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Agenda workshop “Herbicide Tolerant Varieties”

May 21st, 2014 – Lindner Hotel – Frankfurt, Germany

8.30 – 8.40 Introduction

8.40 – 10.00 Environmental impacts

1. Assessing the effect of changes of agricultural practices accompanying herbicide-tolerant crops on agricultural biodiversity. A simulation study with a weed dynamics model; Henri Darmency
2. Ex-ante economic and environmental impacts of Herbicide Tolerant maize cultivation in Europe; Tillie and Dillen
3. NK603 Roundup Ready maize I: opportunity to control weeds more effectively in soil conservation tillage systems; Soukup, J., Holec, J., Jursík, M, Venclová, V., Hamouz, P
4. NK603 Roundup Ready maize: II – impact of weed control strategies and soil tillage on non-target epigeal arthropods; Saska, P., Skuhrovec, J., Řezáč, M., Koprdová, S., Němeček, J., Soukup, J.

10.00 – 10.20 Break

10.20 – 11.00 New developments

5. Novel weed control system in herbicide tolerant sugar beet; Ruediger Hain
6. PRACTICAL USE OF GLYPHOSATE TOLERANT RYEGRASS; Jaime Costa, Rafael De Prado and Ivo O. Brants

11.00 – 11.40 **<u>Herbicide Tolerant Wheat</u>**

7. RESISTANCE TO IMAZAMOX IN *Triticum aestivum* CLEARFIELD: PHYSIOLOGICAL, BIOLOGICAL AND BIOCHEMICAL ASPECTS; Rafael de Prado and Antonia M. Rojano-Delgado

8. IMAZAMOX RESISTANCE IN WHEAT: A NEW TOOL FOR CONTROL WEEDS; Rafael de Prado and Antonia M. Rojano-Delgado

<u>11.40 – 13.00 Break</u>

<u>13.00 – 13.40 Herbicide Tolerant Oilseed Rape</u>

9. Performance of Clearfield Oilseed Rape Hybrids (CL OSR) in the conditions of the Czech Republic; Baranyk, P., Malik, S.

10. Impact of imazamox containing herbicides in Clearfield oilseed rape on the development of resistance in black-grass (*Alopecurus myosuroides Huds*.); Jan Petersen

<u>13.40 – 14.40 Herbicide Tolerant Sunflower</u>

11. Herbicide tolerant varieties (HTV's) in sunflower/rice in Greece: current status and future prospects; Chachalis Demosthenis

12. RESPONSE OF TOLERANT SUNFLOWER HYBRID FROM SERBIA TO TRIBENURON-METHYL; Dragana Božić, Sava Vrbničanin, Marija Sarić-Krsmanović, Danijela Pavlović, Christian Ritz

13. Optimization of ClearField and ExpressSun technologies in sunflower , Jursík, M., Soukup, J., Hamouzová, K.

<u>14.40 – 15.20 Monitoring and Stewardship</u>

14. Imazamox-resistant red rice (*Oryza sativa* L*., var. sylvatica*) in Italian Clearfield rice crop: monitoring and risks; Scarabel L. and Sattin M.

15. Stewardship for HT-Varieties – practical experience and future considerations, Matthias Pfenning, BASF SE

<u>15.20 – 16.00 End discussion (next steps) and wrap up</u>

Abstracts

Environmental impacts

1. **Assessing the effect of changes of agricultural practices accompanying herbicide-tolerant crops on agricultural biodiversity. A simulation study with a weed dynamics model; Henri Darmency**

When herbicide-tolerant (HT) genetically-modified (GM) crops are introduced into cropping systems, they profoundly change agricultural practices, most prominently being the introduction of glyphosate to the detriment of other herbicides. Simplified rotations and tillage are also reported. These changes not only affect weeds but also the trophic guilds feeding on weeds. In order to assess unexpected side-effects of introducing HT crops into cropping systems, we upgraded the existing weed dynamics FlorSys model with indicators of weed harmfulness (crop yield loss, technical harvest problems, harvest pollution, field infestation, crop disease increase) and contribution to biodiversity (weed species richness and equitability, trophic resources for birds, insects and pollinators). Simulations were carried out with FlorSys testing actual and prospective cropping systems with HT maize in South-West France (Aquitaine) and North-East Spain (Catalonia). Weed-related biodiversity was most affected by changes in rotations and tillage; earlier sowing and switching to glyphosate had less effect. For instance, simplified rotations reduced vegetal species richness, flora equitability, trophic resources for seed-eating carabids and domestic bees. Conversely, simplified tillage or no-till improved food availability for birds, carabids and bees. We are presently addingÂ a submodel to FlorSys accounting for potential occurrence of herbicide resistance in weeds.

2. **Ex-ante economic and environmental impacts of Herbicide Tolerant maize cultivation in Europe; Tillie and Dillen**

Herbicide Tolerant (HT) maize tolerant to glyphosate is a possible addition to the weed control toolbox of European farmers. We modelled ex-ante the economic and environmental changes associated with the adoption of HT maize in Europe, based on a survey of maize farmers conducted in seven European countries to construct a baseline of current herbicide use and costs. A stochastic partial budgeting model was used to simulate the impacts of adoption of HT maize on farmers' gross margin.We built a first scenario representing the initial years of introduction of the technology (low, fixed technology fee and an herbicide program for HT maize based exclusively on glyphosate). Under these assumptions, the model predicts very high adoption rates (60% to 98% of maize farmers depending on the country). We also calculated the Environmental Impact Quotient Index (EIQ) associated with herbicide use when switching to HT maize. In countries with a high baseline of herbicide use in maize (e.g. Spain or Portugal), the majority of adopting farmers (60-79%) will also experience reductions in EIQ, realising the economic and environmental potential of the technology. In contrast, for countries with low herbicide use such as Germany or France, only a fraction (19-28%) of adopting farmers experiences a decreased EIQ. In this situation, a purely economic-driven adoption may result in increased EIQ for many adopting farmers.We also explored the effects of additional scenarios introducing more complex herbicide programmes for delaying weed resistance and changes in the technology fee of HT seeds. In these scenarios adoption levels decrease but the technology is still economically attractive for a large share of farmers (14-86%), showing that a sustainable use of the technology to lower the risk of weed resistance development is not in contradiction with its economic attractiveness. The pattern of two groups of countries in terms of potential environmental effects remains and calls for a better identification of the subset of farmers with economic and environmental potential for the technology**.**

3. **NK603 Roundup Ready maize I: opportunity to control weeds more effectively in soil conservation tillage systems; Soukup, J., Holec, J., Jursík, M, Venclová, V., Hamouz, P.**

NK603 is genetically modified glyphosate tolerant maize which tolerance is based on inserted gene coding for the protein CP4 EPSPS production was inserted. Positive EFSA opinion for cultivation in EU was published in 2009 (see http://www.efsa.europa.eu/en/efsajournal/pub/1137.htm). Simplification and higher reliability of weed control using glyphosate are expected especially in situations with plant residues on soil surface typical for soil conservation tillage systems.

Large multifactorial trials with NK603 maize were conducted in Central Bohemia in 2010–2012. The aim of the study was to compare performance of three Roundup Ready (RR) strategies with locally common pre- and postemergence herbicide control in three soil tillage systems: i) deep tillage with plough, ii) reduced tillage with forecrop (wheat) stubbles on the soil surface, and iii) no-till system with mulch from died catch crop. Each plot had 600 m^2 in size; all treatments were replicated three times and randomized in blocks. RR treatments were applied as follows: i) split application acetochlor (pre) + glyphosate (maize BBCH 16), ii) split application of glyphosate (maize BBCH 13 and 16-18), and iii) tank mix acetochlor + glyphosate (maize BBCH 13). Herbicide efficacy was assessed according to EPPO guidelines. Crop was harvested by combine and the yield from entire plot weighed directly on the field.

Based on 3-years results, the efficacy and especially the reliability of RR system were better than of the conventional herbicides. The results demonstrate that only one treatment by conventional herbicide (either pre- or postemergence) did not provide satisfactory weed control effect under the field conditions with hard-to-control weeds species and a large soil seed bank. Especially the species like *Convolvulus arvensis*, *Echinochloa crus-galli*, *Polygonum convolvulus* and *Polygonum lapathifolium* were poorly controlled by conventional treatments and shifted then in weed community. Weed control failures of conventional herbicides caused significant yield decrease if they occurred. All RR treatments provided better control effect than conventional treatments because of lower sensitivity to environmental conditions (soil moisture which influences strongly the activity of conventional soil residual herbicides) and uneven weed emergence (which makes difficult the proper timing of the post-emergence applications). Best control effect was found for split (2 times) application of RR herbicide, especially on perennial *Convolvulus arvensis*. However, combinations of the RR with residual herbicide (acetochlor) provided also very good effect which did not differ significantly from split application of RR herbicide alone. RR treatments were more efficient in soil tillage system with mulch because the organic residues can cover the emerging weeds and can bind some amount of active ingredient which does not reach then the soil- or weed leaf surface. Split application of herbicides in RR system had the best reliability in these conditions.

4. **NK603 Roundup Ready maize: II – impact of weed control strategies and soil tillage on non-target epigeal arthropods; Saska, P., Skuhrovec, J., Řezáč, M., Koprdová, S., Němeček, J., Soukup, J.**

As a part of large multifactorial trials with NK603 maize conducted in Central Bohemia in 2010–2012 and described by Soukup et al. (this volume), we tested the effects of different weed control strategies and soil tillage systems on assemblages of non-target epigeal arthropods in 2010-2011.

The experiment was organized as follows: Three soil tillage systems: (i) conventional deep tillage [CT], (ii) reduced tillage with forecrop (wheat) stubbles on the soil surface [RT], and (iii) no-till system with mulch from the catch crop [MU], were replicated three times in 600 m2 blocks, organized in the Latin square design. Five weed control treatments were used in each of the blocks, of which three were Roundup Ready (RR): (i) split application acetochlor (pre) + glyphosate (maize BBCH 16) [PRE_POST], (ii) split application of glyphosate (maize BBCH 13 and 16-18) [GLY_GLY], and (iii) tank mix acetochlor + glyphosate (maize BBCH 13) [EPOST_GLY], and two conventional references: (iv) acetochlor + terbuthylazine (pre) [PRE_CONT], and (v) foramsulfuron + iodosulfuron (post) [POST_CONT]. Epigeal arthropods (carabid beetles [Coleoptera: Carabidae] and spiders [Araneae]) were sampled by means of pitfall traps (plastic cups, 7 cm diameter, filled with ethylenglycol water solution, two replicates per stand) that were operated in five week intervals (May – September). Prior to analysis the samples from the two traps from one stand were combined and pooled across the season, and expressed as the catch size (N individuals) and species richness (N species). All analyses were conducted separately for spiders and carabids and for each year. In the first step the GEE models with Poisson error structure were used to test for the overall effects of tillage and chemical weed control on catch size or species richness, including the possible spatial effects. In the subsequent steps we used GLM with negative binomial error structure in case of the catch size and Poisson error structure in case of the species richness, separating both major effects.

In general, we found significantly interacting effects of tillage and chemical weed control on both spider and carabid species richness and catch size except for spider catch size in 2011.

When the major effects were analyzed separately, we found that the effects were generally weaker for spiders than for carabids, and hardly any effects can be found for species richness in both groups. In 2010, the catch size tended to be highest in the POST_CONT chemical control treatment and in MU tillage treatment. In 2011 the results were much more variable for carabid beetles and no significant effects were found for spiders. Our results suggest that (1) the response of the epigeal arthropods differs between groups possibly due to specific use of the environment and need for habitat structure, and that (2) rather than the character of the treatment the composition of the weed assemblage may be more important determinant of the composition of epigeal assemblages. The latter remain to be analysed.

New developments

5. **Novel weed control system in herbicide tolerant sugar beet; Ruediger Hain**

A novel weed control system for sugar beet is presented. The system is a result of a joint resaerch and development program between BCS-AG Frankfurt and KWSSaat AG Einbeck. A herbicide tolerant sugar beet line containing a single point mutation in ALS has been selected to make use of the leading BCS ALS inhibitors Foramsuluron and Thienecarbazone in sugar beet. This approach for nonGM trait selection has been pursued successfully to generatee fully tolerant sugar beets. The non GM trait is introgressed into elite sugar beet germplasm of KWS. In parallel herbicide registration trials are performed all over Europe by BCS. The introduction of the new weed control system in sugar beet will be available for the farmer from 2017 onwards.

6. **PRACTICAL USE OF GLYPHOSATE TOLERANT RYEGRASS; Jaime Costa, Rafael De Prado and Ivo O. Brants**

A non-genetically modified *Lolium perenne* cultivar –JS501 or GLY RYE- tolerant to glyphosate was introduced in 2013 for commercial use in golf courses. While the use of this variety seems to be at the ealy commercial stages, there is no evidence that any glyphosate formulate has been registered in Spain for application according to a new use beyond the currently approved application conditions. This biotype has been studied in Córdoba under greenhouse conditions, and found to have a 4,69 x glyphosate resistance factor (Tomás-Fernández *et al.,* 2013), similar to the resistance found in previous *Lolium* biotypes (González-Torralva *et al.*, 2012). The nearly similar Replay *Lolium* variety has been proposed in the USA to facilitate control of undesirable grasses such as *Poa annua* without damaging the desirable summer grass *Cynodon dactylon*; January applications of glyphosate at 0,29 kg/ha seem to be the best timings to control *Poa annua* in a *Lolium perenne* at more glyphosate tolerant tillering stage, in a way compatible with the presence of the desirable *Cynodon dactylon* at a dormant stage or prior to reseeding (Flessner *et al.,* 2013). This was not without risk of *Lolium* damage because of spray overlapping and glyphosate should not be used exclusively for weed control to delay the risk of weed resistance (Flessner *et al.,* 2013). We also recommend inclusion of over the top application of glyphosate in the registered conditions of some glyphosate formulation and chemical or mechanical elimination of the glyphosate-tolerant cultivars before they produce seeds when the continuous mowing program is discontinued.

Herbicide Tolerant Wheat

7. RESISTANCE TO IMAZAMOX IN *Triticum aestivum* CLEARFIELD: PHYSIOLOGICAL, BIOLOGICAL AND BIOCHEMICAL ASPECTS; Rafael de Prado and Antonia M. Rojano-Delgado

Imidazolinone (IMI)-resistant crops exhibit insensitivity to herbicides that inhibit the enzyme acetolactate synthase (ALS). The objective of this work was to evaluate the mechanism by which different wheat cultivars develop resistance to imazamox herbicide. The IMI-resistant wheat cultivars (Bicentenario, Dollinco, Impulso, Invento, and Ikaro), commercialised in Chile, were compared to a sensitive cultivar (Pandora S) using several approaches ranging from in vivo and in vitro experiments. The variables evaluated included the dose-response to the herbicide and ALS enzymatic activity. The imazamox dose, expressed as grams of active ingredient per hectare (g a.i. ha-1) that reduced the wheat fresh mass by 50% (ED50), ranged from 151.0 for Ikaro to 1.6 for Pandora S. The herbicide concentrations that inhibited ALS enzyme activity by 50% (I50) were correlated with the ED50, suggesting that the imazamox resistance could be due to a mutation in the ALS enzyme**.**

8. IMAZAMOX RESISTANCE IN WHEAT: A NEW TOOL FOR CONTROL WEEDS; Rafael de Prado and Antonia M. Rojano-Delgado

Clearfield was developed by mutagenesis, in which there is no insertion of imidazolinone-resistant genes, so they are not considered as being genetically modified organisms (GMO). The herbicide most used is imazamox, which is absorbed via leaf and/or root and travels through the plants. Imazamox effectively controls gramineae like Lolium spp, Bromus spp, Phalaris spp, Alopecurus myosuroides, etc., and dicotyledons such as Amaranthus spp, Abutilon theophrasti, Chenopodium album, etc. The objective of this work was the use od imazamox resistant wheat (Clearfield) in the control of five populations of Lolium spp with resistance to diclofop-methyl, iodosulfuron, imazamox and glyphosate. The result obtained show that the Clearfield wheat is an excellent tool for the control of herbicide resistant gramineae with different modes of action to inhibitors of acetolactate synthase (ALS). However, the selection of biotypes of Lolium multiflorum and L. rigidum resistant to herbicides of the sulphonylurea group, and, to a lesser degree, to imidazolinones, will create control problems in the future. It is of prime importance for farmers to know about herbicide resistant biotypes, as well as the mechanisms implicated, before using this new chemical control option. Thus, farmers should follow the recommendations made in Integrated Weed Management (IWM), to forecast and/or delay the appearance of herbicide resistant biotypes**.**

Herbicide Tolerant Oilseed Rape

9. Performance of Clearfield Oilseed Rape Hybrids (CL OSR) in the conditions of the Czech Republic; Baranyk, P., Malik, S.

The breeding of winter CL OSR varieties for European conditions has started recently and their yield performance in registration trials was usually lower than the yield of the best conventional hybrids. The objective of the study was to compare the yield of newly introduced CL OSR hybrids for the Clearfield technology with the conventional standard. The experiment was conducted in the Czech Republic in cooperation with the Union of Oilseed Growers and Processors which is an independent body.

In 2012, exact field experiments were established at 3 different localities (Humpolec, Kujavy, Krasne Udoli) to test the performance of CL OSR hybrids under different natural conditions, typical for the growing of OSR. Two CL OSR varieties (DK Imminent from Monsanto and RG 29001 from Bayer) were tested in the trial. As a reference, a frequently grown conventional hybrid was used. Fields with low weed occurrence were chosen to avoid the effect of herbicides as much as possible. Trials were arranged in a randomized block design, $20m^2$ per plot in three replications. All varieties were treated by the registered rate of conventional herbicide (metazachlor + quinmerac); the block with the two CL OSR hybrids was treated by Cleravis herbicide (metazachlor + quinmerac + imazamox). Plots were harvested in full maturity and yield data statistically evaluated by ANOVA.

The yield evaluation shows that in all localities a higher yield was achieved for both CL hybrids compared to the conventional standard. The highest yield was achieved for both DK Imminent – (6.41 t/ha) and RG 29001 (6.23 t/ha) varieties treated by Cleravis. The yields differed in both cases significantly from the yield of the standard conventional hybrid treated by conventional herbicide. A significant difference in favour of CL hybrids was found even when they were treated by conventional herbicide. This fact confirms a synergism between CL hybrids and Cleravis herbicide.

The results proved a progress in breeding and high-yielding potential of both tested CL OSR hybrids which exceeded the standard conventional hybrid. What was interesting was also a positive effect of treatment by Cleravis herbicide which secured a higher yield also in conditions with lower weed occurrence compared to treatments of CL OSR by conventional herbicide. However, there are only one-year results available, therefore the testing continues and new trials with more CL OSR hybrids are in progress for the 2014 harvest

10. **Impact of imazamox containing herbicides in Clearfield oilseed rape on the development of resistance in black-grass (*Alopecurus myosuroides Huds*.); Jan Petersen**

Winter oilseed-rape was the most common crop in Western Europe where no ALS-inhibitors were used. Due to the introduction of Clearfield winter oilseed-rape varieties, the use of ALS-inhibitors also in oilseed-rape is possible. If the broader use of ALS-inhibitors increases the selection pressure on herbicide resistant weeds and increases their occurrence in the crop rotation is the question of this investigation. Therefore, an outdoor container trial (Ã¡ 350 l, 0.7 mÂ²) was performed starting in autumn 2011. A typical crop rotation of winter wheat/oilseed-rape/winter wheat was simulated in the following three years. Three different black-grass biotypes with characterised resistance pattern and 5 different herbicide programs were analysed. The black-grass biotypes showed different target-site resistance against ACCase- and/or ALS-inhibitors, as well as metabolic activity. Before and after each treatment the numbers of black-grass plants per container were counted. Also the numbers of heads were counted before harvest. Additionally genetic analysis due to PCRs and pyrosequencing of ten survivors per container and year were performed.Black-grass densities varied in a wide range between treatments and biotypes in the rotation. Interactions between biotypes and herbicide sequences were observed. Frequency of ACCase inhibitor TSR was increased in some cases in other it was stable. Initial ALS TSR was very low and could only be found in one biotype. However, due to the use of imazamox herbicides in CL-oilseed rape up till now no increase in ALS TSR or indications of stronger enhanced metabolic resistance could be found. If additional alternative herbicides beside imazamox (like propazamide) are use in Clearfield oilseed rape, there should be no higher speed in resistance evolution in A. myosuroides compared to rotations without Clearfield varieties.

<u>Herbicide Tolerant Sunflower</u>

11. **Herbicide tolerant varieties (HTV’s) in sunflower/rice in Greece: current status and future prospects; Chachalis Demosthenis**

In Greece, mainly rice (0.4 m ha) and to far lesser extent sunflower (12.000 ha) are important regional crops mainly cultivated in central north of the country. Redrice, barnyardgrass and sedges are probably the biggest problems in rice, whereas broomrape in sunflower. Herbicide tolerant varieties are gaining importance in both crops due to their superior control of the above weed species. Currently, almost exclusively all sunflower is HTV’s whereas about 20% is HTV’s in rice. In this presentation, an account of farmer’s acceptance of herbicide tolerant varieties will be presented in terms of specific cvs and traits. A list of possible non-chemical tactics in controlling weeds, and the timeliness of herbicide applications will be presented. In addition, data will be presented regarding the herbicide use rates applied together with the farmer’s attitudes in keeping the seed soil weed seed bank at the lowest levels, and avoid pollen transfer from rice to redrice. A description of the weed management systems, in terms of well-diversified ones, will be presented aiming to show the sustainability of HTV’s systems in the country.

12. RESPONSE OF TOLERANT SUNFLOWER HYBRID FROM SERBIA TO TRIBENURON-METHYL; Dragana Božić, Sava Vrbničanin, Marija Sarić-Krsmanović, Danijela Pavlović, Christian Ritz

Sunflower hybrid tolerant to tribenuron-methyl were made using wild sunflower population with altered ALS (acetolactate synthase) activity as breeding material. As precise level of tolerance has not been determined, its response to tribenuron-methyl was investigated both in a whole-plant bioassay and in field experiments. Plants were treated post-emergence with tribenuron-methyl at four true leaves (0, 22.5, 45, 67.5, 90, 135 g a.i.ha^{-1}; grown in pots) and at four-six true leaves (0, 11.25, 22.5, 33.75, 45, 67.5, 90, 112.5 a.i.ha^{-1}; grown in field). Plant height, fresh weight, dry weight and leaf area were recorded. Also, ALS enzyme activity in different herbicide concentrations (0, 0.01, 0.1, 1, 10, 100 µM) was determined *in vitro*. In addition, chlorophyll fluorescence *in vivo* were evaluated at plants treated with different rates of tribenuron-methyl.

The estimated GR_{50} values for fresh weight, dry weight and leaf area were 225, 196 and 341 g a.i. ha^{-1}, respectively, while I_{50} value was 63 µM. Chlorophyll fluorescence parameters (Fo, Fv/Fm, Φ_{PSII}, Fv) were responded to tribenuron-methyl, but several days after application they were stabilised. In summary, the results of this study confirmed high level of tolerance of sunflower hybrid tolerant to tribenuron-methyl.

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13. Optimization of ClearField and ExpressSun technologies in sunflower; Jursík, M., Soukup, J., Hamouzová, K.

Four small plot trials were carried out in herbicide tolerant sunflower in Prague in 2010–2013. Aim of the experiments was to optimize the use of ClearField and ExpressSun technologies in sunflower for local conditions of Central Europe.

Herbicide Pulsar 40 (imazamox, for ClearField technology) controlled sufficiently all tested weeds (*Chenopodium album*, *Amaranthus retroflexus*, *Echinochloa crus-galli*, *Mercurialis annua*, *Solanum physalifolium*), when application was carried out in early growth stages of weeds (BBCH 12-14). Late application of herbicide Pulsar 40 (BBCH >16) showed lower and slower efficacy, mainly on *C. album*. In some years, adjuvant Dash increased efficacy of herbicide Pulsar 40 especially on *C. album* and *E. crus-galli*. From Clearfield treatments, highest efficacy and yield of sunflower were recorded after split application of herbicide Pulsar 40 (0.65 + 0.60 l/ha) in all experimental years. Herbicide tank mix (TM) combinations of herbicide Pulsar 40 (tested with flumioxazin, pethoxamid and aclonifen) caused strong sunflower injury and the efficacy usually decreased.

Herbicide Express 50 WG (tribenuron, for ExpressSun technology) had excellent efficacy on *C. album* but did not controlled *E. crus-galli*. Grass weeds can be controlled by ACCase inhibitors or by some pre-emergent herbicides; dimethenamid, pethoxamid and S-metolachlor were tested for this technology. However, in dry condition, efficacy of soil herbicide decreased and *E. crus-galli* was not controlled sufficiently. In cold conditions, TM combination of herbicide Express 50 WG with ACCase inhibiting herbicides caused injuries on ExpressSun sunflower, especially hybrids with lower tolerance to tribenuron (heterozygotes).

Monitoring and Stewardship

14. **Imazamox-resistant red rice (*Oryza sativa* L., var. sylvatica) in Italian Clearfield rice crop: monitoring and risks; Scarabel L. and Sattin M.**

Red rice is a troublesome weed of cultivated rice that is very difficult to control because of its close genetic relationship to the commercial rice. The development of imidazolinone-tolerant rice (known as Clearfield® rice) therefore constitutes a good opportunity to control red rice infestations. In Italy, the cultivation of the Clearfield varieties has been adopted since 2006 and since then it has been increasingly successful with new varieties appearing on the market. Despite the stewardship guidelines for Clearfield technology management to lower the risk of herbicide resistance spreading from cultivated rice to red rice, imazamox red rice survivors were soon reported by farmers. Fields in the Piedmont and Lombardy regions were monitored from 2010 to 2013. Herbicide resistance was analysed by whole-plant imazamox bioassay and molecular analysis in the search for the nucleotide variation in the ALS gene responsible for the tolerant phenotype. The results showed that 29 red rice populations out of 47 were imazamox-resistant and that the Ser to Asn substitution at locus 563 of the ALS gene is responsible for the resistance. Farmers frequently grow Clearfield varieties for more than two consecutive years so increasing the selection pressure exerted by imazamox and favouring the evolution of resistant red rice. To maintain the sustainability of this new technology, proper management must be implemented.

15. Stewardship for HT-Varieties – practical experience and future considerations; Matthias Pfenning

The introduction of “Herbicide Tolerant Varieties” into European agriculture supports agronomic trends like the shift to reduced tillage, postemergence weed control and the aim for integrated weed management (IWM). Herbicide Tolerant Varieties, like all crop production technology, come with benefits but also raise questions in the public and in the agricultural production chain from farmers to distribution and advisory level. Stewardship guidelines have been developed to address issues like weed resistance development, volunteer control and outcrossing of the herbicide tolerance to closely related wild species. Stewardship guidelines are based on Good Agricultural Practice (GAP) as the introduction of Herbicide Tolerant Varieties should not deviate from these tried and true principles. Practical examples for Clearfield sunflower and rice will be discussed. Herbicide resistance issues are considered to have the most impact in a cropping system with HT- Varieties. However, farmers are often adverse to implement proactive stewardship programs for short term economic returns as long as there is no significant problem present. Stewardship practices have to come from a passive implementation (e.g. brochures and labels) to a proactive stewardship on farm and field level.