioeconomic assessment has been conducted in an integrated manner that accommodates the diversity of social and economic conditions, related to weed management, of the targeted production system. For the presentation of the results of the study, farms will be categorized in groups based on their size or another meaningful criterion. Expenditures for pesticides, herbicides and fungicides will be shown analytically for each one of these categories and will be interpreted in association with the economic performance of farms. The results show the degree to which farm profitability and the costs of implemented farming practices are interrelated components and, based on them, further solutions will be proposed, in terms of more efficient and sustainable weed management.

A regional scale study of the contribution of weed management actions and climatic conditions on *Amaranthus* spp. infestation in processing tomato

Roni Gafni [1]; **Lior Blank** [2]; **Hanan Eizenberg** [3]

[1] The Robert H. Smith Institute of Plant Sciences and Genetics in Agriculture, The Hebrew University of Jerusalem, Rehovot, Israel
[2] Department of Plant Pathology and Weed Research, Agricultural Research Organization (ARO), Rishon LeZion, Israel
[3] Department of Plant Pathology and Weed Research, Agricultural Research Organization (ARO), Ramat Yishay, Israel

Oral

Amaranthus spp. are noxious weeds in processing tomato worldwide. Growers in Israel report partial success with controlling *Amaranthus* species in the fields. There are four major tomato growing regions in the northern part of Israel, a geographical region characterized by a unique climatic gradient spreading from east to west over a relatively short distance. Variations in climatic conditions, such as temperature and precipitation, affect many aspects of agriculture, including planting dates and herbicide applications. The objective of this research was to understand the factors associated with failure to control *Amaranthus* across the different regions. An extensive field survey was carried out in 2018 and 2019 growing seasons of processing tomato. A total of 103 fields were surveyed across four growing regions either before or after treatment to control broadleaf weeds (herbicides, cultivation or manual weeding). Additionally, 36 of all the fields surveyed, were mapped both pre and post weed management. Using a mobile GPS-GIS device (Trimble Juno 5), we generated infestation maps for all fields using a 24x30 m grid, thus adequately representing each field, while surveying multiple fields over a relatively short period of time. Infestation level was determined on an ordinal scale from 0 (no weeds) to 10 (complete ground cover). Information regarding weed management was collected at the end of the growing season. Climatic parameters (temperatures, precipitation and global radiation) were calculated based on interpolations provided by the Israel Meteorological Service. We tested the effect of field edge on infestation rates, and performed a boot-strapped model selection for beta regression models with varying dispersion to determine which factors were associated with the (1) overall field infestation rates before weed management; and (2) moderate infestation (levels 2 to 5, inclusive) rates and (3) severe infestation (levels 6 and above) rates following weed management. We found that field edge was significantly more infested than field center (p=0.018). Applying sulfosulfuron pre-planting, as well as the number of means used (i.e. different herbicide types or mechanical operations), were both found to reduce severe infestation rates. The precipitation variable increased infestation rates when occurring before planting in pre-treated fields, while found to be negatively related to both moderate and severe infestation rates when occurring after weed management. The results of this study demonstrate the considerable degree of heterogeneity across fields and regions, and stress the need to adjust management actions to the climatic conditions in order to optimize weed control.

Using Ecoinformatics to Estimate and Characterize Herbicide Effectiveness in Maize (*Zea mays*)

Shlomi Aharon [1]; Ran Lati [2]; Yafit Cohen [3]; Hanan Eizenberg [2]

[1] *Department of Plant Pathology and Weed Research, Newe Ya'ar Research Center, Agricultural Research Organization, Volcani Institute and Robert H. Smith Institute of Plant Sciences and Genetics in Agriculture, Faculty of Agriculture, Food and Environmen, ramat yishay, Israel*
[2] *1Department of Plant Pathology and Weed Research, Newe Ya›ar Research Center, Agricultural Research Organization, Volcani Institute, ramat yishay, Israel*
[3] *Institute of Agricultural Engineering, Agricultural Research Organization, Volcani Institute, Rishon Lezion, Israel., bet dagan, Israel*

Oral

Weeds are the main biotic factor affecting agricultural production. Chemical control using herbicides is considered as the most cost-effective and efficient method to control weeds. However, in recent years there is increasing evidence of reduction in the effectiveness of weed control using herbicides. This phenomenon is associated with over-use of herbicides, misapplication and environmental conditions (e.g global warming). The aim of this study is to characterize the crop-management and meteorological variables that effect herbicide efficacy. To this end, the ecoinformatics approach was used. Ecoinformatic offers new tools for managing data, which was collected by farmers about their agricultural practices and activities, and employ it for generating new insights. Historical data included the cultivated crop, herbicide rotation, mechanical weed treatments and spatial-boundary, were collected over six growing seasons from ~524 plots. These data were organized in appropriate databases for advanced geo-statistical analysis in order to identify trends of reduction in weed control efficiency, and reveal the factors associated with these trends. Since the analysis was based on farmer-driven information and not on sound experimental results, control efficacy was determined indirectly by two indices: the treatment frequency index (TFI), which reflect the herbicide-application days per season, and by the number of active ingredient (NAI) per season. Multiple regression in the framework of generalized linear models (GLM) demonstrated the importance of management factors like frequency of cotton and watermelon crops in the crop rotation and frequency of application of different herbicide groups predicting herbicide effectiveness in maize fields. Results show that TFI and NAI values significantly increased in maize over the last six years (P=0.005, P=0.006, respectively) which indicate on a reduction in herbicide effectiveness in this crop. The major variables associated with these findings were the frequency of cotton and watermelon growing in the crop rotation. TFI and NAI values in maize were significantly lower in plots where the number of cotton in the rotation scheme was high, and higher in plots where the number of watermelon in the rotation scheme was high. These findings suggest on the contribution of cotton to control of weeds within the overall rotation. They also demonstrate the added value that ecoinformatics offers by converting data collected from farmers into scientific insights about the impact of their activities have on weed-control results.

Keywords: *ecoinformatics, herbicide, GIS*

German farmers' and crop advisors' perspectives on herbicide resistance management strategies

Lena Ulber[1]**;** Han Zhang[2]

*[1] Julius Kuehn-Institut (JKI), Institute for Crop Protection in Field Crops
and Grassland, Braunschweig, Germany*
*[2] University of Rostock, Crop Health, Faculty of Agricultural and Environmental
Sciences, Rostock, Germany*

Oral

Studies have shown that the uptake of weed management strategies to mitigate herbicide resistance is highly influenced by farmers' and crop consultants' perceptions of herbicide resistance and the related management strategies. In addition, the weed management actions adopted by farmers are also influenced by their interactions with professional crop advisors. Disentangling these perspectives and relationships is crucial to ensure a wider adoption of sustainable herbicide resistance management programs, especially those including non-chemical weed control options. In 2019, a Germany-wide online survey was conducted among farmers and crop advisors to analyze their perspectives and behaviors on managing herbicide-resistant arable weeds. The application patterns of resistance management strategies by farmers and the perceptions of resistance management strategies by all participants were assessed, and the factors contributing to the adoption of certain strategies were analyzed. In total, 655 farmers and 177 advisors completed the survey. The majority of farmers (78%) and consultants (95%) was concerned about the herbicide resistance situation in Germany, with 42% of the farmers confirming to have resistant weeds on their fields. Resistance management strategies were applied by almost all farmers (98%) who were affected by resistance, and crop rotation diversification was used most frequently (54%) to mitigate herbicide resistance. This strategy was also perceived to be most effective by both farmers and advisors. When asked about the future importance of non-chemical resistance management options, the majority of both farmers (84%) and consultants (93%) suggested that they will be significantly more important in 10-years' time. Regarding potential factors that may influence the adoption of a certain strategy, associated costs, impacts on crop yield, weed resistance status, and weed control efficacies were perceived to be most important. On the other hand, the potential health risk of herbicides was perceived to be less of an issue. This study may increase researchers and consultants' understanding of farmers' perceptions and concerns of herbicide resistance issues, and contribute to developing practical non-chemical resistance management programs that are highly accepted by farmers.

Keywords: *Integrated weed management, survey, herbicide resistance, advisors, farmers*

PestiRed: Weed management based on IPM principles

Judith Wirth [1]; Julie Buchmann [1]; Sandie Masson [1];
Anne-Valentine De Jong [2]; Andrea Seiler [3]; Philippe Jeanneret [4]

[1] *Agroscope Plant Production Systems Herbology in Field Crops, 1260 Nyon, Switzerland*
[2] *Agroscope Plant Protection Entomology in Field Crops and Viticulture, 1260 Nyon, Switzerland*
[3] *Agroscope Plants and Plant Products Extension Arable Crops, 8046 Zürich, Switzerland*
[4] *Agroscope Agroecology and Environment Agricultural Landscape
and Biodiversity, 8046 Zürich, Switzerland*

Poster

All over Europe, there is an increasing demand by policy makers and consumers to reduce the use of chemical plant protection products (PPP) in agriculture due to various problems like contamination of ecosystems and health issues. Additional problems associated with chemical control are a declining availability of active substances and increasing pest resistance. In 2021, the Swiss citizens voted whether the country should completely ban the use of chemical PPP. Even though the majority did not accept the proposal, there is increasing pressure on farmers, researchers and advisors to further develop cropping systems, which are less reliant on PPP and based on the concept of integrated pest management (IPM). The overall goal of the project PestiRed is to reduce the use of chemcial PPP by 75% with a maximum economic yield loss of 10%. In several 6-year rotations with a distinct crop each year (2020 to 2025) on 68 project farms in Switzerland, sustainable preventive and curative IPM measures are implemented and documented. Each farmer cultivates an innovative field with a combination of IPM techniques and a control field with the same crop managed conventionally. The farmers choose IPM techniques from a list of 23 measures. This catalogue will evolve throughout the project period in a co-innovation approach with farmers, advisors and researchers. Throughout the whole crop rotations, the effectiveness of IPM strategies on weeds, pests, diseases and beneficials are monitored and evaluated. Moreover, all cultivation operations are precisely documented technically and economically, including PPP use. The indicator used to evaluate the reduction of PPP is the treatment frequency index (TFI). Weeds are evaluated on the same day for the two fields of each farm, at three different times per year after weed control in spring and fall and before harvest. The weed assessments are conducted as follows: i) a weed species inventory with an abundance class for each species on the field level and an information about seed formation based on a field transect ii) a newly developed method which is a visual estimation of the volume of weeds and crops in an imaginary rectangular space with a soil surface of 0.25 m^2 and the variable crop height iii) determination of weed and crop biomass before harvest. In 2020, 195 different weed species were recorded. During the first two years of the project (2020 and 2021), 128 pairs of innovative and control fields were monitored: wheat (26), barley (17), spelt (7), intercropping with legumes (21), rapeseed (20), maize (18), sunflower (6), sugarbeet (5), potatoes (4) and soybeans (4). In 2020, the average TFI, excluding seed treatment and biocontrol products, was 0.86 in the innovative and 2.22 in the control fields (61% of reduction in the TFI). The average herbicide TFI was 0.20 in the innovative and 0.99 in the control fields (80% of reduction). The main IPM weed control methods used by farmers on the innovative fields were mechanical weeding, false seedbed and undersowing in rapeseed, wheat and maize.

Keywords: *Integrated Pest Management, herbicide reduction, non-chemical weed control*

A participative rice farmer project for the adoption of weed management practices helps to increase environmental and naturalistic value of rice production

Francesco Vidotto [1]; Silvia Fogliatto [1]; Barbara Moretti [1]; Laura Zavattaro [1]; Gabriele Omedé [1]; Maria Martin [1]; Daniele Tenni [2]; Raffaella Pagano [3]; Luca Cristaldi [4]; Francesco Pellicciari [4]

[1] Università degli Studi di Torino, DISAFA, Grugliasco, Italy
[2] Ente Nazionale Risi, Castello d'Agogna, Italy
[3] Provincia di Vercelli, Ufficio Europa, Ufficio Biodiversità e InFEA, Vercelli, Italy
[4] Ente di gestione delle aree protette del Po piemontese, Valenza, Italy

Poster

A rice farmer participative project, named "Riso Amico+", was started in 2020 as a PEI-AGRI Operational Group in the Piedmont region, NW Italy, with the aim of defining 'good' management techniques helping to maintain high rice yield and quality, while increasing resource efficiency and improve the environmental and naturalistic value of rice cropping systems. The project team includes 10 rice farms, agronomy and crop researchers, experts on biodiversity and environmental preservation working for the local authorities and in the protected areas, where part of the rice area is included. The rice farmers, with the help of the other project partners, listed a selection of 'good' agronomic practices, for both dry and wet seeded rice, able to maintain or improve yield, lower the risk of environmental impact from plant protection products and protect high natural value sites. The most promising practices were then selected and introduced in the rice farms as demonstration sites. Some of the agronomic practices, mainly aimed at managing weeds, have positive environmental side-effects, such as early flooding and stale seed bed, winter flooding, mechanical weed control, site-specific weed management, cover crops, green mulching, crop rotation, and mechanical rice transplanting. These techniques are important to reduce herbicide use, increase rice competitiveness over weeds, while preserving the natural environment and the natural animal and plant biodiversity. In addition, the maintenance of field margins and sown or spontaneously vegetated drainage ditches, only managed through mowing, contributes to preserve the biodiversity of the rice area. A set of agronomic, environmental and biodiversity indicators will be calculated to evaluate the farm sustainability and efficiency improvement after the introduction of the 'good' practices. The indicators will be calculated using a specifically developed online tool that will allow farmers to self-evaluate farm performances and to display sustainability scores to attract potential customers. In this way, the project will help design innovative cropping systems able to increase the competitiveness of best-performing rice production, show citizens the ecosystem services provided by the rice cultivation, and build a rice production chain with a focus on its environmental sustainability. Moreover, the demonstration fields of the 'good' agricultural practices will provide useful information and stimulus to other rice growers and to all the stakeholders in the rice chain.

Keywords: *rice, sustainability, indicators, environment, agronomic practices*

A comprehensive comparison between three contrasting cropping systems for barley production in Spain

C. Fernández-Quintanilla [1]; J. Barroso [2]; Y. Lechon [3]; C. Lago [3]; J.M. Peña [4]; J. Dorado [4]

[1] CSIC - Institute of Agricultural Sciences, MADRID, Spain
[2] OSU - Columbia Basin Ag. Research Center, Adams, Oregon, United States
[3] CIEMAT, Energy Department, Madrid, Spain
[4] CSIC - Institute of Agricultural Sciences, Madrid, Spain

Poster

Two alternative approaches, conservation agriculture (CON) and organic agriculture (ORG), have been proposed to solve the challenges faced by current production systems. Growing evidences indicate that neither of them can be the sole basis for the development of environmental-friendly weed management. Organic systems can be very tillage intensive and conservation systems have a high dependence on herbicide use. A middle-way approach, Integrated Weed Management (IWM), can provide better solutions through a judicious use of rotations, tillage and herbicides. In order to test this hypothesis we conducted a long-term comparison of these three systems for dry-land barley production in Central Spain. A no-till winter barley monoculture with systematic use of herbicides (CON) was compared with a 2-year rotation (barley-pea or barley-false flax) with a reduced use of both, tillage and herbicides (IWM), and with a 3-year rotation (fallow-pea-barley) with intensive use of tillage (ORG). A comprehensive assessment, including agronomic, economic and environmental parameters, was carried out. Both, CON and IWM provided a satisfactory long-term weed control whereas the ORG system failed to control *Lolium rigidum*, the dominant weed in all the treatments. After 6 years this species became a serious problem in all the organic crops. In 4 out of the 6 years barley yields of CON and IWM were similar and higher than those of the ORG system. However, this last system resulted in the highest yields in the two remaining years. Gross revenue and net returns were greatest in the CON barley monoculture and least in the 3-year ORG system. The low gross revenue from the organic system was due to the lack of revenue in the fallow years and the low yields from pea crops. Regarding environmental impacts, the results differed depending on the functional unit used. When accounting for impacts per hectare, the lowest values were always obtained in the ORG system. However, and due to the low crop productions obtained in this system, its impacts per ton of product were the highest in some parameters (e.g. water eutrophication, ozone formation, resource use). These results illustrate the importance of using a long-term comprehensive evaluation of the performance of weed management systems. In this specific scenario, although the conservation system resulted in the best weed control, barley yields and net returns, the lowest environmental impacts per land unit were obtained in the organic system. The integrated system provided intermediate results in general.

A grower survey on challenging grass weeds, resistance awareness and weed management practices in Ireland

A. V. Vijaya Bhaskar [1]; Sarah Cook [2];
Susanne Barth [3]; Michael Hennessy [1]; Dermot Forristal [1]

[1] *Teagasc, Carlow, Ireland*
[2] *ADAS, Cambridge, United Kingdom*
[3] *Teagasc, Carow, Ireland*

Poster

A questionnaire survey was conducted on Irish arable farms from 2020 to 2021 to assess growers weed management practices and factors influencing management decisions and actions. A total of 136 farms was selected using a stratified pattern from grower lists provided by Teagasc (state-funded research and farm advisory organisation) and commercial crop advisors. Of 136 farms, 45% were entirely plough-based, 29% were entirely non-plough-based and the remaining farms using both plough and non-plough systems.Of the participating growers, 36% reported that 75 to 100% of their land area was in continuous cereal (spring or winter or both) cultivation for five or more consecutive years with an almost equal number (35%) practicing arable rotations. Sterile brome (*Bromus sterilis*), spring wild oats (*Avena fatua*) and annual meadow grass (*Poa annua*) were the top three grass weeds identified by the participants. The majority of participants (89%) were aware of herbicide-resistant grass weeds in Ireland, with 19% suspecting resistance on their farms. Axial Pro (pinoxaden), Pacifica Plus (mesosulfuron + iodosulfuron) and Falcon (propaquizafop) were the most frequently used post-emergent selective grass weed herbicides, while Flight (pendimethalin + picolinafen), Firebird (flufenacet + diflufenican) and Defy (prosulfocarb) were the popular pre-/early-post-emergent herbicides. Management strategies deployed by growers included: using glyphosate prior to sowing (76%), rotating autumn and spring crops (68%), rotating cereals and non-cereal break crops (63%), using full recommended label herbicide rate (56%), using a stale seedbed technique (44%) and practicing delayed autumn drilling (35%). For specific actions, grower rating for 'always' and 'most of the time' were: walking crops before herbicide application (52 and 30% respectively), hand rogueing (35 and 16%), harvesting fields with high weed pressure last to avoid contamination (18 and 17%) and cleaning combines/machinery before coming into the fields or moving field-to-field (18 and 21%). When asked what risks are involved in using non-plough systems: grass weed pressure, wetter climate challenge and yield insecurity were the anticipated risks most cited by plough practitioners, while poor establishment, grass weed pressure and lack of guidance and support were cited by non-plough practitioners, based on their own experience. Overall, the survey outcomes will help direct future research and knowledge dissemination efforts concerning integrated weed management strategies. This questionnaire was accompanied by weed assessments in fields and collection of samples for resistance testing.

How to manage weeds if glyphosate use is restricted?

Fanny Vuillemin[1]; Ludovic Bonin[2]; Jérôme Labreuche[3]; Franck Duroueix[4]

[1] Terres Inovia, Baziege, France
[2] Arvalis, Pusignan, France
[3] Arvalis, Boigneville, France
[4] Terres Inovia, Agen, France

Poster

A survey on the uses of glyphosate and potential chemical and non-chemical alternatives carried out in 2019 by the technical French institutes of field crops (Acta, Arvalis, Terres Inovia, ITB and Fnams) shows that glyphosate is mainly used for control of perennial weeds (73% of 6921 respondents) or for control of annual weeds during long (e.g. between winter wheat and maize in the following spring) or short (e.g. between winter wheat and oilseed rape in the following autumn) intercropping period (50% of respondents for each) with the aim of sowing the next crop in weed-free soil. The use for terminating cover crops was mentioned by only 30% of the respondents. In 2017, these institutes evaluated the possible alternatives in terms of technical and economic feasibility, as well as in terms of technology readiness level. The methods evaluated were chosen because they are currently available to farmers as alternatives to glyphosate. It emerged that tillage is the most accessible technique, because the only bioherbicide existing today is not very effective, and because electric weed control consumes a lot of energy and is inefficient on tillered grasses under wet conditions. Within the IWM PRAISE project, Arvalis and Terres Inovia performed 20 field trials across France, in various soils, comparing shallow tillage and/or deep tillage, and with different types of coulters, and glyphosate to destroy annual weeds during intercrop, before sunflower or soybean. The results show that all mechanical destruction provides about 100% control of broadleaf weeds regardless of their growth stage, or control of young grasses. However, once grasses start tillering, it is more difficult to destroy them completely, especially under wet conditions. These results have allowed us to draw some practical information for farmers: first of all, tillage tools should be able to work 100% of the surface (wide coulters), without a roller to avoid compacting the soil and preferably equipped with a harrow to keep weed roots on the surface and thus promote their drying out. The rotary harrow also showed good destruction results under certain conditions. It is also important to conduct tillage operations under dry conditions: dry soil and no rain expected in the following days, in order to avoid transplanting or germination of new weed seeds. Finally, as this tillage can promote the emergence of spring weeds (example ragweed), it is also advised to plan out the chemical and mechanical weeding programs in the following crop.

Keywords: *glyphosate, tillage, alternatives, destroy annual weeds, intercrop*

Are no-till herbicide-free systems possible? A simulation study

Nathalie Colbach; Stéphane Cordeau

INRAE - Agroécologie, Dijon, France

Poster

Conservation agriculture (CA) allows farmers to reduce costs and enhance soil health, but tends to increase either weed infestation and associated crop yield loss, and/or herbicide use. We aimed to investigate how much tillage contributes to reducing weed infestation and yield loss, and which systems and weed species are the most affected when tillage is deleted. We collected farming practices on 395 arable cropping systems from Spain and France, and simulated them over 30 years and with 10 weather repetitions, using FLORSYS. This process-based model simulates daily multi-species weed floras and crop canopies from cropping systems and pedoclimate over the years. Three series were simulated, (1) using the recorded cropping systems, (2) eliminating tillage without otherwise changing management practices, (3) eliminating all herbicides without any other changes. Each series was run twice, once starting with a regional weed-flora pool to simulate weed dynamics and their impact on crop production and biodiversity, and once without weeds to predict potential crop yield. Among the recorded systems, herbicide treatment frequency index (HTFI) averaged over rotation increased when tillage frequency decreased. No recorded no-till system was herbicide-free. The untilled crops with the lowest HTFI (0.16) were unusual crops, i.e., relay grass crops or multi-annual crops. Simulations showed no correlation between tillage-frequency and weed biomass or yield loss. When tillage was deleted without any other change, yield loss almost doubled. We identified (1) which weed species and traits increased after tillage suppression and in which cropping systems: species emerging in May-June needing warmth for photosynthesis increased in systems without efficient large-spectrum herbicides but initially with frequent and intensive tillage, species emerging in April with persistent and dormant seeds whose plant height strongly increased with plant biomass and whose leaf area was concentrated at plant top increased in systems with frequent winter crops, frequent pseudo-root herbicides, rare and low irrigation and initially early post-harvest tillage, etc, (2) which recorded systems were robust to tillage suppression (with cover crops, summer crops, efficient herbicides, varying herbicide programmes between years, spreading weed-free manure ...), (3) which no-till systems (recorded or obtained after deleting tillage) had limited yield loss (usually those with frequent and/or efficient herbicides), (4) which management techniques were associated with reduced tillage, herbicide use and yield loss (long and diverse rotations, cover crops, ...). No tested system achieved all three objectives simultaneously. The simulations indicated that two CA pillars (diverse crop rotations, cover cropping) were essential to manage weeds in systems with reduced tillage and herbicide use. More no-till cropping systems must be investigated to determine whether sustainable no-till herbicide-free systems are possible.

Keywords: *conservation agriculture, weed, yield loss, biodiversity, simulation, model*

The monitoring of the tropane alkaloids in corn and popcorn in Republic of Serbia

Tijana Stojanović [1]; Gorica Vuković [2]; Bojan Konstantinović [1];
Milena Popov [1]; Nataša Samardžić [1]; Nikola Puvača [3];
Vojislava Bursić [1]; Aleksandra Petrović [1]; Dušan Marinković [1]

[1] *Department of Plant and Environmental Protection, Faculty of Agriculture,
University of Novi Sad, 21000 Novi Sad, Serbia,*
[2] *Department of Pesticides and Herbology, Faculty of Agriculture,
University of Belgrade, 11080 Belgrade, Serbia,*
[3] *Department of Engineering Management in Biotechnology,
Faculty of Economics and Engineering Management, University
Business Academy, 21000 Novi Sad, Serbia*

Poster

The tropane alkaloids-producing weeds are continuously found in various crops, such as buckwheat, corn, millet and sunflower. The control of these weeds is extremely important, since the impurities in the harvested crop cannot be completely removed. The tropane alkaloids (TAs) represent the secondary biomolecules predominantly synthesized by the genera of the Solanaceae family, i.e. Datura (*Datura stramonium*), Atropa (*Atropa belladonna*) and Hyoscyamus (*Hyoscyamus niger*). More than 300 TAs have been discovered so far and they pose a serious threat to human and animal health due to their strong antimuscarinic effect, with the most prominent ones being atropine, scopolamine and hyoscyamine. However, the effects of the majority of the TAs, as well as of the newly discovered group called calystegines, are still not determined. The limit of quantification (LOQ), i.e. the smallest amount that can be detected with reasonable repeatability and accuracy, for atropine and scopolamine is 2 µg/kg, which was established by the Commission Recommendation (EU) 2015/976. From 2018 to 2021, a monitoring of the atropine and scopolamine concentrations in corn and popcorn samples in the Republic of Serbia was conducted. During the 4-year monitoring, a total of 103 conventional production samples, collected on the territory of the Vojvodina province (northern part of Serbia), were tested, i.e. 64 corn and 39 popcorn samples, using the liquid chromatography-tandem mass spectrometry (LC-MS/MS). In 2018, 55.56% of the tested samples contained atropine and scopolamine concentrations above the established LOQ. In 2019, 30% of the tested samples contained both atropine and scopolamine, while in 10% only atropine was detected. In 32.5% of the tested samples, atropine and/or scopolamine were detected in the concentrations above the LOQ. In 2020, atropine and scopolamine were detected in 19.23% of the tested samples and in all of them the concentrations were above the LOQ. The same was observed in case of atropine and scopolamine detections in 2021, where the percentage of the positive samples was 26.62%. During the 4-year monitoring the atropine detections ranged from 1.03 - 51.80 µg/kg in popcorn and from 1.20 - 361.30 µg/kg in corn, while the scopolamine detections ranged from 1.07 - 28.90 µg/kg in popcorn and from 1.10 - 173.80 µg/kg in corn samples. The highest concentrations of the monitored TAs were detected in a corn sample in 2019, in case of which the atropine concentration was ~180 times higher, while the scopolamine concentration was

~87 times higher than the established LOQ value. These alarming results should accentuate the need for the regular large-scale monitoring of the TAs in various food products and raw materials intended for the human and animal consumption. The reason for that lies in a fact that all the TAs concentrations above 2 μg/kg are considered hazardous towards the human and animal health, with small children and people with heart problems being at most risk. The special attention should be given to monitoring the presence of the TA-containing weeds and their continuous control, since in our research the highest TAs concentrations were noted in the samples collected from the fields mostly infested with *Datura stramonium*.

Keywords: *atropine, scopolamine, LC-MS/MS, Solanaceae, food products*

Reduced weeding compromises Cabbage (Brassica oleracea, var. capitata) yield but shows potential to reduce nutrient leaching in fall

AV Virili; Anna-Camilla Moonen

Scuola Superiore Sant'Anna, Pisa, Italy

Poster

Research has shown that weeds can provide multiple ecosystem services (Blaix et al., 2018) although few studies have quantified the trade-off which comes from reducing weed management. This study focussed on determining whether low weed abundance in a winter vegetable crop can improve the efficiency of nutrient retention in the soil and minimize nutrient losses without hindering crop performance. A completely randomised experiment with four replications was set up in a battery of $1m^3$ lysimeters set aboveground and was replicated for three autumns. Four cabbage plants (*Brassica oleracea*, var. *capitata*) were transplanted in each lysimeter. The treatments consisted of cabbage with no weed pressure (C), weeds grown with the crop from the beginning of the growing season (CI) and weeds grown 20 days after crop transplanting (C20). *Sinapis alba* was sown as a dominant weed to standardize the weed communities in the lysimeters. Drained water was collected in tanks through a faucet at the bottom of the lysimeters and a water sample was taken for analysis every ten days and after each fertilization (once after crop transplanting and once at head formation). We used mineral fertilizer at the dose of 130 kg/ha N, 80 kg/ha P, 150 kg/ha K. Weed presence affected crop growth in 2021, with cabbages in both C20 and CI yielding significantly less than cabbages in the weed-free plots. Regarding nutrient leaching, an effect of treatment was observed in two out of the three years. After the first fertilization in 2020, nitrate concentration from drained waters from CI plots was 36mg*L, while weed-free plots lost 50mg*L of nitrates. Moreover, C and C20 plots lost 20.4 mg L and 19.1 mg L of K, respectively, while CI plots lost 13.4 mg L. In 2021, concentrations were generally much lower, but after the first N application, weedy plots lost only 4.3 mg L of nitrates compared to 15 mg L from the weed free plots. Weedy plots also lost 10 times less phosphorus at the end of the growing season compared to C plots (0.03 mg L vs 0.22 mg L) after the second fertilization. The results show that weeds contributed to reducing nutrient leaching, but competition with the crop was significant. In the future this study could be replicated using weed species with high ground cover or tap root systems in continental climates.

Solanum elaeagnifolium Cav. (silverleaf nightshade): a threat to food security and environmental sustainability across the Mediterranean Basin, Central and Northern Europe

Ahmet Uludag [1]; Javid Kashefi [2]; Bojan Konstantinović [3]; Tijana Stojanović [3]; Necmi Aksoy [4]; Mehmet Arslan [5]; Thomas Alexandridis [6]; Mohamed Abdelaziz Balah [7]; Salmane Ben-Ghabrit [8]; Dragana Božić [9]; Marie Claude Bon [6]; Massimo Cristofaro Cristofaro [10]; Yasin Çiçek [11]; Najla Sayari [12]; Guillaume Fried [13]; Eyüp Gülbandılar [11]; Anastasia Lagopodi [6]; Francesca Marini [10]; Heinz Müller-Schärer [14]; Danijela Pavlović [15]; Miloš Rajković [16]; Ahmet Tansel Serim [17]; Alexandros Tataridas [18]; Rumen Tomov [19]; Peter Toth [20]; Nihat Tursun [21]; Ilias S. Travlos [18]; İlhan Üremiş [22]; Vladimir Vladimirov [23]; Sava Vrbničanin [24]; Giuseppe Brundu [25]

[1] Faculty of Agriculture, Çanakkale Onsekiz Mart University, canakkale, Turkey
[2] USDA ARS EBCL, Montferrier sur-Lez, France
[3] Faculty of Agriculture, University of Novi Sad, Novi Sad, Serbia
[4] Faculty of Forestry, Düzce University, Düzce, Turkey
[5] Faculty of Agriculture, Erciyes University, Talas/Kayseri, Turkey
[6] Faculty of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece
[7] Desert Research Center, Cairo, Egypt
[8] EIA / UIASS, Morocco
[9] Faculty of Agriculture, University of Belgrade, Belgrade, Unknown
[10] BBCA onlus, Rome, Italy
[11] Department of Computer Engineering, Osmangazi University, Eskişehir, Turkey
[12] Higher Institute of Agronomy of Chott Mariem, Algeria
[13] Laboratoire de la Santé des Végétaux, 34988 Montferrier-sur-Lez cedex, France
[14] University of Fribourg, Fribourg, Switzerland
[15] Institute for Plant Protection and Environment, Belgrade, Serbia
[16] Institute of Field and Vegetable Crops, Novi Sad, Serbia
[17] Faculty of Agriculture, Bilecik Şeyh Edebali University, Bilecik, Turkey
[18] Faculty of Crop Science, Agricultural University of Athens, Athens, Greece
[19] University of Forestry, Sofia, Bulgaria
[20] Slovak University of Agriculture in Nitra, Faculty of Agrobiology and Food Resources, Institute of Agronomic Sciences, Nitra, Slovakia
[21] Faculty of Agriculture, Malatya Turgut Özal University, Malatya, Turkey
[22] Faculty of Agriculture, Hatay Mustafa Kemal University, Antakya/Hatay, Turkey
[23] IBER, Bulgarian Academy of Sciences, Sofia, Bulgaria
[24] Faculty of Agriculture, University of Belgrade, Belgrade, Serbia
[25] Department of Agricultural Sciences, University of Sassari, Sassari, Italy

Poster

Solanum elaeagnifolium Cav. (silverleaf nightshade) is a deep-rooted summer-growing perennial plant, native to south-western United States and northern Mexico. Since 2006, it has been included in the EPPO A2 list of pests recommended for regulation as quarantine

pests and has been expanding its range slowly but steadily. Its occurrence is now known in the countries of the EPPO region, in Asia, Africa, North America and in several countries of Oceania, South America and Caribbean. It competes with crops, interferes with livestock, acts as a host for insects and plant pathogens and spreads by forming dense patches from its extensive root system and through seed propagation and adapts to new ecological conditions by developing new morphotypes. Further studies on its biology, ecology, physiology and genetics are needed to develop rapid response methods to tackle the spread and reduce the size of existing populations. Among others, climate change as a reason for the spread of *S. elaeagnifolium* should also be considered for the prioritization of activities. It would be advisable to improve an early detection using satellite images and artificial intelligence by taking advantage of the prominent colors of the plant, its flowers and fruit. Biological control seems to be a promising option to keep *S. elaeagnifolium* under control in highly invaded habitats and to prevent further spread. Currently, *S. elaeagnifolium* has been successfully managed in South Africa by releasing imported biological control agents. Taking into account its native range, *Gratiana lutescens (Chrysomelidae: Cassidinae), Gratiana pallidula (Chrysomelidae: Cassidinae), Frumenta nephelomicta (Gelechiidae), Ditylenchus phyilobius* (Nematoda), *Leptinotarsa texana* (Chrysomelidae) and *Leptinotarsa defecta* (Chrysomelidae) have already been suggested as potential biocontrol agents. However, further studies are needed in order to evaluate their host specificity and detect potential hazards for non-target plants. An efficient control by biocontrol agents would be beneficial for both organic and conventional farming, would improve ground- and surface-water quality and reduce the environmental impact of chemical weed management, soil contamination and the threats to biodiversity and wildlife. Such an approach is a long-lasting method that should guarantee food security and environmental sustainability. Although past attempts for a collaborative European action to manage *S. elaeagnifolium* failed, we want to advocate for a new joint action towards a sustainable management of this plant invader that should include coordination, mapping, education, training and support across the already invaded and the potentially newly invaded countries.

The legume choice in a relay intercropping system with durum wheat determines the economic viability of this IWM strategy in a Mediterranean low-input cropping system.

Federico Leoni [1]; Pauline Triboulet [2];
Anna-Camilla Moonen [1]

[1] *Sant'Anna School of Advanced Studies, Institute of Life Sciences, Pisa, Italy*
[2] *Unilasalle, Mont Saint Aignan, France*

Poster

Relay intercropping is often reported as a promising option for a sustainable intensification of conventional agricultural systems and involves the co-cultivation of two or more crops simultaneously during part of their life cycle. In particular, it has been shown that relay intercropping of subsidiary legumes with cereals supports the optimization of nutrient cycling and improves weed control through the direct competition of the co-cultivated crops on weeds, mainly for light and space. The economic sustainability of this agronomic practice has rarely been studied and it can vary according to the legume species chosen. The present study focused on seven target legume species (*Medicago sativa*, *Trifolium repens*, *Hedysarum coronarium*, *Medicago lupulina*, *Trifolium incarnatum*, *Trifolium resupinatum*, *Trifolium subterraneum*, and *Medicago polymorpha*) investigating their economic sustainability in a relay intercropping system with durum wheat in a Mediterranean cereal based cropping system. The economic sustainability of this system was evaluated through the quantification of the ecosystem services provided by legumes at crop rotation level including the direct effects of legumes on the co-cultivated crop (durum wheat), the residual effects on the following cash crop (forage sorghum), and the costs and saving of changes in soil tillage, fertilizer use, herbicide applications and seeding cost. Therefore, the economic assessment was performed on the entire two-year crop rotation with durum wheat and forage sorghum. In this study, two contrasting management systems were compared: i) Integrated management of a wheat-sorghum rotation with the adoption of legume living mulches as sole method for weed control, and ii) conventional management of a wheat-sorghum rotation with mechanical and chemical weed control. A plot experiment repeating the two-year crop rotation twice, was carried out in Pisa (Italy). Legumes were sown in the already established wheat stand in late winter and maintained in the field until the subsequent spring when sorghum was sown. The overall economic impact of relay intercropping in a wheat-sorghum rotation was estimated by the calculation of the cumulative Gross Income (GIc) as the difference between the Gross Production Value of crops (GPV) and the total production costs (C). Relay intercropping of legumes demonstrated to guarantee a good weed control, to satisfy nutritional requirements for the subsequent sorghum and it allowed to reduce the input costs by up to 253 €/ha compared with conventional management. However, the economic advantages of relay intercropping were affected by the legume choice. The use of *H. coronarium T. repens*, *M.sativa* and *T. subterraneum w*ere economically convenient because of the low seed price and the good agronomic performance and this allowed the relay intercropping system to balance increased

seeding cost with the gains obtained by the ecosystem services that they provided at crop rotation level. Instead, the limited benefits provided to sorghum yield by *Medicago lupulina*, *Trifolium incarnatum*, *Trifolium resupinatum*, and *Medicago polymorpha* did not compensate the increased costs of the legume seed material.

Keywords: *Economic sustainability, crop diversification, subsidiary legumes, living mulch, cover crops, agroecology, gross income*

SESSION VIII

WEED GENOMICS

Bringing Agricultural Weeds into the Molecular Lab

Dana MacGregor [1]; Seanna McTaggart [2]; Hannah Rees [2]; Anthony Hall [2]

[1] *Rothamsted Research, Harpenden, United Kingdom*
[2] *Earlham Institute, Norwich, United Kingdom*

Keynote

The decades of work devoted to advancing understanding of and building resources for model organisms means scientists studying them can move from hypotheses to conclusions quickly and easily. However, comparatively few of these ˝well-developed model organisms˝ cause real-world harm and/or actively hinder agriculture. It is unequivocal that weeds significantly reduce yields and increase agricultural costs, yet the mechanistic and molecular-level knowledge about weeds is insignificant compared to what we have for the crops in which they grow. Knowledge transfer between model to non-model is inadequate and insufficient because the natural and anthropogenic selection pressures that drive weed evolution are unique meaning weeds exhibit traits and genomes that are different from model, crop, or wild plant species. Therefore, to understand how 'weedy' traits have developed, are regulated, and confer selective advantage in the agroecosystem, we need to undertake molecular and physiological analysis of weeds. We are working to bring agricultural weeds into the molecular laboratory and generate the necessary resources and techniques that will allow us to directly do hypothesis-led science in these species to better understand the genetics and genomics of these harmful, impactful plants. Recently, we have made important breakthroughs by generating 'omics and experimental tools. For instance, we now have methods to transiently induce or reduce gene expression and working with collaborators (including the IWGC and ERGA) are generating fully-annotated genomes for *Alopecurus* species weeds. This presentation will discuss those breakthroughs and explain how the genetic and molecular-level understanding of agricultural weeds gained in the laboratory is essential to generate the modern and novel innovations that will control weeds outside of the laboratory.

Keywords: *genomics, reverse genetics, molecular biology, Alopecurus, IWGC, ERGA*

Weed Genomic contribution to unravel herbicide detoxification pathways. A review.

Roland Beffa

Liederbach, Germany

Oral

In all cropping systems the presence of weeds is causing a significant decrease of production in addition to a decrease of *quality* of food, feed, and fibers. Sustainable weed control depends on an integrated approach which includes combinations of agronomic technologies and the use of herbicides. Despite the fact that agronomy practices are essential for weed control, chemical control remains necessary. Unfortunately, repetitive treatments of herbicides, especially when a similar mode of action is used, lead to the evolution of resistance. This is a particular concern due to the fact that very few new chemical families are brought to the market. Weeds can evolve several resistance mechanisms based either on herbicide target modifications (target site resistance), or non-target modifications (non-target site resistance), in particular those involved in herbicide detoxification which can confer a broad spectrum resistance which is increasingly spread and more difficult to overcome. Since recently the genes involved in herbicide metabolism were poorly known. The development of weed genomics, in particular genome sequencing, transcriptome analyses and functional genomics offer the opportunity to unravel faster the herbicide detoxification pathways. Combined with biochemistry and analytics, the functional validation of candidate genes is now possible in a reasonable time frame. The activities of several cytochrome P450s (Cyps) and glutathione transferases (GSTs) on herbicide metabolism are now well characterized in different weed species. It appears more and more that in different populations of a given weed species resistant to the same herbicide(s) different genes are involved in the detoxification of these herbicide(s). Moreover, combined approaches between genomics and genetic allowed in several weed species the discovery of QTLs involved in herbicide resistance and the gene associated with the opportunity to find novel genes potentially involved in resistance. Genome-based work is needed to reveal genetic architecture of Cyps and GSTs driven evolution of metabolic resistance. This review is aiming to establish a picture of the today knowledge and discuss the possible new approaches to establish early resistance diagnostics, find new strategies to overcome weed resistance and identify novel genes which might have a potential application in generating multiple herbicide resistant crops. Finally, the widespread occurrence of metabolism resistance mechanisms questions the ubiquity of strategies based solely on MOA diversity (target site resistance). The knowledge of herbicide detoxification pathways will allow to select the appropriate mixtures and/or combination therapy to mitigate non-target site resistance conferred by the increased metabolism of herbicides.

Keywords: *Genomics, metabolism resistance, Cyps, GSTs, herbicide management, review*

Upregulated glutathione transferases found in resistant black-grass populations can detoxify flufenacet in vitro

Evlampia **Parcharidou** [1]; Rebecka Duecker [2]; Peter Zoellner [3]; Susanne Ries [4]; Roland Beffa [5]

[1] *Georg-August Universitaet Goettingen, Abt. Allgemeine Pflanzenpathologie und -schutz, Grisebachstr. 6, 37077 Goettingen, Germany/Bayer AG, Industriepark Hoechst, H872, 65926 Frankfurt am Main, Germany, Mainz, Germany*
[2] *Georg-August Universitaet Goettingen, Abt. Allgemeine Pflanzenpathologie und -schutz, Grisebachstr. 6, 37077 Goettingen, Germany, Goettingen, Germany*
[3] *Bayer AG, Research & Development, Crop Science, Mass Spectrometry and NMR, FFM, Building G836, R014, 65926 Frankfurt, Germany, Frankfurt am Main, Germany*
[4] *Bayer AG, Research & Development, Crop Science, Mass Spectrometry, FFM, Building G836, R014, 65926 Frankfurt, Germany, Frankfurt am Main, Germany*
[5] *Senior Scientist, Frankfurt am Main, Germany*

Oral

The pre-emergence herbicide flufenacet acts as an inhibitor of the synthesis of very long-chain fatty acids (HRAC group 15) and is an important component in the control of grasses in winter cereals. This is especially the case when resistance to other herbicide groups, in particular to the post-emergence herbicides of the groups 1 and 2, already exists. Decreases in sensitivity due to increased flufenacet metabolism by glutathione transferase (GST) activity has already been described in some black-grass (*Alopecurus myosuroides* Huds.) populations. In that study, we aligned RNA-seq data from two sensitive black-grass populations and two black-grass populations with reduced sensitivity to flufenacet against the recently sequenced black-grass genome using the STAR aligner. Full length cDNA of the upregulated GSTs was obtained by RACE-PCR and the activity of the corresponding recombinant proteins expressed in *Escherichia coli* were validated in vitro with flufenacet and other herbicides as a substrate. It was found that 7% of the *GST* genes in the two populations with reduced flufenacet sensitivity were constitutively significantly upregulated when compared to the two sensitive populations. GSTs with high fold-change (FC) were chosen for the validation. By using analytical methods (LCMS), the metabolite produced by all GSTs tested, except for one isoform, was identified as a flufenacet-glutathione conjugate. In the other case, flufenacet-alcohol was identified for the first time as a reaction product of GSTs in black-grass. Moreover, different GSTs showed activity on different herbicide spectra considering several pre-emergence and post-emergence herbicides active on black-grass. In this study, we show that upregulated GSTs derived from resistant black-grass populations are able to detoxify flufenacet in vitro at a low rate. In conclusion, these GSTs are likely to have an additive effect on flufenacet detoxification and thus explain the phenotypic sensitivity differences. In addition, knowing which GSTs are upregulated in flufenacet resistant populations can lead to the development of diagnostics which may allow to select the appropriate mixtures and/or sequence therapy to mitigate non-target-site resistance conferred by the increased metabolism of herbicides.

Keywords: *black-grass, detoxification, flufenacet, glutathione transferase, non-target-site resistance, transcriptome*

Analysis of genetic diversity and population structure in weedy rice using SSR markers

E Kaya Altop 1; O Güzel 2; H Mennan 3

[1] Ondokuz Mayıs University, Samsun, Turkey
[2] Republic of Türkiye Ministry of Agriculture and Forestry Directorate
of Plant Protection Central Research Institute, Ankara, Turkey
[3] Ondokuz Mayis University,, Samsun, Turkey

Oral

Rice plays an important part in global food security, and it is also an important staple crop in Turkey because of high domestic consumption. The continuous cropping of rice in this system has resulted in highly competitive weed species strongly adapted to the aquatic environment. Continued use of herbicides with the same mechanisms of action leads to the evaluation of herbicide-resistant weed population and the increased number of herbicide-resistant populations in Turkey. Despite the potential importance of weedy rice (*Oryza spp.*) as a weed in many countries, little is known about it in Turkey. This species has been introduced to Turkey recently, and it was adapted to rice cultivation and has become an important weed in many rice fields.

The level and status of the weedy rice, which is a problem in Turkey, regarding cultivated rice is unknown. The study, in which SSR analysis was applied to seeds collected from 78 accessions, aimed to determine the genetic diversity and to interpret its effect on resistance. We assessed the molecular genetic diversity and population structure of weedy rice populations using 11 simple sequence repeat markers. A total of 134 alleles were detected, and the number of alleles per marker (N_A) ranged from 3 to 20, with an average of 13.1 alleles. The frequency of major alleles per locus ranged from 0.165 to 0.578, with an average value of 0.347 per marker. The overall polymorphic information content values were 0.391–0.912, with an average value of 0.742. The average H_O was 0.081 and showed substantial about %77 genetic variability among all of the weedy rice populations. The sample groupings did not strictly follow the geographic affiliations of the accessions. These results, which express a significant genetic diversity for weedy rice in Turkish rice fields, contribute to control strategies by revealing that high genetic diversity can lead to increased adaptive and competitive abilities. In addition, with regard to the evolution of herbicide resistance, further studies examining the frequency of resistance alleles are needed.

Keywords: *Weedy rice, Oryza sativa, SSR, Genetic diversity*

Molecular Identification of Phelipanche species from the western Mediterranean region of Türkiye

Esra CIGNITAS[1]; Yasin Emre KITIS[2]

[1] Bati Akdeniz Agriculture Research Institute, Antalya, Turkey
[2] Akdeniz University, Faculty of Agriculture Department of Plant Protection,
ANTALYA, Turkey

Oral

Broomrapes (*Phelipanche* and *Orobanche* spp.) are obligate root parasitic weeds belong to the Orobanchaceae family. The native of these plants is Mediterranean region including North Africa, Middle East, Southern Europe and Western Asia. These parasites attack many economically important crops including Solanaceae, Fabaceae and Asteraceae causing to severe losses in their yield and quality. For a wide range of areas related to parasitic plant research, including biology, management, host and parasite interaction, identification is a critical point. For Solanaceae crops, *Phelipanche aegyptiaca* and *P. ramosa* are the most reported species of broomrapes. Among Solanaceae crops, tomato is the most sensitive and it is one of the most cultivated crops in the world. The global tomato production is 186.8 million tonnes. Turkey is among the top three countries in the world with 13.2 million tonnes of production in 2020. As in many parts of the world, broomrapes are one of the biggest problems in tomato-growing areas in Türkiye. Although it is known that the broomrape species that are a problem in tomato crops are *P. aegyptiaca* and *P. ramosa*, these two species can be found mixed in the form of accession and are morphologically very similar to each other. Therefore, it is not easy to distinguish these two species morphologically. For this reason, this study aims to carry out molecular identification of broomrape that severely affects greenhouse tomato production areas in the western Mediterranean region of Türkiye. For this purpose, 15 populations of broomrape were collected from highly infected tomato greenhouses in Antalya, Burdur and Isparta provinces and their districts. DNA extraction was done from broomrape seeds. For molecular identification, species-specific primers have been used to identify *Phelipanche* populations. In the previous studies ITS350F/ITS350R and AB101/AB102 primers have been identified for *P.aegyptiaca*, and rps2F/rps2R primers for *P. ramosa*. These two primers were based on unique sequences in the internal transcribed spacer (ITS) regions of the nuclear ribosomal DNA of *P. aegyptiaca* and one primer was based on sequences of plastid ribosomal gene copy (rps2) of *P.ramosa*. Using ITS-350 primers, a specific PCR product (350 bp), was amplified and detected in all samples containing broomrape species. AB101 and AB102 primers gave the product (850 bp) after amplification. Additionally, rps2 primers with a PCR product (550 bp) were amplified. As a result, after optimizing PCR conditions for all primers, ITS350F/ITS350R and AB101/AB102 primers gave the 350 bp and 850 bp product in 12 populations, respectively. The research has enabled the identification of *P.aegyptiaca* as the prominent broomrape species in the sampled locations. Our study has shown that by using genomic tools, broomrape species identification can be made using seed samples.

Keywords: *Broomrape, Molecular ıdentification*

Blackgrass genome sequencing reveals complex patterns of evolved non-target site herbicide resistance

David Comont [1]; Lichun Cai 2; Dana MacGregor 1; Claudia Lowe 1; Roland Beffa 3; Christopher Saski 2; Paul Neve 4

[1] *Rothamsted Research, Harpenden, United Kingdom*
[2] *Clemson University, Clemson, United States*
[3] *Bayer Crop Sciences, Frankfurt am Main, Germany*
[4] *University of Copenhagen, Copenhagen, Denmark*

Oral

Agricultural weeds reduce crop yields more than plant pathogens and insect pests combined, yet to date, the number of genomic resources for problematic weeds remains low. Blackgrass (*Alopecurus myosuroides*) is a pernicious weed affecting cereal production across Northern and Western Europe, and is considered the #1 weed issue in the UK. Driven by a growing epidemic of herbicide resistance, this species alone causes losses in excess of £0.4 billion annually. Here we have assembled and annotated a high-quality genome for *A. myosuroides*, and demonstrate its utility for illuminating historic and contemporary evolution in this species. Two F_2 families segregating for Non-Target-Site-Resistance (NTSR) to the ACCase herbicides were also established from two independent field-evolved NTSR populations. Gene expression and bulk-segregant analysis was used to reveal similarities and differences in the transcriptional and mutational basis of the NTSR trait across these independently evolved lines. Analyses reveal a large (~3.5 Gb), complex, and highly heterozygous genome for this species, shaped by two historic duplication events, one in an ancestor of the Poaceae ~70 MYA, and a second unique to this species. A recent burst of long-terminal-repeat retrotransposon insertions (LTR-RTs) may have contributed to recent blackgrass genome expansion, with expansion identified in many gene families previously implicated in NTSR. Analysis of F_2 families highlighted 68 genes consistently associated with NTSR, including three previously reported candidate genes and a novel Aldo-Keto reductase. Importantly however, we found considerable evidence for specificity in the genomic basis of resistance from separate populations. Of 15 identified QTL regions, none were shared between the two NTSR populations, and a further 341 and 234 differentially expressed genes were unique to each family. These results shed light on the complex nature of the NTSR trait in this species, highlighting the potential of both parallel and non-parallel evolution in the field. More broadly, the genome itself helps to illuminate historic patterns of evolution which have shaped this pernicious weed, and will provide an important resource for further analysis of rapid, anthropogenically-mediated evolution in this species.

Keywords: *Blackgrass, NTSR, genome*

Silverleaf nightshade (*Solanum elaeagnifolium Cav.*) identification using features of pubescence and the development of DNA markers on the chloroplast genome based

Ekaterina Volodina[1]; Juliana Kulakova[2]; Maxim Anisimenko[2]; Oxana Dobrovolskaya[2]

[1] All-Russian Plant Quarantine Center (VNIIKR), Moscow, Russian Federation
[2] All-Russian Plant Quarantine Center (VNIIKR), Russian Federation

Poster

Silverleaf nightshade (*Solanum elaeagnifolium* Cav.) is a member of the genus *Solanum*, the largest genus of flowering plants. It is found in both North and South America and is a noxious invasive weed in arid regions around the world. It began to spread to almost all continents and received quarantine status in Australia, Canada, Georgia, Moldova, Ukraine, Azerbaijan, EPPO countries and the EAEU. In the Russian Federation, this species is absent, but there is a risk of penetration with imported seeds and food materials. Silverleaf nightshade is characterized by very diverse morphological characters (leaf shape, pubescence, etc.), this variability has led to synonymy, therefore, in recent years, most researchers have adopted a broad interpretation of the species. Identification of this species is sometimes difficult, especially by seed, here, we propose several new options for the identification of this polymorphic species. We collected samples of weed species of the genus *Solanum* (herbarium samples, seed samples). The possibility of their identification by a complex of morphological characters was assessed. A search was carried out for polymorphic sites in the chloroplast regions *ndnf-rpl32, matK, trnL-trnT in order to* identify genetic variation in *Solanum elaeagnifolium* Cav. from other members of the genus *Solanum.* Functional leaf analysis of *Solanum* leaves was carried out using scanning electron microscopy.The study revealed high intraspecific and interspecific variations in some regions of the chloroplast genome and identified unique SNPs for *S. elaeagnifolium.* Based on the *trnL-trnT* intergenic chloroplast DNA spacer, DNA markers were developed to identify this polymorphic species. The study analyzed such characteristics of pubescence as: intensity (density) of pubescence, type and size of trichomes, number of lateral rays of stellate trichomes. In nightshade, specific features of pubescence have been identified, which can serve as a reliable taxonomic trait for identifying certain species of *Solanaceae.* The developed test-system will greatly simplify and accelerate the subsequent identification of *S. elaeagnifolium.* The study also revealed intraspecific polymorphism of *S. elaeagnifolium.* Samples from the United States and northern Mexico are characterized by a 24 bp deletion. Samples from southern Mexico, Argentina and the Old World did not show this deletion. Further study of this polymorphism may help to better understand the ways of distribution of the quarantine species and / or its intraspecific polymorphism in different parts of the range. The identified species-specific features of *Solanum* trichomes can be used to isolate this polymorphic species.

Keywords: *Silverleaf nightshade, DNA markers, pubescence, chloroplast genome*

INTEGRATED WEED MANAGEMENT

Customization and field validation of a DSS for IWM named IPMwise in Greek winter wheat

Alexandros Tataridas[1]; Ilias Travlos[1]; José Maria Montull[2],
Founder,; Andreu Taberner Palou[2]; Ole M Bojer[3]; Per Rydahl[3];
Arnd Verschwele[5]; Heidrun Bückmann[5]; Kirsten Torresen[4]

*[1]Agricultural University of Athens, Greece; [2]IPM Advise, Spain;
[3]IPM Consult, Denmark; [4]NIBIO, Norway; [5]Julius-Kühn Institute, German*

IPMwise is 4th generation DSS tool in terms of IT and features for Integrated Weed Management (IWM). IPMwise has been officially released in Denmark, Norway, and Spain. In this paper an introduction is provided to available IWM facilities in IPMwise, and a summary is provided on earlier results from customization to- and field validation Denmark, Norway, Germany, and Spain. A status is also proved on resent results from customization to- and field validation in Greece. IPMwise has been designed to exploit mainly 3 conditions: weed infestations differ in time and space, different weeds have different needs for control under various circumstances and different weeds have different susceptibility to different herbicides. Therefore, in theory IPMwise may identify both specific and potent treatments. The first Greek prototype was constructed in 2019. Using Greek datasets on efficacy against different weed species, from field tests in winter wheat of Greek herbicides in 4 dose rates, estimates of an herbicide dose-response function was produced and entered for 5 herbicides and 10 weeds. A systematic bias was used aiming for suitable safety margins. To account for different growth stages of weeds, default estimates from the Spanish version of IPMwise were used. Before field validation trials were initiated in Greece, 3 levels (versions) of aimed efficacy were defined and implemented: 1) ˙Intended to be safe˙, as defined by AUA with the aim of avoiding yield loss, 2) ˙Intended to be safe -10%˙, 3) ˙Intended to be safe -20%˙. In 2020-21, three field trials were conducted in one region in Greece, which included untreated (control), best standard and 3 versions of IPMwise, to assess and validate the recommendations for control in winter wheat. One field trial was conducted in a field, where only basic fertilization had been applied, to evaluate this co-effect on yield. The field trials were conducted in two different periods, to also evaluate the effect of the herbicide application timing on yield. The results demonstrate potential of IPMwise to save costs and reduce proportions of registered dose rates by 54-65% in Greece. This also emphasise needs for ensuring that herbicides are used effectively. Spraying early in the season and in well-fertilized fields, is a promising strategy to be furtherly developed for winter wheat in Greece. Official release of IPMwise in Greece must be conducted only after field validation in additional major crops (e.g., maize, cotton, perennial crops). The Spanish official version of IPMwise could be a good basis to extend the Greek version of the DSS due to similar climatic conditions, weed flora and agronomic practices.

Keywords: *Decision Support System, Integrated Weed Management, herbicide dose-response, field validation*

Integrated management of *Solanum elaeagnifolium* Cav.: challenges and novel approaches

Alexandros Tataridas[1]; Ilias Travlos[1]; Panagiotis Kanatas[2]

[1]Agricultural University of Athens, Athens, Greece,
[2] Department of Crop Science, University of Patras,
P.D. 407/80, 30200 Mesolonghi, Greece, Unknown

Oral

Silverleaf nightshade (*Solanum elaeagnifolium* Cav.) is a summer perennial invasive and noxious weed species intractable to manage both in agricultural areas and non-agricultural land. The development of an extended network of rhizomes and the regeneration dynamics of the fragmented roots after tillage are leading to herbicide failures and increasing the dispersal of the plant propagules. The prevention of seed set with systemic herbicides applications during summer or repeated mowing for root resources depletion are crucial for the overall management of this species. Pot experiments, dose-response assays, and field trials were conducted during 2019-2021 to assess the efficacy of natural and chemical (EPSPS-, ALS-, PPO-inhibitors, and synthetic auxins) herbicides, mowing, and hot foam on silverleaf nightshade control. In total, eleven herbicides were evaluated when plants were at 8-12 leaves and at 15-30 cm height in the pot experiments. The dose-response experiments were conducted on seedlings at 5-15 cm, originating from seeds or rhizomes. Contact herbicides did not provide adequate control of silverleaf nightshade as regrowth was observed a few weeks after application, though might be efficient to prevent seed set if applied in optimized growth stage. Pyraflufen-ethyl is a highly efficient herbicide to control the weed and prevent seed production, when applied at flowering stage. Glyphosate, MCPA, 2,4-D are a few herbicides that are efficient against seedlings of silverleaf nightshade in rates lower than the recommended. The mixture of glyphosate+MCPA proved the best treatment in an experiment conducted in an olive grove in Volos, Greece, resulting in 85% stem reduction after two years of the first application at flowering stage. Mowing is a common practice in perennial crops and in non-agricultural areas to manage infestations of silverleaf nightshade. Mowing at flowering stage controls in-season infestations and prevents seed production. Nonetheless, stem density during the following years is not reduced without the combined application of systemic or soil residual herbicides. Hot foam is proved inadequate to control silverleaf nightshade, since regrowth is observed shortly after the application and dominance of the weed is ensured as annual weeds have been eliminated. The results of these surveys revealed that reduced herbicide rates and the selection of the optimized growth stage for mowing and herbicide application could ensure the sustainable integrated management of silverleaf nightshade in the long-term. Decision Support Systems could be also used to assist the decision-making for the control of the weed and reduce herbicide input.

Keywords: *silverleaf nightshade, invasive plant species, integrated management, herbicides*

Improving weed management for the naturalized species *Ambrosia grayi*

Danielle vaknin [1]; Daniella Cafri [2]; Nadav Ezra [2];
Hanan Eizenberg [3]; 4Martin Goldway [4]; Maor Matzrafi [5]

[1] *Department of Plant Pathology and Weed Research, Agricultural Research Organization, Newe Ya'ar Research Center, Israel, Ramat yishay, Israel*
[2] *Plant Protection and Inspection Services, Israel; Ministry of Agriculture and Rural Development, Israel, bet dagan, Israel*
[3] *1Department of Plant Pathology and Weed Research, Agricultural Research Organization, Newe Ya'ar Research Center, Israel, Ramat yishay, Israel*
[4] *, kiryat shmona, Israel*
[5] *Plant Protection and Inspection Services, Israel; Ministry of Agriculture and Rural Development, Israel, Ramat yishay, Israel*

Oral

Ambrosia grayi is a perennial weed species of the Asteraceae, endemic to the great plains of the southern United States. In 2017, this species was first documented in Israel at the Shfeya Valley. To date (2021), it has not yet spread beyond the initial invasion site; however, the danger of an outbreak increases as time passes. *A. grayi* has a branched underground root system and it reproduces mainly by root fragments but also via seeds. The aim of this study is to develop new and efficient chemical weed management approaches for the control of *A. grayi*. Root fragments were collected from the infested area at Shfeya Valley, and grown in a quarantine greenhouse at Newe Ya'ar Research Center. Plants were sprayed with several post-emergence herbicides at two different growth stages, 4-6 and 12-15 true leaves. Herbicides applied in this study were: Glufosinate-ammonium 2% (Basta®, 150 g/L, SL), saflufenacil 35g ha^{-1}/ha (Heat®, 70%, WG), fluroxypyr 0.5% (Tomahawk®, 200 g/L, SL), flumioxazin 100 g ha^{-1} (Strike®, 50% WP), glyphosate 2% (Roundup® 480 g/L, SL). The surfactant alkyl-phenol-ethylene-oxide (Shatah 90®, 920 g/L, SL) at 0.1%, was added to the spraying solution for different treatments . Treatments were applied using a chain-driven sprayer delivering 300 L ha^{-1}, with a flat-fan 8001E nozzle (TeeJet®, Spraying Systems Co., Wheaton, IL, USA). Twenty-one days after herbicide application, fresh shoot weight and plant survival were recorded. Regenerative ability was documented after an additional 21 days. Out of 15 tested treatments, combinations of herbicides from different modes of action or with the addition of surfactant were found to be highly effective for the control of *A. grayi*. Reduced plant biomass was recorded for treatment with glyphosate or flumioxazin, however, high survival and regeneration abilities were observed using these herbicides for both growth stages. Treatments with fluroxypyr + saflufenacil + surfactant, glyphosate + saflufenacil + surfactant and the combination of glyphosate + fluroxypyr showed effective results for both growth stages and reduced the regenerative ability of *A. grayi* plants. In conclusion, several herbicidal treatments were found to be highly effective for the control of *A. grayi*. The mixed application of two different modes of action, mainly using systemic and contact herbicides, had improved efficacy as well as reduced regeneration of *A. grayi* plants.

The potential of natural substances as bio-based herbicides to control arable weeds

Sabine Andert

University of Rostock, Rostock, Germany

Oral

Glyphosate as the most frequently used active ingredient for stubble and pre-sowing weed and volunteer management is currently discussed controversially among the scientific and public communities. Henceforth the German government and other EU countries expressed their motivation to stop the use of glyphosate from the end of 2023. In view of climate-smart agricultural land use, shifts back to intensive tillage needs to be avoided. Thus, the stubble cultivation should be more focused as a tool of Integrated Weed Management and innovations for pre-crop management of volunteer crops and weeds are urgently required. Either used alone or in association with other plant protection methods, bio-based control products represent alternative technologies. Bioherbicide products are adapted from natural substances already existing in the environment, so they are expected to be more environment friendly. The present study contributes to improve the state of the art for alternative weed control technologies in arable farming. For this purpose, the results of a three-year greenhouse experiment (2019 repeated twice in spring and summer and 2022) will be presented. We investigated the control of 21 arable weeds with four natural substances. The experimental setup compared an untreated control with four natural substances (acetic, citric and pelargonic acid and magnesium chloride), and glyphosate was used as the common active ingredient for stubble and pre-sowing herbicide applications. The level of necrosis (0-100%) was used to assess the efficacy of herbicide treatment. In 2019, the efficacy differed substantially among the bio-based herbicides. For all natural substances, pelargonic acid had the highest mean efficacy for controlling the weeds tested in the experiments. For most weeds, however, the efficacy of natural substances was much lower compared to glyphosate. For this reason, we will repeat the experiment in spring 2022. We will investigate whether paraffin oil as adjuvant can increase the efficacy of the natural substances on the arable weeds.

Keywords: *Bio-control, Glyphosate alternatives, Greenhouse experiment, Herbicide efficacy*

Aculus mosoniens (Acari: *Eriophyoidea*) a potential biological control agent of Tree of heaven (*Ailanthus altissima*) in an integrated management plan

Francesca Marini[1]; Philip Weyl[2]; Hariet Hinz[2]; Enrico de Lillo[3]; Radmila Petanović[4]; Tatjana Cvrković[5]; Marie-Claude Bon[6]; Biljana Vidović[7]; René F.H. Sforza[6]; Javid Kashefi[6]; Massimo Cristofaro[8]

[1] BBCA onlus, Rome, Italy , [2] CABI, Delémont, Switzerland
[3] Department of Plant, Soil and Food Sciences, University of Bari Aldo Moro, Bari, Italy
[4] Serbian Academy of Sciences and Arts, Belgrade, Serbia
[5] Institute for Plant Protection and Environment, Department of Plant Pests Laboratory
for molecular diagnostics and Laboratory for applied entomology, Belgrade, Serbia
[6] European Biological Control Laboratory, USDA-ARS, Montferrier-sur-Lez, France
[7] University of Belgrade, Faculty of Agriculture, Department of Entomology
and Agricultural Zoology, Belgrade, Serbia
[8] ENEA Casaccia, SSPT-BIOAG-PROBIO, Rome, Italy

Oral

Tree of heaven, *Ailanthus altissima* (Mill.) is a fast-growing deciduous tree native to China, considered a serious invasive species worldwide (Europe, Asia, South Africa, Australia, North and South America). In disturbed urban sites, it competes with autochthonous flora and causes structural damages to railways, roads, and buildings; whereas, in rural areas, it invades croplands, fencerows, forest edges, and rocky areas. Chemical and mechanical methods have limited efficacy in controlling tree of heaven, and efforts should be addressed to the development of biological and integrated control approaches in order to ecologically preserve the ecosystems. *Aculus mosoniensis* (Ripka) is an eriophyid mite that has been recorded to attack tree of heaven in 13 European countries. Since eriophyid mites are obligate plant feeders with high host specificity, they play a relevant role as potential biological control agents; therefore, *A. mosoniensis* could represent a chance to have a candidate agent which does not require to be imported, but would rather be redistributed and/or used in an augmentative approach for the control of tree of heaven in Europe. Field observations, impact, and host range testing have been performed with promising results. The mite appears to be impacting new growth in spring and severely damaging seedlings, and seems to have a narrow host range. In particular, 13 nontarget species either phylogenetically and ecologically related to tree of heaven or economically important in the European contest have been tested, and none of them appear to be potential hosts of this mite. Moreover, since the mite is effective at reducing the fitness of young trees, investigations in the biology and use of this species in an integrated management plan are underway, in order to evaluate if control can be achieved when large trees are cut back then followed by direct inoculation of mites on re-sprouting plants. We believe that the combination of specificity, strong impact on the target, and the ability to increase its population to high levels in a relatively short amount of time, make *A. mosoniensis* a very promising candidate biological control agent which could also contribute to an effective integrated management strategy against tree of heaven with long term benefits in Europe, and potentially in other regions with similar climate.

Keywords: *Tree of heaven; Ailanthus altissima; invasive species; biological control; eriophyid mite; Aculus mosoniensis; integrated management*

Combining chemical and mechanical weeding in wheat.

Christophe Lacroix [1]; Jérôme Pierreux [2]; Gilles Geruzet [1];
Christophe Vandenberghe [3]; Benjamin Dumont [1]

[1] *Uliege- Gembloux Agro-Bio Tech, TERRA Teach. and Res. centre, Plant Sciences,
Gembloux-Belgium, Gembloux, Belgium*
[2] *Uliege- Gembloux Agro-Bio Tech, Experimental farm, Gembloux-Belgium, Gembloux, Belgium*
[3] *Uliege- Gembloux Agro-Bio Tech , Soil - Water - Plant Exchanges,
Gembloux- Belgium, Gembloux, Belgium*

Oral

The European Union wishes to reduce by 50% the use of phytopharmaceutical products by 2030, including herbicides. It implies therefore to adapt weed management strategies in cultivated crops. Among the possible levers, with the technical and technological development, mechanical weeding is again becoming very popular. In particular, different tools can be used in cereal crops, including harrow or rotary hoe. In this context, an experiment aiming to assess different weed control strategies on soft wheat crop was implemented over three consecutive years (2018-2021). The objective was to evaluate to which extend it is possible to reduce herbicide quantities when mechanical control iss applied. The experiment was built on a split-plot design with three factors: (i) *mechanical weeding*, (ii) herbicides and (iii) rate of herbicides. Mechanical weeding consisted of 0,1,2 and 3 passes of harrow applied during the tillering phase (at regrowth after winter period), at stem extension (Z30) and first node (Z31). In addition, a pass of rotary hoe at the tillering stage and a pass of rotary hoe at the tillering stage coupled with two passes of harrow (the following day of rotary hoe and at stem extension (Z30)) were applied. Regarding the use of chemical herbicides, grass- and dicot-weeds control agents were separately applied and also different rates of herbicides were applied (zero, half and full dose). Quadrats of 0.5×0.5 m were marked out to record the number of weeds and to identify them down to the species level before and after every weeding event. Additionally, in 2021, weeds and crop biomass were measured at the flowering stage of wheat. Results showed that mechanical weed control did not significantly reduce grass weed populations. On a dicot type flora, the mechanical weed control treatment combining one pass of rotary hoe with two passes of harrow seemed to result in the highest weed reduction among mechanical treatments ($-48\pm19\%$ compared to the control without regulation which exhibited an increase of $+12\pm16\%$ between the first and last measurement in 2020-2021). However, mechanical weeding did not reach out the efficacy of chemical weed control, which appeared to reduce weed numbers by 55-85%. In order to avoid the use of broadleaf weed herbicides in the long term, improved efficacy of mechanical levers is required. Other combinations of chemical and mechanical weed control will be also tested in the future.

Biodiversity-based agroecological system experiments to test agroecological weed management at various temporal and spatial scales: The CA-SYS and ABY platforms

Stéphane Cordeau [1]; Jérome Boucherot [2]; Pascal Marget [3]; Fabrice Martin-Laurent [1]; David Maupetit [2]; Nicolas Munier-Jolain [1]; Sandrine Petit [1]; Adam Vanbergen [1]; Violaine Deytieux [3]

[1] Agroécologie, AgroSup Dijon, INRAE, Univ. Bourgogne, Univ. Bourgogne-Franche-Comté, Dijon, France
[2] INRAE, P3R, Unité Expérimentale de Bourges, Osmoy, France
[3] INRAE, U2E, Unité Expérimentale du domaine d'Epoisses, Bretenière, France

Oral

Redesigning and planning agricultural landscapes that would sustainably deliver services to agriculture has probably never been so high on the political and research agenda. However, shifting to nature-based forms of agriculture with an emphasis on landscape design will require new models of research enhancing the integration of ecological and agronomical knowledge, targeting research for context-specific solutions, and increased empirical testing of design concepts. For a long time, agronomists have designed and tested cropping systems on system experiments that test the system as a functional entity whose complexity is more than the sum of its parts (i.e. individual farming practices). In advance, we introduce Agroecological System Experiments (ASE), which adopt a system approach that integrates the design of the spatio-temporal arrangement and management of fields along with planned ecological infrastructures (semi-natural or non-crop habitats) at the farm level. As such, ASE are designed to test the combined effects of land management options implemented at multiple embedded spatial scales. Their scientific focus on both the temporal dimension and a spatial dimension of cropping systems is highly relevant to the organisation of an ecologically and agronomically coherent farming strategy at the farm scale. We present two examples of ASE in France, the CA-SYS (Co-designed Agroecological System experiment,125 ha) and ABY (Agroecology in Berry, 90 ha) platforms. Both use diverse spatio-temporal crop rotations and managements (e.g. till/no-till) and ecological infrastructures (grass/flower strips and hedges) to evaluate the impact of a farm-scale restoration of biological processes deployed in a zero-pesticide context on economic, environmental and social performance. A crucial part of these research tools has been the active co-development with farmers and other agricultural stakeholders to guide the development of ambitious but practicable biodiversity-based management systems. We detail the strategies deployed to manage weeds in pesticide-free landscapes, either at the annual and/or rotational temporal scale, and field core and/or field margin spatial scales.

Keywords: *agroecology, cropping system, semi-natural habitat, agroecological infrastructure, ecosystem service, pollination, biological control, zero-pesticide farming*

Weed control in a mineral–ecological cropping system (MECS) including wider crop rotations and stubble tillage compared to organic- and conventional cropping systems

Marcus Saile [1]; Roland Gerhards [2]

[1] *Universität Hohenheim Deparment of Weed Science, Hohenheim, Germany*
[2] *Universität Hohenheim, Deparment of weed science 360 b, , Unknown*

Oral

The harmful impacts of pesticides on the environment, food systems and increasing populations of herbicide-resistant weeds call for alternative and more sustainable cropping strategies. One alternative is to establish a mineral-ecological cropping system (MECS) (no pesticides use but including mineral fertilizers and non-chemical weed control). The target of mineral fertilization is to enhance crop competitiveness against weeds and increase crop yields compared to organic farming. Herbicides are replaced by the integration of false seedbed, cover cropping and precise mechanical weed management to suppress weeds. Three field experiments were established at three locations in Germany in 2019 to investigate the impact of MECS on weed abundance, weed control efficacy and crop yields compared to conventional and organic farming. MECS was characterized by a 6-year crop rotation including winter wheat, maize, triticale, soybean, winter wheat and spring barley, precise seeding and hoeing techniques and precise placement of fertilizers close to the crop rows. The conventional rotation only included 3 crops. All crops were grown in every year. Two additional experiments at one location focused on the effect of different stubble treatment including ploughing (20 cm deep), flat soil tillage (5 cm), deep chisel ploughing (15 cm), no-till and no-till plus seedbed preparation (2 cm). All experiments were realized in a complete randomized split plot design with four repetitions. Weed density by species was counted before and after each treatment and weed control efficacy was calculated based on the first and last measurement. Crop yields were recorded for each plot. The five most common weed species within all experiments were *Veronica persica* with a dominance of 35 %, *Chenopodium album* (20 %), *Thlaspi arvense* (12 %),*Cirisum arvense*(7 %) and *Alopecurus myosuroide s(*5 %*).* Lowest weed density was observed in the conventional systems with up to 10 weeds m^{-2} averaged over all crops. Highest densities were found in the organic cropping system and the MECS with up to 202 weeds m^{-2} after weeding was completed. The systems were not significantly different in weed density despite of the precise seeding, hoeing and fertilization operations. However, average crop yields were significantly higher in MECS with 5.6 t ha^{-1} compared to 3.5 t ha^{-1} in the organic systems. The highest yield (6.5 t ha^{-1}) was achieved in the conventional-cropping system. The flat stubble tillage treatment resulted in highest weed control efficacy of all stubble tillage treatments tested. After two years of experiments, we can conclude that MECS did not suppress weed densities, but increased crop competitiveness and crop yields due to mineral fertilization compared to organic farming.

Innovative solutions to manage and monitor broomrapes in industrial tomato in Greece

Demosthenis Chachalis [1]; Dimitrios Argyris [1]; Maria Gerakari [2];
Nikolina Cheimona [1]; Anastasia Tsekoura [1]; Angeliki Kousta [1];
Antonis Kavvadias [3]; Eleni Tani [2]

[1] *BENAKI PHYTOPATHOLOGICAL INSTITUTE, ATHENS, Greece*
[2] *Agricultural University of Athens, Laboratory of Breeding and Biometry, ATHENS, Greece*
[3] *Agricultural University of Athens, Department of Natural Resources Management and Agricultural Engineering, ATHENS, Greece*

Oral

As part of the EU Prima project that is a consortium of ten partners from eight countries (Zeroparasitic; https://zeroparasitic.eu/), several innovative approaches were studied, by the Greek partners. As such, in this presentation, results will be given as follows: a) biological control utilizing soil microorganisms; b) stimulants for soil depletion and suicidal germination; c) using rootstocks; d) sensing and mapping of field parasitism. In the biological control studies, the external application of five commercial products based on soil microorganisms such as bacteria (e.g. rizobacteria) and fungies (e.g. *Glomus* spp., *Bacillus* spp., streptomycetes, *Trichoderma* spp.) were measured. Experiments were conducted to determine both the direct effect of microorganism spore exudates and effects of mycorrhizal plant on broomrape seed germination (petri dishes and pot experiments). Results demonstrated that both promotion and inhibitory effects depending on the type of the microorganism application. In stimulant studies, three types (NE-1, GR24 and strigol) at different concentrations, temperatures and time of treatment were measured. Screening of the stimulant effect across many broomrape populations was also measured. Results could support the effective *in-vivo* stimulant application for soil broomrape seed depletion through suicidal germination. In rootstock studies, the effect of grafting such as two different rootstocks (namely, Echelon F1 and Armstrong F1) and the scion (namely, Rio Grande, a commercial industrial tomato hybrid) on broomrape parasitism was measured. Greenhouse (pot experiments) documented a decrease (from 87% to 32% parasitism) in the rootstock compared to the hybrid. In the sensing and mapping studies, aerial photography (a UAV with a multispectral sensor) over the study area of industrial tomato field, in three different stages of the growing season was done. The vegetation indices (e.g. NDVI) and the high spatial resolution orthophoto maps of the study field area were correlated with groundtruthing. Results from the ZeroParasitic project highlighted several innovative solutions to manage broomrapes in industrial tomato.

Revealing the interaction between compost rate and non-chemical weed control methods on control efficacy in organic field crops

Itai Shulner [1]; Meidad Kissinger [2]; Ran Nisim Lati [1]

[1] Department of Phytopathology and Weed Research, Agricultural Research Organization, Ramat-Yishay, Israel
[2] Department of Geography and Environmental Development, Ben Gurion University of the Negev, Beer Sheva, Israel

Oral

Weed infestation is the main biotic factor affecting crop plants' agro-systems and can result in significant yield quantity and quality losses. Weed control becomes a more difficult challenge in organic field crops, where no herbicides are allowed. Fertilization is another key aspect affecting organic crops, reflected by the applied compost rate. However, the interaction between these two important aspects was not determined yet. The main goal of this research is to test the efficacy of different non-chemical weed control, mechanical (cultivation) or physical (flaming), and their interaction with different compost regimes for forage and sweet corn (*Zea mays*) and broccoli (*Brassica oleracea*). Weed control treatments included inter-row cultivation, intra-row cultivation using finger-weeder, and flaming. Fertilizer treatments included chemical (control) and compost at 10, 30, and 60 m^3 ha^{-1}. The compost rate affected weed biomass, and the higher treatment (60 m^3 ha^{-1}) in sweet corn resulted in average weed biomass of 1.67 Kg m^{-2} compared to 1.52 Kg m^{-2}in the $10m^{-2}$. However, the compost had no significant impact ($0.13 < p < 0.55$) on the control efficacy in all three crops. In addition, different compost rates did not affect weed species diversity and their density or biomass. Furthermore, the compost did not affect the weed composition and the number of weeds of each species. The Finger-weeder was the most effective control tool, and in forage corn it reduced the weed biomass by 75% more than the inter-row cultivation and flaming. For sweet corn, the finger-weeder, cultivation, and flaming reduced weed biomass by 90%, 54%, and 32% compared to untreated control, respectively. In broccoli, finger-weeder, inter-row cultivation, and flaming reduced weed density by 85%, 77%, and 32%, respectively. Even though higher compost rates promote weed development, they had no significant effect on the control efficacy, and the weeding tool was the prime factor affecting weed control. These results show the potential of alternative weed control methods for field crops and establishing scientific research for environmentally weed control for these crops in organic field crops.

Keywords: *compost; cultivation; flaming; non-chemical weed control; weed;*

Purple nutsedge Control through Improved Crop Rotations under Cotton-Wheat System

Javaid Iqbal; Muhammad Sohail Saddiq; Muhammad Hassaan Javaid

Ghazi University, Dera Ghazi Khan, Pakistan

Oral

Cyperus rotundus is C4 and fast-growing plant dispersed through the extensive underground system and tuber. It is highly competitive and causes a significant reduction in cotton production. Both chemical and non-chemical methods have been practiced to control this noxious weed species. Field studies were conducted from 2018 to 2020 to determine the influence of crop rotation (with or without dry periods) and the effect of herbicide on the control of purple nutsedge in cotton, maize, sunflower, and mungbean. During this study, crop rotation sequences included (1) cotton-wheat-cotton-wheat-cotton, (2) DO(dry out period) after wheat-maize-wheat-DO-maize-wheat-cotton (3) DO after wheat-sunflower-wheat-DO-sunflower-wheat-cotton (4) mungbean-DO-wheat-mungbean-DO-wheat-cotton. The experimental field layout was RCBD in a split-plot arrangement with four replicates. The crops were grown in main plots, and in the subplot, the weedy check and weed-free were maintained. Overall, herbicide treatment significantly suppressed the *C. rotundus* growth than weedy check and improved the crop growth and yield. In crop rotations, the maximum weed infestation was recorded in the cotton crop. Purple nutsedge infestation was suppressed in the sunflower crop, followed by maize and mungbean crops. Fallow tillage (dry out period) might have played a significant role in controlling purple nutsedge in sunflower and maize field crops that depress the purple nutsedge. In 3rd-year cotton, improvement was evaluated in crop rotation field having the dry-out period. Crop rotation significantly improved the cotton yield by suppressing the purple nutsedge growth. Effect of herbicide was also determined in 3rd-year and enhanced cotton yield was recorded. It is concluded that nonchemical methods such as crop rotation having a dry-out period can be included as a reliable approach for controlling *C. rotundus* under the cotton-wheat rotation.

Keywords: *Cyperus rotundas, crop rotation, dry out period, cotton, sunflower, maize*

Managing Cirsium arvense, Sonchus arvensis and Elymus repens in northern European arable farming – where are significant knowledge gaps?

Kirsten S. Tørresen [1]; Jukka Salonen [2]; Lars Olav Brandsæter [3]; Björn Ringselle [1]; Marian M. Weigel [4]; Eliyeh Ganji [4]; Bärbel Gerowitt [4]

[1] *Norwegian Institute of Bioeconomy Research (NIBIO), Ås, Norway*
[2] *Natural Resources Institute Finland (Luke), Jokioinen, Finland*
[3] *Norwegian University of Life Sciences (NMBU), Ås, Norway*
[4] *University of Rostock, Rostock, Germany*

Poster

The perennial creeping weeds *Cirsium arvense* (L.) Scop., *Sonchus arvensis* L. and *Elymus repens* (L.) Gould cause large problems in agricultural production in northern Europe. The management of these species is difficult in organic farming, but easier in conventional farming using herbicides. We collected and analysed literature on the response of these weed species to management practices in order to find knowledge gaps. *C. arvense* and *E. repens* are more studied compared to *S. arvensis*. Both *C. arvense* and *E. repens* have recently been the subjects of extended reviews. *Elymus repens,* a rhizomatous grass, is vulnerable to disturbance and competition due to weak seasonal dormancy, shallow creeping rhizomes and short-lived and low-spreading seeds. Tillage and mowing can effectively control *E. repens*, but efficacy varies between clones, seasons and treatment frequencies. Combined effects of direct control and competition from main crop/subsidiary crop merit further research. *Cirsium arvense* and *S. arvensis* are dicot species with creeping roots, with *C. arvense* roots being situated deeper in the soil than *S. arvensis* and both having deeper roots than the rhizomes of *E. repens*. *Cirsium arvense* can sprout from the intact root system even below the plough layer. Spring tillage has been shown to control *C. arvense* better than autumn tillage, and horizontal root cutter (prototype) have promising results on this species. *Sonchus arvensis* sprouts mainly in spring and summer thus indicating seasonal dormancy. Therefore, spring tillage controls *S. arvensis* better than autumn tillage. The effect of competition from main crop and subsidiary crops needs further investigation. While *E. repens* and *C. arvense* can be significantly controlled by a simple mechanical control strategy alone (repeated tillage and deep root disturbance, respectively), *S. arvensis* must be managed by a combination of different non-chemical methods. Identified gaps focus on the deep root system and sexual reproduction (*C. arvense*), the link between disturbance, competition, withering and dormancy in roots (*S. arvensis)*, and the long-term effect of different integrated weed management strategies on the population dynamics (*E. repens*). We conclude that more research on all three species is needed, especially on the less studied *S. arvensis*.

Redesign of an Integrated Weed Management strategy for arable cropping systems

M.M. Riemens; Timo Sprangers; Hilfred Huiting

WUR Plant Research International B.V., Lelystad, The Netherlands

Poster

Developments in weed management have strongly focused on increasing the efficiency of herbicides or substituting herbicides with other single tactics such as mechanical control. To increase sustainability of agricultural systems in practice, a paradigm shift in weed management is needed: from a single tactic and single growing season approach towards holistic integrated weed management (IWM) considering more than a single cropping season and focusing on management of weed communities, rather than on control of single species. Within the H2020 IWMPRAISE project a framework was developed (Riemens et al, 2021, accepted) to support researchers, advisors and farmers to redesign IWM strategies. The framework consists of five pillars: 1. Diverse cropping system, 2.Cultivar choice and establishment, 3.Field/soil management, 4.Direct control, 5. Monitoring and evaluation. The framework was used to design an IWM strategy for an arable cropping system experiment that was established in 2018 in Lelystad, the Netherlands. An eight-year rotation based on the IWM principles is compared with a conventional four-year rotation, where weed management is primarily based on direct control with herbicides. The crops in the four-year rotation are potato, seed onion, sugar beet and spring wheat, all common crops in an arable rotation on clay soil in the Netherlands. These crops were also included in the eight-year IWM rotation, but to increase crop diversification (pillar 1), the rotation was extended with winter cover crops, cabbage, carrot and an additional potato crop. Cultivars with early soil coverage were chosen to improve competition for light and sowing pattern was adjusted to enable mechanical weeding and seed rate was increased to improve crop competition. With the diversification of the crop rotation through these additional crops, crop management is more variable during the growing season and growing conditions more variable for weed species. In both rotations the soil was ploughed, however, in the IWM rotation the main soil treatment was followed by stale seedbed treatment when possible. Targeted control tactics included in the IWM rotation were mechanical weeding, thermal weeding, mowing and herbicides, which were applied site specific in patches or with band spraying, depending on the weed density and crop. Results from the first 4 years of the experiments will be presented: these indicate that weed management based on the IWM principles provides sufficient weed control to maintain yield levels and herbicide dependency is reduced significantly.

Contribution of long-term crop rotation to weed control in maize

Milena Simić; Milan Brankov; Vesna Dragičević

Maize Research Institute Zemun Polje, Zemun-Belgrade, Serbia

Poster

Crop rotation is an essential part of IWM system proposed to be implemented in maize weed control. It is especially appropriate to be used in sustainable maize production in order to suppress weed abundance on ecological and low-pesticide way. In comparison to maize continuous cropping, which is not suggestible, two- and three-years crop rotation with legume crop is more efficient in weed biomass reduction, including basic herbicide application. The aim of the study was to investigate the efficacy of combined application of crop rotation and mixture of soil (PRE) herbicides on weed species distribution. A long-term field trial organized as split-plot experiment has started in 2009 with maize sown in all four fields at the Maize Research Institute, Belgrade, Serbia. The basic treatment was a rotation system: maize continuous cropping (MC), maize-winter wheat rotation (MW), maize-soybean - w. wheat (MSW) and maize - w. wheat - soybean rotation (MWS). A pre-emergence herbicide mixture of isoxaflutole and metolachlor (Merlin 750-WG+Dual Gold 960 EC) in recommended rates (105 g a.i. ha^{-1} + 672 g a.i. ha^{-1}) was applied immediately after drilling with a CO_2 backpack sprayer with a four nozzle boom, using extended range nozzles (XR11002-SS, Tee Jet Spraying Systems, Wheaton, IL, USA) calibrated to deliver a spray volume of 140 L ha^{-1} of solution at 275.8 kPa. Herbicides were not applied in the control plot. After twelve years and completion of four rotations, maize was present again in all fields in 2021. Weed infestation level was estimated six to seven weeks after the application of herbicides. Samples were drawn randomly by the one square meter and number of weed individuals (WI) and their biomass (WB) were calculated. The data were processed by ANOVA. Our results indicated that in comparison to 2009, WI were increased in 2021 in untreated control by 44.2% in MC, 23.6% in MW, 24.6% in MSW and 18.6% in MWS. On the other hand, in treated plots WI have increased only in MC, by 62.5% and lowered by 7.7% in MW, 29.4% in MSW and 60.0% in MWS. WB has been reduced in 2021 significantly on treated as well as untreated plots in all rotation systems. The highest reduction of WB was achieved in untreated control of MWS (42.6%) and treated plot in MC (45.6%). Conclusively, it was proved that even with basic herbicide treatment with soil herbicides crop rotation could be very effective in weed control. On the other hand, maize continuous cropping has to be avoided in order to reduce potentials for weed infestation.

Non-chemical RNAi-based approach as an integrated weed management tool: a case study on the troublesome weed *Amaranthus hybridus L.*

Silvia Panozzo[1]; Serena Bordignon[1]; Silvia Farinati[2]; Andrea Milani[1]; Laura Scarabel[1]; Serena Varotto[2]

[1] CNR- Institute for Sustainable Plant Protection (IPSP), Legnaro, Italy
[2] University of Padova- Department of Agronomy, Food, Natural resources, Animals and Environment (DAFNAE), Legnaro, Italy

Poster

The new European legislation on the sustainable use of pesticides aims to significantly decrease the reliance on pesticides and promote integrated pest management strategies through the development of innovative methods that lead to a greater environmental sustainability and lower the risks to animal and human health. One of the major issues in cropping systems is represented by weeds, responsible for high yield losses. Herbicide applications are the most effective method to control weeds, but the over-reliance on chemical control has led to environmental issues and the evolution of resistant biotypes. There is therefore a need to develop new technologies that may help to manage weeds and weed resistance. In general, the development of a strategy based on RNA interference (RNAi) technology could: i) represent a potential improvement of non-chemical weed control, ii) provide an emerging GMO-free strategy for managing invasive and resistant weeds and iii) be a valid opportunity to get inside the molecular functioning of weed biology. In this study, a model system was developed to test the effectiveness and applicability of a non-chemical RNAi-based approach for endogenous gene silencing and weed control: the acetolactate synthase (*ALS*) gene of *Amaranthus hybridus* L. was used as the target of silencing. *A. hybridus* is a monoecious and self-pollinated weed that has evolved multiple resistance to herbicides with different sites of action including ALS inhibitors, which are the most widely used herbicides in soybean. *ALS* represents an optimum target for RNAi mechanism mediated by dsRNAs because it is an intron less gene, nucleotide-stable, and present in single-copy in *A. hybridus* genome. These characteristics make *A. hybridus ALS* gene an excellent bench test for the development and future application of dsRNA-induced RNAi mechanism for weed control. We initially focused on the identification and synthesis of dsRNAs of various lengths targeting different regions of the *ALS* gene. Three types of dsRNA molecules were synthetized *in-vitro* and applied externally to the abaxial leaf surface of *A. hybridus* plants. We observed that external applications of synthetic *ALS*-dsRNAs could downregulate the expression of *ALS* transcripts in treated plants. Our investigations are currently focused on application methods and dsRNAs delivery techniques to maximize the efficiency of their exogenous application. In parallel, we are analysing the expression patterns of the genes putatively involved in the RNAi pathway in *A. hybridus*, to verify their activation following dsRNA applications.

Keywords: *non-chemical weed control, RNAi, Amaranthus hybridus, acetolactate synthase, weed management*

Integrated weed management in olive orchards: influence on biodiversity, crop production and quality

Veronica Pedraza [1]; Juan Antonio Lezaun [2]; Irache Garnica [2]; José L. González-Andújar [1]

[1] *Instituto de Agricultura Sostenible (IAS-CSIC), Cordoba, Spain*
[2] *Instituto Navarro de Tecnologías e Infraestructuras Agrarias (INTIA), Navarra, Spain*

Poster

Conventional soil management and weed control methods in olive orchards have caused, over the years, serious problems of water availability, erosion, the appearance of herbicide resistance, as well as a decrease in farmland biodiversity and the associated ecosystem services. In this context, this study highlights the importance of using integrated weed management techniques (IWM), which allows farmers to combine crop production with the protection of the agroecosystem and the conservation of the soil's productive potential. A 2-year study with four IWM strategies in 3 plots and a randomized complete block design with 4 replications per strategy was established. Strategy CC included 'no-tillage with chemical control' in the intra-row spacing and 'cover crops' in the inter-row spacing. The cover crops comprised spontaneous grasses (*Bromus* spp.) in southern Spain and sown crucifers (*Sinapis alba*) in northern Spain. Strategy TL involved 'tillage' combined with pruning wood residues in both sampling areas of southern Spain and strategy NT 'no-tillage with chemical control' in both areas of northern Spain. Effects on the weed community and olive crop were evaluated analyzing the richness, abundance, diversity (Shannon index) and equity (Pielou eveness index), as well as the olive yield and quality. Linear mixed-effects models were used to test for differences between IWM strategies and were adjusted using the *lmer* function from the *lme4* library in the R environment. In all cases, the variable 'plot' was included as a random effect and the variables 'IWM strategy' and 'sampling area' were included as fixed effects. The statistical significance of the effects was obtained by the function *Anova* and *Tukey* test at a 5 % significant level. Results showed a greater richness, abundance and diversity in the CC intra-rows than TL, as well as a greater richness and diversity in the CC inter-rows in southern Spain. In the north of Spain, a greater richness was observed in the NT inter-rows, but diversity and equity indices only showed significant differences in the CC intra-rows in the second year. Moreover, yield and quality results were not affected by the IWM strategy at any location. These preliminary results seem to indicate that the introduction of IWM in olive orchards makes it possible to reconcile crop production and beneficial weed flora at a manageable threshold if a sustainable agricultural system is to be achieved in the long term.

Keywords: *Cover crop, no-tillage, tillage, weed flora, yield*

Crop rotation effect on weed flora and yield in durum wheat

Christina Bourganou; Anestis Karkanis; Kyriakos Giannoulis;
Christos Karamoutis

*University of Thessaly, Department of Agriculture Crop Production
and Rural Environment, Volos, Greece*

Poster

In integrated weed management systems the selection of appropriate cultural methods can make a significant contribution to weed control. Among the cultural practices, crop rotation features important role in reducing weed density. Thus, a field experiment was conducted to evaluate the effects of two ˝long˝ crop rotations on weed flora in durum wheat crop. The treatments of this study were as follows: 1) durum wheat -milk thistle-durum wheat-milk thistle-durum wheat-durum wheat and 2) maize-maize-maize-sunflower-sunflower-durum wheat, while there were four replicates for each rotation system. The first and second rotation system include only winter and summer crops (maize and sunflower), respectively. Durum wheat was sown on 11 November 2020 at a rate of 250 kg seeds ha^{-1}. Various crop and weed parameters were measured during the experimental period. Weed density and biomass were recorded at the end of heading (BBCH growth stage 59) of wheat plants. The results indicated that the rotation system significantly affected weed density and biomass. The highest total weed density (88.75 plants m^{-2}) was recorded in the first rotation system and was greater by 76.4% compared to the second rotation system. Similarly, the weed dry biomass varied between the two crop-rotations with the highest values recorded in the first rotation system. Moreover, in the first rotation system the dry biomass of *Sinapis arvensis*, *Papaver rhoeas*, and *Scandix pecten-veneris* were greater by 100%, 49.3%, and 62.1% than that in the second rotation system. Regarding the effects of crop rotation on growth of durum wheat, the results showed that the highest aboveground dry biomass was recorded in the rotation system including summer crops. Moreover, in the latter rotation system the seed yield (4845 kg ha^{-1}) was greater by 21.9% compared to the first rotation system. In conclusion, the results revealed that a well-designed crop rotation can significantly reduce the weed density and biomass in winter cereals.

Determination of genetic and morphological diversity of *Avena fatua (L.)*

E Kaya Altop[1]; O Güzel[2]; H Mennan[3]

[1] Ondokuz Mayıs University, Samsun, Turkey
[2] Republic of Türkiye Ministry Of Agriculture and Forestry Directorate
of Plant Protection Central Research Institute, Ankara, Turkey
[3] Ondokuz Mayis University, Samsun, Turkey

Poster

Avena fatua is one of the main weeds of winter grains with very strong adaptability and competitive ability. While incorrect herbicide applications in its control raise the problem of resistance, this resistance can be supported due to many interacting environmental factors, high genetic variability and ecotypic diversity. This study was carried out to provide integrated approaches in its struggle. Furthermore, this study aims to determine the morphological diversity and characterization of DNA polymorphism of the susceptible and resistant wild oat populations to ALS and ACCase inhibitor herbicides, which is a problem in winter wheat in Turkey, and to reveal the existing relationship (if any). For this purpose, 11 morphological features and DNA polymorphisms were investigated using the SSR method. While there were statistically significant relationships between seed setting and flowering onset parameters in susceptible populations, this was not statistically significant in resistant populations. Relationships with some DNA fragments were found suggesting the presence of molecular markers of the examined morphological features. It is considered highly probable that gene flow may occur between resistant and susceptible populations. This study is significant because it includes the evaluation by associating genetic/morphological diversity and herbicide resistance. These results will contribute to developing strategies for *A. fatua* control for sustainable agricultural production systems within the scope of integrated weed management practices in Turkey.

Keywords: *Avena, genetic diversity, morphological diversity, ALS, ACCase*

SESSION X

WEED BIOLOGY AND PHYSIOLOGY

Exploring the dioceious nature of weeds: The case of *Amaranthus palmeri*

Nikolaos Korres [1]; Jason K. Norsworthy [2]; Toby FitzSimons [3];
Trenton L. Roberts [2]; Derrick M. Oosterhuis [2]; Govindjee Govindjee [4]

[1] *University of Ioannina, Arta, Greece*
[2] *Crop Soil and Environmental Sciences, University of Arkansas, Fayetteville,
AR, 72704, United States*
[3] *PepsiCo Inc., St. Paul, MN, 55108, United States*
[4] *Biochemistry, Biophysics and Plant Biology, University of Illinois at
Urbana-Champaign, Urbana, IL 61801, United States*

Keynote

Research on the dioecious nature of weed species, such as *Amaranthus palmeri*, a fast adapting and highly competitive weed in many row and vegetable crops worldwide, under abiotic stress has received little attention. In addition, climate change enacts a strong selection pressure on weeds that ultimately will adapt rapidly to changes through alterations in their biology, physiology, and phenology. Therefore, knowledge of the biology and physiology of these species is essential for the development of effective weed management systems, especially under abiotic stress. Here, we have examined the interactive effects of abiotic stress on biological and physiological characteristics of *A. palmeri* such as biomass, flowering initiation, along with mineral accumulation, chlorophyll *a* and *b* content, and the operating capacity of Photosystem II (PSII) in male and female *A. palmeri* plants grown under three different light intensities (150, 450 and 1300 µmol photons m^{-2} s^{-1}) and N, K or P deficiency. Differential gender responses were observed for all the growth, phenology, and photochemistry parameters measured. Female plants, for example, invested more in height, stem, and total dry weight, whereas male plants invested more in leaf area and leaf dry weight. Initiation of flowering of female plants occurred six to eight days earlier compared with male plants. Mineral content of the leaves and stems showed intra- and intersexual differences. Chlorophyll *a* content and chlorophyll *a/b* ratios were lower in the female than in male plants at high light intensity as the flowering progressed with comparable reductions in operating capacity of PSII. The differential response of dioecious species gender possesses inherent weaknesses offering pathways for ecological management of dioecious weeds.

Keywords: *Abiotic stress, mineral deficiency, biological characteristics, phenology, photochemistry, chlorophyll, mineral content, sex*

A framework for Critical Control Windows using weed emergence and phenology models

TA Reinhardt Piskackova [1]; Ramon Leon [2]

[1] Czech University of Life Sciences PragueAgroecology and Crop Production, Prague 6 - SUCHDOL, Czech Republic
[2] North Carolina State University, Raleigh, United States

Oral

Successful weed management, by herbicide or other means, is most importantly linked with timing. Weed control should be early enough to avoid yield losses from competition to the crop and to effectively kill the target species. However, weed control actions that are too frequent can be a waste of time, fuel, human labour, product (e.g. herbicides), or any combination thereof. Finding weeds early can be time consuming, and the best scouting methods can still be inaccurate. While increased precision placement of herbicides has been studied in many crops, using weed predictive models for precision timing is not as well studied, and certainly not as widely used. However, the access to accurate soil temperature and moisture monitoring networks throughout the countryside, paired with predictive models for crop and weed life cycles, could provide real-time alerts to farmers and, consequently, better timed applications. This work explores the potential for using weed emergence and phenology predictive models, the critical period for weed control, and crop growth in a decision management framework for timing weed control actions in annual cropping systems. We use observed and predicted emergence of a weed community to determine control 'windows' for timing weed control in the winter grown biofuel crop *Brassica carinata.* We used observed emergence of *Anthemis cotula*, *Stellaria media*, *Lamium amplexicaule* , and *Oenothera laciniata* to validate previously published thermal time models with over 70% variability explained. Combining weed emergence and phenology predictive models for the driver weed species *Raphanus raphanistrum* with the timing of the economic tool of the Critical Period of Weed Control, we identified critical control windows (CCW) for Clayton, in North Carolina, and Jay, in Florida, based on planting timing. This shows to be a promising framework for making economic decisions based on biological patterns of crops and weeds. While this work focuses on the winter weed community in *B. carinata* , it has the potential for being integrated into other crops and geographies.

Keywords: *predictive models, precision timing, thermal time, thresholds*

What are the biological determinants of regeneration of perennial weeds? Effect of fragment weight and bud number on the regrowth of five perennial weed species

Solèmne SKORUPINSKI; Nathalie Colbach; Annick Matejicek; Hugues Busset; Eric Vieren; Delphine Moreau

Agroécologie, INRAE, Institut Agro, Univ. Bourgogne, Univ. Bourgogne Franche-Comté, F-21000 Dijon, Dijon, France

Oral

Perennial weeds have become an increasing problem with the reduction of herbicide use and tillage. Because of their capacity to regenerate from vegetative organs, such as roots and rhizomes, they must be controlled with different management techniques than annuals. To date, few studies exist on this topic and farmers often lack solutions to control perennials in their cropping systems. Management strategies must focus on the depletion of the regenerative organ reserves to hamper the production of new shoots. However, there is a need for a better understanding of below-ground organs' physiology and the determining factors of their regrowth capacities. Our aim was to assess the number of shoots and their growth speed from one below-ground fragment according to 1) its weight, which is related to the amount of available reserves, and 2) the number of buds initially present (visible) on it. Five species were studied: *Cirsium arvense, Sonchus arvensis, Convolvulus arvensis, Elymus repens* and *Rumex crispus*. They were chosen for their frequency and harmfulness in arable crops in temperate regions and for their difference in terms of multiplication strategy, which implies different vegetative organs. A pot experiment was carried out in a greenhouse: fragments of roots and rhizomes with different weights and different visible bud numbers were buried into 6-L pots, and the number and length of the produced shoots were measured dynamically during the experiment. The effects of fragment nature (creeping root, rhizome, taproot), weight and the number of buds on (1) the probability that a fragment produce a shoot, (2) shoot growth rate, (3) shoot number and (4) maximum shoot length were analyzed. Also, shoot length was quantified as a function of hydrothermal time since bud sprouting. These results will be used to model the regrowth of perennials from below-ground fragments after tillage in a cropping system simulation model (FlorSys). This model simulates daily weed dynamics and crop production over the years, considering the cropping system and pedoclimate. The ultimate goal will be to identify agroecological weed management strategies and to help farmers to redesign their cropping systems.

Keywords: *Perennial weed, vegetative reproduction, root, rhizome*

Sprouting potential of Sonchus arvensis under defoliation treatments in Northern Europe

Eliyeh Ganji[1]; Jukka Salonen[2]; Bärbel Gerowitt[1]; Kirsten S. Tørresen[3]

[1] *University of Rostock, Faculty of Agricultural and Environmental Sciences, Crop Health, Rostock, Germany*
[2] *Natural Resources Institute Finland (Luke), Plant Health, Jokioinen, Finland*
[3] *Norwegian Institute of Bioeconomy Research (NIBIO), Division Biotechnology and Plant Health, Department Invertebrate Pests and Weeds in Forestry, Agriculture and Horticulture, Ås, Norway*

Oral

Perennial sow-thistle (*Sonchus arvensis* L.) is a problematic weed in arable crops in northern Europe. To control *S. arvensis*, strategies which reduce both seeds and creeping root production are essential. Inducing repeated sprouting should result in depleting root reserves and reduction in the subsequent shoot emergence. Earlier studies of *S. arvensis* in the northern European countries have shown a restricted sprouting ability from July/August/September to October/November. To better understand the sprouting patterns, we conducted joint outdoor pot experiments from March 2020 until July 2021 in three northern European regions: Northern Germany, Norway, and Finland. In each pot, root pieces of 5 cm from local plant material were planted at 5cm depth. Above-ground plants were cut at the soil surface in the growing season of 2020 at 1) flower-bud stage, 2) first visible open flowers, 3) start of seed production, and 4) withering stage. Shoots were counted monthly in 2020 and 2021. In the year 2020, in Germany, sprouting, flowering, seed-set, and withering started earlier than at the other two sites. Significantly more shoots showed up at the flower-bud stage in Germany and Finland compared to Norway. In Finland, significantly more shoots were observed at the later cutting stages compared to the first counts at the flower bud stage. As a subsequent effect, fewest shoots showed up in 2021 at the German and Finnish sites after cutting at flower bud and early flowering stage. The lowest emerged shoot number in 2021 for Norway tended to occur after cutting at the flower bud stage and the start of seed production. Accordingly, cutting at the flower-bud stage decreases the ability to produce shoots in the next year.

Keywords: *Perennial sow-thistle, sprouting, cutting, shoots*

Weed seed decay after passing through cow digestive system

Nebojša Nikolić; Franco Tagliapietra; Stefano Schiavon; Roberta Masin

*University of Padova, Department of Agronomy, Food, Natural resources,
Animals and Environment (DAFNAE), Legnaro (PD), Italy*

Oral

One possible way to introduce weed seeds in plant production systems is with the manure used for soil fertilization. Before seeds arrive with manure, almost all of them have to undergo the passage through the digestive system of animals. During this passage, seeds are exposed to different microbial activity and pH conditions connected to the animal diet that may alter their vitality. In this work, the level of seed degradation of nine different weed species was measured after the passage through the cow digestive system. The species used were: *Abutilon theophrasti*, *Alopecurus myosuroides*, *Amaranthus retroflexus*, *Avena sterilis, Chenopodium album, Datura stramonium, Echinochloa crus-galli, Lolium multiflorum* and *Sorghum halepense.* For each species, 100 seeds were placed inside nylon bags, permitting the microorganism passage. Seeds were exposed to microbial activity simulating the cow ruminal activity using the Ankom artificial rumen ˙Daisy incubator˙ for three different times 12 h, 24 h and 48 h, and with two diets: one for heifers and another for lactating cows. After the passage through the rumen, the bags containing the seeds were exposed to different in vitro conditions to simulate gastro-intestinal and cecal conditions. Four repetitions were used for each time/diet combination and seed species. After this process was concluded, the tested seeds plus control (not exposed to microbial activity) were sown in Petri dishes with the addition of deionized water and were sealed with parafilm and placed inside incubation chambers, at 15-25°C (winter weed species) or at 18-30°C (summer weed species), with 12/12 h light/ dark photoperiod. Germination was monitored every 2-3 days, germinated seeds were counted and removed, and the germination was considered terminated after all the seeds germinated or after 10 days without germination. Tetrazolium test was performed on non-germinated seeds for their viability assessment. The results indicate that most seeds can maintain their viability high even after 48 h exposure to ruminal microbial activity, with the only exception of *A. sterilis,* whose viability is almost completely lost after 48 h. Moreover, it was also observed that the two diets influenced seed viability differently. The lactating cows diet influenced the thick coated seeds more negatively, while for the thin coated seeds the heifers diet had more negative effect.

Keywords: *Weed seed biology, Weed dispersal, Seed longevity, Organic fertilizers*

Development of a temperature-based seed germination model for silverleaf nightshade (Solanum elaeagnifolium)

Omer Kapiluto; Hanan Eizenberg; Ran Lati

*ARO agriculture research orgnizationDepartment of Weed Research
Newe Ya'ar Research Center, RAMAT YISHAY, Israel*

O al

Silverleaf nightshade (*Solanum elaeagnifolium* Cav.) has become a highly troublesome weed in irrigated summer crops and drylands in Israel and other Mediterranean countries. This noxious species has both vegetative and sexual reproduction. The main objective of this study was thus to determine the impact of temperature on seed germination dynamics of *S. elaeagnifolium* and to develop a temperature-based (thermal) model for three *S. elaeagnifolium* populations growing in different ecosystems in Israel. A laboratory study was undertaken in which the germination proportion of *S. elaeagnifolium* seeds was monitored under seven temperature regimes: 2/8, 7/13, 12/18, 17/23, 22/28, 27/33 and 32/38 °C (night/day). In addition, the impact of temperature oscillation on the germination pattern of the three populations was estimated by meta-analysis approach. Six oscillation regimes were tested (0, 2, 4, 6, 8 and 10 °C), that were averaged over two temperature, 20 and 25 °C (total 12 regimes). The three populations shared similar germination pattern and dynamics. An oscillation regime of 6 °C and above was needed for optimal germination, however, no germination was observed under constant temperatures. In all three populations, the lowest temperature regime at which germination occurred was a 12/18 °C (night/day), with the final germination proportion lying between 0.36 and 0.25. The highest final germination proportion of 0.8 was observed for the 17/23 °C regime in all three populations. Modeling the germination rate as a function of temperature allowed us to determine cardinal temperatures for all three populations taken together, with the values being T_b = 10.8 °C (base temperature), T_o = 23.8 °C (optimal temperature) and T_c = 35.9 °C (ceiling temperature). These biological parameters allowed accurate (RMSE<0.06%) prediction of *S. elaeagnifolium* seed germination over the entire temperature range. The biological data regarding the impact of temperature on *S. elaeagnifolium* germination can be used to improve the control of this weed in smart decision regarding tilling, control timing and control tool.

Functional leaf anatomy of the invasive weed Solanum rostratum Dunal and its role in herbicide response

Jackline Abu Nassar [1]; Assaf Distelfeld [2]; Ilana Shtein [3]; Maor Matzraf [1]

*[1] Department of Plant Pathology and Weed Research, Newe Ya'ar Research Center,
Agricultural Research Organization (ARO),, RAMAR YESHAI, Israel
[2] Department of Evolutionary and Environmental Biology, Haifa, Israel
[3] Eastern R&D Center, Milken Campus, Ariel, Israel*

Poster

Solanum rostratum Dunal (Buffalo bur) is an annual noxious thorny weed belonging to the *Solanaceae* family, native to the Mexican highlands. This weed was introduced to the Israeli flora in the 1950's, and in recent years its spread has increased in Israel. Several populations have been identified in the Jezreel Valley, Western Galilee and the Golan Heights, as well as the western part of the Negev. *S. rostratum* is considered an aggressive troublesome weed in vegetable crops in Israel, which spans on over 50,000 hectares. Based on the different response of young and mature plants to herbicides, and the increased efficacy when using surfactants, even at later growth stages, in this study the functional leaf surface anatomy of *S. rostratum* is explored in order to better understand the role of the cuticle structure in changing herbicide efficacy. Leaves from two growth stages were structurally characterized using a scanning electron microscope, and leaf wax was quantified. Also, cuticle penetration estimations were conducted by calcofluor staining, and droplet distribution and area with or without the addition of surfactant to the spraying solution. In young *S. rostratum* leaves, the leaf surface was densely covered with stellate trichomes on both leaf sides; however, in the mature leaf, stellate trichomes density became low. Wax amount was significantly higher for mature leaves, while density of stomata was higher in young leaves. Young leaves showed high leaf permeability, with the fluorescent dye permeating the leaf and staining the vascular bundles. In young and mature leaves treated with a spraying solution with the addition of surfactant, low droplet number alongside higher coverage area was recorded. Our data highlights the notable differences in leaf epidermal structure of young versus mature plants. The current research is of major importance as it elucidates the differences in herbicide efficacy and penetration through the leaf cuticle at different plant growth stages, thus leading to differential control efficacy. The data obtained by this study can be utilized to improve *S. rostratum* chemical control and help in the efforts to halt its rapid spread.

Investigating the germination and phenology capabilities of Parthenium hysterophorus populations in Israel

Sahar Malka [1]; Hanan Eizenberg [2]; Maor Matzrafi [2]

[1] The Robert H. Smith Faculty of Agriculture, Food and Environment,
The Hebrew University of Jerusalem, Rehovot, Israel; Department of Plant Pathology
and Weed Research, Agricultural Research Organization, Newe-Ya'ar Research Center,
Ramat Yishay, Israel
[2] Department of Plant Pathology and Weed Research, Agricultural Research
Organization, Newe-Ya'ar Research Center, Ramat Yishay, Israel

Poster

Parthenium hysterophorus is a noxious weed species of the *Asteraceae* family that had invaded more than 50 countries worldwide. In Israel, *P. hysterophorus* was first documented in 1980 near a fishpond in Tirat Zvi, located in north-eastern Israel. In recent years, there has been an increasing concern about the spread of this noxious weed in agricultural and non-agricultural habitats, along with the identification of several populations in southern areas. Our work aims to study the germination of different populations of *P. hysterophorus* under changing environmental conditions. We examined seeds that were collected from five climatically different locations across Israel: Dgania Beit, Tirat Zvi, Hahotrim, Amikam and Newe Ya'ar. Seed weight was recorded alongside other seed parameters that were measured using electronic microscope (Hirox RH, 2000). Seed germination was documented for each population under dark conditions at several constant temperatures (10, 15, 20, 25, 30 and 35°C) and water potentials (0, -0.2, -0.4, -0.6, -0.8 and -1 MPa at 20°C). Thirty-two plants of each population were grown in a greenhouse under controlled conditions, and several life cycle traits, such as emergence, bolting and flowering, were recorded for each plant. No significant differences were observed for seed weight, nor for other seed parameters among populations. For germination studies, different germination characteristics among populations were observed: seeds of Tirat Zvi and Amikam showed higher germination rates over a wide range of temperatures. However, for seeds of all populations, optimal germination was recorded at ~20°C. Germination was recorded at all water potentials except -1MPa, but low germination rates were observed at -0.8 and -0.6 MPa for all populations. However, seeds of the Amikam population presented the higher germination rates under negative water potentials than the other populations. Differences in phenological characteristics were also observed, Tirat Zvi bolting the earliest Hahotrim the latest. It was noticeable that the growing rate of the plants (rosette diameter, plant height) was also different between populations, although no significant differences were observed in the plants' final weight. Understanding the variation in the biology and in the phenology of different populations of *P. hysterophorus* may serve as a key factor for creating new and integrated weed management approaches for the control of this noxious weed species.

Keywords: *Asteraceae, Invasive weed, Seed germination, Temperature, Water potential, Phenological attributes*

Studies on stimulants and screening of germplasm to manage broomrape (Orobanche spp.) parasitism

Dimitrios Argyris[1]; Maria Gerakari[2]; Nikolina Cheimona[3];
Christos Megas[4]; Dimosthenis Katsis[4]; Eleni Tani[2];
Demosthenis Chachalis[5]

[1] BENAKI Phytopathological Institute, KIFISIA, Greece
[2] Agricultural University of Athens, Laboratory
of Breeding and Biometry, ATHENS, Greece
[3] BASF Hellas SA, ATHENS, Greece
[4] AGROLAND SA, Sofades, Greece
[5] BENAKI PHYTOPATHOLOGICAL INSTITUTE, ATHENS, Greece

Poster

As part of the EU Prima project that is a consortium of ten partners from eight countries (Zeroparasitic; https://zeroparasitic.eu/), studies on the effect of germination stimulantsand tomato germplasm screening to manage broomrape parasitism in industrial tomato are presented by the Greek partners. Laboratory experiments were conducted to investigate the effect of stimulants in the preconditioning and germination phase of seeds of three broomrape species (*O. ramosa*, *O. aegyptiaca*, *O. cumana*). In the preconditioning experiments, the effect of two stimulants (GR24, NE-1), applied at two concentrations (10^{-6}, 10^{-8}M) on seeds was studied at three temperature regimes (constant 17 and 25°C, and 25-35°C) maintained over three duration periods (1, 2, and 3 weeks). In the germination experiments, the optimum condition at the preconditioning phase was selected (25°C for two weeks). Afterwards in the germination phase, the effects of the same two stimulants (GR24, NE-1), applied at four concentrations (10^{-6}, 10^{-8}, 10^{-10} and 10^{-12}) and maintained at the same three temperature regimes (17, 25, 25-35°C) were measured. For the germplasm screening, ten (10)introgression lines (ILs), which are crosses between *Solanum lycopersicum*× *S. pennellii*,provided by the Spanish partner (CSIC-SEBAS; Center for Edaphology and Applied Biology of Segura), were placed for seed multiplication to acquire the needed amount of seed samples. The screening aims to characterize the germplasm for relative tolerance/resistance to broomrape parasitism, and document physiological parameters of the host plants. Results of these studies would provide critical information to understand plant-parasite interactions.

Studies on the biology of bur chervil (Anthriscus caucalis)

Rebecka Dücker[1]; Jean Wagner[1]; Johannes Herrmann[2];
Martin Heß[2]; Manja Landschreiber[3]

[1] *Plant Pathology and Crop Protection, Georg-August University Göttingen, Göttingen, Germany*
[2] *Agris42, Stuttgart, Germany*
[3] *Landwirtschaftskammer Schleswig-Holstein, Lübeck, Germany*

Poster

In the past decades, bur chervil (*Anthriscus caucalis* M. Bieb.) has newly established as an arable weed in several regions of Germany. It primarily occurs in winter crops, where it is often not controlled by standard treatments with herbicides. To assess the potential of non-chemical control measures, studies were conducted on its biology. The dormancy of bur chervil seeds, collected in summer 2020, was studied by burying them in a wheat field at a depth of 10 cm, and subsequent sowing in the greenhouse in two-month intervals. The majority of the seeds showed at most a weakly pronounced dormancy and germinated already in autumn. In a field trial in which bur chervil plants were newly introduced, seeds that were shed that year germinated continuously until the end of the growing season. Studies conducted in a greenhouse with open side walls showed that the optimal germination depth was between from 0 to 5 cm. However, some individuals germinated with a delay from down to 10 cm depth. Finally, studies on the temperature dependence of germination indicated considerable cold tolerance of the species, as bur chervil germinated between 1 and 26 °C, with an optimum around 16 °C. Moreover, bur chervil plants also survived winter 2020/2021 in field conditions, with snow cover and cold spells below -20 °C, and the milder winter 2021/2022. Overall, the species was shown to be a weed well adapted to winter crops in temperate climates and could possibly be further promoted by reduced tillage.

Keywords: *Apiaceae*

Effect of salinity and temperature interaction on germination and early growth for five weed species

Aurora Ghirardelli; Nebojša Nikolić; Roberta Masin

University of Padova, Department of Agronomy, Food, Natural resources, Animals and Environment (DAFNAE), Legnaro, Italy

Poster

Soil salinization is increasingly affecting agroecosystems and spreading towards temperate regions, where the sea-level rise and groundwater overexploitation cause saltwater intrusion in coastal and inland aquifers. Although weed adaptability might favour their spread in adverse environments, including salt-stress conditions, so far limited attention has been given to weed communities. To understand whether salt stress might exacerbate the spreading potential of weeds in temperate regions, we assessed the effects of salinity on germination and early growth stages of five species infesting spring-summer crops: *Abutilon theophrasti*, *Amaranthus retroflexus*, *Digitaria sanguinalis*, *Setaria glauca* and *S. viridis*. Seeds of these species were collected in the Po Valley (Northern Italy) in non-saline soils. For germination tests, seeds were placed in Petri dishes, lined with filter paper and moistened with a salt solution. Treatments consisted of four levels of salinity (4, 8, 12, 16 dS/m) plus a control (distilled water), prepared by dissolving pure NaCl in deionised water and measuring electrical conductivity. For growth tests, seeds were sown in nutrient-agar media and placed in autoclave-sterilized boxes. Treatments consisted of the same salt-stress levels as in the germination test, obtained by dissolving pure NaCl in the solution used to prepare the agar medium. Both boxes and Petri dishes were kept in growth chambers at four constant temperatures: 12, 15, 18, 24 °C (12/12h light/dark). Seed germination was monitored every two days, while the early growth was assessed after five weeks of incubation, when root and shoot lengths were measured. Results show that even weed ecotypes unexposed to salt stress can germinate and develop roots and shoots when treated with moderate to strong salt stress (4-16 dS/m). *S. glauca* and *S. viridis* showed high germination rates (90.5%) at 18-24 °C, which significantly decreased in salt-treated seeds at 12-15 °C, reaching 5.5 and 3% at 16 dS/m respectively. Conversely, *A. theophrasti* showed high germination rates (over 70%) at all temperatures, while *D. sanguinalis* and *A. retroflexus* germination rates were seriously affected by salt stress ≥8 dS/m, with less than 1% of the seeds gerimnated at 16 dS/m. In the case of *A. theophrasti*, even mean germination time was not significantly affected by high salt stress. The mean root and shoot lengths of *S. glauca* and *S. viridis* were not affected by salt stress ≤12 dS/m and even reached higher values at 8-12 dS/m compared to the control. In conclusion, the analyzed species, particularly *A. theophrasti, S. glauca* and *S. viridis*, show high salt tolerance at germination and early growth stages, potentially representing an increased threat in temperate regions affected by salinization.

Weeds pollen rupture due to thunderstorms electric fields can increase allergy risk

Y. Yair [1]; Y. Yair [2]; J. Silverman [3]; B. Rubin [4]

[1] The Hebrew University, Faculty Agriculture, Food and Environment,
R H Smith Institute of Plant Science and Genetics in Agriculture, REHOVOT, Israel
[2] School of Sustainability, Reichman University,, Herzliya, Israel
[3] Israel Oceanographic and Limnological Research, National Institute
of Oceanography,, Haifa, Israel
[4] The Hebrew University, Faculty Agriculture, Food and Environment,
R H Smith Institute of Plant Science and Genetics in Agriculture, Rehovot, Israel

Poster

Exposure to pollen grains often cause an allergic reaction in sensitive population, which is increased during thunderstorms. At the mature stage of thunderstorm evolution, cold outflows may develop below the cloud-base because of evaporation and precipitation of particles. These strong down-drafts reach the ground and can eject large concentration of pollen and dust particles into the air. Based on the results of a recent laboratory study, it was suggested that pollen rupture and release of sub-pollen particles (SPPs, r<2.5 μm) following their exposure to the humid conditions occurs during a thunderstorm. SPPs can be inhaled into the respiratory system, where they often cause an acute allergic response. At flowering season of certain plants, which are known for their allergenic potential, this process may result in Thunderstorm Asthma Epidemics, which are expressed as severe respiratory problems, especially in sensitive populations (infants, senior citizens). However, previous studies did not account for the role of the sustained exposure of pollen to strong electric fields occurring inside and below the thunderclouds, and this is the objective of this study. Laboratory experiments were conducted with four wind pollinated plants: *Ambrosia confertiflora, Ambrosia artemisiifolia, Ceratonia siliqua* and *Artemisia monosperma*. Pollen grains were exposed to electric fields with strengths of up to 30 kV m^{-1} for 0-20 minutes with or without one drop of distilled water. These pollen grains were then examined with a scanning electron microscope (SEM). The images show damages to the pollen grains after exposure to the electric fields. They were ruptured, broken, collapsed, swollen and their contents were expelled. Adding moisture aggravated the damage caused by the electric fields, confirming the hypothesis of SPP production and the release of allergens to the air thus creating a greater risk to sensitive people during thunderstorms.

Keywords: *Ambrosia confertiflora; A. artemisiifolia; invasive weeds; Thunderstorm Asthma Epidemics*

Alopecurus myosuroides seed production and shedding pattern

Z Bitarafan [1]**;** C Andreasen [2]

[1] *Norwegian Institute of Bioeconomy Research (NIBIO), Division of Biotechnology and Plant Health, Ås, Norway*
[2] *University of Copenhagen, Department of Plant and Environmental Sciences, Taastrup, Denmark*

Poster

Harvest Weed Seed Control (HWSC) systems are used to collect and/or kill weed seeds retained on the weed plants at crop harvest. The effect of HWSC methods depends on the weeds seed retention at harvest. Therefore, delay in crop harvest reduces the efficiency of HWSC. In 2018, we studied the seed production and shedding pattern of *Alopecurus myosuroides* in a semi-field experiment in Taastrup, Denmark, to find the seed shedding time range of this species. In 2017 and 2018, we also followed the seed shedding pattern of *A. myosuroides* in a wheat field. Seeds of *A. myosuroides* were planted in pots in a greenhouse with a constant temperature of 5°C. In December 2017, the seedlings were transplanted in a box (120 × 80 cm^2) located outdoor. In spring 2018, the number of plants was reduced to 14 providing a space of 685 cm^2 for each plant. We surrounded each plant with a porous net to collect the seeds. The nets were checked once a week to record the beginning of the seed shedding period. Hereafter, seeds were collected weekly using a portable vacuum cleaner. Plants in the box started seed shedding in the second week of June and seed shedding continued for 12 weeks (end of August). In the wheat field, *A. myosuroides* plants surrounded by a net started to shed seeds in the third week of June and continued until wheat harvest on 31 July in 2017 and in the second week of July and continued until wheat harvest on 15 August in 2018. We found a significant difference between the weekly number of shed seeds in all three experiments (P< 0.001). On average, 1493 seeds were produced by each plant in the semi-field experiment. A linear function described well the relationship between the dry weight of plants and seed production for the two field experiments (R^2=0.8).

Keywords: *Harvest weed seed control; Seed shedding time range; Weed seed retention*

Methods to identify of Silverleaf nightshade (Solanum elaeagnifolium) for the phytosanitary in Russia

Ekaterina Volodina [1]; Yuliana Kulakova [1]; Oxana Dobrovolskaya [2]; Maksim Anisimenko [2]

[1] All-Russian of Plant Quarantine Center (Invasive Plant Department), Bykovo, Ramenskoe district, Moscow Oblast, Russian Federation
[2] All-Russian of Plant Quarantine Center, Bykovo, Ramenskoe district, Moscow Oblast, Russian Federation

Poster

Silverleaf nightshade (Solanum elaeagnifolium Cav.) is a noxious invasive weed in arid regions around the world. It is recognized as a quarantine organism for EPPO countries, Georgia, Moldova, Ukraine, Azerbaijan, Kazakhstan, Belarus, Kyrgyzstan, Russia, Canada and Australia. The species is absent in the Russian Federation, but there is a high risk of its introduction with imported seed lots, feed for livestock and birds, and food materials. Silverleaf nightshade is characterized by very variable morphology (leaf shape, pubescence, etc.). Besides its seeds are not visually distinguishable from those of other Solanum species. We aimed to develop suitable methods distinguish this species from other nightshades. Herbarium and seed samples of weedy Solanumspecies were collected from different parts worldwide. Microscopic analysis of Solanum leaves was carried out using SEM (HitachiiTM4000 Plus 00) and types of leaf pubescence were assessed. Intra- and interspecific genetic polymorphism between S. elaeagnifolium and other Solanum species in the chloroplast regions ndnf-rpl32, matK, trnL-trnT was studied, and the trnL-trnT intergenic chloroplast DNA spacer were used to develop DNA markers to identify this polymorphic species. The study also analysed pubescence characteristics such as intensity (density) of pubescence, type and size of trichomes, and number of lateral rays of stellate trichomes. Results revealed high intraspecific and interspecific polymorphism in some regions of the chloroplast genome, and identified unique SNP (*ndhF-rpl32 и trnL-trnT*) for *S. elaeagnifolium*. Based on specific features of pubescence have been identified, which can serve as a reliable taxonomic trait for identifying certain species of *Solanam genus*. Specific pubescence features have been identified, which can serve as reliable taxonomic traits for identifying *Solanum* species, and mainly *S. elaeagnifolium*. The developed test-system will greatly simplify and accelerate the identification of *S. elaeagnifolium* in the quarantine laboratories. The study also revealed intraspecific polymorphism of *S. elaeagnifolium*. Samples from the United States and northern Mexico are characterized by a 24 base pairs deletion. Samples from southern Mexico, Argentina and the Old World did not show this deletion. Further study of this polymorphism may help to better understand the distribution paths of the species and/or its intraspecific polymorphism in different parts of the non-native range. The identified species-specific features of *Solanum* trichomes can be used to detect *S. elaeagnifolium*, which's pubescence is not affected by its phenotypic plasticity, and this characteristic is retained in the different areal parts of the plant.

Weed Seed Bank Model

Markola Saulić [1]; Ivica Djalovic [2]; Mostafa Oveisi [3];
Dragana Bozic [4]; Sava Vrbnicanin [4]

[1] *Academy of Applied Technical Studies, College of Professional Technical Studies, Pozarevac, Serbia*
[2] *Institute of Field and Vegetable Crops, National Institute of the Republic of Serbia, Novi Sad, Serbia*
[3] *University of Tehran, College of Agriculture and Natural Resources, Department of Agronomy and Plant Breeding, Karaj, Iran*
[4] *University of Belgrade, Faculty of Agriculture, Belgrade, Serbia*

Poster

Weed seed banks are an inexhaustible and permanent source of weeds, but they also have a stabilizing effect on the ecosystem and biodiversity in plant production systems. Scarce research on this topic has shown great variability in results, in part, due to different methodology of the seedbank estimation. The aim of this research was to compare two methods of estimating weed seed bank: 1) physical extraction of seeds, and 2) seedling emergence method. The plots of the stationary experiment "Plodoredi", Institute of Field and Vegetable Crops, Novi Sad, Serbia (N 45° 19', E 19° 50') were used for these research. Soil samples were taken from two experiments, a 50-year winter wheat monoculture, and from a three-year crop rotation (winter wheat-maize-soybean), over the course of three years (2014-2017). The method of physical extraction, although longer and physically more exhaustive, showed better results. In winter wheat monoculture 12 weed species were recorded, with a total of 21575 seeds m^{-2}, while in the three-year crop rotation 25 weed species were detected, with a total of 16300 seeds m^{-2}. Using the seedling emergence method only five weed species and 8500 seeds m^{-2} were estimated in monoculture, while in crop rotation five weed species and 4500 seed m^{-2} were estimated. This indicates that the entire weed seed bank is not active: some seeds are not able to germinate, while others are dormant, but present a potential danger. The estimated number of seeds per m^{-2} by the more efficient method of physical extraction was used to create the ˝*Artificial Neural Network*˝ model which had been previously tested using the Random-Holback method. The model answered the key question: how monoculture and crop rotations can change the soil weed-seed bank and diversity in a long-term cropping system.

Keywords: *weed seed bank, physical extraction of seed, seedling emergence method, ANN model*

Validation of hydrothermal model AlertInf for barnyardgrass emergence in Croatia maize crop

Valentina Šoštarčić [1]; Roberta Masin [2]; Donato Loddo [3];
Zlatko Svečnjak [1]; Vedran Rubinić [1]; Maja Šćepanović [1]

[1] University of Zagreb Faculty of Agriculture, Zagreb, Croatia
[2] University of Padova Department of Agronomy, Food, Natural Resources,
Animals and Environment (DAFNAE), Legnaro, Italy
[3] Institute for Sustainable Plant Protection, National Research
Council of Italy, Legnaro, Italy

Poster

Barnyardgrass (*Echinochloa crus-galli* L.) is the most common grass weed in maize fields in Croatia and an important weed in many crops worldwide. Since weed species can differ in the time and duration of emergence, to achieve appropriately weed control timing, it is necessary to determine the field emergence period of the largest proportion of the weed population. Soil temperature and soil moisture are the two main factors driving weed emergence. Therefore, hydrothermal models can be used to predict weed emergence in agricultural crops. AlertInf is an Italian hydrothermal time (HTT) model for weed emergence prediction in maize. The possibility of validating this model for Croatian maize crops was tested with barnyardgrass. Prior the validation, AlertInf model was calibrated with the values of germination parameters of the Croatian population (base temperature 10.8°C and base water potential -0.97 MPa). Field experiments were conducted in maize crops in continental Croatia to quantify barnyardgrass emergence pattern from natural seedbanks. Barnyardgrass emergence was monitored in a 2-yr experiment in an experimental maize field Šašinovečki Lug (45°50'59.6 "N 16°09'53.9 "E). Emergence monitoring was carried out three times a week in 12 squares (0.3 x 0.3 m^2) between maize rows. The first visible true leaves of barnyardgrass were counted and removed. Monitoring of emergence ended when no emerged seedling was observed for at least two weeks after closing the maize canopy. Soil temperature and soil moisture were recorded daily during experimentation. The obtained emergence data was used for the validation of the Italian HTT model. Results showed the successful applicability of the AlertInf model for simulating the emergence of barnyardgrass in maize (EF =0.97 and EF = 0.98in 2019 and 2020, respectively), although a slight underestimation of the onset of emergence in 2019 and overestimation in 2020 was observed. However, the model successfully predicted the mid- and end of emergence in both years. According to the model, the onset of emergence needed 29 and 27 HTT units in 2019 and 2020, respectively; 93 HT units for the middle emergence in both years; and 312 and 342 HT units for end of emergence in 2019 and 2020, respectively. Our findings showed the potential use of the AlertInf model for the simulation of barnyardgrass emergence in Croatian maize crops and in similar geographic areas.

The effect of crop rotations on the soil weed seed bank in rainfed agroecosystems

María Inés Santín-Montanyá [1]; María Luisa Gandía [1];
Juan Pablo Del Monte [2]

[1] The National Institute for Agricultural and Food Research and
Technology (INIA-CSIC), Madrid, Spain
[2] ETSIAAB-UPM. Department of Agrarian Production, Madrid, Spain

Poster

Background and objectives: Soil seed banks reveal changes occurring in the spontaneous flora linked to shifts in agroecosystems. This is because the seed bank contains weed seeds from the present and previous years, and shows a compilation of management practices and environmental conditions. It has been considered that a well-planned crop diversification can be a strategy to sustain yields in rainfed conditions, and a promising way to adapt cropping systems under a changing climate. In the short-term, there is scarce information about how the soil weed seed bank response to a previous crop within a rotational scheme. We hypothesised that contrasting rotation systems would affect the weed seed reservoir differently. In this work, we aimed to test whether the seed density and diversity of weed seed banks vary between different crop rotations. **Methods:** The soil seed bank was assessed by germination tests over three seasons in four crop rotation schemes: fallow/cereal/legume; fallow/legume/cereal; fallow/cereal/rape and fallow/rape/cereal. The experimental design was a randomised block with four replicates. The weed seed density and diversity (Pielou and Margalef indices, respectively) in the soil were yearly determined in each plot. Then, a contour map of the species number distribution (6-points by 16 plots) was obtained for this trial, each year. Both density and diversity data were statistically analysed with an analysis of variance (ANOVA), considering year and rotation scheme as fixed factors. **Results:**The seed density decreased over the three years, although differences were not significant until the third year, which would confirm the resilience of seed banks to vary in short periods of time. Crop rotations significantly affected the weed density and diversity in the seed bank. The rotations with cereal and legume crops decreased the seed bank density. Regarding the diversity indices, the richness of species (Margalef index) was significantly affected by year but not by rotations. Pielou index increased significantly with the year and decreased with the rotation fallow/oilseed rape/cereal. The last year of study, a low richness of species and high evenness in the soil seedbank led to the presence of dominant species. Particularly, the rotation that came from fallow, without competition with a crop, followed by a late establishment of oilseed rape favoured the soil seed reservoir of some weed species. In our study these species were Amarantus blitoides (26.5%) and Portulaca oleracea (49.5%). **Conclusions:**The selected sequence of crops within a rotation system affected the seed bank density and the evenness of weed species.

Keywords: *crop diversification, density, diversity, dryland conditions, soil seed bank*

How to pit weeds against parasitic plants. A simulation study with Phelipanche ramosa in arable cropping systems

Olivia Pointurier [1]; Delphine Moreau [1]; Stéphane Cordeau [1]; Stéphanie Gibot-Leclerc [2]; Carole Reibel [2]; Eric Vieren [1]; Nathalie Colbach [1]

[1] *INRAE - Agroécologie, Dijon, France*
[2] *AgroSup Dijon, Dijon, France*

Poster

Branched broomrape (*Phelipanche ramosa*(L.) Pomel) is a parasitic plant that causes severe yield losses in major crops worldwide. Because of its broad host range, including numerous non-parasitic weed species, the persistence of its seeds in the soil, and the poor efficiency of available management techniques, broomrape management is complex. The objective of the present work was to develop a broomrape-dynamics model and then use this model to support the design of management strategies combining multiple techniques aiming at long-term control of broomrape. Towards this goal, we developed a simulation model with formalisms and parameters based on data from our own experiments and the literature. This model called PheraSys combines 1) a demographic submodel to predict broomrape seed bank dynamics, 2) a trophic-relationships submodel to predict the effect of parasitism on crops and weeds, and 3) a submodel of weed dynamics in agroecosystems to predict the growth of crops and weeds from cropping techniques and pedoclimate. Thanks to an individual representation of each host plant, PheraSys is able to simulate complex heterogeneous canopies. We then used this simulation model to (1) check the consistency of simulations vs. literature data, (2) evaluate the potential of cropping systems to manage the combination of branched broomrape and weeds, (3) investigate whether weeds can biologically regulate parasitic plants in agroecosystems. Five contrasting cropping systems including different levers known to influence broomrape dynamics were simulated with different weather series. Four simulation series were run, with or without broomrape and with or without weeds, to discriminate the individual effects of weeds and broomrape on crop production as well as the effect of weeds on broomrape dynamics. Simulations with PheraSys showed that delayed sowing combined with the use of trap and catch crops are promising for reducing broomrape infestation and yield losses in the long term. Tolerating a temporary and/or low-density weed flora in such cropping systems could improve broomrape management because spring/summer weeds could reduce broomrape seed bank by triggering broomrape germinations that would not reproduce. During cash-crop growth, weed contribution to broomrape infection would be negligible. However, these conclusions are only valid if broomrape-attaching weeds reproduce before broomrape has time to do so, which needs to be checked with field experiments for most weed species.