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Recent advances in IWM of perennial and annual weeds, with a special emphasis on the role of crop-weed interactions

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EUROPEAN WEED RESEARCH SOCIETY
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EWRS

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SEMINAR SUMMARY

NJF/EWRS Workshop on Recent Advances in IWM of perennial and annual weeds, with special emphasis on the role of crop-weed interactions

January 27-29, SLU, Uppsala, Sweden

The workshop was organized as collaboration between the NJF working group "Perennial weeds" and the EWRS working group "Crop-Weed Interactions" and was held at the Ecology Center at the SLU Campus in Uppsala, Sweden from 27-29 January 2014. The workshop was attended by 23 participants from 12 countries. The twenty presentations were arranged in five sessions and gave rise to interesting discussions. On Monday and Tuesday, the conversations were continued during joint dinners organized at the Ecology Center and at Sunnersta Herrgård, the location were most foreign participants stayed overnight. The local arrangements by the SLU staff and students are gratefully acknowledged.

The first session, on perennial weeds, focused on the factors influencing both growth and control of the most common perennial weed species in the Nordic-Baltic countries. Integrated control measures were addressed in terms of crop-weed competition, mechanical control methods and timing of treatments. New interesting results related to the compensation point of perennial species (the time when the energy resources in underground regenerative structures are at minimum level) were presented.

The second session focused on cultural control. In winter wheat, crop density, time of sowing and cultivar were identified as important factors, whereas spatial distribution did not seem to be of importance. The methodology for identifying crop traits, responsible for competitiveness against weeds was discussed and the various aspects related to seed vigour were presented. Also the first results of a long-term experiment for studying the influence of crop rotation in maize based cropping systems were shown. This session continued on Tuesday and then dealt with the importance of synergism among cultural weed control measures and the competitive ability of cereal cultivars. Future research should identify where in the life cycle of weeds cultural control measures can reinforce one another to reduce the size of the weed population most efficiently. The suppressive ability of cereal varieties is an important component in this context as it reduces the impact of weeds on crop yield including the weed seed return to the seed bank. Ongoing research in the UK is adding more understanding to the attributes of varieties that play a major role in the suppressive ability of varieties.

In the third session the attention was on competition and growth. Investigations on a range of different crop-weed combinations were presented. The more traditional arable cropping system was represented by large sized field trials on the competition between wild oat and spring wheat and the comparison of the competitive ability of different spring barley varieties. Perennial weeds in grasslands were represented by a study on the competitive effect and spread of soft rush and compact rush (*Juncus* spp.) in extensive pastures and more intensively managed leys along the western coastline of Norway. Focus was on the influence of soil moisture and organic matter on the competitive ratio between *Juncus* spp. and *Poa pratensis*. A further two presentations discussed the role of crop-weed competition during the establishment phase of *Salix* genotypes (willow). In a first presentation the commonly practiced winter-storage of willow cuttings was questioned. Establishment of willow stands derived from stored cuttings was compared to fresh cuttings under both weed-free and weedy conditions. In another presentation the weed-free period of willow plantings was discussed. In this study white mustard and spring barley were used as model weeds, resulting in a discussion on 'how to select your ideal model-weed'.

In the fourth session, different aspects of direct weed control measures were discussed. In Finland, practices for tillage have changed. Stubble cultivation and direct drilling have become more common, which influences on the composition of the weed flora. In Norway, the effects of different timing of soil cultivation on perennial weeds have been studied and interesting results were presented. A study on combinations of mechanical and chemical weed control in oilseed rape performed in Sweden was presented and it was shown that such combinations can be implemented with advantage to further develop integrated weed management strategies.

The last session was on integrated weed management, an issue that in fact had already been an important topic throughout the workshop. In an informative and interesting talk on 'Challenges for Integrated Weed Management implementation in EU crops', the consequences of the new EU policy were illustrated. This was followed by a fruitful discussion on the role of GM-crops and the opportunities and problems with implementing IWM in Europe. After this final session, the local organisers were thanked once more for facilitating the workshop and for their great role in turning this workshop into a success.

Organizing committee

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Session 1. Perennial weeds

The suppression of *Cirsium arvense* and *Elytrigia repens* exerted by competitive crops plays a key role for their management in organic cropping systems

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Cirsium arvense and *Elytrigia repens* are perennial weeds prevalent in organic cropping systems in Scandinavia. This study analysed the population dynamics of both species in long-termed crop rotation experiments conducted at three sites (coarse sand, silt and sandy loam) in Denmark from 1997-2008. The purpose was to gain insights into the factors influencing perennial weeds population changes over time, especially those important for outbreaks of *C. arvense* and *E. repens* infestations. Data were obtained from three cycles of four-year crop rotations with various cash crops and annual grass-clover subjected to four treatment combinations: with and without animal manure and with and without catch crops.

The perennials were controlled by different tillage and mowing strategies between and within crops. The experiment on coarse sand was quickly infested with *E. repens* while *C. arvense* gradually invaded the experiment on sandy loam. At the third site, perennial weeds did not become noteworthy problems in the 12-year period. The reason for this could not be explained in differences of fertility among sites but rather in site characteristics and weed management measures employed. Pulse crops and spring cereals caused the highest population increases of *E. repens*, especially when preceded by grass-clover. However, grass-clover with mowing had the opposite effect on *C. arvense* growth and crops succeeding grass-clover were predominantly least infested. Similar to *E. repens*, vigorous *C. arvense* growth was associated with pulse crops but spring cereals versus winter cereals were not markedly different in their suppressing abilities against *C. arvense*. Potatoes grown in ridges and winter rye suppressed the *E. repens* population, but tillage between crops was necessary to decrease the population. In contrast, stubble cultivation had very little effect on *C. arvense*. Manuring generally reduced *E. repens* growth by 28% whilst no differences were seen for *C. arvense* between manured and non-manured treatments. Apparently, the improved crop growth caused by fertilisation increased crop competition enough to counterbalance any growth stimulation of *C. arvense*.

This study clearly revealed the importance of benefitting from significant crop competition for the management of perennial weeds under circumstances with no access to strong weed control methods such as herbicides. Well established and fast growing crops producing large quantities of crop biomass are valuable tools for the suppression of perennial weeds in organic cropping systems. Grass-clovers and similar crops suited for mowing also play an important role for the control of *C. arvense* while mechanical interventions are more important to supplement the management of *E. repens*.

Mechanical control of *Elymus repens* – farm tests

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MTT and ProAgria are conducting a two-phase study about mechanical control of perennial weeds (2012 – 2014). Targets of the study are to get knowledge about optimal use of Kvick-Finn weed-cultivator and how it works in different soil types, weather conditions, crop rotations and weed control strategies. Kvick-Finn has been developed for mechanical control of perennial weeds, especially against *Elymus repens*. The first part of study consists of three field experiments at MTT's research station. In the second part we started co-operation between the farmers, advisers and researchers. This paper describes the results from 1) farm-tests and farmer interviews during growing period 2013 and 2) one field experiment at MTT's research station during 2012-13.

Kvick-Finn machine and principles of fallowing

The basic idea of Kvick-Finn machine was born in Denmark in the beginning of 2000, but now the machine is further developed and manufactured by Finnish company. Goosefoot tines loosen the soil and after that PTO-driven rotor throws soil and weed roots into the air. Because weed roots are lighter than soil, roots will settle on the soil surface, where they are dried out by the sun and wind.

If the weather is not dry, the roots are using their energy when they begin to grow again. Repeated treatments with Kvick-Finn can destroy *Elymus repens* also during wet conditions, but it takes longer time to achieve sufficient results than during dry period.

Traditional whole summer lasting bare fallow can be effective method to destroy perennial weeds, but it is expensive (no crop, much work and fuel), it can be harmful for soil structure and it can lead for nutrient leakage. Kvick-Finn is one way to accelerate and shorten bare fallowing. Other machine types which can be used for bare fallowing are for example S-tine harrow, tined cultivator, rotary spade harrow and disc harrow.

There are at least 5 possible strategies in bare fallowing: 1) quick fallow in spring before cereal sowing (2-4 weeks), 2) fallowing May-June and sowing green manure (2 months), 3) harvest one silage yield and fallowing after that (3 months), 4) bare fallowing the whole summer (5 months) and 5) stubble cultivation after cereal harvest (1-2 months).

1) Farm tests

The farms for farm-tests were selected by utilizing ProAgria's local advisers. The target was to find organic farms, which have already couple of years experience of Kvick-Finn cultivator. Two of farms are situated in North-Ostrobotnia, one in South-Ostrobotnia and one in Southern-Finland. All farms are organic crop-production farms, but some of them have co-operation with cattle farms. Soil types and weed problems vary as follows: Farm 1: peat soil (much *Elymus* present), Farm 2: loam soil (*Elymus* well-controlled), Farm 3: fine sandy soil (much *Elymus* and some *Cirsium* present) and Farm 4: loam sandy soil (*Elymus* present).

Farms 1 and 2 have crop rotation, which consists of 3-year ley and 1-2 year cereal. In the last ley year the farmers harvest only one silage yield in the end of June and after that they start to cultivate soil with Kvick-Finn. Roots of *Elymus repens* are growing in surface layer of old ley, so it is quite easy to lift up the roots. Typically the farmers cultivated leys with Kvick Finn 4-5 times during July – August and twice next spring before sowing cereal. Farmer 2 has even abandoned ploughing and seedbed harrowing and he does all the tillage works by Kvick-Finn. We monitored visually fields at Farms 1 and 2 during 2013: in May there was lot of dead *Elymus* roots on soil surface and little roots alive. In August before harvest of pea-oats crop Farm 1 and 2 had very clean fields, but Farm 1 had some *Elymus* alive among the crop.

Farms 3 and 4 have 1-2 years green manure ley and 2-3 years cereals in their crop rotation. In 2012 both farms had cereal growing in demo fields. The fields were not cultivated autumn 2012 because of wet weather. In spring 2013 both farms used Kvick-Finn only one time before seedbed tillage and sowing. Because weather was dry that time, the effect of Kvick-Finn seemed to be good enough in August. On the Farm 3 there were two 20 m^2 plots left without Kvick-Finn treatment and difference was clear: there were more *Elymus repens* and *Cirsium arvense* growing on the plots compared to the surrounding areas.

2) Field experiment at MTT's research station

Methods

Target of this field experiment was to find the best ways to manage bare fallow when breaking up old ley. As mentioned above, roots of *Elymus repens* are growing in surface layer of old ley, so it is quite easy to lift up the roots. Ploughing the ley in the beginning is not maybe the best strategy.

Our research field is situated in Ruukki (64° 41 N; 25° 05 E). Soiltype is peat soil and the field had been as ley since 2010 (previous crop was barley). Glyphosate had last been used in 2008. In 2012 one silage yield was harvested in the end of June. After that randomized complete-block experiment was set up on the field. The experiment had 5 treatments and 4 replications (plot size 6 x 25 m). The treatments were:

1) No tillage in 2012, two silage harvest
2) One pass with rotary spade harrow + three passes with Kvick-Finn
3) Four passes with Kvick-Finn
4) Four passes with tined cultivator
5) Eight passes with rotary spade harrow

The treatments were started 19.7.2012. Because the grass had grown quite much after silage harvest, it was firstly crushed down. The treatments were repeated after 10-15 days, when *Elymus* had grown 1-2 leaves. Rotary spade harrow was old and light model, so the plots were cultivated twice per day to achieve tolerable result. The last treatments were conducted in 29.8. The summer 2012 was very wet, thus strategy of drying weed roots was not fairly effective.

In May 2013 treatments 2 and 3 were cultivated once by Kvick-Finn. One week after that the whole area was ploughed, harrowed and fertilized with 18 ton/ha beef slurry. Finally, 190 kg/ha Brage-barley was sown on the experimental area. In the end of August two 0,25 m^2 biomass sample per plot was cut above of 5 cm. The samples were fractioned to 1) barley, 2) *Elymus* and 3) other weeds. The experimental plots were harvested in the beginning of September. The results were analysed by using SAS PROC MIXED.

Results

Treatments with Kvick-Finn decreased amount of *Elymus repens* to very low level (fig. 1, treatments 2 and 3). Also tined cultivator was fairly effective, but it differed from treatments 2 and 3. Rotary spade harrow decreased *Elymus repens* compared to treatment 1, but its efficiency was the weakest. The amount of *Elymus* was not analysed in the beginning of the experiment, but the pressure had been high, because dry matter yield of *Elymus* was 2700 kg/ha in treatment 1. Standard deviation was moderate, which indicates that *Elymus* had been spread over the experimental area. Although weather in summer 2012 was wet, mechanical weed control methods were surprisingly effective.

Barley yields were about 1000 kg/ha higher in treatments 2 and 3 compared to treatment 1 (fig. 2). This can be seen to be an advantage of proper weed control, because ploughing, seedbed tillage, fertilisation and sowing were conducted similarly in every treatment. There were no differences in hectolitre weights between the treatments.

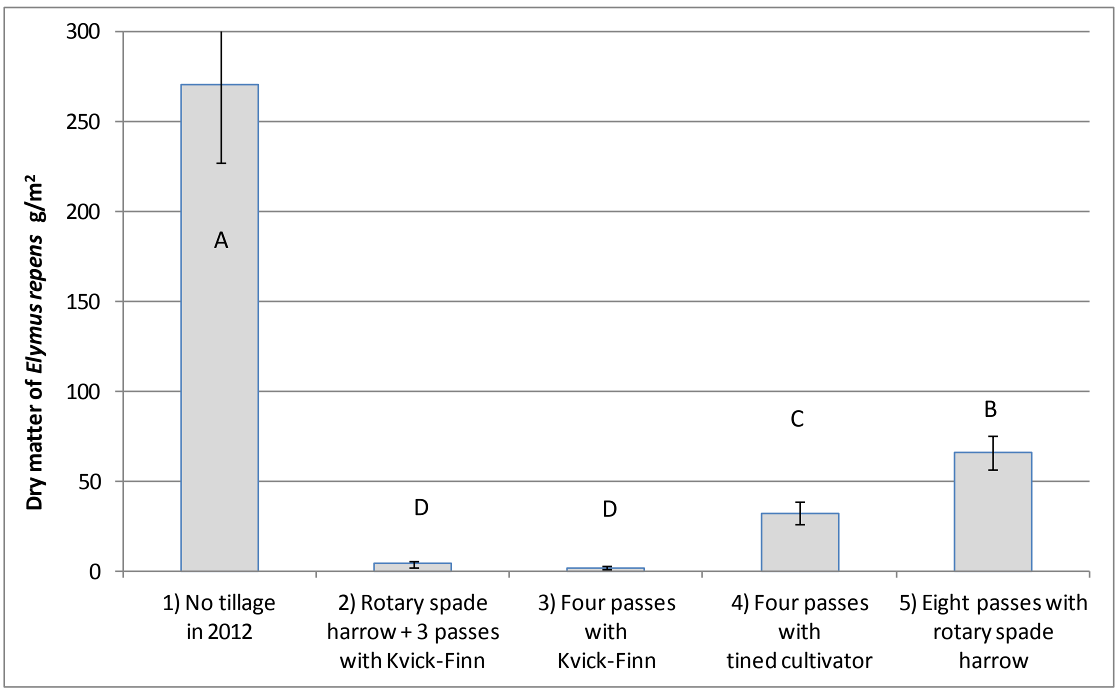

Figure 1. Dry matter of Elymus repens in the end of August 2013. The bars indicate standard deviation. The treatments without a common letter were significantly different at p=0.05.

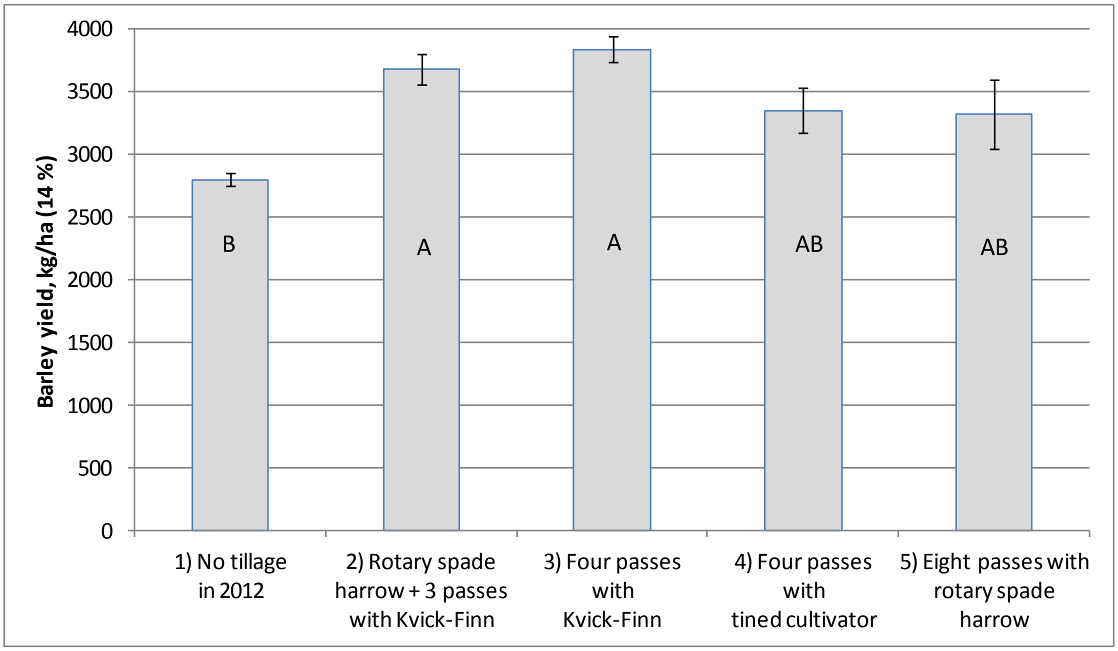

Figure 2. Yield of barley in 2013. The bars indicate standard deviation. The treatments without a common letter were significantly different at p=0.05.

Conclusions

Kvick-Finn seems to be an effective method to control *Elymus repens* if glyphosate cannot be used. According to farm tests very few passes can be efficient enough, if the weather is dry and soil is not the lightest possible. In peat or mould soil a half summer fallow is often necessary and it seemed to work also during wet season. Fallowing can be also done by other machinery, but Kvick-Finn offers possibility to shorten fallowing time and decrease number of passes. Number of passes in different conditions needs still optimization. Furthermore, there is lack of knowledge the efficiency of the machine against *Cirsium arvense* and *Sonchus arvensis*.

Kvick-Finn machine has been criticized to be slow. Driving speed with Kvick-Finn can be 5 – 7 km/h, thus capacity of 3,0 m machine could be about 1,3 ha/h. Costs of one treatment will be about 60 eur/ha. If we assume that it is needed 6 treatments when old ley is broken up, the method is not very cheap. On the other hand, if ploughing and seedbed tillage can be excluded, the costs of 6 treatments would be about 175 - 225 eur/ha. This is acceptable price for rigorous perennial weed control, because there is no need to repeat the treatment every year.

The effect of cover crops and mowing on the abundance and biomass of *Elymus repens*

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Couch grass (*Elymus repens L.*) is a problematic weed on northern latitudes. It propagates mainly through rhizomes and once established it can quickly spread throughout a field. Currently, the two main control methods are herbicides and extensive repeated tillage. Cover crops are mainly used to prevent nitrogen leaching during fallow periods. Cover crops may also provide other beneficial effects to the cropping system, such as competing with weeds, supply nitrogen to the subsequent crop, and provide food and shelter to beneficial insects. The main aim of the study was to investigate if two cover crops with different functional traits, alone or in combination, could be used to control couch grass during autumn, after harvest of a cereal crop. The cover crop treatment was combined with mowing (cutting of aboveground biomass). If successful, the control method would avoid the negative impacts of herbicides and extensive tillage, while adding services of e.g. nutrient conservation and nitrogen fixation.

The cover crop-mowing experiment was conducted in three locations in southern and eastern Sweden in 2011-2012, and repeated in 2012-2013. The design was a split-plot with randomized complete blocks. Main plots were mowed zero, one or two times. In the subplots, cover crops were under-sown in conjunction with the sowing of main crop spring cereals. The cover crop treatments were: none, red clover (*Trifolium pratense*), perennial ryegrass (*Lolium perenne*) and red clover/perennial ryegrass. The ryegrass is an efficient nitrogen scavenger and the clover has horizontal leaves that more efficiently prevents light from reaching the soil surface than grasses with more erect leaves. Measurements taken were abundance of couch grass shoots, aboveground biomass (cover crops and couch grass), rhizome biomass and soil mineral nitrogen.

The couch grass shoot abundance did not differ depending on cover crop, but the rhizome biomass increased (about 20%) with red clover compared with the control (2013; $p=0.0006$, 2012; $p=0.15$). There was no significant difference in soil mineral nitrogen amounts between the different cover crop treatments. This indicates that the competition for nitrogen was not severe in the experiment. In the first trial, but not in the repetition, mowing twice in the autumn resulted in significantly lower shoot abundance ($p=0.05$) and 34% less rhizome biomass than in the control ($p=0.03$) (though this not reduce it below the starting biomass). Mowing also increased the crop yield in the subsequent year by 15%.
For cover crops to be effective against couch grass it might be necessary to test other species and/or cultivars, and to increase the plant density. Mowing twice did suppress the couch grass growth (rhizome weight and shoot abundance) significantly one year, but it did not reduce it below the starting biomass. More frequent mowings, better timing and a more optimal combination with cover crops might make the method more suitable for couch grass control.

The effects of competition, root weight and root depth on compensation point and phenological development of *Cirsium arvense* (L.) Scop.

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Introduction

When soil tillage is used for controlling perennial weeds, farmers are usually recommended that mechanical weed control should be done at the developmental stage when the plant is most sensitive for disturbance, which coincides with minimum below ground dry weight (i.e. compensation point). In 1997, Dock Gustavsson showed that *C. arvense* in experimental monocultures reached the minimum dry weight of below ground biomass at 8-10 true leaves. However, factors such as crop competition, degree of root fragmentation and depth of root pieces in the soil may influence at what phenological stage the compensation point of *C. arvense* is reached. The aim of the study was to assess the influence of competition, root depth and root size on the phenological stage, at which minimum dry weight of below ground biomass occurred in *C. arvense*.

Material and methods

An outdoor bucket experiment was performed in Uppsala, Sweden in 2013. Plant material used was *Cirsium arvense* (L.) Scop. and spring barley (*Hordeum vulgare* L.). The experiment consisted of three factors: (1) with and without competition from spring barley, (2) two planting depths (5 and 15 cm), and (3) two root weights (0.8 and 2.4 g, which is about 7 and 21 cm in length respectively). Sequential harvests were performed at 12 developmental stages of *C. arvense*, i.e. 1-12 true leaves.

Results and discussion

The results showed that the compensation point for all treatments occurred below leaf stage 6. In plants without competition, it occurred below leaf stage 5. The phenological development of *C. arvense*, in terms of development of numbers of leaves over time, was delayed by competition with spring barley. The effects of planting depth and initial root weight were inconclusive.

The results imply that *C. arvense* should be controlled earlier than previously was recommended.

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The effects of competition on compensation point and phenological development of *Sonchus arvensis* L.

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Introduction

Sonchus arvensis L. is a perennial weed which has become more common in Scandinavian countries owing mainly to the increase of organic farming which limits the use of herbicides. When soil tillage is used for controlling perennial weeds, farmers are usually recommended that mechanical disturbance should be done at the developmental stage when the plant is most sensitive for disturbance which coincides with minimum below ground dry weight. Håkansson (1969) has shown that *S. arvensis* reaches its minimum dry weight of underground regenerative structures at 5-7 true leaves. The phenological stage at which the dry weight minimum is reached may depend on environmental factors like temperature but may also be influenced by competition from other plants. The aim of the study was to assess the influence of several factors, such as competition, root depth and root size on the phenological stage, at which minimum dry weight of below ground biomass occurred in *S. arvensis* (i.e. the compensation point).

Material and methods

A greenhouse box experiment and two outdoor box experiments were performed at Ultuna, close to Uppsala, Sweden (59º 48’N, 17º39’E) during 2012 and 2013. The plant material used in the experiment was *Sonchus arvensis* L. (perennial sow-thistle) and *Hordeum vulgare* L. var Judit (spring barley). The experiment 1 (greenhouse) and 2 (outdoor) consisted of two treatments: *S. arvensis* (1.5 g fresh weight) and a planting depth of 3 cm, grown (1) with (C+) and (2) without (C-) competition from spring barley. In experiment 3, depth (2 levels) and root weight (2 levels) were used as factors. Sequential harvests were performed at a range of developmental stages, characterized by the number of true leaves of *C. arvense*.

Results and discussion

The compensation point in competing plants occurred at leaf stages 4 and 5, while it occurred at the 4 leaf stage in plants without competition. For given phenological stages, weight loss of below-ground structures did not differ between the C+ and C- plants, apart from the 5 leaf stage, at which the C+ plants had lost more in weight that the C- plants. The initially planted root parts of C+ plants lost more weight than the C- plants. Phenological development of *S. arvensis*, in terms of development of numbers of leaves over time, was delayed by competition with spring barley. Shallow planting depth and larger initial root weight partly counteracted depletion of the below ground parts of *S. arvensis*, but only marginally affected the compensation point.

For agronomy practice, these results imply that *S. arvensis* should be controlled earlier than previously was recommended, and that competition from a crop can be used in addition to greatly deplete the below-ground resources in *S. arvensis*.

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Session 2. Cultural control

Impact of crop structure and delayed drilling on winter wheat competition

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The impact of canopy structure, crop seeding rate and delayed drilling on crop-weed interactions in winter wheat was investigated in two years field- and semifield experiments. In field experiments, six different crop spatial arrangements were established by sowing three seeding rates (200, 400 and 800 seeds/m^2) in rows at 12.5 cm distance and in a more random pattern using a Horsch system. Each combination was established at two sowing times and effects were mainly recorded for the growth of grass weeds such as *Alopecurus myosuroides* and *Apera spica-venti*. Based on images from the field experiment similar crop spatial arrangements of two winter wheat varieties were established in boxes (0.4 x 0.4 x 0.15 cm). Crop-weed competition was studied under outdoor conditions combining each crop structure with two densities (100 and 300 plants/m^2) of *Apera spica-venti* and *Veronica persica.* Seeding rates had a high impact on weed biomass while crop spatial distribution did not affect crop-weed competition in any of the two experimental set-ups. In the field experiments delayed sowing and seeding rate significantly reduced weed growth and in the semifield experiments competitiveness of the two winter wheat cultivars were reflected in different weed biomass production.

The results indicate that theoretically, it is possible to achieve more than 80% reduction in weed biomass using optimum combinations of delayed sowing, competitive cultivars and increased seeding rates. Some of these measures may however affect grain yield negatively and increase the need for plant growth regulation and disease control. Possible implications in adopting the different methods in practice will be discussed.

The influence of crop rotation on annual and perennial weed control in maize field

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Crop rotation is important strategy within Integrated Weed Management System which requires planned and aimed implementation of different measures and advocates a combination of weed control methods. A single weed control measure is not feasible due to the number of different weed species and their highly variable life cycles. Sequences with row and grain crops, legumes and cereals allow growing of many genotypes, application of different tillage practices, fertilizers and herbicides etc. All this influences weed community composition, abundance of individuals and even soil seed bank richness (Ball, 1992; Demjanova et al., 2009). The alternation of crops breaks the life cycle and prevents high distribution of any single weed species (Bastiaans, 2010). Crop rotation influences weed species diversity and community composition abundance with annual and perennial weeds (Anderson, 2006). In order to investigate the effects of crop rotation and herbicide application on maize infestation with annual and perennial weeds, we started long term study.

A split-plot trial was settled on slightly calcareous chernozem on the experimental field of the Maize Research Institute, Zemun Polje near Belgrade, Serbia in 2009. The basic treatment was a plant production system: maize continuous cropping (MC), maize-wheat rotation (MW), maize-wheat-soybean (MWS) and maize-soybean-wheat rotation (MSW). The hybrid ZP606, winter wheat variety Takovčanka and soybean variety Lana were conventionally sown within optimal periods in all production systems. Conventional tillage was used in the trial. A total of 30 t ha^{-1} of manure was incorporated in autumn of 2008 and then every third year in maize monoculture and MSW. In autumn of 2008 and 2010, 20 t ha^{-1} of manure was incorporated in MW rotation and every second year after. Different herbicide rates represented treatments in sub-plots. After sowing and prior to maize emergence the combination of isoxaflutole and acetochlor was applied in two rates: HR-recommended (105 g a.i. + 1536 g a.i.) and ½ HR - half of the recommended rate (52.5 g a.i. + 768 g a.i.), while herbicides were not applied in the control. Each treatment had four replications. In wheat and soybean, usual combination of herbicides for broadleaf and grass weed control was applied in all variants. Weed estimation was done 45 days after the application of herbicides. Samples were drawn randomly by one square meter area method. Number of weed species, number of weed individuals per species and fresh biomass of weeds were estimated in maize, after one rotation cycle – in 2012 for MC, in 2011 for MW and in 2012 for MWS and MSW.

Terophytes *Chenopodium* sp., *Solanum nigrum* and *Amaranthus* sp. and geophytes *Convolvulus arvensis*, *Cirsium arvense* and *Sorghum halepense,* were the most abundant weed speceis. Applied herbicides, in accordance with their mode of action, were more effective against annual weed species. Results obtained in maize monoculture show that number of annual weed species and their biomass is different according to herbicide application level and it was approximately the same or lower after three years. The increase was noticed for *Solanum nigrum* and *Amaranthus hybidus* as annual and *Sorghum halepense* as perennial species. In all three years, total weed biomass was significantly lower after herbicide application than in the control variant, but differences between application of recommended and half of recommended herbicide rate were not significant.

In MW, number of annual and perennial species and their biomass decreased after one rotation cycle and much more with the level of herbicide application. Biomass of *Datura stramonium*, *Abutilon theophrasti*, *Atriplex patula* and *Iva xanthifolia* was lower after one cycle of rotation at the control variant without herbicide application, while abundance of *S. nigrum*, *Chenopodium* sp., *A. hybridus* and *P. convolvulus* is still high. However, perennials were better controlled when rotation with cereal crop is applied, especially biomasses of *S. halepense* and *C. arvense* have decreased. Herbicide application significantly decreased total biomass of all annual and perennial species. In this cropping system, the lowest weed biomass (120.7 g/m^2) was obtained in 2011, after application of recommended herbicide rate.

Three crop rotations showed dissimilarities because of their different structure. In previous period, MSW system was mostly adopted in Serbia because of big farms that provided manure. So, farmers used manure and grow maize after wheat. Recently, presupposition of land owners, highlighted the MWS system from the reason of N content in the soil which is left after soybean. Although in MWS rotation manure was not applied, higher number of annual and perennial weeds was still obtained independently of herbicide application. The most distributed was *S. halepense* as perennial species and *P. convolvulus* as annual species. Total biomass of all species was higher in 2012 than in 2009, but also significantly different between herbicide treatments.

In regard to weed control, the best effects showed MSW rotation. In this rotation system, although manure was applied, biomass of annual and especially perennial weeds was lowered after three years. Herbicide application supported this trend and the lowest total weed biomass (189.4 g/m2) was obtained in 2012, after one cycle of crop rotation, in the plot with recommended rate of herbicide. *Chenopodium* sp., *D. stramonium*, *S. nigrum*, *I. xanthifolia* and *P. convolvulus* biomasses were reduced, and perennials *S. halepense* and *C. arvensis* were kept under reasonable level. Wheat as a cereal crop, together with herbicides used for its production were better for effective weed control and maize production than soybean. Reduced herbicide rate together with rotations that include cereals or forage crops can facilitate suppression of some troublesome weeds (Heggenstaller and Liebman, 2005).

Crop rotation in combination with herbicides can reduce level of weed infestation in maize even in the simplest maize-wheat crop rotation. Rotations facilitate the changes of herbicides with the ability to control different weed species i.e. annual and perennial species. Because crop rotation expressed its effects after several years, the study will be continued in order to achieve more precise results.

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Studies on crop-weed competition as affected by seed vigour

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Crop-weed competition might be affected by seed vigour through germination, emergence and establishment of vigorous seedlings. This competition might be attributed to two components: firstly germination and emergence patterns, and secondly growth characteristics of plants derived from high/low vigor seeds and weed plants.

Data will be mainly presented from greenhouse experiments on the early crop-weed competition of plum tomato with 2 weed species [green foxtail (*Setaria viridis*) and jimsonweed (*Datura Stramonium*)]. Although, little difference on times to Final Emergence (tFE) was measured (tFE = $t\_E_{90;}$ 7.4 vs. 7.8 d; in plants derived from HV and LV seeds, respectively), great differences were measured on: a) uniformity (U) [U = t_(E90-E10); 1.8 vs. 4.6d in HV, LV plants, respectively), and b) mean time to emergence (mTE) [mTE = t_(E50); 7.1 vs. 5.3 d in HV, LV plants, respectively). Green foxtail was more competitive than jimsonweed, for most growth characteristics, to the crop regardless of the plum tomato vigor level.

In addition, preliminary data will be shown from a field experiment on the effects of timings of emergence patterns of crop (plants derived from HV and LV seeds) and weeds on maize crop development and yields.

These results would help us to quantify the effect of seed vigour on crop-weed interaction.

Environmentally friendly weed management strategies: selection of competitive crop variety

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Introduction

Weed management is one of the most essential issues in agriculture, especially in environmentally friendly cropping systems as organic or integrated farming. In organic cropping systems the use of chemical herbicides is forbidden, however, also in integrated agriculture the need for alternative weed management strategies is stressed in relation with cropping systems high dependence on use of herbicides, weed resistance against herbicides and also environmental pollution risks. A selection of field crop varieties that can suppress or withstand weed competition could be as one of such alternative measures for integrated weed management. Choice of appropriate for growing conditions and competitive field crop variety could help to minimize additional costs for weed management.

This report introduces with some results on two projects – 1) the European Social Fund co-financed project "Development, improvement and implementation of environmentally friendly and sustainable crop breeding technologies" (2009/0218/1DP/1.1.1.2.0/09/APIA/VIAA/099) with one of the objectives to identify competitive traits in cereal species in order to contribute to development of a methodology for estimation of cereal genotypes for their competitive capacity against weeds, to establish more effective criteria of the selection by significant crop aboveground characteristics in organic breeding; and 2) the practical applied research project supported by Ministry of Agriculture of Latvia „Legumes - as an alternative to soybean in the production of protein-rich fodder: agrotechnical and economical substantiation for cultivation in Latvian conditions" with an sub-objective to evaluate weed competitiveness of field crop species mixtures – as one more alternative measure for integrated weed management.

Material and methods

The first investigation was carried out at State Priekuli Plant Breeding Institute in Latvia from 2010-2012. Field experiments with 21 morphologically and phenologically diverse spring barley genotypes (varieties 'Abava', 'Anabell', 'Anni', 'Dziugiai', 'Idumeja', 'Inari', 'Primus', 'Rasa', 'Rubiola', 'Vienna' and 11 breeding lines) were arranged in organic crop rotation, characterized by sod-podzolic loamy sand soil (Table 1), to detect the most important (found in scientific literature, as well as already used in barley breeding practice) crop aboveground characteristics, which provide the competitiveness against weeds in spring barley. Harrowing was not performed in the trials, to exclude the impact of this factor.

Table 1
Soil characteristics in organic crop rotation in Priekuli

Year	2010	2011	2012
pH_{KCl}	5.7	5.4	5.7
humus, g kg^{-1}	28	21	23
P_2O_5, mg kg^{-1}	111	116	160
K_2O, mg kg^{-1}	144	98	93
Pre-crop	peas – green manure		

Different observations were been made and the data were collected during the investigation period. Various crop traits were taken into account to evaluate a competitiveness of cereal genotypes: crop plant development rate in terms of days from sowing to such phenological phases as tillering (BBCH 21), stem elongation (BBCH 30), heading stage (BBCH 50) and fully ripening (BBCH 90) was determined; the number of germinated plants and the number of productive stems were counted; growth habit at tillering (BBCH 25-29) and at stem elongation (BBCH 39) was evaluated visually (using the scale: 1 – erectophile; 9 – planophile); canopy height at the beginning and at the end of stem elongation (BBCH 31-32 and BBCH 47-51, respectively) and plant height before the harvesting (BBCH 90-92), as well as a length and a width of flag leaves (BBCH 47-51) was measured; crop ground cover was assessed visually in percentage several times from the end of crop tillering to fully ripening. Weed samples were collected at anthesis of cereal cops, dried and weighted.

Data on correlations of cereal plant traits with weed dry weights (total, annual, perennial) were included in present investigation. Bivariate correlation method (by IBM SPSS Statistics 19) was applied to calculate Pearson correlation coefficients for relations between different crop aboveground traits and weed dry weights at the probability levels 0.05 and 0.01. According to detected crop traits, that were important in barley competitiveness against weeds (Piliksere *et al*., 2013), all 10 investigated barley varieties were compared mutually, using ANOVA.

The second investigation was started in 2013. Field trials were arranged with three legume species (peas, beans and lupine) in mixtures with hulless barley or with hulless oats in the organic crop rotation at State Priekuli Plant Breeding Institute. Weed suppression ability of the crop mixtures was assessed visually.

Results and discussion

In the first investigation, detection of the most important crop characteristics, which provide the competitiveness against weeds in spring barley, was stressed as a desired result, and some significant crop aboveground traits could be included in a methodology for cereal competitiveness against weeds for organic breeding purposes for barley – as growth habit, canopy height, and crop development rate. It can be prospective to include measurements of crop ground cover in the methodology for estimating competitiveness of cereal species against weeds.

On the basis of three-year field experiments, the most competitive varieties, among 10 investigated, were 'Idumeja' and 'Dziugiai' (Table 2). Plants of variety 'Idumeja' can be characterized by rapid development and soil shading, early maturing and quite good tillering, however worse N uptake ability. Also plants of variety 'Dziugiai' have rapid development, erectophile growth habit at tillering and worse N uptake ability. Less success in competitiveness showed variety 'Annabell', although with good tillering ability, and variety 'Anni', characterized by slower development, planophile growth habit at tillering, but with good yield stability.

Table 2
Leading spring barley varieties by their potential competitiveness related with competitive traits

Crop trait	Year	Varieties
Plant density after germination	2010-2011	*Differences among varieties were not statistically significant*
	2012	Abava, Idumeja, Inari, Primus, Rasa, Rubiola, Vienna
Growing habit (BBCH 25-29)	2010	Dziugiai, Idumeja
	2011	Dziugiai, Idumeja*, Rasa
	2012	Idumeja
Growing habit (BBCH 39)	2010	Dziugiai, Idumeja, Inari, Primus
	2011	Dziugiai
	2012	Dziugiai, Idumeja
Canopy height (BBCH 31-32)	2010	Abava, Dziugiai
	2011	Dziugiai
	2012	Abava, Dziugiai, Idumeja, Rasa, Rubiola
Canopy height (BBCH 47-51)	2010-2011	Dziugiai
	2012	Dziugiai, Idumeja
Sowing-heading, days	2010-2012	Idumeja
Plant height (BBCH 90-92)	2010	Abava, Idumeja, Rasa, Rubiola, Vienna
	2011	Inari, Rasa, Rubiola
	2012	Idumeja, Rasa, Rubiola
Crop ground cover (BBCH 23-29)	2010	*Was not observed*
	2011	Abava, Anni, Dziugiai, Idumeja, Inari, Primus, Rasa, Rubiola, Vienna
	2012	Abava, Idumeja, Inari, Primus, Rubiola, Vienna
Crop ground cover (BBCH 29-31)	2010	*Was not observed*
	2011	Abava, Anni, Idumeja, Inari, Primus, Rasa, Rubiola, Vienna
	2012	Abava, Idumeja, Inari, Primus, Rubiola, Vienna
Crop ground cover (BBCH 31-39)	2010	Primus
	2011	*Differences among varieties were not statistically significant*
	2012	*Was not observed*

*Underlined varieties had also significantly higher yields as others

Cereals suppress weed growth; however diverse cereal genotypes could have different competitiveness against weeds that depends on crop growth and aboveground characteristics. Competitive ability is usually not attributed to a single characteristic, either within or between varieties, but the interaction among a series of desirable characteristics is important. It would be a perspective direction to improve the results of the present study by adding some new crop traits or merging the current different crop traits to get some coefficients with stronger correlations with weed dry weight. The results of crop aboveground traits correlated only slightly with weed ground cover; therefore, the weed development could be affected by other factors than crop aboveground characteristics included in the investigation. Little is known about crop: weed belowground competition, that could be one of the factors of great impact.

More competitive variety does not mean also higher yield. However, the performance of such varieties can result in higher yield stability along variable growing conditions and can promote an elimination of weed seed-bank. The competitive ability against weeds is an individual potential of the variety, which can be useful for weed management aims, especially in environmentally friendly cropping systems.

The results obtained can be extrapolated to regions with similar soil and weather conditions, as they were in Priekuli.

Only one year results from the investigation with legume mixtures with hulless barley or with hulless oats were very provisional. The weather conditions were not favourable for development of legume plants during growing season, and first conclusions therefore could be very doubtful. First visual observations demonstrated a slight trend of legume mixtures with hulless oats to be more competitive against weeds than the mixtures with hulless barley. However, the results could not be tested statistically yet.

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Searching for synergy among cultural weed control measures

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In many agro-ecosystems, weeds are an important biological production constraint, causing considerable economic damage. In most instances, investments are made in weed control operations, resulting in opportunity costs. Alternatively, if weeds are left uncontrolled, crop yields will be severely reduced. In conventional agriculture, focus is often on herbicidal control of weed seedlings. Herbicides are usually effective and comparatively cheap. The existence of such an effective control strategy can be considered a luxury, as it allows farmers to focus on the short-term, where avoidance of yield reduction in the current crop is the most important issue.

The sustainability of herbicidal control is, however, at stake. Due to increased concerns regarding the environment and human health, stricter regulations regarding the admission of herbicides have been put in place and several of the formerly released herbicides have been banned in recent years. Relying on a smaller number of herbicidal products increases the likelihood that herbicide resistant weed populations will develop, and this severely undermines the durability of this strategy. In organic farming systems, herbicides are not allowed and also for this particular segment alternative control strategies are needed.

Mechanical weed control is a sound component of weed management, but not as effective as herbicides. The methodology also has a strong dependency on prevailing weather conditions. If weed seedlings are uprooted, rainfall in the days shortly after application, might instigate regrowth of a large fraction of the weed seedlings. Hand weeding is another alternative, but relatively expensive and demanding a lot of manpower. The required labour investment is strongly dependent on the weed infestation level: at higher infestation levels, more time is required to clean the field. This means that it is very important to keep the weed density at a low level. The consequence is that the weed problem should be perceived on a much longer time scale. Rather than only focussing on yield reduction in the current crop, weed population dynamics becomes increasingly important. As a result, weed control turns into weed population management.

In a weed population management strategy, focus is not necessarily on the weed seedling stage. The life cycle of weeds offers many more opportunities to interfere and these interventions can be brought about through modifications in cropping practices, like the use of more competitive cultivars, transplanting, or the application of a false seed bed technique. The intention of all measures is to lower the weed seed bank density (representing the potential weed problem), to lower the weed plant density (the plants that are actually competing with the crop) and/or to lower the impact of the weeds on crop production (competitive ability). It is well-established that cultural control measures are not as effective as herbicidal control and it is for this reason that the strength has to come from a combination of measures. In this context it is relevant to investigate whether certain measures are contra-productive when combined, whether they strengthen one another, or whether the impact of a measure is indifferent to the measures it is combined with. For this reason the current research explores the likelihood that synergy is created by combining specific cultural control measures that target different phases of the weed's life cycle.
At the core of the presented research is a life cycle stage weed population model. This model was used to calculate the steady state of a weed population under standard

management as well as the changes in steady state following individual and combinations of cultural control measures. The equation to express the equilibrium weed seed density reinforces that the weed life cycle consists of two major flows. The first flow represents the plant phase and more in particular the development of the weed seedling to a seed producing plant. Curative control is typically focussed on this part of the life cycle. From a weed population perspective this flow determines how many plants will be contributing to the production of new seeds. The second flow represents the passage of newly produced weed seeds to their settlement in the weed seed bank. Losses here might be due to predation or the collection of newly produced weed seeds, through for instance bailing of straw immediately after the combine harvester.

Both streams are connected through two important transitions and both transitions severely contribute to the weedy character of those plant species that we collectively refer to as weeds. The first transition is from plant to seed and is characterized by multiplication. Typically, each weed plant is able to produce thousands of seeds, contributing to the pioneer character of most arable weeds. Lowering this seed production capacity, for instance through an increased weed suppressive ability of the crop, is an important component of cultural weed control. Transplanting, an increased crop density and using more weed suppressive varieties are just a few of the measures through which this strategy is implemented. Also the second transition, from seed to plant, is elemental. Typically weed seeds contain a certain level of dormancy, which allow them to form a stock, which we know as the weed seed bank. Consequently, germination not automatically takes place, not even if the environmental conditions are suitable. Germination, predation and mortality are the means through which seeds disappear from the weed seed bank. Taken together, these processes determine the average residence time of seeds in the weed seed bank and thus reflect the ability of a weed species to form a weed seed bank. Increasing the loss rates will reduce the residence time of the seeds and substantially contribute to lowering the size of the weed seed bank.

In the presentation it will be shown how the flows and transitions that together form the life cycle of the weed are connected. It will be argued whether synergy is likely to be expected from a set of measures that is focused on a specific combination of life cycle stages. Special attention will be given to the dual position of germination. If germination is stimulated, more weed seeds will leave the weed seed bank and as a consequence the size of the weed seed bank will decline. At the same time, a high germination rate increases the number of weed plants that will contribute to weed seed production and thus help to maintain the replenishment of the weed seed bank. Obviously, weed management involves much more than just curative control and a better understanding of how the various processes in the weed’s life cycle are interrelated will assist in exploiting these alternative measures in the best possible way.

Is there a future for predicting the competitive ability of cultivars?

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It is appreciated that cultivars of wheat, barley and oats vary in their ability to suppress and tolerate weeds, but this has seen limited application to agriculture. This is, in part, due to a perceived trade-off between competitive ability and yield in weed-free situations. It is additionally complicated by the interaction of these traits, and performance of cultivars and weeds, across different years and locations. There is renewed interest in the contribution of competitive cultivars in UK arable agriculture in response to increasing herbicide resistance and a lack of new modes of action.

This work is part of a PhD project that focuses on the identification of competitive traits in wheat, barley and oats, with a particular focus on wheat. It assesses their contribution to competition across different locations and seasons, and how they contribute to other weed management strategies. The target weed species is *Alopecurus myosuroides*, a problematic species in UK arable agriculture

Work has been conducted both in the field and in containers that are kept on outdoor sandbeds at Rothamsted Research, UK. Each cultivar was grown alongside *A. myosuroides*, with numerous crop traits measured throughout growth. Final biomass and seed return of *A. myosuroides* were collected in July and correlated with cultivar traits. In the 2012/13 growing season, *Stellaria media* was included in the sandbeds experiment, to test if traits that suppressed *Alopecurus myosuroides* would suppress a weed with a different growth habit.

Ecophysiological traits at the earliest stages of growth are of interest, as these investments could be yield penalty-free traits that increase a crops ability to suppress weeds. A number of early traits were identified as contributors to suppressive ability in the 2011/12 experiment, but many of these traits were not correlated with seed return or biomass of either weed species in 2012/13. The results of these experiments will be discussed in the presentation.

Session 3. Competition and growth

Investigation of competition between wild oat (*Avena fatua*) and spring wheat

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Avena fatua has become the most dangerous and aggressive annual grass weed species in the seed growing farms in Latvia due its ability to cause tremendous yield losses. Weed-crop competition is one of the main tasks of the new project "Integrated pest management for weed control in arable crops for sustainable use of the environment and resources" supported by European Agricultural Fund for Rural Development (EAFRD) started in spring 2013 in Latvia. Data from these investigations will be used to develop practical recommendations for the local farmers.

Field trial was conducted to investigate competition between spring wheat 'Zebra' and *A. fatua* at different weed plant densities. Trial treatments consisted of ten different *A. fatua* densities (including 0 plants per m^2). The maximum density of *A. fatua* plants targeted in the trial was 500 plants m^{-2}. Seeds of *A. fatua* were broadcast on plots at a range of densities immediately after spring wheat sowing on 7 May 2013. The experiment was conducted in randomized block design with tree replicates. The study area was fertilized according to good agricultural practices and herbicide MCPA 750 was applied for dicotyledonous weed control. Other plant protection measures were applied to the whole trial as necessary.

The date of emergence of spring wheat and *A. fatua* was recorded. The number of emerged *A. fatua* seedlings per 1 m^2 was counted and measured regularly at 5-10 day intervals until crop flag leaf emergence stage. In each plot ten plants of spring wheat and *A. fatua* were marked for assessments and measured during whole growing season up to harvest time. Spring wheat and *A. fatua* plants were sampled two times: during crop flag leaf emergence stage (on 13 June) and at maturity of the crop (on 6 August) to determine above-ground biomass and dry weight for both species.

The time of the beginning of *A. fatua* germination and emergence in the field was detected nine days after sowing (on 16 May). Data of our first year study show that spring wheat was much more competitive against wild oat as expected. Good quality crop seeds, amount of mineral fertilizer applied on the field, soil properties and tillage as well as favourable weather conditions for crop and weed growth during vegetative season 2013 increased crop ability to compete against *A. fatua*. Further investigation is necessary to investigate the impact of *A. fatua* to the growth and development of spring wheat.

The effect of soil moisture and soil type on growth of *Juncus* spp. and *Poa pratensis*

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Soft rush (*Juncus effusus* L.) and compact rush (*J. conglomeratus* L.) are perennial, native weeds in Norwegian flora that have spread substantially along the western coastline during the last decades. The species have become problematic in both extensive pastures and more intensively managed leys thereby reducing forage yield and quality. They are often considered as the greatest challenge in grassland areas with a high annual precipitation combined with high contents of organic matter in soil. Rush species may cope better with such growth conditions than the forage grasses.

In this study we tested the hypotheses that 1) the high moisture of soil promote competitiveness of rush and 2) the increased organic matter content of the peat soil are beneficial to rush establishment and harmful to grass growth. The factors of the experiment were (i) *Juncus* spp. (soft rush and compact rush), (ii) competition (all species grown separately, *Juncus* spp. grown in mixtures with equivalent of 100 % or 50 % *P. pratensis* L sowing rate) (iii) water levels (a=1 cm, b=4 cm and c=10 cm height of water table), (iv) soil types (100 % peat soil and mix of 75 % peat and 25 % fine sand).

The pot experiment was conducted at Ås (59°40′N, 10°46′E, 90 m ASL) in greenhouse chambers in autumn/winter 2012-13 (results presented here) and repeated in 2013-14. Shoot length and shoot number where recorded every second week. After 10 weeks dry biomass of above- and underground plant parts were weighed.

The response variables, biomass of roots, rhizomes and aboveground shoots, responded strongly on the experimental factors. High humid conditions (4cm and 10cm) in the mixture of peat and sand were more favorable for both *Juncus* spp. than for *P. pratensis* when all species were growing separately. The properties of 100 % peat soil in combination with high soil moisture stopped completely the development of underground stems of meadow grass. A positive effect of companion species on reduction rush growth was grater for *J. conglomeratus* than *J. effusus* growing in the mixture of peat and sand especially for lowest water level.

Results so far indicated that above- and underground plant parts of *Juncus* spp. respond similarly on peat soil mixed with fine sand and that strong competitive companion grass may reduce growth of rush especially in drier conditions.

Biomass production of stored versus fresh willow cuttings under weed pressure in a controlled outdoor experiment

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Introduction

In commercial practice, willows are propagated vegetatively by means of fragments (cuttings) of dormant stems (Hartmann et al., 2002) which are usually harvested during winter and stored until planting in spring next year. The main aim of the cutting preparation procedure is to obtain a rapid establishment of the willow crop, which is key factor for subsequent productivity of the willow stands. However, in commercial plantations, growth of young willow plants is severely reduced by weeds (Sage, 1999; Hollsten et al., 2012). For that reason, weed control is an indispensable practice during the early phase of the willow coppice establishment (Albertsson, 2012). In order to assess whether overwinter storage of willow cuttings in a cold-store can be made redundant by using fresh cuttings immediately prior to planting, and reveal how these two types of cuttings will stand competition with weeds, we compared the growth, survival and above-ground biomass production of fresh and stored cuttings grown with and without weed pressure in a controlled outdoor experiment.

Methods

In March 2013 dormant one-year-old shoots of three willow genotypes: Jorr (*Salix viminalis*), Olof (*Salix viminalis* × (*S. viminalis* × *S. schwerinii*) and Tora (*Salix schwerinii* × *S. viminalis*) were randomly harvested from the field and stored in a cold-room. These shoots gave the origin to cuttings named 'stored' (S) throughout the experiment and they mimicked cuttings used commonly in commercial practice. Besides, fresh shoots from the same willow genotypes were randomly harvested on five occasions ranging from late spring to summer (May to June) and they gave the origin to the cuttings denoted 'fresh' (F) throughout the experiment. Four cuttings of 20 cm length and a diameter of ≥ 10 mm at their base were produced from each willow shoot. The original position of the cutting on the mother shoot was noted in order to track possible differences in their phenology. The cuttings were simultaneously produced from stored and fresh shoots and planted in a commercial growth medium (Special kvalitet for yrkesodling, Hasselfors Garden, Skultuna, Sweden) in 12-L polyethylene buckets. Each bucket accommodated four either stored or fresh willow cuttings. Both cutting types were grown without (W-) and with (W+) competition from a model weed, spring barley. Spring barley was sown 5 days after planting of willows at approximately 2.0 cm below the growth medium surface. In order to standardize competition pressure in all experimental units, each of them was sown systematically with 25 seeds what represents a seeding density of 400 plants m2 applied in swedish agriculture. Consequently, the experiment had four treatments: F-W, F+W, S-W and S+W. For each planting occasion, willow genotype and cutting type the harvest of the newly grown shoots was performed when the largest shoots of willow genotype Tora in each experimental unit reached a stage of 60-66 unfolded leaves. The bud burst of the cuttings following the scale by Edelfeldt et al. (2012) was assessed for all planting occasions and willow genotypes. Moreover, survival of the willow plants, the number, length and biomass of newly produced shoots was recorded for all planting occasions and treatments.

Results

When planted earlier in the season, fresh cuttings sprouted prior to stored cuttings (Fig. 1) and produced more above-ground biomass (Fig. 2) for all willow genotypes. When planted latter in the season, the trend was reversed. There were significant interactions of biomass production with willow genotype, planting occasion and competition with model weed. In general, a three to four-fold reduction of the biomass due to weed competition was observed for all willow genotypes and throughout all planting occasions. Moreover, under weed competition an approximate two-fold reduction in height, mainly for willow genotypes Jorr and Olof, was observed.

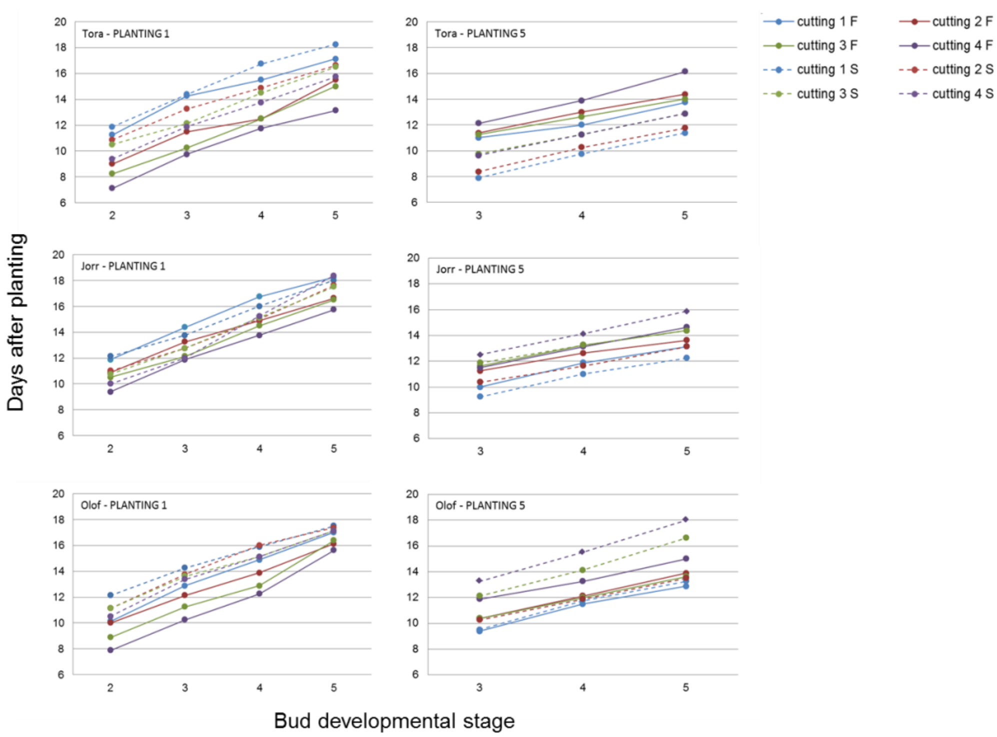

Fig. 1. Bud burst for fresh (F) and stored (S) cuttings depending on their location on the mother shoot (1 – shoot base; 4 – shoot apex) assessed for three willow genotypes: Tora, Jorr and Olof for first (left panel) and fifth (right panel) planting occasion.

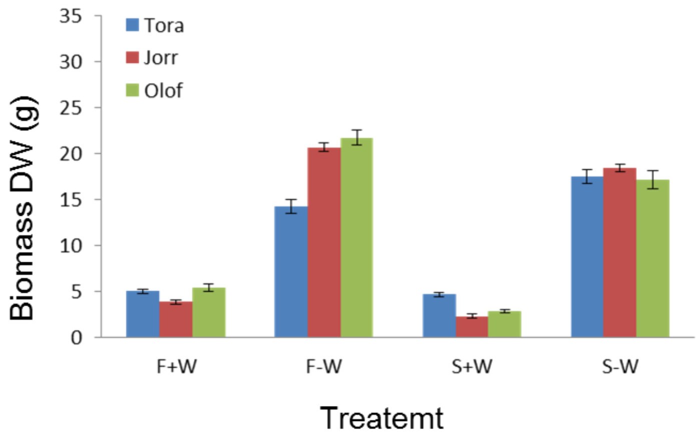

Fig. 2. Dry weight of above-ground biomass produced by three willow genotypes for the first planting occasion, depending on the treatment.

Conclusions

We conclude that winter storage of cuttings can be avoided when cuttings are planted early in the season. A comparatively good performance of fresh cuttings is obtained during first planting occasions, i.e., throughout May and becomes weaker toward end of June. Under all circumstances, weed control is important and should be performed in order to obtain a successful establishment of willow stands.

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Establishment of Salix in different Salix-weed mixtures

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When growing Salix for bioenergy production, a successful and even establishment of plant stands is crucial for high biomass yields. Weeds may hinder this establishment by competing for resources such as light, water and nutrients. Furthermore, some parts of the stand may be more affected than others by this competition due to field and plant differences, leading to an uneven establishment. As the stand grows and competition increases, this may lead to gaps in the stand and result in production losses at harvest.

To assess the effects of early competition for light and nutrients on different mixtures of weeds and Salix, an irrigated outdoor experiment was conducted in central Sweden in summer 2011. The experiment consisted of 2 model weed species, one with broad and one with narrow leaves, in 4 Salix-weed mixtures placed in buckets with 2 fertilizer levels and 12 replicates. Control buckets with pure weed mixtures for each Salix-weed mixture and fertilizer level using 4 replicates were also planted. In each bucket, 5 Salix cuttings of the clone Tora (*S. viminalis* x *S. schwerinii*) were planted. Mixtures with different Salix-weed compositions were created by planting weeds at 3 different times after the initial planting of the cuttings. White mustard and spring barley were used as model weeds due to their well-known early growth pattern. The buckets were harvested after nine weeks and total weed and Salix biomass measured for each bucket.

Compared to the pure Salix mixture, less biomass was produced when weeds of either kind were planted 15 days after the Salix cuttings. No differences were found between the pure Salix mixture and mixtures with weeds planted after 26 or 30 days. When comparing buckets with weeds planted at the same specific time, weed biomass production was less in buckets that also included Salix, at all four planting times. No Salix-weed mixture showed any differences in biomass production when comparing high and low levels of fertilizer.

We concluded that, for the given high experimental planting density, weed control the first two-three weeks is important for Salix establishment; however, later control is of less importance as the Salix plants by then has grown large enough to withstand weed competition.

Variation of weed dry matter and LAI in different competition of spring barley crop

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The agricultural policy of the European Union directs Lithuania's agriculture towards modernization and demands economic and ecological assessment of the measures used. It has been noted that intensive agricultural crops cultivation technologies exert a negative effect not only on soil but also on climate. Alternative cropping without the use of herbicides is becoming increasingly important for weed management in agricultural crops, therefore it is essential to form a crop stand with a high weed suppressive ability. Research into biological changes in segetal flora in spring barley of contrasting competitive ability was done by field trials over the period of 2008-2010 at the Institute of Agriculture, LRCAF (N55.2315.74; E23.5234.24). The soil of the experimental site was Endocalcari-Endohypogleyic Cambisol. Weeds incidence was analyzed in spring barley crop of different plant density: 0. 2. 4 and 6 mln. viable seeds per ha. During intensive growth, at the end of barley booting stage, in each plot's four 0.25 m^2 sites the weeds were counted, identified and air-dried weight were determined. The leaf area index was measured by a hand-held instrument SunScan. The leaf area index of spring barley was measured 5 times in sprayed and not sprayed field experiments from the beginning of tillering to the end of maturity.
Spring barley tall plants provide better coverage of soil compared with short plants. Due to this fact, weed density and weight in the crop of the tall variety were lower. Spring barley plant height weakly but significantly negatively ($P \le 0.01$) correlated ($r=-0.34^{**}$) with weed dry matter content. Some literature evidence suggests that weed weight positively correlates with the crop height (Watson et al. 2006). A negative correlation was established between leaf area index and weed weight (Garrity et al. 1992). Investigation of the variation of leaf area index among the spring barley varieties at the stem elongation stages revealed a negative ($r = -0.36^{**}$) significant ($P \le 0.001$) correlation between spring barley crop leaf area index and dry matter weight of weeds. With increasing spring barley crop leaf area index, dry matter content of weeds significantly declined. While assessing the data from the three experimental years, it was noticed that the variety of barley influenced both LAI and dry matter weight of weeds. The lowest LAI was measured in the crop of the short variety, while the highest LAI was recorded in the crop of the tall variety. The crops of the short variety were characterized by significantly highest total dry matter weight of weeds. In all experimental years, the dry matter weight of weeds was significantly ($P \le 0.05$) highest in the barley crop with the lowest plant population density. The data averaged over the 2008-2010 period showed that LAI correlated with weed weight, a significant negative relationship was established between LAI and dry weed weigh ($r = -0.36^{**}$).

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Session 4. Weed control

Tillage matters

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Practices for primary tillage have changed in Finland during the last ten years; stubble cultivation (29% of fields) or direct drilling (17%) have become more common, particularly in cereal cropping. Such a fundamental change from traditional autumn ploughing combined with a shallow seed-bed preparation in spring cereals evidently affects the composition of weed flora.

A field study was carried out in Jokioinen in 2005-2007 with the aim to compare three tillage intensities on the composition of weed flora. The previous crop in the experimental field was spring barley. In general, a rapid increase in the infestation of grass weeds, *Elymus repens*, *Phleum pratense*, *Poa pratensis*, was demonstrated in direct drilling (Fig. 1). On the other hand, *Fumaria officinalis* became the most abundant species in ploughed plots and *Taraxacum officinale* in stubble cultivated plots of winter wheat/spring wheat rotation. Need for intensive grass weed control was evident in direct drilling, particularly in winter wheat which was sown in unfavorable conditions resulting in a less competitive crop stand.

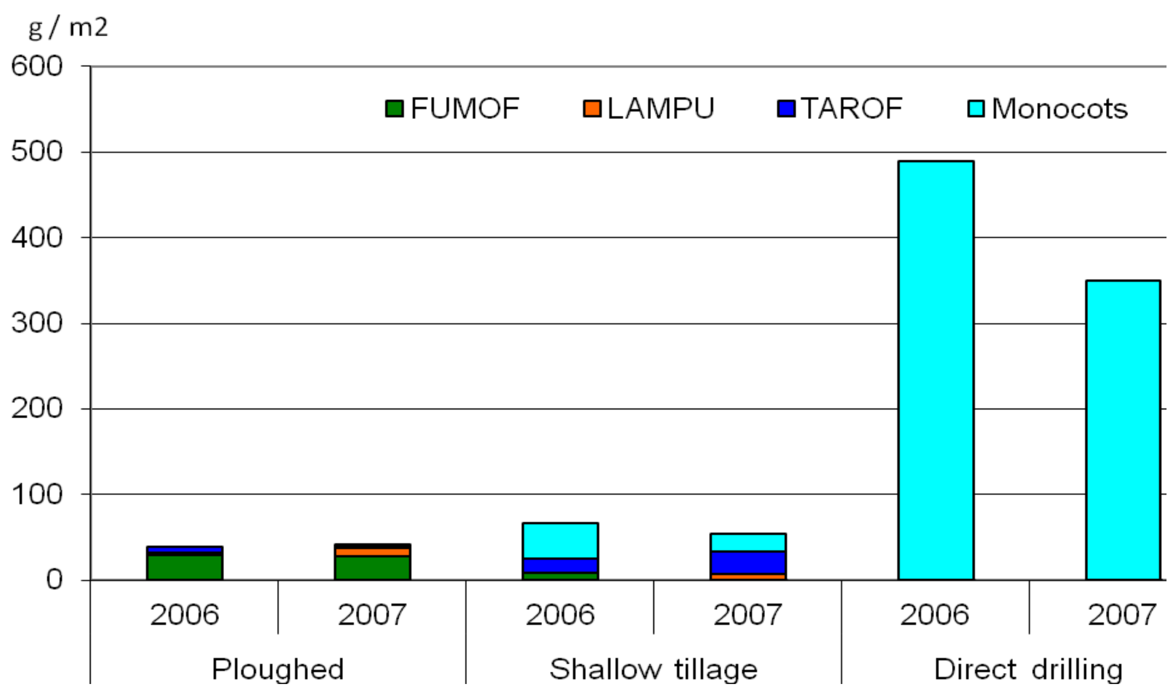

Fig. 1. Effect of primary tillage on the abundance and composition of weed flora in winter wheat (2006) followed by spring barley (2007) in a rotation.

Likewise, the recent survey of weed flora in Finnish spring cereal fields, conducted in 2007-2009, demonstrated the impact of primary tillage on weed shift. The most common annual broad-leaved weed species like *Chenopodium album*, *Galeopsis* spp. and *Viola arvensis* were associated with conventional ploughing whereas overwintering species like *Galium spurium*, *Lapsana communis*, *Poa annua* and *Taraxacum* spp. thrived in reduced tillage systems (Fig. 2).

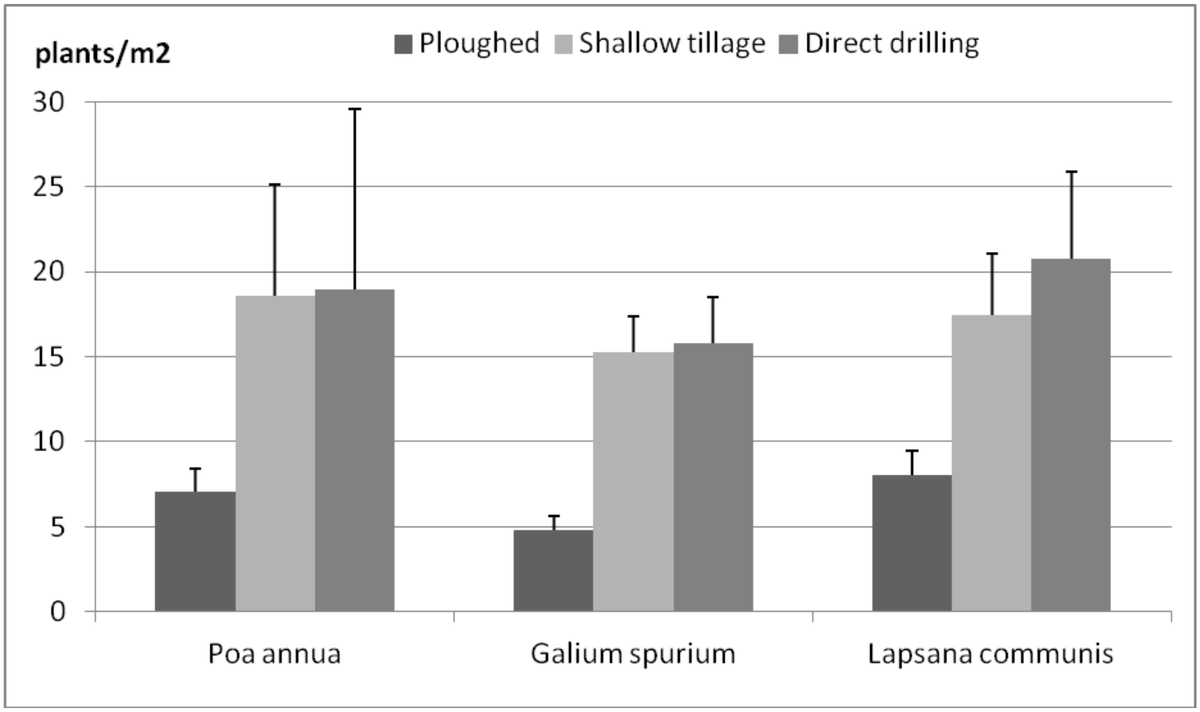

Fig. 2. Effect of primary tillage practices on overwintering weed species.

In practice, most of the farmers stick to annual use of glyphosate as a curative weed control in reduced tillage systems, particularly in direct drilling. Declining infestation of *Elymus repens* in the weed survey fields demonstrated the interaction between tillage and weed control practices; *E. repens* thrives in non-ploughed cropping systems but can be efficiently controlled with glyphosate treatments when repeated annually.

The latest weed survey in spring cereals in Finland indicated that tillage practices have changed more in conventional farming whereas in organic cropping almost all cereal fields are still ploughed to manage with the weeds.

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Timing of bare fallow and ploughing for control of perennial weeds

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Introduction

Cirsium arvense (L.) Scop (creeping thistle) and other creeping perennial weeds such as *Elymus repens* (L.) Gould (common coach-grass) are of major concern in organically grown cereals in the Nordic countries and elsewhere. In the present paper, the effects of different timing, autumn versus spring, of a soil cultivation period and plouging on weeds and crop yield were studied.

Methods

The experiments were carried out at two sites during a 2 and 3 year period with the treatments repeated on the same plots. The treatments were (i) soil cultivation (disc harrowing) followed by ploughing, and (ii) only ploughing. The effects studied were the number and above-ground biomass of the perennial weed species *C. arvense*, *E. repens, Sonchus arvensis* L.*, Stachys palustris* L. and the grain yield of the spring cereal crop (oats).

Results and Discussion

In our study, the control efficiency of *C. arvense* and *S. arvensis* was closely related to timing of ploughing. Spring ploughing decreased the growth of both species significantly compared to autumn ploughing. For *E. repens,* however, timing of ploughing or bare fallow had no significant effect: the most important factor was whether bare fallow was carried out (best control) or not. The overall best strategy for controlling weeds was a bare fallow period in spring, but that caused delayed sowing of the cereal crop and lower crop yield. The better general effect of spring tillage may be explained by weed species having a higher growth rate in spring than in autumn, and that some species like *C. arvense* probably may make most of the shoots from the intact root system. Another important aspect is that spring tillage gives less soil erosion and nutrient leakage from fields than autumn tillage.

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Integrated control of annual weeds by inter-row hoeing and intra-row herbicide treatment in oilseed rape

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Introduction

Herbicide application is the most commonly used weed control method in oilseed rape. However, the number of available herbicides is decreasing. At the same time, the development of herbicide resistance is increasing in Europe (Kudsk et al., 2013). Also, farmers within the European Union have to apply integrated pest management (IPM) from 2014 (European Parliament & Council of the EU, 2009). This has increased the need for development of alternative weed control measures with reduced amounts of herbicides.

The aim of this project is to develop and evaluate an integrated weed control strategy against annual weeds in oilseed rape by means of a combined mechanical and chemical weed control which will be performed concurrently and separately.

Material and methods

An implement for intra-row spraying combined with row hoeing was developed and evaluated in field experiments. A sprayer boom was constructed and sprayer nozzles were mounted on the boom. The sprayer boom together with the sprayer tank and pump were installed on an inter-row hoe.

Two field experiments in winter oilseed rape and two field experiments in spring oilseed rape (*Brassica napus* L.) were performed in the southern part of Sweden 2012-2013. The experimental design consisted of randomised block experiments with four blocks. The treatments included control, broadcast spraying, inter-row hoeing, and inter-row hoeing + intra-row spraying. Intra-row spraying was performed when the weed plants had reached 1-2 leaf stage and inter-row hoeing was performed about a week after herbicide application.

Results and discussion

Preliminary results showed that in the field experiments with spring oilseed rape, the best weed control effects were obtained with the combination of inter-row hoeing and intra-row spraying in both experiments. Regarding crop yield, the yield was higher in the combined treatment in one of the experiments while no effects on the yields were obtained in the other experiment. Preliminary results from the field experiments with winter oilseed rape showed that the combination of inter-row hoeing and intra-row spraying gave similar weed control effects as broadcast spraying.

We envisage that the inter-row hoeing and intra-row herbicide treatment will diminish the overall use of herbicides in comparison with the more conventional chemical weed control methods, while having the same weed control effect.

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Session 5. IWM

Challenges for Integrated Weed Management implementation in EU crops

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Implementation by all professional users in 2014 of the general principles of integrated pest management is one of the 130 EU environmental policy targets and objectives described by the European Environment Agency (EEA, 2013). According to EC Directive 414/91 (and later EC Regulation 1107/2009) Member States shall ensure that a plant protection product is not authorized unless its active substances are listed in Annex I and it is established, in the light of current scientific and technical knowledge that –among other conditions- it is sufficiently effective, it has -when use as directed- no unacceptable effect on plants or plant products, it has no harmful effect on human or animal health and it has no unacceptable influence on the environment, with particular attention to contamination of water including drinking water and groundwater and its impact on non-target species. Some additional environmental impact indices have been proposed for herbicide treatments in Canada (Beckie et al., 2013), but they have not been applied to mechanical weed control and do not necessarily reflect adverse effects on the environment.

The inclusion of a herbicide active ingredient in Annex I of EC Directive 414/91 or EC Regulation 1107/2009 means that it can be applied with acceptable adverse direct effects on human health or the environment, and Directive 128/2009/EC sets the stage for sustainable use of herbicides and other crop protection products. The general principles for integrated pest management are described in Annex III of this directive, and efforts to apply these principles to integrated weed management (IWM) are being taken by public (such as Gobierno de Aragón, 2013) and private (such as Costa et al., 2013) institutions. While the general objectives of IWM are well accepted, the deployment and adoption of specific recommended practices is facing some strategic and tactical challenges. Strategic challenges are found when the use of alternative biological pest control methods –such as cultivation of genetically modified (GM) varieties- is arbitrarily banned or delayed by an disputable application of the precautionary principle (Marchant et al, 2013); Following 18 years of extensive cultivation and consumption of GM varieties over an accumulated surface larger than 1.500 million ha (James, 2012) no evidence has been found of serious or irreversible damages –conditions defined for application of the precautionary principle according to the 1992 United Nations Conference on Environment and Development- to people or the environment.

Herbicide reduction targets, in some cases not supported by preferred agronomic practices, have been proposed in some EU countries, but for substances approved according to Directive 414/91 this implies overregulation and advancing towards this particular goal could imply going back in other goals at least as important, such as:

- Increased CO_2 emissions, damage to soil biodiversity and soil erosion by excessive mechanical tillage (Jeffery et al, 2010).

- Footprint increase per unit of produced food/feed when the impact on the farmed area is minimized.
- Damage to biodiversity habitats –often in other world areas- by local extensification measures (Witzke and Noleppa, 2010).

Other challenges are more related to short term actions but not less important, such as:

- Reduced number of registered alternative mechanisms of action. No new herbicide mechanisms of action have been discovered in the last 20 years, and the use of photosystem-II inhibitors (C group) is practically not registered anymore for use in perennial crops.
- Choice of weed management programs which are at the same time integrated and economically sustainable for the farming community can have an economic cost. The most commonly used herbicides are usually the most affordable and rotation with other active ingredients to reduce the risk of herbicide resistance often involves lower profitability.
- Timing for adoption of alternatives to optimized crop management. The early detection of herbicide resistance should allow more competitive deployment of alternative chemical and/or mechanical tools to reduce seed production by herbicide resistant biotypes.
- Compatibility of weed control by wild species with farm operations. In perennial crops such as olives or citrus, the foliage of *Lolium* biotypes resistant to glyphosate is eaten by wild populations of rabbits and deer, but farmers are not happy in summer when these animals damage the crop or the drip irrigation systems.
- Communication in updated formats to advisors and farmers in user friendly language. Product stewardship measures are easily justified if herbicides are still patented, but it becomes more difficult when the same active ingredient is offered at low prices by many competing manufacturers, with little room to accommodate training programs.
- Training of commercial and crop management advisors to enable implementation as soon as possible. January 2014 is the target date for adoption of the EC Directive 128/2009 for sustainable use of pesticides (EEA, 2013), but it may not be easy to reach full compliance with all people involved. Although the EU tolerances for traces of herbicides in groundwater have not considered the degree of toxicity of each product, the European crop protection industry association has been developing training LIFE-projects to reduce the risk of point source and non point source water contaminations (ECPA, 2013).

Potential answers and alternative views on these points will be discussed in the IWM Uppsala EWRS Workshop.

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