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Polskie Towarzystwo Ochrony Roślin

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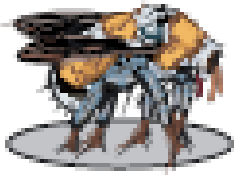

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IPM for Annual crops

WINTER WHEAT BASED ROTATIONS – AGRONOMIC EVALUATION OF IPM STRATEGIES

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Six multiyear field experiments were conducted comparing the agronomic, economic and environmental performance of current practice and two IPM strategies (named intermediate and advanced IPM, respectively) in winter-wheat based crop rotations. In this presentation, the results of the agronomic performance are presented. The experiments were conducted in Denmark, France (2 locations), Germany, Poland and Scotland. The experiments in Denmark, Germany, Poland and Scotland were initiated as part of PURE and have only run for three years while the two French experiments were on-going experiments designed to study other aspects than IPM implementation. The four experiments in Denmark, Germany, Poland and Scotland were 3-year rotations including only the three strategies. The French experiments had more treatments and current practice and the two IPM strategies were chosen among the treatments. In one of the French experiment advanced IPM was a 'no pesticide' scenario while in the other one it was an 'organic' scenario. Except for the German trial, crop rotation was part of the IPM strategies. Decision on pesticide use varied between trials. In some trials Decision Support Systems were used while in others the same pesticides were used in the IPM strategies as for the current practice but at reduced doses. Advanced IPM typically included mechanical weeding and resistant varieties, variety mixtures, delayed sowing and other non-chemical tactics.

In general weeds, diseases and pests were well controlled with current practice and the intermediate IPM strategy while unsatisfactory control was observed with the advanced IPM strategy in some years at some locations. Winter wheat yields at intermediate IPM were comparable to and in some cases lower than those at current practice while yields at advanced IPM generally was lower than at current practice. Yield losses were highest in the two French trials where the advanced IPM received no pesticide applications. In some cases yield losses could be attributed to the applied IPM measures, e.g. delayed sowing, while in other cases it was caused by an insufficient pest control. Pesticide use was significantly reduced in both the intermediate and advanced IPM treatments compared to current practice. Lessons learnt from the experiments were that variety mixtures are a very effective tool for reducing the impact of disease pressure and thus fungicide use, that inter-row cultivation is very effective in winter oilseed rape while the performance of weed harrowing was variable. The study also showed that omitting the use of pesticides can result in pronounced yield losses in winter

wheat but also revealed that there is considerable scope for reducing pesticide use in winter wheat by adopting IPM measures without significant yield penalties.

No significant long-term effects of the IPM strategies were observed but the experiments will continue for another 3 years where e.g. a potential long-term effect of a reduced herbicide input on the weed flora is expected to become visible.

WINTER WHEAT BASED ROTATIONS – ECONOMIC AND ENVIRONMENTAL EVALUATION OF IPM STRATEGIES

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The Directive 2009/128/EC requires the reduction of risks for human health and the environment as well as the mandatory implementation of the general principles on IPM. The assessment of the environmental impact and the economic feasibility of IPM systems are essential for farmers across Europe to meet the challenge.

The PURE the work group on winter wheat based rotations tested two different levels of IPM, an intermediate IPM (IS) and an advanced IPM strategy (AS), during three years in three geographical regions: i) North: Denmark and Scotland, ii) Central: Germany and Poland and iii) South: two locations in France. The on-station experiments covered the natural variation in pest occurrence, pest pressure and current practices (CS). Intermediate IPM and advanced IPM are employ a more diverse crop rotations by including spring-/ summer crops, the use of disease resistant varieties, diversification of cultural practices, extended use of existing warning and forecasting systems and crop-pest models. The IS focused on controlling the pests individually by employing a mixture of preventive and direct control methods to optimise control and minimise the risk of outbreaks. Additionally, cover/mulch crops, variety mixtures, delayed sowing dates in winter wheat and soil cultivation techniques and non-chemical tactics, including electron treatment of seeds, were tested in the AS. The interactions between pest categories were considered and preference was given to non-chemical methods also when these methods are not as effective as pesticides. Pesticide use was significantly reduced and preference given to selective pesticides.

The outcomes of the region-wise environmental assessment with SYNOPS and the results of the cost-benefit-analysis are presented.

Pesticide use was significantly reduced in the IS and AS compared to CS. As a result, the environmental risk assessment with SYNOPS shows a reduction of risks for aquatic organisms and the overall risk respectively for CS, IS and AS.

The cost-benefit-analysis evaluated the performance of the rotations across all on-station experiments. The gross margins were lower than in the CS in IS (2–44%) and AS (11–60%) respectively. An exception are the results of the Grignon on-station experiment (France) were the yields were higher and pesticides costs lower in the IS than expected, which resulted in higher production value and a 13% increase of gross margin compared to CS. The results indicate that the intermediate IPM systems in winter wheat based rotations can achieve a reduction of the environmental risks. The economic results deviate from the reference systems depending on the region and the possible yield penalties of the new IPM elements.

MAIZE-BASED ROTATIONS – AGRONOMIC EVALUATION OF IPM STRATEGIES

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Previous analyses highlighted that weeds and the European corn borer (ECB, *Ostrinia nubilalis* Hübner) are the major maize pests in Europe. Within the European Project PURE, fifteen on-farm trials were set up in five European countries (France, Germany, Hungary, Italy and Slovenia) during 2011–2014, to evaluate various IPM tools in grain maize, compared to the conventional strategy (CON). IPM tools tested against weeds included: 1) early post-emergence herbicide band application combined with hoeing (all countries), 2) early post-emergence herbicide broadcast application when indicated by a predictive model of weed emergence and after performing one scouting in the field (Italy), 3) tine harrowing at 2–3rd leaf stage of maize and low dose of post-emergence herbicide (Slovenia), and 4) mechanical weed control with harrowing and hoeing (Germany). Overall, IPM tools tested provided sufficient weed control without significant differences in yields and greatly reduced maize reliance on herbicides. Exception was the mechanical weed control that had low weed control and significantly reduced yields. IPM tools tested against ECB included biological control 1) using *Trichogramma brassicae* (all countries) and 2) Bt spraying (bio-insecticide using *Bacillus thuringiensis* var. *Kurstaki*) in Italy, Hungary and Slovenia. No differences were determined between IPM tools and CON in terms of plant damage and yields, whereas ECB pressure differed between countries.

Long-term on-station experiments (in France, Hungary and Italy) were also conducted during this period to evaluate two systems with different IPM level (IPM1-advanced and IPM2-innovative) against the CON in maize-based rotations. In France, IPM1 and IPM2 consisted of maize/soybean rotation with different levels of IPM against the CON continuous maize. In Italy and Hungary, IPM1 consisted of maize/winter wheat/soybean (peas in Hungary) rotation and IPM2 of maize/winter wheat/ (cover crop) soybean (peas in Hungary) (cover crop) rotation, both against the CON maize/maize/winter wheat rotation. Maize plant stand was optimal in all plots-countries due to general low pressures of soil pests. In France, weed control and maize yields were similar between CON (broadcast pre- and post-emergence herbicide) and IPM1 (broadcast pre-emergence, post-

emergence in band plus hoeing), whereas weed control and yields were lower in IPM2 (pre-emergence in band plus hoeing). First analysis of the data in Italy showed that CON (broadcast pre- and post-emergence herbicide plus hoeing) had higher weed control and maize yield, followed by IPM1 (pre- and post-emergence in band plus hoeing) and IPM2 (post-emergence in band plus hoeing). Total broken plants (below and above maize ears; %) by ECB was higher under the IPM2 strategy (bio-insecticide; Bt) compared to the selective insecticide in IPM1 and broad spectrum insecticide in CON. In Hungary, CON (broadcast application) had higher weed control than IPM (band application) but similar yield with IPM1. Overall, it can be concluded that IPM implementation and success depend on specific local conditions as well as the level of weed and pest pressures. Knowing the history of the field in terms of weeds and monitoring pests and weeds during the growing season will determine the choice of IPM tools and the level of IPM implementation.

MAIZE-BASED ROTATIONS – ECONOMIC AND ENVIRONMENTAL EVALUATION OF IPM STRATEGIES

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Within the European Project PURE, on-farm trials were set up in five European countries (France, Germany, Hungary, Italy and Slovenia) during 2011–2014, to evaluate IPM tools against weeds and the European corn borer in grain maize, compared to the conventional strategy (CON). IPM tools tested against weeds included: 1) early post-emergence herbicide band application combined with hoeing (all countries), 2) early post-emergence herbicide broadcast application when indicated by a predictive model of weed emergence and after performing one scouting in the field (Italy), 3) tine harrowing at 2–3rd maize leaf stage and low dose of post-emergence herbicide (Slovenia) and 4) mechanical weed control with harrowing and hoeing (Germany). Cost-benefit analysis and the SYNOPS model were used to assess the economic and environmental impact of IPM tools vs. CON. Averaged over all tested IPM tools, total costs were lower in IPM compared to CON (–€5/ha). Gross margin was reduced in IPM (–€70/ha), but similar to CON when the only mechanical weeding tool was excluded. IPM tools against ECB were the biological control with *Trichogramma brassicae* (all countries) and Bt spraying (bio-insecticide; *Bacillus thuringiensis* var. *Kurstaki*) in Italy, Hungary and Slovenia. Total costs were higher in IPM compared to CON and ranged between +€20 to +€140/ha, with an average of +€70/ha. If only the trials in which a spraying was done in CON (Italy and Hungary) were considered, total costs increase ranged from +€5 (Bt-spraying) to +€20/ha (*Trichogramma*) in Italy and +€70/ha (*Trichogramma*) in Hungary. The difference in gross margin between IPM and CON ranged from –€155 to +€85 €/ha, with an average of –€55/ha. SYNOPS evaluation indicated a lower environmental risk of IPM vs. CON.

Long-term experiments were also conducted to evaluate two systems with different IPM level (IPM1-advanced and IPM2-innovative) against CON in maize-based rotations. In France, IPM systems consisted of maize/soybean rotation with different levels of IPM against the CON continuous maize. In Italy and Hungary, IPM1 consisted of maize/winter wheat/soybean (peas in Hungary) rotation and IPM2 of maize/winter wheat/ (cover crop) soybean (peas in Hungary) (cover crop) rotation, both against the CON

maize/maize/winter wheat rotation. IPM-based strategies aimed at the reduction in or sustainable use of pesticides (e.g. band application of herbicides, mechanical weeding, bio-insecticide to control ECB). The ex-post assessment of their sustainability using an adapted version of the DEXiPM model indicated that the environmental sustainability of CON is “low” in the three countries, but improves to “medium to high” in the IPM systems. The economic sustainability of CON is medium in all three countries. The IPM systems had higher sustainability in Italy (in both IPM systems), but lower in Hungary (in both IPM systems) and France (in IPM2) as the gross margin averaged over the rotation level was lower than for CON.

Overall, IPM was found to have lower environmental impact, whereas its economic sustainability depends on changes in costs of IPM tools, possible yield reductions and type of crops in the rotation compared to CON systems. IPM implementation is more profitable when replacing intensively managed conventional systems.

FIELD VEGETABLES – IPM-SOLUTIONS READY TO USE IN PRACTICE

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Due to new regulations IPM is mandatory in the EU since 1st January 2014. In the framework of the PURE-Project a range of different IPM solutions were designed for diverse *Brassica* crops as a model crop. These solutions were tested in six European countries with different growing and climate conditions: Denmark, France, Germany, Scotland, Slovenia and the Netherlands. *Brassica* crops were chosen as they require a high input of pesticides due to a wide range of pests attacking cultivated plants. The overall aim of the project was to reduce the reliance on pesticides and their risk to human health. Several innovative approaches were tested in on-station experiments. Promising IPM strategies were then tested on-farm.

The challenge for weed control was to get along with no herbicides. Experiments with non-intelligent and intelligent mechanical weed control techniques, including innovative devices, show that in principle the cultivation of transplanted *Brassica* crops is possible without using any herbicides. The trials also indicated that successful mechanical weed control was strongly dependent on the weather conditions. Non-chemical methods performed well in dry periods and were less effective when the soil was wet.

Several approaches were tested to control the cabbage root fly *Delia radicum* as it is the most important pest in cruciferous crops. Besides some approved chemicals like spinosad, only the use of entomopathogenic nematodes *(Steinernema feltiae)* and to some extent the release of predatory mites (*Macrocheles robustulus*) show promising results for controlling this major pest. At the moment the use of entomopathogenic fungi such as *Beauveria bassiana* or *Metarhizium anisopliae*, nitrogen lime (PERLKA®) and straw mulch cannot be recommend to combat this pest. Push-pull' strategies have also been tested against adults (France) and larvae (Scotland), but require further development (eg slow release formulations of bio-active plant volatiles).

Concerning aphid and caterpillar control, all tested products like the broad spectrum insecticides thiacloprid (Calypso®) and lambda-cyhalothrin (Karate Zeon®)), the selective insecticides indoxacarb (Steward®) and pirimicarb (Pirimor®) and biological products *Bacillus thuringiensis* subsp. *aizawai* (XenTari®) and rape oil (Micula®) performed well in controlling these pests even when applied after action thresholds were exceeded. When using biological products the number of sprays per season

was slightly higher and their efficacy lower compared to chemical pesticides.

As swede midge and flea beetles are an increasing problem in several countries such as Slovenia, more attention have to be paid on these pests in the future.

CHEMICAL ECOLOGY STUDIES OF BRASSICAS TO UNDERSTAND AND INFLUENCE INFESTATION LEVELS BY THE CABBAGE ROOT FLY ADULTS AND LARVAE; TOWARDS A 'PUSH-PULL' STRATEGY FOR IPM

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Several plant traits above and below ground affect plant-insect interactions and shape host range and performance of herbivorous insects according to their degree of dietary specialization. Understanding these traits is of interest for the development of alternative crop protection strategies. In an Integrated Pest Management (IPM)context, an appropriate selection of plants can modify pest distribution at the field and plant scale. *Delia radicum*, the cabbage root fly (CRF), is a major pest of brassicaceous crops for which sustainable control strategies are currently lacking. In order to develop a "push-pull" strategy against the adults of cabbage root fly, we conducted a field study to both determine which plants affected pest infestation levels and influence egg-predation activity. This revealed that infestation levels of brassicaceous plants can vary considerably according to plant genotype and species, while the number of predated CRF eggs is only slightly affected by plant species. In a "push-pull" context, we demonstrate that different plants could be used to redistribute cabbage root flies in broccoli crops without compromising hcontrol by natural enemies. The importance of plant volatiles for infestation levels suggests a potential for developing a semiochemically assisted 'push-pull' system in which trap plants would be enhanced by release of attractive compounds.

Volatiles resulting from plant herbivore interactions play an important role in the behavioral decisions of phytophagous, predatory and parasitoid insects and could be used forIPM. However, documented studies on applications in the field remain extremely scarce. We have shown that dimethyl disulfide, a major compound emitted by brassica roots heavily infested by *D. radicum* larvae, was attractive for its main natural enemies and could lower the number of eggs laid by 60%. We conducted another field study to select additional volatiles that could be used in a push-pull approach. Several synthetic HIPVs, selected for potential action on the behavior of both the fly and its natural enemies, were placed in odor dispensers in broccoli plots. We confirmed the role of dimethyl disulfide in reducing *D. radicum* egg numbers on broccoli plants and identified other compounds that both influenced plant infestation by the fly and regulation by its main natural enemies. This is a first step in designing a push-pull method to control the adult CRF.

Specialised sampling techniques for identifying root volatiles *in situ* were developed and verified under laboratory, glasshouse and field conditions. SPME sampling combined with GC-MS analysis of time course studies identified a number of key root volatiles induced by larval damage. Several non-hosts were compared with host root volatiles using a video tracking bioassay (Ethovision software).

Like CRF adults, larvae strongly responded to DMDS, showing a characteristic dose response. Root volatiles of onion (which share similar sulfur-based metabolites) was also highly attractive to larvae, indicating that adults make a more informed choice but larvae also respond to selected root volatiles. The identification of phytochemicals which either attract, repel or are toxic to larvae will be discussed in relation to future 'push-pull' strategies based on the chemical ecology of above-below ground interactions of this important pest and its natural enemies.

DECREASED FITNESS OF HERBICIDE RESISTANT WEEDS SUGGESTS OPTIONS FOR MANAGEMENT. CASE STUDY: *ECHINOCHLOA CRUS-GALLI*

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One of the major issues in weed management is herbicide resistance. The continuous build-up of herbicide resistant populations urges the implementation of Integrated Weed Management (IWM) to establish more sustainable cropping systems. This suggested new studies on the population dynamics to check if and how the resistance evolution process may be reversed through the implementation of important components of IWM such as crop rotation. Theoretically, to change the R/S plant ratio it is necessary that an agronomic fitness cost is present.

Several ALS-resistant populations of *Echinochloa crus-galli* have been found in Italian maize crops, mostly where continuous maize is cultivated. The aims of the research were: 1) to follow the evolution of R/S allele ratio when the selection pressure exerted by acetolactate synthase (ALS)-inhibiting herbicides is removed through the introduction of crop rotation and the use of alternative herbicides with a different site of action; 2) to characterize the possible fitness costs associated to the ALS-resistant *Echinochloa crus-galli* biotype.

Two situations were monitored in a field heavily infested by ALS inhibitors cross-resistant *E. crus-galli*:

a) continuous maize with the best herbicide resistance weed management based on chemical solutions;

b) three-year rotation (maize-wheat-wheat) plus final year with maize and no ALS treatments. Two seed stocks, susceptible (S) and resistant (R) with similar genetic background, were preliminarily selected from plants harvested in the experimental site and a three-year comparative growth analysis was conducted in the field. Barnyardgrass plants were grown without competition or in competition with plants of the other biotype (i.e. the S target was surrounded by plants of the R biotype and vice-versa) at three plant densities (3, 7 and 20 plants m^{-2}).

Molecular analysis indicates that a target-site mediated resistance mechanism due to a double mutation GC-AA, giving an Ala-Asn change in position 122 of the ALS gene, is involved in the R biotype. Weather conditions were very different during the three-year experiment (in particular in the second year). In general, a different development of the two biotypes was observed: R seeds germinated later than S ones and the development of R plants was delayed by about one week. This delay was maintained during the whole plant life cycle. In the first and third year, S plants produced significantly more panicles than R ones at all densities, whereas in the second year results were different for the spaced and 7 plants m^{-2} treatments. This indicates that a fitness cost is present in the resistant biotype, but that it is affected by weather conditions and, in particular, by rainfall and sowing time.

These results could be a good starting point for devising a resistance management strategy based on the differential population dynamics between R and S biotypes. The tested crop rotation coupled with the lack of selection pressure from ALS-inhibiting herbicides did not induce any change in the R/S plant ratio. This indicates that in a situation where ALS-resistance is well established, crop

rotation and lack of selection pressure alone do not provide short-terms effects, so depletion of the resistant seed bank is the only way forward.

DECREASED FITNESS OF HERBICIDE RESISTANT WEEDS SUGGESTS OPTIONS FOR MANAGEMENT CASE STUDY: *ALOPECURUS MYOSUROIDES*

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Quantifying fitness cost has practical implication in HR management programs especially in IPM. This study investigated the main characteristics determining plant fitness in the entire life cycle of susceptible (S) and resistant (R) phenotypes from two Danish non-target site resistant *Alopecurus myosuroides* populations (ID33 and ID914). The competitiveness of S and R phenotypes in winter wheat was compared using the target-neighbourhood method. No significant differences were found in vegetative and reproductive ability between S and R phenotypes in two years glasshouse experiments and one year field experiment. The effects of temperature regimes (optimum; 17/10°C and low; 10/5°C day/night) and sowing depths (0, 1, 3, and 6 cm) on seedling emergence of non-dormant seeds were evaluated in pot experiments in a growth chamber. No significant differences in final emergence (E_{max}) across sowing depths were found between S and R phenotypes selected within population ID33. In population ID914, E_{max} of the R phenotype was lower than the S phenotype. Seeds of S phenotypes tended to emerge faster (low T_{E50}) than their corresponding R phenotypes especially at sub-optimal conditions. The burial depth inhibiting 50% of the final emergence (D_{50}) was similar for phenotypes of ID33 population. In contrast, the resistant ID914 phenotype had significantly lower D_{50} compared with the susceptible ID914 phenotype at low temperature. The results clearly revealed that at sub-optimal conditions the NTSR loci conferring herbicide resistance to R-ID914 were associated with lower fitness considering seedling emergence traits. The subtle fitness costs in R phenotype of ID33 population corresponded with a low resistance level compared with R-ID914. The results suggest that deeper soil cultivation and delayed sowing of autumn sown crops can make an unfavorable environment for R phenotypes. This study provides evidence for the hypothesis that fitness cost will increase in stressful condition. The results could easily be implemented in simulation models to predict the impact of timing and depth of soil cultivate on the proportion of resistant individuals in an *A. myosuroides* population.

AIRBORNE SAMPLING AND OPTICAL SENSING METHODS FOR MACRO SCALE MAPPING

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Emerging technologies evaluated in the PURE project can provide practical solutions to improve disease control in response to temporal and spatial differences in epidemics of fungal plant diseases. Evaluation of optical sensing methods to map disease foci for spatially selective treatment, found that remote sensing using satellite images has limited potential for disease control, except for mapping relatively static patches of some soil-borne diseases. Currently available data has relatively poor resolution (usually >1m^2 pixel size) and there are problems of revisit time and cloud cover. Secondly, because most fungicides are protectants rather than eradicants, established disease foci, which harbour a zone of incubating symptomless disease around them, are not controlled so for widely-dispersed polycyclic pathogens such as powdery mildews and rusts, by the time a few foci have been detected in a field, it is necessary to spray the entire field. More sophisticated proximal imaging techniques have greater ability to detect earlier, even pre-visible symptom stages of disease development for targeted control.

For diseases that develop from airborne inoculum, timing of disease control methods can now be improved using automated air sampling devices, integrated with appropriate diagnostic methods. A system developed under the 'SYield' project using an air sampler developed partly in the PURE project, has produced promising results for automatic detection of spores of *Sclerotinia sclerotiorum* in recent testing in Canada. Further development is ongoing to integrate the same MVI air sampler with novel isothermal DNA-based diagnostics. We can expect a new approach to precision agriculture to emerge from this technology – farm-based devices that give precision on when to apply fungicides and when to omit applications that may have previously been advised purely on weather-based infection risk, but which growers will know can be omitted if inoculum is not present. The technology will reduce costs and the environmental impact of farming.

Air sampling integrated with DNA analysis can also be used to monitor species composition and genetic changes within a species, such as fungicide resistance. Burkard seven-day spore traps were operated at rooftop level at Rothamsted Research (UK), Wageningen (NL) and at Slagelse (DK) for periods in the autumn and spring during 2011–2013. DNA extracted from daily samples was analysed using 454 amplicon sequencing. Numerous genera of fungal plant pathogens were detected.

A GENERIC DECISION SUPPORT SYSTEM FOR INTEGRATED WEED MANAGEMENT

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In the EU project 'ENDURE', 9 European Decision Support Systems (DSS) on integrated weed management (IWM) were analyzed. In the context of Directive 2009/128/EC, 'best parts' were identified, and a 'proof of concept' was designed. This DSS design specifically addresses 7 of the 8 general principles in the directive.

The DSS design includes best parts originating from 3 DSS, designed in Italy, France and Denmark, respectively. The DSS IT system architecture was designed as a generic frame suitable for customization for different countries, crops, climatic zones, etc. Using maize as a model crop, operational, online DSS prototypes were customized and made operational online for weed control in Slovenia, Italy and Germany.

These DSS prototypes include two different principles for quantification of needs for weed control, and integration of chemical and non-chemical (mechanical) control was enabled, too, however as proof of concept only.

Field experimentation in 2011 and 2012 in the 3 countries showed that the efficacy of pre-emergence applications of herbicides (existing practice) did not differ significantly from early post-emergence applications. This time-shift enables the DSS to evaluate needs for control and to target the use of control measures, including inherent characteristics of weed species, which is a basic principle in context of IPM.

In 2013 and 2014, field validation trials were conducted in the 3 countries, where DSS prototypes were tested against local 'best practice' recommendations. For practical reasons, mechanical control was not included in these trials. Results on yield and residual weed infestations indicate that some DSS prototypes controlled the weeds on level with local best practice treatments, and in some cases with a relatively low input of herbicides, too. These results indicate that the DSS design possess generic qualities, which may be suitable and potent for upscaling.

DELIVERING SUSTAINABLE FARMING THROUGH ON-FARM IMPLEMENTATION OF INTEGRATED FARM MANAGEMENT

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Land, water, biodiversity and natural habitats are under pressure from competing demands. Sustainable intensification is not about increasing the use of inputs, it is about wisely using knowledge and technologies, to grow production efficiency and intensify natures' interactions and benefits, through a more integrated approach.

Farmers need to be recognised for how they have adapted to the radically changed demands placed on our food system over the last 20 years. Encouragingly, new management approaches, environmental stewardship, market demands, social and environmental responsibility, improved engagement with retailers and closer relationships with consumers are all starting to help re-design our food systems.

Measuring such approaches is critical in order to help identify the most effective means of production; benchmark strengths; and create new solutions for reducing negative impacts. The LEAF Audit, and its new phase: the LEAF Sustainable Farming Review, built around the framework of Integrated Farm Management (IFM), is one such tool. Supporting farmers to build on their strengths and develop their businesses in a more sustainable, robust and resilient way.

The LEAF Audit is an online self-assessment management tool used by farmers in 33 countries, representing over 1.1million hectares, to help continually improve their implementation of IFM, a whole farm business approach that delivers sustainable farming.

Since its development in 1991, technology has changed significantly and the LEAF Audit has tracked changes over time of practices and processes implemented by farmers. LEAF has developed scoring based on responses from the LEAF Audit that show farm businesses are performing better in economic performance and environmental quality with a lower, but more rapidly improving, score in social health.

The LEAF Audit as a decision support system provides benefits in two ways: directly to farmers to encourage continual improvement of on-farm practices consistently throughout a world-wide supply chain base; indirectly through reporting on scores which allows information and support to be targeted in areas which most need it and demonstrating the performance of supply bases to others in the supply chain.

In 2015, the LEAF Audit will be replaced with the LEAF Sustainable Farming Review which will further improve usability, and implementation, for farmers, allowing more effective analysis and interpretation of the data for the benefit of LEAF, supply chains and the industry. In addition to the qualitative data, new metrics for more quantitative data are being developed.

As the need to develop farming systems that deliver more sustainable production increases, it is critical that we have the capability to track the changes that work and those that do not. The LEAF Audit and its new replacement: the LEAF Sustainable Farming Review, are effective management tools used by farmers to develop their farm businesses for the long term.

MANIPULATING FIELD MARGINS TO INCREASE PREDATION INTENSITY IN WINTER WHEAT (*TRITICUM EASTIVUM*) FIELDS IN DENMARK

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Habitat manipulation is a well-known practice in conservation biological control in order to enhance natural enemy density, and is a valid alternative to pesticide use. However, due to the striking differences in their ecology, generalist and specialist predators may show different response to habitat manipulation interventions. Moreover, clear evidence that to higher density of predators correspond higher density of predation may be not easy to find, due to possible undesired effects (i.e. intraguild predation, cannibalism, hyperparasithism). Additionally, quantitative estimations of predation rate are difficult to obtain, as predation may remain undetectable (i.e. hidden, night). We recorded the composition of predatory arthropod guild and predation rate within and along the edges of winter wheat (*Triticum aestivum*) fields surrounded by flowery or grassy strips from May to July 2014 in Denmark. Predators were collected using pitfalls traps and a suction sampler, while predation rate on aphids was measured using various exclusion cages (open, partially excluding, and totally excluding as control), and sentinel prey made of plasticine, that allows the identification of the predator marks. Ground beetles (Carabidae), rove beetles (Staphylinidae), spiders (Aranea), and parasitoid and predatory wasps (Hymenoptera) were the most common natural enemies during the experiment. We found significantly lower number of generalist predators (but not specialists) in flower vs grass margins ($p<0.05$) from the suction samples. Activity density recorded using pitfall traps did not show significant difference in flower vs. grass margins for either specialist or generalist predators. Mean survival time of in-field aphid colonies was shorter (5.8 days) near flowery vs. grassy (9.9 days) edges. However, the Biological Control Index was not different. Forty-six % (n=756/1637) of the sentinel prey were attacked after 24 h mostly by chewing insects (88%, n=665/756 of the bites), followed by small mammals (13.2%, n=100/756), and birds (1.3%, n=10/756). Predation rate by chewing insects was higher in grass than flowery margins (48.9%, n=436/892 vs. 30.7%, n=229/745), and also higher in the edge than within field (45.3%, n=371/819 vs. 35.9%, n=294/818). In the flowery strips, predation was slightly higher within the field than in the edge (30.9%, n=115/372 vs. 30.6%, n=114/373, respectively), while in grassy ones, it was higher in the edge than within field (57.6%, n=257/446 vs. 40.1% n=179/446). Our preliminary results suggest that flowery strips enhance specialist but not generalist predator abundance in the field edges, and that a correlation between generalist predator abundance (especially of ground beetles) and predation rate on artificial sentinel prey may exist.

IPM-STRATEGIES FOR CEREAL PRODUCTION – A NORWEGIAN CASE STUDY 10

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In Europe there is an on-going process on implementing regulations aimed at reducing pollution from agricultural production systems, i.e. the Water Framework Directive and the Framework Directive for Sustainable Use of Pesticides. At the same time, there is an increasing focus on food security possibly leading to continued intensification of agricultural production with increased use of external inputs, such as pesticides and fertilizers. Application of sustainable production systems can only be achieved if they balance conflicting environmental and economic effects. In Norway, cereal production is of large importance for food security and reduction of soil and phosphorus losses, as well as pesticide use and leaching/runoff in the cereal production are of special concern. Therefore, we need to determine the most sustainable and effective strategies to reduce loss of top soil, phosphorus and pesticides while maintaining cereal yields. A three-year research project, STRAPP, is addressing these concerns.

A catchment area dominated by cereal production is our common research arena within STRAPP. Since 1992 a database (JOVA) with data for soil erosion, nutrient and pesticide leaching/runoff (i.e. concentrations in stream water), yield, and agricultural management practices (fertilization, use of pesticides, soil tillage and rotations) has been established for this catchment allowing us to compare a unique diversity in cropping strategies in a defined location.

An important part of STRAPP focuses on developing 'best plant protection strategies' for cereal fields in the study area, based on field inventories (manual and sensor based) of weeds and common diseases, available forecast systems, and pesticide leaching risk maps. The results of field studies during the growing seasons of 2013 and 2014 will be presented, with a focus on possible integrated pest management (IPM) strategies for weeds and fungal diseases in cereal production. We will also present the project concept and methods for coupling optimized plant protection strategies to (i) modelling of phosphorus and pesticide leaching/runoff, as well as soil loss, and (ii) farm-economic impacts and adaptations. Further, methods for balancing the conflicting environmental and economic effects of the above practices, and the evaluation of instruments for increased adoption of desirable management practices will be outlined.

TRACING EXPERIMENT TO EVALUATE THE FATE AND BEHAVIOUR OF A PESTICIDE'S MIXTURE UNDER 11

CONTROLLED CONDITIONS FOR DRAINED SYSTEMS

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The diversity of processes involved in pesticide fate in the groundwater resulted in a large variety of models. 1 dimension leaching has been studied many times with various models. However, drains have influence on the watertable shape and consequently the drained flow might differ from a classical vertical water transfer. In order to understand the characteristics of pesticide leaching under drained conditions, a tracing experiment with 28 different molecules was realized under controlled conditions. The study was mainly focused on the hydraulic part of the drained flow and the modelling using HYDRUS software combined with the use of ideal fluorescent tracers helped to set up the specificities of the water flow. The selection of the pesticides was based on agricultural practices in the Northwestern part of France and therefore the concentrations applied were calculated to reproduce the practices on the field. We used 4 fungicides and 23 herbicides with a wide range of sorption potentials (from 15 to 2000 cm^3/g). The experimental device MASHYNS is a 1 m^3 bunk (2m*1m*0.5m) that simulates drainage flow. The soil is a mixture between silt and sand that results in a hydraulic conductivity of 1m/day, the organic matter content is 2% and the porosity 43%. 3 dye tracers are first tested to find the most ideal water tracer in a 1D system tracing and then used on MASHYNS to determine the hydraulic flow. Both tracers and pesticides were spread on top of the device trough a sprinkling system and the water inlet was set up to represent the annual hydrology that happens on the field (350mm of drained water). Thus a constant high flow rate is needed to allow the complete leaching of all molecules. Pesticides are spread at different periods, to which a specific watertable height corresponds. Data are collected at the outlet for both tracers and pesticides (spectrofluorimeter, chemical analyses). Those data are then compared with results from modelisation using the software HYDRUS based on Richards equation and the convection-dispersion equation. Parameters such as hydraulic conductivity, saturated water content, dispersivity both longitudinal and transversal are evaluated by inverse modelisation. Complex processes such as physical non equilibrium with immobile water content, preferential flow or even macropore flow, may occur during the experiment and have to be tested by the model. Amino-G acid (AG) appears to be almost an ideal water tracer. Tracings in both 1D and 2D proved that electrical conductivity and AG's concentration breakthrough curve (BTC) were almost simultaneous. Tracing in 2D though shows some unexpected behaviour, with several peaks on the BTC and a long solute tail mainly due to the drain effect. And modelling highlighted the fact that numerous processes combined might have resulted in so many peaks in the BTC. Chemical analyses allowed the pesticide's sorption potential evaluation via comparison within results from modelling.

GLOBAL SENSITIVITY ANALYSIS OF PESTICIDE LOSSES IN STRUCTURED TILE-DRAINED SOIL

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Diversity of processes involved in pesticide fate leads to create complex modelling tools. Interactions between processes and parameters can make results interpretation difficult or superficial. In order to understand which parameters influence pesticide exportation in a drainage context, a global sensitivity analysis was conducted with the model MACRO on one of the six European drainage scenarios from FOCUS (2002) called “La Jaillière” and based on a western French site. Sensitivity analysis (SA) appears as a useful tool to identify key parameters. However, the most used SA practice seen in the literature is that of ’one-factor-at-a-time’ (OAT) which consists in analysing one parameter variability influence on various models outputs while the other inputs are fixed. As criticized by Saltelli et al. (2010) OAT strategy is definitively not a sufficient option. Thus, this work objective is to use global sensitivity analysis methods to determine key sensitive parameters in regards of water and pesticide fluxes in drainage and runoff flows with a calibration perspective. Two complementary sensitivity methods have been selected. The first one called: “Morris method” was used to analyze influence of 48 main parameters on water and solute fluxes. This screening method provides qualitative information and is here performed to select the most significant parameters to be analyzed with a more quantitative method. Secondly, Sobol method was chosen as it’s a very robust one which provides first and total sensitivity indices (Yang, 2011)]. Simulations were performed with the software CEMAFOR (Cheviron, 2012) which couples MACRO, used as slave model, with the optimisation tool PEST (Doherty, 2004). This study focuses on the evolution of parameters influence depending on adsorption and degradation initial value. For that, a set of 16 hypothetical substances were evaluated. A C.V of 20% was used for adsorption and degradation parameters. Others inputs values (distribution and ranges) were based on literature values as far as possible. Results show a strong influence of initial physico-chemical properties on key processes that govern pesticide exportations. Thus, calibration of pesticide leaching seems to be highly substance specific. Influent parameters related to water output (balance and dynamic) don’t necessarily fit well with solute results. Thus, this study tends to prove that water and pesticides transfers should be calibrated in a unique step, as was suggested by Moeys et al. (2012).

INNOVATIVE INTEGRATED PEST MANAGEMENT (IPM) FOR WINTER WHEAT BASED ROTATION: FIRST RESULTS OF *EX POST* ASSESSMENT OF FRENCH TRIALS AFTER ONE COMPLETE ROTATION

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Given the increase of pesticide amount in surface and ground waters and the society concern about this, innovative cropping systems taking into account farm level constraints and limiting the use of pesticides need to be proposed. Within the context of the PURE project (WP2), innovative IPM solutions were designed for winter wheat based rotations in France (Paris basin area). Three cropping systems were designed according to a gradient of pesticide-use intensity (i) current agricultural practices (CS) with a conventional use of pesticides, (ii) intermediate level of IPM (IS) with a reduction in pesticide use and (iii) advanced level of IPM (AS) where no pesticides are allowed. We used a three-step prototyping method: (1) crop successions and agricultural practices were defined for each system, (2) the prototypes underwent an *ex ante* sustainability assessment with the DEXiPM tool (Pelzer et al., 2012) and, (3) the most promising systems were tested in field trials starting in 2009. As they have all completed their first rotation in 2014, the experimental results can thus be analysed according to the pesticide use (frequency treatment indicator, FTI), environmental pesticide impacts (Synops tool), different environmental components, yield and economic margins. This enables an *ex post* reassessment of the system's sustainability.

The IS and AS differ from the CS by their high diversity of crops and long rotations, the regular use of mechanical weeding, and the choice of seeding dates, densities and varieties in order to reduce pesticide uses. For the *ex ante* assessment, FTI and environmental impacts of the prototypes are ranked according to the gradient of pesticide use: AS < IS < CS. All systems achieved a "medium" score of overall sustainability, obtained by different combinations of performances on the three sustainability pillars. For the *ex post* assessment, only preliminary experimental results are available because all crops of the AS are not harvested. However, the three systems gave same ranking, in terms of FTI and environmental impacts, than those of the prototypes. In the IS, yields are higher and pesticides costs lower than expected, leading to higher production value and gross margin. In term of overall sustainability, the CS and IS both achieve "medium" score as expected. The completed assessment will allow a more thorough analysis. The results will be discussed from both an agronomic and a methodological point of view in order to answer the following questions: (i) Is it possible to reach simultaneously the objectives set regarding pesticide use reduction and regarding economic gains? (ii) Are all the agricultural practices used in these cropping systems innovative?

RESIDUE ANALYSIS OF CANDIDATE PESTICIDES FOR PROTECTION OF MINOR CROPS APPLYING GC-MS/MS AND UPLC-MS/MS

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National authorities are responsible for enforcement of pesticide legislation following Regulation 1107/2009 and Directive 2009/128/EC while professional users are responsible for proper application of plant protection products, thus ensuring that treated crops will be free of excessive pesticide residues. We will present application of new pesticide residue analytical methods as monitoring tools to confirm safe and proper use of candidate pesticides having potential to be applied on selected minor crops to control pests, weeds and diseases affecting the production of these crops.

The main objective of our work was to develop, validate and apply to real samples a new approach to determination of pesticides in minor crops of high chlorophyll content. We focused on such crops as lupin, white mustard, soya bean, field bean and sunflower. We selected 25 candidate pesticides of the pesticides already approved for use on other crops in Poland (i.e. major crops). For sample preparation, we used the QuEChERS procedure with some modifications. Because green matrices, high in chlorophyll, represent a particular challenge due to massive amounts of coextractives, we employed a new type of sorbent, known as ChloroFiltr, to reduce chlorophyll from the extracts. The final determination was carried out by concurrent analysis using gas chromatography and ultra-performance liquid chromatography coupled to tandem quadrupole mass spectrometry (GC-MS/MS and UPLC-MS/MS).

Once the method conditions were established, the method was subjected to comprehensive validation study which was carried out on lupin, white mustard and sorghum. The overall recoveries at the three spiking levels of 0.01, 0.05 and 0.5 mg/kg were in the range between 68 and 120% (98% on average) and 72 – 104% (93% on average) with relative standard deviation (RSD) values between 2 and 19% (7% on average), and 3 and 16% (6% on average) by GC-MS/MS and UPLC-MS/MS technique, respectively. Quantification was always done by using matrix-matched standards to achieve accurate results [1].

Up to now, the proposed method has been successfully used to study the dissipation patterns of pesticides after application on lupin, white mustard, soya bean, sunflower and field bean in experimental plot trials conducted in Poland. Our results reassured the correct pre-harvest intervals since, in most cases, the pesticides completely disappeared on the treated plants before harvest. We can conclude that the proposed plant protection products can be safely used on the studied minor crops, without the risk of leaving problematic pesticide residues.

MULTI-ANNUAL RESULTS OF DATA OF THE DEMONSTRATIONS FARMS FOR INTEGRATED PEST MANAGEMENT IN ARABLE CROPS IN MECKLENBURG – WESTERN POMERANIA IN COMPARISON WITH FARMS OF REFERENCE FARMS NETWORK FOR PLANT PROTECTION

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The project "Demonstration farms for integrated pest management (DIPM)" was established in Mecklenburg-Western Pomerania with five farms in arable crops in 2011. These typical farms for this region demonstrate the IPM with an intensive support by state advisory service and a special consultant.

In 3 winter wheat (WW), winter barley (WB) and winter oilseed rape (WOR) fields per farm the pesticide use and monitoring expenses by the consultant were collected in the years 2010 and 2011 (before the project started) and in the first years of the project (2012 and 2013). These multi-year data at field level (n=15 fields per year) were compared with the data of the farms of the reference farms network for plant protection (RF). Finally, the environmental risk by the pesticide use has been analyzed for aquatic and terrestrial organisms by the model SYNOPS-GIS. The results showed that the treatment frequency index (TFI) in winter wheat, winter barley and winter oilseed rape during were 13%, 25% or 18% significantly lower in depending on the year in the DIPM the project period (2012–2013) in comparison to the RF (Tab.). The reduction of the TFI was mainly achieved in fungicide (WW, WB) and insecticide use (WW, WB, WOR). This was achieved by the intensive monitoring by the special consultant.

Tab. Pesticide use intensity (TFI) in winter wheat, winter barley and winter oilseed rape in DIPM and RF in Mecklenburg-Western Pomerania in 2010 to 2013

		Before project started				**Project period**			
		2010		**2011**		**2012**		**2013**	
		DIPM	**RF**	**DIPM**	**RF**	**DIPM**	**RF**	**DIPM**	**RF**
WW	⌀	6,4	6,7	6	6,7	4,7	5,4	5,4	6,9
	s	1,9	1,3	1,2	1,4	1,1	1,7	1,4	1,8
WB	⌀	3,8	4,1	3,9	3,8	3,7	4,7	3,5	4,9
	s	1,2	0,6	1,1	0,9	1	1,3	0,8	1,1
WOR	⌀	6,1	6,6	6,8	8,1	5,3	6,7	6,1	7,2
	s	1,4	1,9	1,3	0,9	1,5	0,8	1	1,2

The reduction of pesticide use was mainly based on intensive field monitoring by the consultant and the state advisors supporting of the managers of the DIPM. The first results from MV show that

monitoring activities for the implementation of integrated pest management in arable crops in the amount of 2.8 h in winter wheat, 1.8 h in winter barley and 3.1 h in winter oilseed rape were needed. In 2012, the chronic aquatic risk was medium in the two networks but twice as high in the DIPM as the RF. In 2013, the chronic aquatic risk was approximately at the same level in both networks and lower than 2012. The analysis of chronic terrestrial risk (earthworm) exhibited and networks at a low risk in both years. It should be noted that the chronic aquatic and terrestrial (earthworm) risk was strongly determined by the TFI and the choice of pesticides. The work is financially supported by the German Federal Ministry of Food and Agriculture (BMEL) through the Federal Agency for Agriculture and Food (BLE), grant number 2810MD001.

IDENTIFICATION OF WHEAT PROTEASE INHIBITORS ACTIVATED IN RESPONSE TO CEREAL LEAF BEETLE FEEDING 60

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Cereal leaf beetle (CLB, *Oulema melanopus*, Linnaeus) is an important economic pest of cereals, especially of wheat and barley. Both, beetles and larvae damage the leaves of cereals, which has a significant impact on the quality and quantity of crop yield. To limit damages of pests in the first place agronomic and biological methods should be applied, according to the principles of integrated pest management. Since many insect species of agricultural importance has adapted to insecticides, recent studies are focused on the investigation of insect digestion and a potential possibility of application of natural enzyme inhibitors for pest control. Plants are known to produce their own protease inhibitors as a defense mechanism against feeding damage caused by insects. Protease inhibitors can restrain proteolytic enzymes produced by the digestive system of insects. Therefore, protease inhibitors might constitute an important element in protection of plants against herbivorous insect in the future.

In this study, we have undertaken first to identify the proteolytic enzymes of digestive system of CLB using set of in gel activity assays and spectrophotomeric measurements. Then, we have analyzed the expression levels of plant genes encoding for protease inhibitors in response to feeding of CLB larvae. The gene expression was assessed by using real-time PCR technique. We found out significant differences in expression of plant protease inhibitors treated by CLB. The plant response differed depending on the kind of treatment, time of analysis after leaf damage, and on wheat variety analyzed.

DEVELOPMENT OF IPM-TOOLS FOR THE CONTROL OF CEREAL LEAF BEETLE AND APHIDS IN GRAINS

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That insects reduce yield of cereals has been proved before by a large number of researchers all over the world. The cereal leaf beetles *Oulema melanopus, Oulema gallaecianna* and *Lema Cyanella* are common plague insects in small grain cereals in the northern half round. Knowledge of optimal timing for chemical pesticide-application is absent in Europe, as well as selective pesticides approved in Flanders for the control of CLB (Cereal Leaf Beetle). Controlling grain aphids (*Metopolophium dirhodium, Rhopalsiphum padi* and *Sitobion avenae*) can interfere with the chemical control of the CLB. For the control of these leaf beetles, farmers often use broad-spectrum pesticides (pyrethrines such as lambda-cyhalothrin) in tank-mixes with another application (fungicides/nitrogen). As the –arbitrary- application is often done with wrong timing, they kill all present insects in the crop, including natural enemies. This can cause an even faster regrowth of the aphid/CLB populations, and therefore the need for a second application. With the introduction of IPM (Integrated Pest Management) by the European Parliament, January 2014, farmers are obligated to use a more integrated way to control the pests in their crops. One way to accomplish this is using selective pesticides to keep the natural enemies alive and let these "*Farmers' Friends*" help controlling the plague. In a 4 year-research-program, the aim of this study is to develop a model that predicts optimal timing of application, as well as give an advice to the farmer what selective pesticide to use. This model would be based on data from numerous fields that lay all over Flanders, Belgium. These fields are chosen based on variation in region, rotation, border management, e.g. . During growth season, parameters as population growth of the CLB, grain aphids and natural enemies of both plagues as well as the controlling effect of the natural enemies will be measured. How these parameters interact with other variables such as weather data and other field specific characteristics will be implemented into the model as well. Lastly the correlation between population density and yield will be tested. This provides the ability to set specific economic thresholds.

THE ANALYSIS OF RISK AND EFFECTIVENESS OF APPLICATION OF *SCLEROTINIA SCLEROTIORUM* (LIBERT) DE BARY IN BIOLOGICAL CONTROL OF CREEPING THISTLE IN MEADOW AGROCENOSES

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The infestation of meadows and pastures with weeds decreases the value of grass and hay. Creeping thistle (*Cirsium arvense* (L. Scoop.) is one of major unwanted plants in meadow agrocenoses. Due to the fact that the weed is capable of vegetative reproduction, it rapidly colonises stations and simultaneously, it is difficult to control. The specific character of meadows and considerable difficulties in controlling the weed encourage the application of fungal pathogens to limit the population of *C. arvense.*

There were two aims of the study. The first aim was to select the most pathogenic *S. sclerotiorum* isolate against *C. arvense* from a few isolates deriving from different species of plants. Apart from that, in view of the wide feeding range of the fungus, the study analysed how dangerous the isolates applied for weed control would be to commonly grown vegetables and ornamental plants.

The *S. sclerotiorum* isolates selected for the study came from creeping thistle, ranunculus, rapeseed, forsythia and vegetables (courgette, beans and parsley). There were greenhouse and field experiments assessing the harmfulness of selected *S. sclerotiorum* isolates to commonly grown vegetables (beetroot, cabbage, field tomato, green beans) and tobacco. The other group of assessed plants consisted of ornamental plants (chard, gillyflower, ornamental kale, cherry tomato). Ten-day cultures of each *S. sclerotiorum* isolate under investigation were used as inoculums. They were cultured in Petri plates on a PDA medium (Sigma).

Experimental infections proved that the pathogenicity of the *S. sclerotiorum* isolates under investigation was diversified both with regard to *C. arvense* and to the other crops to which the fungus was potentially dangerous. Among the isolates under study 5C S. *Sclerotiorum* isolate proved to be the most useful. It was isolated from creeping thistles growing on natural meadows. The 5C S. *Sclerotiorum* isolate was classified into the group of isolates with medium pathogenicity against *C. arvense* and simultaneously it was characterised by low pathogenicity against crops. On the other hand, the isolate derived from rapeseed was particularly harmful not only to creeping thistle but also to common crops. Inoculations with the 5C isolate conducted in a meadow agrocenosis caused the death of 50% of the plants during the first year. The experiment proved that the isolate was useful for the limitation of the weed population.

THE EFFECT OF SELECTED AGRICULTURAL PRACTICES ON THE INCIDENCE OF DISEASES AND WEED INFESTATION IN WINTER OILSEED RAPE

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Recently the area of agricultural crops based on no-tillage cultivation systems has increased significantly in Poland. The simplified tillage system, used under good soil conditions with proper agricultural technologies allows to maintain a good stable level of crop yields. Except for oilseed rape culture , which requires properly cultivated soils.

The aim of the long-term experiment set up in 2011 was to compare some selected agricultural factors (system of cultivation, crop rotation with variable level of protection) on the incidence of fungal diseases and weed infestation in winter oilseed rape. The first tested factor was a tillage system: I – reduced tillage; II – ploughing. The second tested factor was the level of protection: b_1 – standard (current practice); b_2 – integrated (low pesticide input, including non-chemical methods). For the standard practice (b_1) winter oilseed rape was sown in rows at a row-spacing of 24 cm, with chemical weed control and winter wheat as a stable forecrop. In the integrated system (b_2) band-row sowing was used (band sowing 33 cm with inter-row 50 cm wide). Mechanical weeding of inter-row was made by hoe and the herbicides were applied only for band spraying of oilseed rape rows; narrow-leaved lupine was used as a forecrop.

In both tillage systems the same protection measures against pests (TFI value) were used. For the second tested factor the level of protection varied and the total value of TFI (sum herbicide and fungicide) was as follows: b_1 = 1,97 and b_2 = 1,0. With broad-leaved weed the following species were dominant: *Centaurea cyanus*, *Geranium pusillum*, *Viola arvensis, Matricaria inodora*, *Anchusa arvensis* and grass weed species: *Elymus repens* and *spica-venti Apera*. In the simplified tillage system weed infestation was significantly higher as compared to the ploughing.

The results of the sampled oilseed rape revealed the symptoms of infection with grey mould (*Botryotinia fuckeliana*), stem canker (*Leptosphaeria* spp.), stem rot (*Sclerotinia sclerotiorum*) and black spot (*Alternaria* spp.). The incidence of rape diseases mostly depended on the weather conditions in the particular seasons. During the first no stem rot infection was observed. The highest level of stem rot incidence in oilseed rape was recorded in the second year. In the same year a significant percent of oilseed rape plants were infected by stem canker as well as the oislseed rape siliques showed the symptoms of gray mould and black spot. Occasionally, the occurrence of funfal diseases depended on the crop rotation and on the cultivation system. In the reduced tillage system there was a greater percentage of infected plants, especially by the pathogen causing stem rot.

The results showed that despite the reduced use of chemicals in the integrated system the decrease of weed infestation and infection by fungal diseases was recorded, as well as higher yields of oilseed rape. The obtained differences between the protection practices were more evident in the reduced tillage. In the ploughing cultivation the yield od winter oilseed rape was significantly higher as compared to the reduced tillage, regardless of the level of protection and crop rotation.

EFFECT OF CULTIVATION SYSTEMS AND CROP ROTATION ON WEEDS AND DISEASES OCCURRENCE IN WINTER WHEAT

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The deteriorating economic and energy efficiency as well as environmental considerations require to search for alternative systems of cultivation and plant protection. The replacement of traditional farming systems based on plowing by simplified cultivation increases the interest among the farmers, especially those ones with large farms. They work best in the cultivation of cereals and legumes. A proper sequence of crops is of great importance especially in reduced tillage. The use of reduced tillage in simplified crop rotations may cause an increase in the risk of the infestation with certain weed species, as well as the incidence of diseases and pests.

Three year static long-term experiment was established in the autumn of 2011 in the Institute of Plant Protection. The aim of the studies was to assess the impact of cultivation systems and crop rotation on the incidence of wheat pests as well as the yield of winter wheat. The first tested factor was a tillage system: a_1 – reduced tillage; a_2 – ploughing. The second tested factor was a place of winter wheat in crop rotation: b_1 – winter wheat (forecrop: winter wheat, fore-forecrop: winter oilseed rape); b_2 – winter wheat (forecrop: winter oilseed rape, fore-forecrop: spring wheat); b_3 (integrated system) – winter wheat (forecrop: winter oilseed rape, fore-forecrop: narrow-leaved lupine). In the levels b_1 and b_2 the only one variety of wheat (Legend) was sown but in b_3 a mixture of two varieties (Legend + Ostroga) were used. For both cultivation systems a_1 and a_2 the same level of protection against pests (TFI value) was used. Within the second tested factor the protection level (TFI) varied as follows: $b_1 = b_2 > b_3$. Weed control for b_1 and b_2 was based on the use of herbicides in autumn (TFI = 1.0), and in b_3, autumn harrowing and spring herbicide treatment (TFI = 0.4) were applied.

In the third year after the full rotation cycle it was reported a significant effect of the cultivation system and crop rotation on the occurrence of weed diseases and the level of weed infestation as well as wheat yield and its quality parameters. Within broad-leaved weeds the following species were dominant: *Centaurea cyanus* and *Matricaria inodora* and in the case of grass weed species: *Elymus repens* and *Apera spica-venti* were the most frequent. Weed infestation in the reduced tillage system was significantly higher as compared to ploughing cultivation. The total cover by weeds was as follows: for the reduced tillage system (a_1): b_1 = 55.9%; b_2 = 18.6%, b_3 = 0.6%: for the ploughing cultivation system (a_2): b_1 = 38.8%; b_2 = 8.0%, b_3 = (0.1%).

During the experiment we also observed fungal diseases on wheat leaves, spikes, culm bases and roots. During the observation at the heading stage (BBCH 55) the flag leaf was infected by the casual agents of brown rust (*Puccinia recondita*) and septoria on leaves (*Mycospharella graminicola* and *Phaeosphaeria nodorum*). Winter wheat cultivated in the conventional system a_2 (both in crop rotation and monoculture) in reduced tillage was more infested by the fungal pathogens causing Fusarium foot rot in the culm bases and roots than wheat grown in the tillage cultivation system. The smallest number of infested plants with symptoms of this disease was observed for the integrated

system (b_3), both for reduced tillage and ploughing. In the case of Fusarium head blight, the smallest number of plants infested by *Fusarium* spp. was observed in the combination with the integrated system (b_3), with the use of ploughing.

The level of yield obtained in cultivation system with ploughing was significantly higher as compared to the reduced tillage system. The increase in crop diversification had a beneficial effect on wheat yield and its quality parameters (the higher the protein content, gluten, weight of 1000 grains).

MUTUAL FUNDS ARE A KEY TOOL FOR IPM IMPLEMENTATION: A CASE STUDY OF SOIL INSECTICIDES IN MAIZE SHOWS THE WAY

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Integrated Pest Management (IPM) may cause risks of crop damage, especially when it is implemented for the first time and when farmers are inexperienced. The risks apply mainly to arable crops, as IPM strategies have not been used extensively on them. Therefore a simple, reliable tool that compensate mistakes in IPM implementation may help avoid any decrease in cultivation net income and make farmers more comfortable with IPM implementation. Mutual funds, i.e. farmer-managed no-profit insurance tools, are an effective solution. They cover risks that private insurance companies currently do not (e.g. climatic adversities, such as flooding and damage by wild animals and pests, just before and after the emergence of arable crops). When the damage risk is low, mutual funds cost less than large-scale pesticide use. The lower the damage risk, the more convenient a mutual fund becomes, even without EU funding. This funding, which is based on EU legislation, may cover a significant part of the financial compensation for damaged fields, making mutual funds far more convenient. This approach has been implemented for soil insecticides in maize in Italy. Long-term data suggest that the majority of Italy's maize farmland does not need to be protected with insecticides at sowing. Indeed, the percentage of land with high populations of wireworms (a major soil pest in maize farmland) is often very low (e.g. less than 5% in the Veneto region, an area with large-scale maize production). At European level, the PURE project has produced similar results. After four years of monitoring, no significant wireworm/other soil-pest damage in the experimental maize fields of France, Hungary, Slovenia, Germany and other Italian regions was detected. Hundreds of plots have been examined in studies from Italy, and in the large majority of the experiments there were no statistically significant differences, in terms of yield between maize treated with soil insecticides and non-treated plots because of low wireworm damage and/or the compensation capacity of the crops. Because of this general low risk level, a crop insurance program where growers may purchase insurance, instead of soil insecticides to provide financial compensation when yield losses can be attributed to pests would be more convenient than insecticide protection on large scale. The total cost of damage to maize (need of re-sowing and yield loss due to delayed sowing or reduced stand) is often much lower than the total cost of the soil insecticide treatments of most fields. Furthermore, it does not consider the environmental side effects of insecticides. Therefore the successful approach is to implement IPM in accordance with Directive 2009/128/EC as follows:

a) risk evaluation: the factors that increase the risk of soil-pest damage have been studied analyzing a comprehensive database built up over 30 years, correlating soil-pest damage with a vast range of agronomic, climatic and pest information. The main information includes: type of the main soil

pest; organic-matter content (>5% significant risk increase); and type of previous crops;

b) no risk factors greatly decrease the chance of economic damage and make the application of soil insecticides in most fields useless. Where risk factors are present, it is good practice to assess wireworm populations with bait traps and to introduce control strategies only when and where economic thresholds for maize are exceeded. Mutual funds cover the risk of mistakes in IPM is implementation, including any underestimation in the size of the area with wireworm economic populations.