EUROPEAN
WEED
RESEARCH
SOCIETY

Abstracts

10th EWRS Workshop on Physical and Cultural Weed Control

Alnarp, Sweden

16 – 19 March 2014

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Photographs on the covers courtesy of **Johan Ascard**.

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Scientific programme

10^{TH} WORKSHOP OF THE EWRS WORKING GROUP: **PHYSICAL AND CULTURAL WEED CONTROL**

Alnarp, Sweden
16 – 19 March 2014

Sunday 16 March

16.00 **Afternoon and Evening: Registration**
20.00 **Welcome drink**

Monday 17 March

08.00 *Walk from hotels to bus (local organisation will guide you)*
08.30 *Bus to Alnarp (local organisation will guide you)*

09.00 **Registration**
09.30 **Opening address**
Bo Melander, coordinator and scientific organiser
Fredrik Fogelberg et al., local organising committee

Session 1 – Practical experiences with physical weed control
Chair: Fredrik Fogelberg

11.00 Discussion including coffee

Session 2 – Thermal weed control

Chair: Bo Melander

Session 2 – Thermal weed control (continued)

Session 3 – Poster session (10 posters)

Session 4 – Climate and cover crops

Chair: Fredrik Fogelberg

Tuesday 18 March

07.30 *Walk from hotels to bus*
08.00 *Bus to Alnarp*

Session 5 – Machines for weed control

09.00 Introduction to weed control machines
Sven-Erik Svensson (SWE)

09.30 Indoor show of some interesting machines for weed control eg Garford RoboCrop

Excursion

11.00 Departure from Alnarp. Lunch at the first stop.

Evening: Dinner at a local place in the region of Skåne.

Wednesday 19 March

07.30 *Walk from hotels to bus*
08.00 *Bus to Alnarp*

Session 6 – New approaches

Chair: Marleen Riemens

09.40 Discussion
10.00 Coffee, tea

Session 7 – Cropping systems

Chair: Johan Ascard

Posters

Physical and cultural weed control in Scandinavia

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An overview of current techniques and new developments for physical and cultural weed control in Scandinavia is presented. Examples are given both from conventional and organic farming systems, in cereals, potatoes, sugar beets, vegetables and fruit production. In Scandinavia there are relatively few available herbicides, due to restrictive legislation and market reasons. Therefore, many conventional vegetable growers rely mainly on mechanical weed control in combination with herbicides or hand weeding. Organic growers often use a combination of cultural and physical weed control and finish up with hand weeding.

Several techniques are used for soil cultivation and mechanical weed control. For in-row weed control, special tools are used such as finger weeders, torsion weeders and weed harrows. Larger producers also use precision guided tools with cameras, GPS systems and sensors for inter-row and in-row cultivation. Some new tools for cutting thistles and other tall weeds above the crop are also used as well as special PTO-driven harrows to uproot perennial weeds. Thermal weed control is also used with flame weeding and steaming in high value crops. When you compare machineries, the timing and adjustment of the machineries are often more important than the choice of tools.

Cultural and physical methods are often combined into strategies in order to reduce the need for hand weeding. This includes repeated stale seedbeds, delayed sowing, flaming and row crop cultivation in late sown vegetable crops such as carrots. Mulching is also used in some vegetable crops. Many growers use clever tools and platforms to facilitate hand weeding.

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Practical experiences from physical and cultural weed control in reduced tillage maize growing systems

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In the Netherlands maize is often grown in monoculture and the crop is associated with several sustainability issues, such as increasing pest and weed pressure, pesticide runoff and leaching to the subsoil and surface water. As pesticide use in Dutch maize cultivation today virtually completely consists of herbicides a call for more sustainable maize cultivation directly touches upon alternative weed control strategies. The additional need to improve nutrient efficiency and possibly reduce energy input increases growers' interest in optimising or changing growing systems.

To work on these issues a multifactor field experiment has been running since the spring of 2009 on a marine loam soil (c. 25% clay) in Lelystad (the Netherlands). It compares five maize cultivation systems:

- Reference cultivation: Ploughing (c. 25 cm) followed by power harrow for seedbed preparation;
- Non-inversion tillage: deep tine cultivation and rotary hoe for seedbed preparation;
- Ridge tillage: sowing in permanent ridges, built up after sowing and top removal in following spring prior to sowing;
- Strip tillage: rotary harrow cultivation on 15 cm wide strip in existing grassland;
- No tillage: deep tine cultivation and direct seeding.

Cover crops were used where possible to address nutrient efficiency questions. Earlier research has shown weed control to be a key element in reduced tillage growing systems. Therefore (chemical) weed control strategies practiced by farmers were compared with physical and cultural alternatives, adjusted to each cultivation system when necessary. For any non-chemical weed control strategy to be economically competitive in a conventional practical situation, it should not take more than three field passes with a harrow and/or hoe + intrarow weeders. The weed control strategies were setup with this limitation in mind.

In the set of cultivation systems compared, strip tillage is the maverick, as weed control is based on suppression of weeds by remaining the grass cover from the previous grassland, rather than controlling them at the remaining systems. This system is used in practice in combination with grass cover termination by glyphosate, but in the experiment we intended to maintain the grassland as much as possible in combination with a proper maize yield. We aimed to achieve this by non-chemical strategies such as mowing and flaming.

In the reference system and at non-inversion tillage and at no tillage the practical system of (superficial) harrowing and hoeing was applied as best as possible. For harrowing a powered flex-tine harrow (Agrotechniek Holland BV) was used, preventing the machine from shoving up the possible remains on the topsoil, thus providing a good effect of the machine. Harrowing was applied once each season in all systems without grass cover. Hoeing was combined with finger weeders to reach intrarow efficacy and was applied depending of each system's possibilities. In minimum tillage also strip rotary cultivation was applied.

At the ridge tillage system the ridging after crop establishment caused challenges since the typical and robust equipment used for this system in North America was not available. Both for loosening the soil and ridging various machines were used, with equally various results.

Results will be discussed, including weed control, weed pressure buildup, yield and components and economic aspects.

Expert and farmer "Mental Models" for weed management in organic farming systems.

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Goals of this project were to inform weed management research agendas with the experiential knowledge of organic farmers, and to facilitate transfer of scientific knowledge regarding weed control to the farming community. Our trans-disciplinary team used mental models and bio-physical data to bridge farmer knowledge, perception and attitudes regarding weeds, to actual outcomes on their farms. Mental models are complex webs of beliefs, often operating below the conscious level, that affect how an individual defines and reacts to a problem, gathers and assesses information, and makes decisions. Mental models of target audiences can help educators develop targeted communications designed to change attitudes, beliefs and behaviors. The initial phase of mental models research is to develop a technical, or so-called 'expert model' that is used as an analytical framework for a data collection with audience members. For the technical model 16 'experts' including successful organic farmers, weed researchers and extension educators were interviewed. From the technical model an open-ended interview protocol was developed that was used in interviews with approximately 100 farmers from the USA, and The Netherlands. Subsequently, soil seed bank samples were collected at each farm and determined through exhaustive germination.

Farmers, with their varying risk tolerances and perceptions of weeds and farming practice, incorporated attributes of the farm to develop heuristics that seemed to work for them. Generally, farmers did not highly value advice provided by extension services. Whereas experts expected farmers' applications of ecological weed management principles to be deficient, the data indicated broad-exposure and in-depth knowledge. Seed bank reduction and weed identification were particular foci of farmers' management; however, farmers generally overestimated the longevity of seeds in arable soils, resulting in a perception of inevitability. Farmers took personal responsibility for weed problems, in contrast to many conventional farmers who blame weeds on factors outside of their control. Farmers focused on risks associated with various tactics more so than experts. For instance while relying heavily upon cultivation tools for control, farmers worried about costs, crop injury, timing and soil degradation more than did experts. Farmers valued and utilized cover crops; however, in contrast to experts, their rationale focused on sustaining healthy soils capable of withstanding extensive cultivation rather than on direct suppression of weeds. Several relationships between individual mental models and weed management outcomes were identified. Lower seed bank densities were observed on US farms where more emphasis was placed on 'experience/ risk perception', long-term seed bank management, and less on soil cation exchange site 'balancing', and other 'alternative' knowledge. US farmers who expressed lower risk tolerances for cultivation and flaming, had higher seed bank densities. Like US farmers, Dutch farmers who emphasized the importance of long-term seed bank management also had lower seed bank densities than those who emphasized critical-period weed free management. In contrast to the US, soil cation exchange site balancing was not an issue in The Netherlands. These results indicate that extension teaching should place more emphasis upon farmers' perceptions and needs regarding conservation of their resources, the experiential learning model farmers use to develop heuristics for weed management, and the importance of values in their decision making.

Thermal, mechanical and chemical control of ragweed (*Ambrosia artemisiifolia*) in different habitats

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Two experiments on thermal control of ragweed were conducted in two consecutive years (2012 and 2013). Small plot (2 x 3 m) field experiments with transplanted ragweed in gravel and grassland (10 plants per treatment) and large scale field experiments with natural infestation (0.80-1.50 x 50 m). The experimental layout was a partly randomised block design with the following treatments: (a) flaming 600 °C (Green-Flame 850 E), (b) hot air 370 °C (Combi Compact), (c) hot water 99 °C (Wave High Series), (d) mowing, (e) chemical: dicamba and MCPA.

Dry matter of the remaining ragweed plants was determined 9 weeks after the treatment in gravel and grassland and 4 weeks after the treatment on two 0.25 m² areas at the roadside banquette.

The results of the gravel and grassland experiment showed that ragweed dry matter in grassland was significantly reduced by thermal control at BBCH 16-18 and 22-29. In gravel thermal control by hot air at BBCH 16-18 and 22-29 led to significant lower ragweed dry matter compared to the untreated plots. Mowing (mechanical control) lead to significant lower ($P<0.05$) dry matter at both growth stages in both habitats. All treatments at BBCH 16-18 were more effective in reducing ragweed dry matter compared to ragweed dry matter of plants treated at BBCH 22-29.

The herbicide treatment was most successful in ragweed suppression: This treatment resulted in a complete eradication of the Ambrosia plants in grassland and gravel, both in the plots with treatment at BBCH 16-18 and 22-29, too. The results of the roadside banquette trial showed that the thermal control treatments flaming and hot water led to significant lower ragweed dry matter than the untreated plots. The hot water treatment resulted in the lowest dry matter which differed significantly from flaming. The following order of the treatments point out the best eradication: Hot Water > Mowing > Herbicide > Flaming > Untreated. It was observed that the surviving vegetation in the plots consists of grasses mainly.

These findings demonstrated the efficiency of thermal control methods based on hot air and hot water. Recent investigations in Germany and other European countries also identified hot water systems as a promising tool (Rask *et al.*, 2007; Dittrich *et al.*, 2012). They concluded that at least 2 applications are necessary for successful weed control. In general the hot water treatment is applied up to 4 times during the vegetation period but in our studies it was carried out one time only with very promising results. However, there are still gaps of knowledge in terms of the dose-response relation for Ambrosia and also in terms of the correct timing. Investigation of the earlier Euphresco project on Ambrosia clearly pointed out the low competitiveness of Ambrosia (Holst, 2010). Therefore any direct control method should be as selective as possible to inhibit growth of Ambrosia by the competition of the surrounding vegetation. Despite its high regrowth capacity, there are no indications that Ambrosia is less susceptible against heat treatments like most of other weed species.

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Post-dispersal weed seed flaming

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Flaming is commonly used on organic and low-external-input farms to control weed seedlings, especially annual dicots in slow-to-emerge crops such as carrot and beet. Flaming could, however, also be used to kill weed seeds before they enter the seedbank, a strategy used in recent years by Rob Johanson on the Goranson Farm in Dresden, Maine. In our field studies, pre-dispersal flaming did not affect viability of common lambsquarters or redroot pigweed seeds. Flaming, however, shows promise as a method to reduce density of weed seeds following dispersal. Greenhouse and field studies conducted on-farm demonstrated that flaming could kill weed seeds on the soil surface. Typical tractor speeds used for other flaming operations, e.g., 2.6 kph, killed about 50% of the most sensitive species (i.e., hairy galinsoga), however, with the flame dosage doubled, i.e., to 1.3 kph, flaming reliably killed 75% or more seeds of mustard, large crabgrass and hairy galinsoga. There was no advantage to further doubling the flaming dosage, as seed mortality was similar with both 1.3 and 0.6 kph treatments. With an estimated cost of \$370 ha^{-1} for 1.3 kph treatment, fall flaming could prevent large weed seedbank credits, especially relatively sensitive species including hairy galinsoga.

Optimisation of efficacy and eco-efficiency of hot water weed control

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Non-chemical weed control on pavements needs more frequently repeated treatments than the application of glyphosate (i.e. the most commonly applied herbicide on pavements) and often use large amounts of fuel. In order to obtain an effective hot water control with a minimum energy consumption the following research questions were addressed: (1) Which water temperature allows an effective and eco-efficient weed control? (2) Does hot water sensitivity depend on plant species and growth stage? (3) Which treatment interval and cumulative energy dose (i.e. total energy applied over a 12-week period of consecutive treatments) is most effective and eco-efficient? (4) Do plant species show daytime variation in hot water sensitivity?

Three dose response pot experiments were conducted in open air using dominant, hard to control weeds on pavements. Impacts of plant species, growth stage and water temperature were determined by exposing 39-, 60-, and 81-old plants of seven plant species to water at 78°C, 88°C and 98°C (Exp. 1). Doses applied were 0, 164, 328, 492, 656, 819 and 983 kJ/m². Impact of treatment interval and cumulative energy dose was studied by treating *Lolium perenne*, *Taraxacum officinale* and *Plantago major* at 2-,3-,4- and 6-weekly intervals for 12 weeks with hot water at 98°C and cumulative energy doses of 0, 656, 1311, 1967, 2622, 3278 and 3934 kJ/m² over a 12 –week period (Exp. 2). Daytime variation in hot water sensitivity was investigated by treating *Lolium perenne*, *Taraxacum officinale* and *Cerastium fontanum* 2, 7 and 12 hours after sunrise. Parameters used to quantify the responses to hot water were weed coverage by living biomass 7 days after treatment (Exp. 1 and 3) and total (i.e. aboveground and underground) dry biomass 12 weeks after the first treatment (Exp. 2).

In general, hot water sensitivity was highest for *C. canadensis* and *T. officinale* (species with big, planophyl-orientated leaves) and lowest for the grasses *L. perenne* and *P. annua* (species with small erectophyl-orientated leaves), irrespective of growth stage or water temperature. Sensitivity was intermediary for *C. fontanum*, *P. major* and *T. repens*. Species were most sensitive at early growth stages. Compared to seedlings treated with water of 78 and 88°C, energy doses of hot water required to obtain a 90% reduction in biomass, were 2 to 6-fold and 2 to 3-fold lower for respectively 39 old and 81 old plants treated with water at 98°C. Reduction of total dry biomass over a 12- week period was higher for the 2 to 4-week interval than for the 6-week interval, irrespective of cumulative energy dose. Amongst treatment intervals, treating at 3-weekly intervals was most eco-efficient, irrespective of species. Hot water sensitivity of all species was lowest in the morning and highest 7 (*C. fontanum*) or 12 hours (*T. officinale*, *L. perenne*) after sunrise. Overall, in order to achieve an effective ànd eco-efficient control of weeds, it is recommended to schedule hot water applications for the (late) afternoon, to operate at high water temperature (98°C) and to treat plants at-3-weekly intervals as young as possible.

Evaluation of an automatic steam applicator in strawberry

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Soils in California strawberry fields have since 1960 been fumigated with methyl bromide (MB) to kill soil pathogens and weed seed. Methyl bromide has nearly been phased out in the USA under the Montreal Protocol. Fumigants such as chloropicrin (Pic) and 1, 3-dichloropropene (1, 3-D) have largely replaced MB in recent years. However, local regulations make the use of any fumigants increasingly difficult in California, and there is great interest in developing strawberry production systems that do not use fumigants.

Steam-disinfestation of soil as an alternative to chemical fumigation was investigated at four sites during the 2011-12 and 2012-2013 production seasons. Application of steam was made by a tractor-towed wagon with a propane fueled Clayton SF100 74 KW steam generator (Clayton Industries, City of Industry, CA USA) which produced 1,565 kg h^{-1} of steam set up to treat one 1.3 m wide raised bed per field pass. Steam was injected and mixed into the soil through a bed shaper equipped with rototillers, with multiple steam injection shanks delivering steam through injection nozzles in the tillers and also from the sides and top. The bed shaper was adjustable in pitch and height, resulting in steam being delivered at approximately 35, 25, and 18 cm depths. The cross sectional area of the formed bed treated was 35.6 x 91.4 cm (81.3 top, 101.6 bottom, 35.6 height), or 0.33 m^2 cross section. The soil volume treated was $2.46 \cdot 10^3 m^3$ ha^{-1}.

Steam was applied with the custom made applicator described above calibrated to raise soil temperature to 70˚C for 20 minutes. In the 2012-13 season only, amendments of 3,360 $kg \cdot ha^{-1}$ pelletized mustard seed meal (MSM; Farm Fuels, Inc., Watsonville, CA USA) were made immediately prior to steam treatment of the beds, thus exposing the MSM to the heat of the steam treatment. In the 2011-12 studies, 56.7% Pic, 37.1% 1, 3-D was included as a fumigant standard at 28 and 39.2 g m^{-2} in Salinas and Watsonville, respectively. Fumigants were not included in the 2012-13 studies. All sites used randomized complete block designs with four or five replications.

Results included significant suppression of weeds and soil borne pathogens equal to commercial application of Pic: 1, 3-D. Also, the combination of steam treatment with MSM, a fertilizer and source of additional organic matter, showed very favorable strawberry production in terms of weed and pathogen control. Steam and steam plus MSM treatments consistently gave higher yields than non-treated strawberry beds, and comparable yields to fumigated soils. Future efforts will be focused on development of a commercial-scale steam applicator.

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Relating plant traits and climate change to the distribution of agricultural weed species in Maine, USA

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The most effective physical and cultural weed control practices take into consideration the growth characteristics of the species present. Therefore as weed species distributions shift with climate change, farmers need to know which species are likely to invade so that management practices can be tailored to preempt establishment. Plant traits such as photosynthetic pathway, life cycle, and fecundity have been identified as significant in determining species success in a changing climate (Ziska & Dukes, 2011). We hypothesized that these traits would explain variation in weed species distribution along the varying climate of our region. To test this, we measured the abundance of weed species by exhaustively germinating soil from 30 organic farms in the state of Maine, USA. These farms spanned USDA Hardiness Zones 3b (average annual extreme minimum temperature from 1976-2005 of -37.2 to -34.4°C) to 6a (-23.3 to -20.6°C). The climatic variation in Maine's three degrees of latitude is equal to that of 20 degrees in Europe; roughly 50-70° N (Jacobson *et al*., 2009). Abundance was recorded for 89 species and only 0.005% of the seedlings were unable to be identified. The density of seeds per meter squared for each species ranged from zero to over 27,000, with a mean of 242.68. Literature values for photosynthetic pathway, life cycle, fecundity, and mass per seed were recorded for each species and compared to abundance in each hardiness zone. The proportions of total abundance of C3:C4 species varied between the hardiness zones ($P = 0.002$) with the proportion increasing in the colder zones. This coincides with global trends of decreased C4 frequency in cooler climates. Annual species showed a greater mean abundance than perennials ($P < 0.001$). The abundance of perennials varied significantly across hardiness zones ($P = 0.008$) and the proportion of perennial:annual abundance was greater among the five farms located on islands than the mainland farms ($P < 0.001$). Due to the temperature moderating effect of the ocean, the latter result lends support to the notion that climate change may disfavor perennials due to an increase in freeze/thaw damage caused by more variable winters (Jacobson *et al*., 2009). Eleven of the 89 species significantly decreased in abundance with increasing latitude at the 0.1 alpha level, indicating that these species are at the northern extent of their range. This group of species exhibited increased fecundity ($P < 0.001$), decreased mass per seed ($P < 0.001$), and increased abundance of the C4 pathway ($P < 0.001$) when compared with the other species. The high fecundity and low mass per seed of these species may encourage favorable dispersal as the climate further north becomes newly tolerable. The high composition of C4 among these species is logical due to the advantage of C4 in warmer climates; however, the predicted advantage of C3 species due to increasing future atmospheric CO_2 concentration (Ziska & Dukes, 2011) may limit the northward shift of this group.

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The effect of different cover crops and nitrogen split on weed control in forage maize (Zea mays)

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In order to evaluate use of cover crops to control weeds in forage corn a factorial experiment with three factors and three replications in a randomized complete block design was done at the Agricultural Research Station in Ardabil in 2012. The first factor was cover crop type: rye, hairy vetch, clover and no cover crop including weedy and weed free. The second factor consists of nitrogen split of 225 kg urea per hectare with 2 levels, the first level was two split (1/2 at sowing + 1/2 in the 8 to 10 leaf stage of corn), second level was three split (1/3 at planting + 1/3 in the 8 to 10 leaf +1/3 a week before tasseling of corn). The third factor consisted of two sampling time: 60 days and 90 days after corn planting. Analysis of variance showed that rye, hairy vetch and clover decreased annual weed biomass 90, 84 and 66 percent and weed biomass 70, 54 and 32% respectively. Also these cover crops decreased perennial weed biomass 62, 50 and 22% and perennial weeds density 80, 76 and 59% respectively. Cover crops and nitrogen split interactions have significant effect on plant height, diameter and length of corn ear, so the maximum height, diameter and length of corn ear was in weed free treatment with three nitrogen split. The highest fresh forage yield of corn was 51.3073 ton per hectare in weed free treatment. The next treatment was hairy vetch cover crop, with the most significant difference in compare to other treatments. Overall, the optimum treatment was hairy vetch cover crop with two nitrogen split.

UAS (unmanned aircraft systems) imagery as a tool in physical weed management

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The objective of this presentation is to demonstrate two applications of unmanned aircraft systems (UAS) imagery in physical weed management: (1) mapping of perennial weeds and (2) the assessment of crop heterogeneity as a consequence of weed harrowing or other physical weed control methods. In spring 2012, we did our first RGB photo sessions with a six rotor UAS hexacopter (Hexa XL, HiSystems GmbH, Moormerland, Germany) with GPS waypoint navigation (Fig 1). For us it was important that the UAS offered low-cost sensing with high flexibility in terms of spatial and temporal resolution. Furthermore, the UAS should be user-friendly, reliable and with low maintenance costs. In 2012 our focus was on methodical questions related to the assessments of vegetation indices and in 2013 we started our work with identification and mapping of noxious perennial weeds in agricultural crops.

Fig. 1 Hexacopter with RGB camera

Our work shows that UAS imagery offers great potentials for fast and reliable estimations of crop leaf cover and other vegetation indices in plots and fields. When it comes to weed mapping, our work has just started and the presentation will give an updated status on mapping of perennial weeds in cereals. The perspectives of both applications will be discussed in relation to physical and cultural weed management.

Reference

Rasmussen J, Nielsen J, Garcia-Ruiz F, Christensen, S & Streibig JC (2013) Potential uses of small unmanned aircraft systems (UAS) in weed research. *Weed Research* **53**, 242–248

Site-specific physical weed control by autonomous unmanned unit

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Effective physical weed controls can be performed in row and between-row using both “low-tech” mechanical and thermal tools and machines and “high-tech” innovative systems. Especially for in row weed control, site-specific management enables to save a large amount of inputs. Studies on autonomous weed control systems, provided with proper sensors and able to acquire and process all the data needed to discriminate weeds from crop plants, have rapidly increased in recent years. Machine vision can represent a superb technological system and it is increasingly incorporated on autonomous robots able to perform site-specific treatment in agriculture.

In 2010 started the RHEA European Project (Robot fleets for Highly Effective Agriculture and forestry management) that aims to create a fleet of autonomous aerial and ground mobile units able to perform crop protection and weed control operating in different scenarios. The activities of the research group of the University of Pisa concerned with the study and realization of an automatic implement, to be coupled to an autonomous unmanned ground mobile unit (GMU) and able to carry out precise and targeted physical weed control on maize.

The operative machine was designed and realised in order to perform mechanical and thermal weed control at the same time removing weeds mechanically from the inter-row space and performing in row precise and targeted cross flaming. The 3 m wide PWC machine is mounted on a GMU provided with a perception system for weed and crop detection, communication facilities to receive command and report information to a remote base station. The complete automated system includes also an autonomous aerial unit (flying drone) provided with perception and location systems, in order to provide useful information automatically processed and analysed for planning the mission of the GMU.

In order to evaluate the LPG consumption for a precise flaming treatment, a simplified simulation of a 16 rows maize field infested with weeds was performed. The crop rows were divided in cells 0.25 m wide and 0.50 m long. Then, three ranges of weed cover to three level of treatment were associated:

$0 \leq$ weed cover $< 5\%$ no treatment;
$5 \leq$ weed cover $< 25\%$ treatment at 0.3 MPa LPG working pressure;
weed cover $\geq 25\%$ treatment at 0.4 MPa LPG working pressure.

In order to prepare a weed distribution map, 100 pictures with a digital camera (taken in a surface of 0.25 m wide and 0.5 m long) along the crop row in a real maize field were collected. Weed cover was then determined analysing the pictures with Imaging Crop Response Analyser.

Starting from this map considering the three level of treatment mentioned above and a constant working speed, the consumption of LPG per unit surface was calculated. The total LPG consumption per hectare was reduced by 44% and 55% with the precision and targeted flaming with respect to a continuous flaming treatment performed at 0.3 and 0.4 MPa working pressure.

The final demonstration of the RHEA Project will take place in Madrid in May 2014.

Effect of Cropping Diversity and Input System on Weed Populations in a 18-Year Cropping System Study

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The Alternative Cropping Study is a multi-disciplinary study that investigates the long-term impact of tillage inputs and cropping diversity, including organic production, on economic and environmental sustainability. The study was established in 1994 at Scott, SK near the geographic centre of the Canadian Prairies, in the Moist Mixed Grassland eco-region between the semi-arid and sub-humid prairies. The split-plot experiment consists of three levels of inputs comprising the main plots and sub-plots comprised of three levels of cropping diversity each on a six year rotation cycle. Input levels are described as Organic (ORG), Reduced (RED), and High (HIGH) and cropping diversity levels as Low (LOW), Diverse Annual Grains (DAG), and Diverse Annual and Perennial Crops (DAP). The study utilizes a six year crop rotation cycle, with treatments repeated on the same plots every 6 years. The study completed its 18th year in 2012. Initial site characterization of the 216 plots covering 16 ha was done by conducting weed counts twice (pre- and post- weed control) in the set-up year of 1994. Weeds were identified and counted in twenty randomly selected 0.25 m^2 quadrats per plot. After the initial site characterization, weed data was collected using the same methodology 4 times a year (spring, prior to in-crop weed control treatment, post in-crop weed control treatment, and late fall). Organic systems generally had higher weed densities than the Reduced and High Input systems; however, densities varied greatly year-to-year and did not steadily increase in the Organic systems over the 18 years of the study. Decomposition of the variance in the residual post-treatment weed community data found that spatial factors (based on initial site characterization) accounted for about 50% of the total variance initially and declined slightly over the time period of the study. The effect of year-to-year variation initially accounted for about 30% of the total variation and increased slightly over time. The impact of system initially accounted for only about 20 % of the total variance, also showing only a slight but steady increase over time. Principal response curves indicate that species such as *Setaria viridis*, *Chenopodium album*, and *Thlapsi arvense* were associated with Organic systems, while *Avena fatua*, *Crepis tectorum*, and *Capsella bursa-pastoris* were associated with Reduced systems. Successful interpretation of trends in weed communities must consider both initial spatial variation and yearly fluctuations.

Evaluation of the impact of organic weed control practices on soil seed banks of organic farms in California, USA

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Organic vegetable farms have different levels of weed pressure due to factors such as grower skill, access to equipment and labor, and the type of crop rotations. Some growers may have lower weed pressure and lower weeding costs while others may have weedier fields with higher weeding costs. Weed control techniques used by organic producers include cultural and production practices such as crop rotations, use of preirrigation followed by tillage, as well as mechanical cultivation and hand weeding. On the central coast of California, USA, temperatures are mild due to the proximity to the Pacific Ocean and leafy vegetables are the dominant vegetable type produced. Bed configurations range from traditional 1.0 m wide beds with two seedlines to 2.0 m wide beds with 5-6 seedlines; in addition, 2.0 m wide beds are used to produce high-density (24-32 seedlines), short-term (30 days) baby type vegetables.

A survey of 20 organic vegetable farms was conducted in 2010-2011 to evaluate the impact of grower production and weed control practices on the soil weed seedbank. Composite soils samples were collected to a depth of 15 cm from five areas of a representative block on each farm. Soils were placed in trays 25.5 cm x 51.0 cm and 6 cm deep. The trays were placed in a greenhouse and watered to germinate a flush of weeds. Weeds were identified and counted; the soil was remixed and the germination process was repeated 4-5 times to estimate the number of seeds in the soil seedbank.

The number of seeds on the various farms ranged from 13 to 20,384 m^{-2}. The five ranches with the lowest seedbank values (<110 seed m^{-2}) were all larger farming operations that specialized in the production of high-density, baby vegetables. Baby vegetables routinely mature and are harvested before most weed species set viable seed, and it is presumed that these rotations, over time, exhaust the seedbank. In addition, these farms instituted strict zero weed seed philosophies and they had sufficient resources to carry out timely weeding operations during all phases of the crop cycle, thereby successfully achieving the zero weed seed mandates. All other farms with higher levels of seeds in the soil (mean = 2,319 m^{-2}) had more diverse rotations that included few if any high-density, short-term crops; they grew longer-season crops such as lettuce, garlic, onions, peppers and cole crops. These operations did not have strict zero weed seed policies, and as a result, allowed more weeds seed production during the cropping cycle. The farm with the most seed in the seedbank (20,384 m^{-2}) produced leeks over the winter and had a severe problem with annual blue grass (*Poa annua*); the seed from this weed comprised a large proportion of the weed seeds in the seedbank.

The results of these evaluations indicated that organic vegetable operations with a zero weed seed philosophy with the resources to realize this philosophy had the lowest number of seeds in the soil seedbank. These farms were larger-scale operations that specialized in short-term, high-density baby vegetable production. These growers stressed that achieving the low soil seedbanks levels took a number of years, but was necessary to keep weeding costs low enough to be able to economically produce high-density baby vegetables.

Weed control effect of covering seed rows of an organic carrot crop with sand, compost or soil

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In a three-year study at Raggården, Västra Götaland, Sweden, the weed control effect of covering the seed rows of an organic carrot crop with sand, compost or soil was examined

The first experiment (2009) showed that covering the seed rows with 2 or 4 cm sand, garden compost or dry arable soil as the sole weed control method was not sufficient and had to be complemented with flaming, row hoeing and hand-weeding to produce a satisfactory effect.

The second experiment (2010) studied the combined effect of sowing the carrot seed at different depths (2, 3, 4 cm) flaming prior to carrot emergence and soon thereafter covering the seed rows with 0, 1 or 2 cm compost. Sowing at 2 cm depth in combination with 2 cm compost gave the lowest number of weeds (approx. 30 per m^2), while sowing at 2 cm depth in combination with 1 cm compost or no compost gave twice as many weeds. Carrot emergence was faster and early post-emergence growth greater in the treatments involving covering with compost. Thus the compost layer did not delay carrot emergence.

The third experiment (2011) also studied the combined effect of sowing to different depths, flaming prior to carrot emergence and then covering with compost. Sowing at 2 cm depth in combination with 2 cm compost (requiring approx. 40 m^3 compost per ha) lowered weed numbers by approx. 60%, but also reduced the number of carrots per row-metre by 30%, compared with no compost covering. The period following application of the dark garden compost was cloudy and rainy in this year, which probably contributed to lower emergence after covering with 2 cm compost. However, final yield remained unaffected at approx. 75 ton hand-harvested carrots per ha.

Fertilizer placement and competitive ability of spring barley varieties – Results from two years of organic field trials

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Average annual yields of organic spring barley in Denmark 2008-2012 ranged from 37 to 40 hkg per hectare, whereas yield levels of conventional barley in the same time frame ranged from 46 to 55 hkg per ha (StatBank Denmark, 2014). Organic yield levels are thus significantly lower than conventional yield levels, and competition from weeds is a major cause of yield loss. One of the previously demonstrated management methods, to decrease weed effect on grain yield, is fertilizer placement. Another method is to grow a variety with a high competitive ability towards weeds. To investigate the effects of combining fertilizer placement with crop competition in organically grown spring barley, a two-factor field experiment was conducted at certified organically grown fields in 2012 (3 locations) and 2013 (5 locations). The fertilizer/plant nutrient treatments were 0 kg; 500 kg Biogrow per hectare (Biogrow is an organic fertilizer product based on meat and bone meal, NPK 10-3-1, dosage equivalent to 50 kg N per hectare) broadcast at time of sowing; or placement of 500 kg Biogrow per hectare between the rows of spring barley at 6 cm depth. The second factor was variety, where the variety Simba was chosen as a variety with low competitive ability towards weeds whereas Quench (2012) or Evergreen (in 2013) were chosen as competitive spring barley varieties, these varieties were approximately 6 cm taller than Simba. The experiments were harvested in August when the crop was fully ripe and grain yield recorded. Data from the 8 experimental locations were statistically analyzed by the Nordic Field Trial system.

Results of these experiments showed a significantly higher grain yield per hectare in the competitive variety compared to the variety with lower competitive ability, and the fertilizer placement resulted in a significantly higher grain yield than the broadcasted fertilizer application. Furthermore, fertilizer placement resulted in significantly lower weed coverage at flowering, than broadcasting the fertilizer. A further objective of the study was to investigate if the experiment would reveal an interaction between the two factors. The statistical analysis of grain yields at each experimental location revealed a statistically significant interaction between fertilizer treatment and variety at two locations; however 6 locations showed no significant interaction. A similar pattern was found for weed coverage. The experiment therefore implies that using fertilizer placement and growing a competitive spring barley variety will have mostly additive effect on the expected grain yield per hectare.

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Timing of stubble cultivations is important for the control 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.

Both control methods has a number of negative side-effects. For example, stubble cultivations, especially if repeated, are time and fuel demanding and could cause increased nitrogen leaching. However, previous experiments and theory indicate that a single cultivation will cause massive reshooting of the couch grass, which could exacerbate the problem. Thus repeated tillage is recommended. The main aim of the study was to investigate how the timing of the stubble cultivation affects the control of couch grass. The hypothesis was that with good timing, i.e. at harvest, one stubble cultivation would reduce couch grass biomass more compared with less optimal timing (three weeks later). Repeated cultivations were expected to further improve the control, even if the primary cultivation was delayed a few days.

The experiment was conducted in three locations in southern and eastern Sweden in 2011-2012, and repeated in 2012-2013 in two of the locations. The design was randomized complete blocks with five treatments of stubble cultivation: (a) none, (b) twenty days after harvest, (c) at harvest, (d) at harvest and repeated twenty days after harvest, and (e) five days after harvest repeated twenty days after harvest. Measurements taken were abundance of couch grass shoots, and aboveground and rhizome biomass.

Preliminary results show that treatments (c), (d) and (e) consistently had significantly lower couch grass shoot abundance ($p<0.0001$) and about a quarter as much rhizome biomass ($p<0.0001$) as the control, in both 2012 and 2013. In 2013, the couch grass shoot biomass in treatments c-d was about one third of the biomass in the control ($p<0.0001$) (no data from 2012). The crop yield was approximately 26% higher ($p=0.0002$) in treatments c-d than in the control. The effect of treatment (b) was much more variable compared to the control than the effect of c-e, but was on average an intermediate between the control and the other treatments.

The results show two interesting things. Firstly, timing is very important for single cultivations, as shown by the more consistently positive results of (c) compared to (b), but perhaps not for two cultivations, (d) vs. (e). Secondly, the single early cultivation could not be distinguished from the treatments with two cultivations in the effect on couch grass. This seemingly contradicts earlier experiments and theory and could potentially lead to reduced tillage and new control combinations e.g. an early stubble cultivation followed by a cover crop.

Perennial weed control: comparison of herbicidal, mechanical and anaerobic soil disinfection treatments

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Integrated pest management is increasingly important, not only from an environmental perspective, but also due to European legislation demanding a reduction of pesticide use. Today's agriculture is highly dependent on herbicides, alternatives usually being more expensive and less effective. The development of alternative control strategies is therefore required. The development of these control options requires insight in the species life cycle. We conducted a field trial investigating the effect level of eleven strategies used to control these species under local Dutch conditions.

Dutch farmers were asked to rank the ten most problematic weed species: *Sonchus oleraceus, Cirsium arvense, Rorippa sylvestris, Mentha arvensis, Convolvulus sepium, Rumex obtusifolius, Equisetum arvense, Elymus repens, Stachys palustris, Tussilago farfara* and *Persicaria amphibia*.

For each of these species root pieces were collected during the fall of 2008 and planted in two fields in furrows of 5-10cm deep in the last week of March 2009. The first field had a marine loam soil in Lelystad and the other field a Eutric Fluvisol (texture loamy fine sand) soil in Wageningen. The weeds were planted in four blocks, in rows measuring 38m, of which 8m was reserved for destructive measurements. Root pieces were placed 33 cm apart.

In the second year after burial, control trials started. A rod weeder mounted behind a rigid-tine cultivator was compared with a broadcast root knife operating at two depths: 5 cm and 15 cm. Anaerobic soil disinfection treatments comprised the combined incorporation of 40 tons/ha fresh grass and weed biomass or incorporation of the weed biomass alone into the plough layer (~ 25 cm). Both treatments were covered with black plastic sheets immediately after incorporation. Sheets were kept into place between end of July and mid October. Three herbicide treatments were tested, one of which was an experimental species specific herbicide treatment differing for all species, one was MCPA application (Aramo for *E. repens*) and one was glyphosate application. The percentage cover preceeding every action during the growing season and the root dry matter present in the following spring were used to determine the control level. In the untreated control plots, cover of all species reached 100% in the course of the season.

The rod weeder was the most effective mechanical weed control method in the absence of a crop. Seven passes with the rod weeder in the period April-August reduced the cover from 90% for *Rorippa sylvestris* upto 99% for the other species during the growing season. In the following spring the effect was still noticeable: root mass in the rod weeder treated plots was 86-99% less than in the control plots for all species, except for *T. farfara* and *M. arvensis*. These long term effects were better than the long term effects of the herbicides (14-83% control). The broadcast root knife operating at 15 cm depth was the most effective method to control *M. arvensis* and *S. arvensis*, both short and long term (99% control during season and 94% following spring). Cover of *R. sylvestris*, *C. sepium*, *E. repens*, *R. obtusifolius* and *P. amphibium* was reduced by 88-98% after the anaerobic soil disinfection treatment. The highest long term control level obtained for *T. farfara* was 64% after treatment with MCPA. We conclude that for most specious non-chemical control options can provide us with good alternatives to herbicide treatments.

The dynamics of *Cirsium arvense* and *Elytrigia repens* in long-termed organic crop rotation experiments

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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 1997-2009. 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* on coarse sand, especially when preceded by grass-clover. However, grass-clover with mowing had the opposite effect on *C. arvense* growth on sandy loam 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 that were rotary tilled 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 suppression 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 might be valuable tools for the suppression of perennial weeds in organic cropping systems, especially *C. arvense* while this is less clear for *E. repens*. 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*.

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Acroptilon repens (L.) Dc essential oil phytotoxic activity and its possible use as a bioherbicide

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Acroptilon repens (L.) Dc (Asteraceae) is a wide distributed plant that is native to Mongolia, Western Turkistan, Iran, Turkey and captain Asia and was introduced into America and Canada at the beginning of previous centaury. A study was conducted to assess the phytotoxic effects of hydrodistillated essential oil from *Acroptilon repens* (L.) Dc (Asteraceae) against two weeds germination as a bioherbicide for devise in organic farming. The hydrodistillated essential oil from aerial parts of *A. repens* was analyzed by GC-MS. Totally 26 compound were identified. Main component of the oil are: Caryophyllen oxide (9.69%), β- cubebene (9.57%), β -Caeyophyllen (9.21%) and α-copaen (8.71%). The results of phytotoxic assay indicated that the essential oil obtained from *Acroption repens* significantly reduced seed germination of *Abutilon theophrasty* and *Cirsium arvense*, two noxious weed, in a dose dependent manner. On the hand, the essential oil of *A. repens* inhibited the root growth of *A. theophrasty* and *C. arvense* seedlings significantly. The oil strongly reduced the shoot growth of *C. arvense* seedlings. These results suggest that *A. repens* should be further explored as a bioherbicide for weed management.

The effect of mechanical weed control methods and nitrogen fertilizer on growth and yield of Sugarcane

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In order to study the effect of mechanical weed control in combination with nitrogen fertilizers methods in Sugarcane farms, an experiment was conducted in applied research center of Amir Kabir Sugarcane Agro-industrial (2009-10) (IRAN). In this experiment 2 methods of nitrogen fertilizer application and 4 methods of mechanical weed control include cultivator and broadcast nitrogen fertilizer application, cultivator and band nitrogen fertilizer application, subsoiler and broadcast nitrogen fertilizer application, subsoiler and band nitrogen fertilizer application, subsoiler+cultivator and broadcast nitrogen fertilizer application, subsoiler+cultivator and band nitrogen fertilizer application, cultivator+cultivator and broadcast nitrogen fertilizer application, cultivator+cultivator and band nitrogen fertilizer application were examined and their efficiency in reduce of weed damage was compared. Experimental design was randomized complete block and in 4 replicates. 3 months after planting and one month after nitrogen fertilizer application, dry weigh of weeds, and ultimately growth and cane yield was estimated. Result showed that there was no significant difference in sugarcane high, but between treatments was significant difference at 5% level in density and yield and respectively disc and subsoiler with 23.23 and 14.23 kg/m^2 maximum and minimum yields were produced. Also the best and worst results in terms of weed control treatments were the same.

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Study the effect of band herbicide application in combination with mechanical weed control on weed control and growth of sugarcane

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With care to Sugarcane cultivate condition and for study the effect of herbicide band method application on weed control and reduce application of herbicides, a research was done in Amir kabir Sugarcane Agro-industrial research center in 2010-2011 (Iran). Experimental design was randomized complete block and in 4 replicates. The treatments include: band application of metribuzin 4 kg/ha before first irrigation and inter row cultivation, band application of metribuzin 4 kg/ha before second irrigation and inter row cultivation, one time inter row cultivation, band application of metribuzin+ atrazine (2 + 3 kg/ha) before the first irrigation and inter row cultivation, band application of metribuzin + atrazine (2+3 kg) before the second irrigation and inter row cultivation, two times inter row cultivation, control (weedy) and weeding. The results showed differences between treatments in terms of density and weed dry weight was significant at 1 percent. Best results in reduce of density and weed dry weight specially in control of grass obtained from spraying before second irrigation+ inter row cultivation and they were significantly better than spraying before first irrigation+ inter row cultivation and mechanical weed control treatments. Also in spraying before second irrigation because of better weed control and reduce of weed competition, made better growth condition and yield production for Sugarcane. And the worst result belongs to one time inter row cultivation.

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An evaluation of two sweep cultivator types on annual weeds control in sugarcane fields

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At present the sweep cultivator is the main tool for weed control in sugarcane fields of Iran. In order to evaluate two types of sweep cultivator on annual weeds control in inter-row of sugarcane crop, an experiment was conducted at Farabi Agro-industry Co., in Khouzestan province in 2013. The experimental design was split split-plot with RCBD arrangement in three replications. Soil moisture content in three levels of 12-14%, 14-16% and 16-18% were considered as main plot, three cultivation(travel) speed of 6, 8 and 10 km hr^{-1} and two types of sweep cultivator include three and five C-shanks ones for each inter-row formed as sub plot and sub-sub plot respectively. Weed mortality, survival and reemergence data were collected from the cultivated area of each of the two cultivators, at each cultivation speed. Environmental data were also collected at each replication. The effects of environmental and operational variables, on postcultivation weed survival was evaluated.

The primary results immediately few days after cultivation showed that soil moisture content and cultivator type both were more effective factors in reducing weed population. The favorable condition for uprooting and cutting of weeds as for its heavy soil texture(silty clay loam) obtained in the soil moisture content of 14-16% with 3.67 per m^2 and gave the maximum weed mortality by 96.26%. The soil moisture and cultivation speed also had interactions on weed mortality in the same time. Over time, and in the final sampling of weeds, the effect of soil moisture factor on weed control decreased. The five shanks cultivator, 21 and 50 days after cultivation, showed more efficacy on weed control(in comparison with three shanks cultivator) with 90.52 and 91.91% respectively.

The travel speed of 10 km hr^{-1}, 50 days after cultivation was the best speed limit on weed control with 92.08%. The travel speed and cultivator type both, 1day after cultivation, were the most important factors in the surface clod formation(clod size >5cm diameter) in inter-row(furrow bed). The soil moisture and cultivator type also showed interactions in clods formation.

Generally the experiment results emphasized that annual weeds over a period of approximately 8 weeks after cultivation, are affected the more by travel speed and cultivator type factors compared to the soil moisture. In this regard, weed control increases with increasing travel speed.

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Experiences on physical weed control in nursery container production

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Weed control represents a major issue not only in agriculture but also in nursery production of ornamental species. This is also a key problem in nursery container production, where weeds can relevantly affect the aesthetical and commercial value of the plants.

Usually this problem is overcome using liquid or granular herbicides or special disks (i.e. coco-fibre disks) which suppress/avoid weed emergence. However, the use of herbicides is often associated with possible environmental drawbacks while the disks may represent a relevant cost for the farmers. Moreover no natural substances with herbicide action are labelled in Italy for nursery production at the moment.

In this respect, a specific trial has been carried out at the University of Pisa since 2012 in order to test different physical weed control methods, which may be a possible alternative to herbicide application and disk use in nursery container production. The treatment where made in *Photinia × fraseri,* growth in common commercial pots filled by peat-based potting soil artificially infested by *Oxalis corniculata* L.

Two different physical treatments were compared:

- flaming performed with a trolley machine connected to a manual lance equipped with a 10 cm wide open flame rod burner;
- steaming performed with a professional steam generator (power 2.4 kW and steam outflow 3.12 kg h^{-1}) equipped with a manual lance and an on purpose designed and realized dispenser.

Two different frequencies were tested for both the thermal applications.

This trials is still on-going but the preliminary results showed that steaming could represent a real effective and economically sound system of weed control in nursery container production. However, further studies to closely evaluate steaming performance and long-period effectiveness as well as generator efficiency are needed in order to optimize this technique.

Mechanical and cultural methods improve weed control of herbicide resistant weeds

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Globally, herbicide resistance has rendered many herbicides unusable for controlling problem weeds. Many weeds in the crop lentil have evolved resistance to imidazolinone herbicides in western Canada. Cultural and mechanical weed control systems for organically grown lentils have been developed that have no reliance on herbicides. The objective of this research project was to determine the effect of integrating mechanical and cultural methods with alternative herbicides for the control of herbicide resistant weeds. Two studies were conducted to test this objective. The first study was examined the interaction between increasing seeding rate in lentil and the dose response relationship of fluthiacet-methyl on wild mustard (*Brassica kaper* L.). Results of the experiment show that increasing lentil seeding rate decreased the total mustard biomass when herbicides were not applied. In addition increasing lentil seeding rate lowered the herbicide dose required to result in a given reduction in mustard biomass. These results suggest that the practice of increasing seeding rate can work with herbicide application to reliably and effectively control weeds, even in situations where herbicides may not achieve good control. A second study evaluated the effect of integrating rotary hoeing, increased lentil seeding rate and metribuzin on control of wild mustard. Integrating multiple tactics resulted in reduced wild mustard biomass and higher lentil yields, especially at lower herbicide rates. At higher herbicide rates there was usually less response to integrating non-herbicidal methods. In conclusion integrating non-herbicidal weed control methods can aid in control of herbicide resistant weeds.

Impact of chaff collection, primary tillage and cultivation on ragweed (*Ambrosia artemisiifolia*) population

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Common ragweed is a very competitive weed and can decrease organic soybean yield by as much as 30 % (Cowbrough *et al.*, 2003). Under organic production systems, a few ragweed plants can escape cultivation on the crop row and can continue to grow and reach heights exceeding that of soybean. They flower, produce pollen causing allergies, and produce viable seeds which fall down on the soil and increase weed seed bank. These escaped plants, because they are still green at soybean harvest time, can make harvesting difficult and decrease seed quality when they stain the crop seeds. Our hypothesis is that a portion of common ragweed seeds could be collected during soybean harvesting and consequently reduce this weed's population the next year. The objectives of this project were to determine the effects of chaff collection and cultivation techniques on common ragweed population over time.

Field studies were conducted from 2009 to 2011 on the same ragweed infested field at the Research Center in Saint-Hyacinthe, Québec, Canada. There were 15 treatments, including 2 controls. A manual weeding treatment was harvested conventionally, then it was either ploughed, offset disked or without primary tillage (3 treatments). The second control was a weedy check harvested with or without chaff collection that was ploughed, offset disked or without primary tillage (6 treatments). The other six treatments were all cultivated three or four times, harvested with or without chaff collection and then ploughed, offset disked or without primary tillage. Treatments were arranged in a randomized complete block design with four replications, with plots 3 m wide by 7 m in length. Soybean variety 'S10-B7' was seeded using a 4-row planter in 76-cm rows at a density of 517 000 plant ha^{-1}. Ragweed density was measured in a quadrat of 0,2 by 1,0 m.

Cumulative data indicate that the type of primary tillage influenced ragweed establishment the following year. After three years, cumulative ragweed emergence was lower in ploughing treatment than in the treatments that were offset disked or that were not tilled. In cultivated soybean, chaff collection decreased ragweed density by 57, 46 and 76% the year following the primary tillage, respectively in ploughing, offset disking and no tillage treatments. After two years, ragweed density decreased by 32 and 38 % in the treatments offset disked or not tilled when chaff was collected but there was no significant difference between the treatments that were ploughed. The best cropping management system in soybean to reduce ragweed population was ploughing and mechanical control during the season. Chaff collection could help to decrease ragweed abundance if ploughing is not an option.

References

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Brassica juncea biofumigation effect on weed seed viability

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Biofumigation is an agronomic practice that can be used in organic farming in order to deplete the weed seed bank. It consists of using volatile chemicals, released from decomposing *Brassica* tissues, to decrease weed seed viability. The most common volatiles produced during the breakdown of *Brassicas* are isothiocyanates (ITCs) which are released following tissue disruption when myrosinase enzymes hydrolyse glucosinolates (GLSs) in presence of water. Growth chamber experiments were conducted to evaluate the herbicidal activity of different amounts of dry mustard tissues on seed viability of *Ambrosia artemisiifolia*, *Chenopodium album*, *Daucus carota*, *Setaria viridis*, and *Vicia cracca*. Mature weed seeds were randomly collected in 2012 from fields at the IRDA research station, St-Hyacinthe, Qc, Canada. Fifty seeds per species were placed in a sealed 9-cm Petri dish in a completely randomized design with six treatments: 0 (control), 0.152 (x/3), 0.228 (x/2), 0.456 (x), 0.911 (2x), and 1.367 (3x) g Petri^{-1} of dry tissue of *Brassica juncea* var Caliente 199. The growth chamber was set to 22°C, 16:8 light:dark. Petri dishes were unsealed after 4 days in order to mimic field situation where ITC volatiles mostly disappear 4 days after soil incorporation. The middle dose x (0.455 g) was equivalent to 10% of the field dry mustard biomass (7 t/ha) when efficiency of conversion of GSLs in *Brassica* tissues into ITCs is 10% in soil (worst situation). *Brassica* plants were grown in 19-cm pots placed in a growth chamber at 25°C until flowering, cut at soil surface, and dried at 35°C for 5 days. Analysis by headspace gas chromatography-mass spectrophotometry showed that allyl-isothiocyanate was the main ITC produced and released at 2455 (± 53 S.E.) µg g^{-1} of dry plant tissue. The study was conducted twice, with five replications per treatment. Seed germination was recorded every 2-3 days for one month. The viability of non-germinated seeds was evaluated using tetrazolium test. Results indicated that *Brassica* biofumigation had a negative effect on seed germination and viability. Seed germination of *A. artemisiifolia* decreased by 52 and 90% and mortality increased by 16 and 69% respectively at doses x and 2x. Survival of dormant seeds decreased by 55% at dose 2x. *C. album* germination declined by 82% at a dose x and 98% at doses 2x and 3x. Mortality and survival of dormant seeds at dose 2x respectively increased by 92% and decreased by 75%. *D. carota* showed 93% lower seed germination with the dose x and 100% of mortality at 2x and 3x. Control treatment of *S. viridis* and *V. cracca* had a lower rate of seed germination, 25 and 4%, respectively compared with other weed seeds were more than 70% germinated. For *S. viridis* and *V. cracca*, the dose 2x is required to observe a significant impact on mortality and survival of dormant seeds. This bioassay demonstrates the herbicidal activity of ITCs released in *Brassica* tissue, specifically by reducing the viability of dormant and non-dormant seeds. The use of *Brassica* cover crops in organic cropping systems could provide increased weed management options and could be used to deplete the weed seed bank.

Evaluation of hand tools for weeding

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Hand weeding is the most common weed management practice on small- to mid-scale diversified organic farms. While exceptionally effective, high labor costs make hand weeding an expensive input. Moreover, time required for high levels of weed control by hand increases with increasing weed density. Hand weeding may rely on pushed, wheeled tools, long-handled tools, short-handled tools, and/or hand pulling. We conducted eight field experiments, measuring working rate (i.e., row-feet weeded per minute) and efficacy (i.e., proportion of weeds controlled) in a standardized crop/surrogate weed system of corn and condiment mustard (*Sinapis alba*, 'Idagold'). Wheeled tools generally had highest working rates, but occasionally lower efficacy than other tools or hand pulling. Importantly, working rates for wheeled tools were independent of weed density. Thus, even though efficacy may only average 60%, wheeled tools should be used before other hand methods because of their very high working rates. Long-handled tools may offer improved efficacy over wheeled tools, but generally with lower working rates. Short-handled tools and hand pulling offer potentially complete weed control, but with increasing time proportional to weed density.

Overall, wheeled tools should be the first step in a hand weeding program, followed by long- and then short-handled tools, with hand pulling a final step where very high efficacy is required. A comprehensive weed management plan focused on reducing the weed seedbank will result in both improved weeding outcomes with the use of hand tools, and lower hand weeding costs. Surprisingly, qualitative surveys of hand tools indicated a high level of variation in user preference. The Glaser® stirrup hoe was top-ranked in aggregate user scores for "feel," "efficacy," and "overall," followed closely by the Glaser® wheel hoe. Contrary to expectations, tool rankings were, with a few minor exceptions, generally unaffected by gender, age, years of experience or scale of enterprise. It was difficult to get users to carefully evaluate many of the tools; some they would pass over based on observation or after only a brief test, moving quickly to a tool they were more interested in. Future qualitative tests should consider using focus groups or other "expert panels" to evaluate groups of five to ten tools that have a similar intended use (e.g., precision weeding; control of large weeds; wheeled tools).

Fighting weeds with mulches on forest tree nurseries

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Most of the forest tree seedlings in Finland are nowadays produced in containers which are packed tightly on large platforms. While this method maximizes greenhouse space usage, it has a downside that the containers are not easily accessible, making weeding very slow and expensive.

Majority of the weed species found in forest tree nurseries have anemochorous seeds (seeds dispersed by wind). The easiest way to estimate weed seed rain during growth season is to place sticky traps on site and analyze the traps weekly. We monitored the seed rain at Suonenjoki research tree nursery in years 2011 to 2013, and found that in the springtime majority of the weed seeds observed consist of species of *Salix*. During midsummer the seed numbers are relatively low and in late summer the total seed numbers and species diversity on airborne seeds is greatest, *Epilobium, Betula*, *Asteraceae* and *Cichoriaceae* being the most important groups observed.

Since majority of the weed seeds are not found on the growth peat, but instead arrive by wind during the growth season, different mulch substances could prove to be effective against those weeds. In 2013 we conducted four experiments to investigate the efficiency of different mulch substances against two of the main weed groups, *Epilobium* and *Salix*, and to see whether mulching has negative effects on crop plants (Norway spruce). The mulch substances were used in different compositions in the experiments, and included mulches made of bark, wood chips, sawdust, sand and foam glass. Containers were covered with mulches and weed seeds were sown over the mulches. Later the weeds that had emerged were counted.

Most of the mulch substances were found to be effective against weeds and sawdust was the only substance which performed worse than untreated controls. Best performance recorded against *Salix* was with one type of crushed bark and with one type of wood chips (weed quantity compared to controls was 44 % and 56 % respectively). Best performance against *Epilibium ciliatum* was with another type of crushed bark, with another type of wood chips and with foam glass (weed quantity compared to controls was 23 %, 23 % and 35 % respectively). We also found that thick layer of mulch may have negative effect on germination speed of Norway spruce, which may cause ununiform quality of crop in some cases.

Environmentally friendly weed management strategies: the role of crop rotation

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This report introduces with some results of PhD thesis project "Impacts of different crop management systems and climatic variability on arable weed flora" with an aim to discuss the role of crop rotation in environmentally friendly weed management strategies.

The research included early summer arable weed data collection from long-term investigation field at State Priekuli Plant Breeding Institute (57˚19´ N, 25˚20´ E) in 22-year period within 1973 and 2009. Investigation field consisted of five different crop rotations that were established in six different fertilization systems. Crop rotations were: 1) summer cereals (barley or oat) – potatoes – summer cereals; 2) summer cereals – perennial grasses – winter cereals (rye or wheat) – potatoes; 3) summer cereals – perennial grasses – summer cereals – winter cereals – summer cereals – potatoes; 4) summer cereals – perennial grasses – potatoes; 5) summer cereals – perennial grasses – perennial grasses – winter cereals – summer cereals – potatoes. Fertilization systems were: 1) unfertilized; 2) animal manure (20 t ha^{-1}); 3) $N_{66}P_{90}K_{135}$; 4) animal manure + $N_{66}P_{90}K_{135}$; 5) $N_{132}P_{180}K_{270}$; 6) straw + $N_{66}P_{90}K_{135}$. No herbicides were applied on the field since 1958, when the long-term investigation field was established.

For data analysis six general linear models (GLMs) were created, that included dependent variables – weed density (plants m^{-2}) and wed species diversity of total, annual and perennial weeds-, and five factors: crop rotation, fertilization system, crop-precrop interaction, weather conditions (air temperature and amount of precipitation), soil chemical properties (pH, amount of organic matter, P_2O_5 and K_2O).

Crop rotation had a significant impact ($\alpha = 0.05$) on total, annual and perennial weed density and annual and perennial weed species diversity, explaining 13.1% of variation in total weed density, 10.5% - in annual weed density, 17.7% - in perennial weed density, 4.8% - in annual weed species diversity and 7.6% - in perennial weed species diversity. However, higher influence on weed density, as well as on weed species diversity had crop-precrop interaction, which explained 23.3% of variation in total weed density, 25.1% - in annual weed density, 13.0% - in total weed species diversity, 25.1% - in annual weed species diversity and 8.2% - in perennial weed species diversity. Joint of crop rotation and fertilization system had no significant impact nor on weed density, neither on weed species diversity.

The results can be extrapolated to other areas, which have similar soils and weather conditions as they were for the investigation in Priekuli. However, one should be marked, - crop rotation will have a required effect on weed control only, if crop management is used in properly time and way.

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