EUROPEAN
WEED
RESEARCH
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Abstracts

6th EWRS Workshop on Physical and Cultural Weed Control

Lillehammer, Norway

Hedmark University College

The Norwegian Crop Research Institute

8-10 March 2004

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6TH WORKSHOP OF THE EWRS WORKING GROUP:
PHYSICAL AND CULTURAL WEED CONTROL

Lillehammer, Norway
8-10 March 2004

Sunday 7 March
17.00 Registration
19.00 Welcome drink

Monday 8 March
08.00 Registration
08.30 Opening address
Bo Melander, Coordinator of the working group
Jan Netland, Local organising committee
Johan Ascard, Scientific organising committee

Session 1 - Cultural and physical weed control
Chair: Paolo Bàrberi (IT)

09.50 General discussion

10.00 Coffee

Session 2 - Mechanical weed control

Chair: Ilse Rasmussen (DK)

11.50 General discussion

12.00 Lunch

13.00 Poster session incl. coffee (see list of posters below)

Session 3 - Engineering in physical weed control

Chair: Fredrik Fogelberg (SE)

16.00 General discussion

16.10 Short break

Session 4 - Thermal weed control

Chair: Johan Ascard (SE)

17.20 General discussion

17.30 End of session

17.30-19.00 EWRS General Assembly, Paolo Bàrberi et al. (IT)

19.00 Dinner

Tuesday 9 March

Session 5 - Control of perennial weeds

Chair: Mette Goul Thomsen (NO)

09.00 General discussion

09.10 Poster session (continued) incl. coffee

10.00 Round-table discussions (three parallel sessions)

1. Guidelines for physical weed control research
Organisers: Petri Vanhala (FI) & Dirk Kurstjens (NL)

2. Can computer models be used to simulate long-term population dynamics of annual weeds?
Organiser: Ilse Rasmussen (DK)

3. Organic plant production without livestock - combining weed control and nutrient supply
Organisers: Anne-Kristin Løes, Lars Olav Brandsæter & Hugh Riley (NO)

12.00 Lunch

Excursion

13.00 Departure from Øyer

14.15 Welcome to Hedmark College

14.30 Research on organic farming in Norway
By Ragnar Eltun, Norwegian Crop Research Institute

15.30 Coffee

15.45 The ØkoTek project - a link between science and farmers.
By project leader Mats Tobiasson

16.15 Machinery exhibition

18.00 Departure from Hedmark College

19.00 Dinner at a local place

Wednesday 10 March

Session 6 - Tillage systems and cultural weed control
Chair: Jan Netland (NO)

09.00 General discussion

09.10 *Coffee*

09.40 Reports from round-table discussions (plenary session)

Chair: Daniel Cloutier (CA)

09.40 Guidelines in physical weed control.
Petri Vanhala (FI) & Dirk Kurstjens (NL)

09.55 Computer models and weed population dynamics.
Ilse Rasmussen (DK)

10.10 Weed control and nutrient supply.
Anne-Kristin Løes, Lars Olav Brandsæter & Hugh Riley (NO)

10.25 General discussion

10.35 Short break

Session 7. Information from other working groups

Chair: Bo Melander (DK)

12.00 Concluding remarks and working group affairs

(future plans, web site, next workshop etc)
Bo Melander et al (DK)

12.45 *Lunch*

End of workshop

Posters

Introduction to three Round table discussions

Mechanical weed control and engineering

Thermal weed control

Control of perennial weeds

Weed control in organic farming systems

Integrated weed management

Cultural weed control and crop weed interactions

Development of a Decision Support System (DSS) for weed management in organic winter wheat production

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Within the framework of the EU-funded project 'Strategies of Weed control in Organic Farming' (WECOF, Internet: http://www.wecof.uni-bonn.de/), various methods of cultural weed control in organic winter wheat are investigated and evaluated over different sites in Europe (UK, Germany, Poland and Spain). The experimental programme includes trials on competitive ability, mechanical control, photocontrol and allelopathy. Results from the experiments will be complemented by expert knowledge and literature reviews and integrated within a Decision Support System (DSS) that assists advisers and farmers in selecting site specific strategies for effective weed management. The DSS is based on a Java script compiler able to produce internet pages within which the inquiry and the subsequent evaluation are carried out. The main features of the DSS are a critical evaluation of current individual weed management practices utilised, and suggestions for their improvement mainly based on if / then decisions. A farmer's data input on weed flora, site conditions and management practices will be analysed resulting in a list of recommendation. The primary output consists of an estimation as to whether or not weed pressure is expected to be controllable by indirect methods, e.g. improved crop competition, rotation, or whether direct methods, in particular mechanical, control should be applied as well. By categorising weeds with respect to their main germination period, the expected critical periods of weed competition can be determined to allow specification of varietal choice in terms of shading characteristics. Furthermore the DSS user is able to get detailed encyclopaedic and practical information on main weed species occurring in winter wheat, helping to select appropriate control measures. Apart from variety choice, further approaches on how to increase the competitive ability of the crop are evaluated, dependent on the data entered by the farmer. These options include crop spacing, fertility management, soil tillage, seed quality and other factors expected to promote crop growth and shading ability. For example, the analysis of site conditions may result in recommending the use of specific mechanical control measures. Crop rotation plays a key role in preventing high weed pressure in Organic Farming Systems. Therefore an analysis of the farmer's crop rotation (crop types and their sequence) with respect to weed management will be carried out by the DSS. Competitive crops also need a sufficient supply with nutrients. Based on the farmer's data input, e.g. on livestock units, manuring and crop rotation, an overall estimation of the fertility status of the farm/ field will be calculated, producing a practical recommendation for appropriate improved fertilisation strategies. The overall aim of the DSS in providing the farmer with the best current knowledge on weed control in organic/ ecological farming systems is expected to result in an improved weed management and higher revenues.

Literature:

DAVIES, K. & D.TAYLOR (2003):'Selecting cereals'. Organic Farming, Spring 2003, **76**

DREWS, S., D. NEUHOFF, P. JUROSZEK & U. KÖPKE (2002): Competitiveness of winter wheat stands against wheats: effects of cultivar choice, row distance and drilling direction. In: Proceedings of the 12th EWRS - Symposium, Wageningen 24 – 27. June 2002, 282 – 283.

GAWRONSKI S.W. (2003): Allelopathy as a strategy for weed control in organic farming. Acta Physiol. Plantarum, **25**, 3, supplement p. 25.

Row distance as a key to efficient weed management in organic sugar beets

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In sugar beet growing, as well as in most other crop production systems, weed control is essential to obtain profitable yields. At the same time, the costs related to achieving an effective weed control reduce this profit. In The Netherlands, the opportunity to process organically grown sugar beets separate from conventionally produced sugar beets has considerably raised the interest of organic growers in this particular crop. In organic sugar beet growing mechanical weeding in between the rows, hand weeding in the row and suppression of the weeds by the crop are the main means of weed control. Currently, farmers perceive that the labour required to obtain an effective weed control, which is mainly related to the amount of hand weeding, is far too large. The question arose whether an adaptation of the standard row distance, which currently in The Netherlands is put at 0.50 m, can contribute to a more effective weed control.

Two directions were explored. A decreased row distance will result in a more homogeneous distribution of crop plants and consequently the competitiveness of the crop is expected to increase, reducing the late development of weeds. Another option would be to increase the row distance, as this will reduce the total length of crop rows per unit area. As a result, the need for hand labour will decrease, as hand weeding is mainly needed to control the weeds in a small band in and alongside the sugar beet rows. Between the rows weeds can be controlled rather easily by mechanical means.

In 2002 and 2003, the effects of row distance on weed growth, crop competitiveness and sugar beet yields were studied in a number of field experiments in the Netherlands, both at Wageningen UR (WUR) and IRS. In the trials, row distances were varied between 0.30 m – 0.80 m. In some of the WUR trials, the drilling distance was kept constant independent of row distance, which led to a lower plant number with greater row distance. In other WUR trials, plant number was kept constant by decreasing the drilling distance with increasing row distance. Also in the IRS trials the drilling distance was decreased with increasing row distance. In these trials, plant density was not exactly constant, but the obtained plant number was between 60,000 and 90,000 per hectare. From earlier trials it is known that plant numbers in this range hardly affect sugar beet yield and quality.

From the trials it can be concluded that row distance and drilling distance hardly affected the number of weed plants per meter of row length. This means that increasing the row distance will reduce the amount of weeds per hectare and thus the labour requirement for hand weeding. An additional advantage of a larger row distance was that the weed seedlings present in the crop row were growing slower, due to the smaller drilling distance. For the row distances used in the current trials, no significant differences in yield and quality characteristics were observed, as long as plant number was maintained. Only in the situation were the larger row distance of the sugar beet crop was not compensated through a reduced drilling distance a reduction in yield was observed at the widest row distance. This means that within a reasonable range, the sugar beet crop can compensate largely for row distance provided that plant number is kept at the same level and not lower than about 60,000 plants per hectare.

Based on these results it is concluded that an increased row distance offers good opportunities for a more effective weed management in organically grown sugar beets. Increasing the row distance from 0.50 to 0.75 m means a reduction of the total row length, and thus a reduction in hand labour requirement for weeding, with one third. As these adjustments do not have a negative effect on yield and quality of the product, it is not surprising that organic growers have already shown great interest in adopting larger row distances.

Physical weed control in organic carrot production.

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A four years experiment (2000-2003) was carried out on the possibility to perform the physical weed control of carrot in the typical cultural and environmental condition of the Fucino Valley (that is the most important area of carrot production in Italy), in order to obtain a "biological" product.

Firstly, the strategy of physical weed control of carrot in the Fucino Valley was defined and included the realization of the false seed-bed technique, a flame treatment before crop emergence and one or more mechanical (precision hoeing) and manual interventions in post-emergence.

False seed-bed technique was performed by means of a specific spring tine harrow two meters wide, while flaming was performed by means of an operative machine equipped with four "open flame" rod burners 50 cm wide.

A specific precision hoe with eleven units (inter-row of about 18 cm) was built, tested, improved and set up to perform weed control both between (by means of a rigid tine supporting a 9 cm wide orizontal blade) and in rows (by means of vibrating teeth or torsion weeders).

During the testing period the evolution of weed flora (both presence and biomass) was monitored and carrot root yield was recorded. Moreover work chains characteristics, manpower use and physical weed control cost were determined.

The results were quite good and put in evidence that physical weed control in biological carrot cultivated in the Fucino Valley can be performed, obtaining relevant and high quality yields, without the need of too many hours of manual labour and with fully acceptable costs, taking also into account that in Italy the market price of "biological" carrot is quite high.

Defining optimal conditions for weed harrowing in winter cereals on *Papaver rhoeas* and other dicotyledoneous weeds

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Thirteen field trials have been conducted in Catalonia between 1998 and 2003 on different winter cereal fields highly-infested with *Papaver rhoeas* L. or, in two cases, with mixed dicotyledoneous weeds. The tine-harrow was used in a single pass as the only weed control method. Different climatic characteristics, state of the soil, size of the weeds and development of the crop were compared with weed control efficacy. Highest efficacy (>85%) was obtained in those trials with sunshine during and some time after the treatment and where no rainfall occurred at least 15 days afterwards. Efficacy was generally higher with *P. rhoeas* plants having a diameter less than 5 cm even if good results were also found for bigger plants provided that the crop was well-developed and showing competitive capacity. Another observation was that similar final efficacy values were achieved starting with different initial efficacy values. Initially low efficacy increased due to weed mortality caused by non-favourable climatic conditions for the weeds during the cropping cycle after harrowing or by strong crop competition. Initially high efficacy decreased in some cases due to new germination stimulated by the harrowing. The results observed for *P. rhoeas* were very similar for other tap-rooted dicotiledoneous weeds as *Lamium amplexicaule, Daucus carota, Anthemis arvensis, Lactuca serriola* and *Capsella bursa-pastoris*, frequent at two of the trials.

After confirming and defining the potential use of the harrow in the present conditions the next step is to combine this tool with cultural or other preventive methods as sowing delay, soil ploughing, crop density modification or crop rotations, this is, using the tool within all the crop management practices.

The effect of blind harrowing using a flex-tine harrow or a rotary hoe combined with manure amendment on bread wheat yield

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The first part of this research project was conducted to assess bread wheat susceptibility to mechanical weeding using a flex-tine harrow and a rotary hoe in a weed-free situation. The bread wheat was systematically cultivated at 7 growth stages, from pre-emergence to leaf erect stage. Two and three cultivations were done on a combination of growth stages. Wheat population decreased when cultivated with the flex-tine harrow at the 2- and 3-leaf stages and when more than a single cultivation was done. Wheat yield decreased in the treatments receiving 2 or 3 cultivations when including the 2-leaf stage treatment. After two years of field experimentation, the 2-leaf stage was identified as being the most sensitive stage to flex-tine harrowing. The rotary hoe did not reduce yield at any wheat growth stage and no sensitive stage was identified.

The second part of this study was to determine the effect of the type of nitrogen amendment (organic (pig slurry, cow manure) or mineral) on weed populations combined with blind harrowing in bread wheat. There was no significant interaction between cultivation and fertilization treatments. As expected, the treatment with the flex-tine harrow done at the 2-leaf stage and at the second tiller stage was the most aggressive treatment in decreasing weed density, wheat population and yield. Also, weed development was greatest in the space that was left after wheat plants were removed by the cultivator. The control with the lowest weed density and biomass was the treatment with the rotary hoe done at the 2-leaf stage and at the second tiller stage compared to the conventional herbicide treatment. There was no significant difference between fertilization treatments.

Cultivations with the flex-tine harrow reduced final wheat population at harvest by 22 to 35% compared to the treatment that was not cultivated. Cultivations with the flex-tine harrow done at the 2-leaf stage and at the second tiller stages reduced yield by 8 % compared to the treatment that was not cultivated. The final wheat population was not affected by the type of fertilization. Pig slurry application increased yield by 7 % compared to the conventional mineral application. Yield decreased by 12 % without fertilization compared to the conventional

Modelling the effectiveness and selectivity of mechanical weeding

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After many years of field experiments with available mechanical weeders, their possibilities and limitations are roughly known. To compensate for the limited selectivity in young sensitive crops, the limited effectiveness on established weeds and limited workability in spells of wet weather, current research emphasises more on the integration of multiple complementary tactics. Combining mechanical weeding with adapted planting times, false seedbeds, flaming, cover crops, tillage and other tactics is expected to increase non-chemical weed control reliability, reduce herbicide use or the need for manual weeding in organic farming.

Choosing appropriate combinations of tactics and mastering them in variable conditions requires considerable knowledge and skill. Models could be useful tools to derive practical guidelines, train farmers in making complex decisions and test how well the interactions between several weed management tactics are understood. Existing population dynamics models generally use fixed values for mechanical weeding effectiveness. Although the effect of varying effectiveness on long-term weed population dynamics could be approximated, these models are probably not sensitive enough to account for interactions between individual control measures. More sensitive approaches need to be developed because mechanical weeding effectiveness is very time-sensitive and highly influenced by environmental conditions and the way cultivations are carried out.

Detailed assessments and common field studies revealed that models should account for within-population variability in weed sensitivity arising from species- and weather-related emergence patterns and larger weeds escaping control. Models should also account for differences in working intensity of the implement as related to type, adjustment and soil conditions. It might as well be desirable to account for weather conditions that influence plant recovery after cultivation. This paper proposes a model to predict the selectivity and effectiveness of mechanical weeding that takes account of these factors and time-dependent phenomena.

The core of the envisioned model is a database containing a large number of crop and weed plants and their individual attributes at various times (e.g. biomass, anchorage force, height, flexibility, type of damage, desiccation status, position, growth stage). Various modules adapt these attributes by simulating continuous dynamic processes (e.g. plant growth, desiccation of uprooted plants), switching plant status at discrete (but individual-dependent) times (e.g. from “seed” into “white thread” and “emerged”), applying empirical relationships (e.g. between plant mass and sensitivity to uprooting), or other state transitions. This framework allows a flexible exchange of modules (e.g. replacing an empirical by a mechanistic model) and including various processes (e.g. competition, seed displacement) without major implications for the data structure.

The prospects of this approach are demonstrated by a dynamic spreadsheet model that links 1) crop and weed emergence patterns in time, 2) assumptions on early growth, 3) empirical species-, soil- and weeder-specific relationships between plant biomass and the probability of being buried and/or uprooted assessed in field experiments, and 4) assumptions on plant mortality resulting from uprooting and growth delay induced by burial. The model predicts weed control and crop damage (both density and biomass reduction) induced by multiple cultivations, accounting for population heterogeneity. If emergence patterns, growth rates and recovery of damaged plants are related to weather conditions, this model could predict effects of cultivation timing. When combined with workability predictions, the model could help assess weather dependency and evaluate solutions to weak spots in weed management systems before testing them in long-term experiments.

Are we making significant progress in mechanical weed control research?

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This study investigates whether researchers' perceptions of good research are in agreement with current research practice as reflected in *Weed Research*. A high degree of agreement is assumed to indicate progress.

The instrument used to survey researchers perceptions was a questionnaire consisting of 28 items related to (1) research methodologies, (2) research priorities, (3) quality of publications, (4) future developments in technology and agriculture and (5) general attitudes to alternative and conventional agriculture. Questions about gender and personal research engagement were also laid down in the questionnaire. The questionnaire was sent out by e-mail to about 140 researchers on the mailing list of the EWRS – Physical and Cultural Weed Control Group and 60 questionnaires were completed and returned. An analysis of all Weed Research publications in the period 1998-2003 investigated current research practices.

The questionnaire showed that researchers in the working group are not specialized. Of the respondents, only 4 researchers (7%) used 50% or more of their research hours on mechanical weed control but a total of 44 researchers (73%) were active within this area.

Views on research and agriculture varied significantly within the group and two counter paradigms were identified often refereed to as alternative and dominant. The alternative paradigm was connected with organic farming and the dominant paradigm was connected with conventional agriculture. Alternative paradigmatic positions prevailed among the respondents although strong dominant positions were also represented. Females (N=15) held more alternative positions than males ($P < 0.01$) and researchers engaged in herbicide technology (N=13) held more dominant positions than the rest ($P < 0.05$).

By using an alternative-dominant scale, it was evident that respondents' perceptions of good research was linked to basic values and beliefs that determine the overall understanding of how agriculture works and should be developed. Alternative perceptions of good research, however, seemed to be inconsistent with the current research practice as reflected in *Weed Research*. Consistency between ideals and reality should result in (1) more multidisciplinary studies to facilitate broader perspectives on weed control, (2) more studies carried out on working farms, (3) more system approaches that include whole agro-ecosystems with farmers and other stakeholders, (4) value inquiries, (5) participative research and (6) reflective approaches. Papers published in Weed Research clearly demonstrate, that alternative research in the ideal is different from research in reality. The main difference between alternative and dominant research is in what gets studied, not in how it is studied.

In conclusion, research in physical and cultural weed control may be evaluated successful in a dominant paradigmatic perspective but progress is very limited in an alternative paradigmatic perspective. There seems to exist a mismatch between ideals and reality in weed research, which challenges ideals as well as practice.

Comparison of alternative interrow weeder steering systems

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The success of interrow weeding depends on being able to quickly and accurately guide the weeder along the rows. This can only be done by automatically guiding the weeder. Any automatic weeder steering system requires a sensor/s to provide an error or guidance signal and a mechanism to move the hoes to the correct lateral position at the correct time in response to this error signal. Many different guidance sensors have been developed for this application and much is known about their different characteristics (Jahns, 1976; Tillett, 1991). However, little has been reported about the steering system design.

This paper describes the different methods of mounting weeders onto the tractor and discusses in detail the alternative commercial steering designs used on rear-mounted weeders. It also describes the development and validation of a mathematical modelling technique that can be used to predict the behaviour of a tractor and weeder (Pullen & Cowell 2000). Three different steering techniques, ie sliding the weeding blades from side to side, steering by changing the weeding blade direction and using steered wheels, in response to an error signal were evaluated using the theory.

Results of the study show the modelling technique was accurate. The amplitude of the predicted weeder path was within 2% and the phase angle within 2 degrees of the actual value. The study also suggests fitting steered wheels, whose position moved proportionally with the error signal was overall the most suitable method of steering the weeder. For this steering system the model shows the critical parameters affecting overall performance were the steering gain and hoe position. The tractor type (ICR position), the sensing position, the steered wheel position and steered wheel axle position did not significantly influence performance. However, positioning the steered wheels behind the headstock but in front of the weeding blades would be better practically.

References:

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JAHNS G (1976). Automatic guidance of farm vehicles - a monograph. Agricultural Engineering Departmental Series No 1. Agricultural Experiment Station, Auburn University.

TILLETT ND (1991). Automatic guidance sensors for agricultural field machines - a review. J. agric. Engng Res. **50**, 167-187.

Different strategies to improve mechanical intra-row weed control in bulb onions

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Objective

In organic farming weed control involves a lot of hand labour to remove the escaped weeds. From 2000 till 2002 research with new intra-row weeders showed the possibilities to improve farmers strategies. Reduction of manual weeding by 40 till 70 % was achieved. Most years crop yield reduction was less than 2 to 3 %.

In onions the period between sowing and emergence is mostly very long, 4 – 6 weeks. In this period a lot of weeds are emerging. In organic farming flame weeding is common practice. This is a standard strategy for organic farmers to start with a weed free crop of onions. An important disadvantage of flame weeding is the energy consumption. The question arises how important the strategy of weed-control before emergence of the onion is, for the way weeds can be controlled afterwards. Possibilities to improve mechanical weed control after emergence of onions was investigated as well.

Method

In a field experiment the effect of flaming or harrowing before emergence of the onions and the combination with different options for the mechanical weed control after emergence of the onions were tested.

In another trial at the same field the importance of the steering precision was tested for the finger- and the torsion weeder. The treatments in the trial were combinations of different; working depth, overlap and the position of the intrarow weeders compared to crop row position. The beds in the trial had five rows and the three rows in the middle of the bed were used for the observations. Also this experiment had 4 replicates.

Results and discussion

Before emergence of the onions the treatments with the harrow were treated twice. Harrowing was done by a flexible chain harrow, which was turned upside down, working depth was about 1 cm. The last time of harrowing the onions were about 0,5 cm below the soil surface. In one of the treatments the harrow was covered by black plastic and a canvas plaid, to prevent new emergence of weeds. The effect of this measure was neglectable. Flaming when the first onions emerged resulted in more weed reduction than harrowing prior to emergence.

The yield at the harrowed plots was much lower (about 10%) than at the flame weeded plots. Probably weed competition (density and the size of the weeds) were the reason of this lower yield. The treatments after crop emergence showed that mechanical intra-row weeding starting when the onions had 2 leaves was possible. Weed population decreased by 50 to 60 %. The other trial demonstrated that working depth and overlap of torsion- and the finger weeder determined plant loss and weed control to an importand extand. The steering precision was more important when using the torsion weeders than with the finger weeders.

To improve efficacy of mechanical weed control, innovations should focus sensoring techniques, to determine position of crop rows and plants, and accurate steering devices for weeding equipment.

Analysis and definition of the close-to-crop area in relation to robotic weeding

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The objective of our contribution to the workshop is to get further input for the analysis and definition of the field conditions close to the crop plants of sugar beet (*Beta vulgaris* L.). The aim of the contribution is to focus on the choice and development of new physical weeding methods to target weeds at individual plant scale level. So far, we have reached a definition of the close to crop area for sugar beet based on a description of; i) the above and below ground properties for both sugar beet and weed plants, ii) crop and weed establishment factors, iii) crop and weed tolerance to physical interactions, and iv) the sugar beet:weed competition with focus on neighbourhood effects. It was found that the close to crop area is like a ring structure, comprising an area between an inner- and outer-circle around the sugar beet seedling. Physical weeding should not be applied to the area within the inner circle. The radius of the inner circle increases with the appearance of young beet leaves during the growth season. It was also found, that no weeds were germinating within 1 cm around individual sugar beet seedlings. Therefore this distance should be added to the radius of the inner circle. The space between the inner and outer circle is termed the close to crop area where physical weeding should be applied. The size of this area is defined by the developmental stage of the sugar beet fibrous root system and foliage. Thus, the determination of the growth stage of individual crop plants is necessary before any physical weeding can take place in the close to crop area.

Uprooting, cutting between stem and root or damage of main shoot can do the physical control of most weed species located in the close to crop area. However, the targeting of weeds from above and from different angels above ground is limited in the close to crop area. This is caused by the fact that sugar beet leaves do not leave much space between leaves and ground and that our own study indicate that 26.4% of sugar beet plants at the 4-6 leaf stage are covering the main shoot of weeds. The most problematic weeds are the species, which have their main shoot and leaves located close to ground level. These species can either be controlled by damage of the main shoot or with a combination of shallow surface cutting and burial.

Discrimination between weed species is beneficial under certain circumstances. First, the efficiency of the physical control of individual weed species is depending on the timing. Secondly some weeds species do not have significant negative impact on the yield, but instead leaving these species uncontrolled could benefit to an increased bio-diversity and reduced time and energy input for a physical weeding process. This paper is contributing to the ongoing Danish research project Robotic Weeding.

Recent results in the development of band steaming for intra-row weed control

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The idea of band steaming for intra-row weed control in row crops was introduced at the 5th workshop on Physical and Cultural Weed Control in Pisa 2002. The work on band steaming has been continued since then, and new results on technical and biological aspects have been produced.

The biological studies have shown that soil type, soil moisture content and soil structure (aggregate size) influence the lethal effect of soil steaming when the maximum soil temperatures are below 70°C. Steaming was more effective in a sandy soil than in a loamy soil, and increasing soil moisture content generally increased the susceptibility of weed seeds. More weed seeds survived the lethal effect of steam in soil containing many large aggregates as compared with soil having fewer large aggregates, presumably due to poorer steam penetration of the large aggregates. However, all the factors mentioned no longer had any effect when maximum soil temperature reached more than 70°C.

Studies of sowing crop seeds immediately after steaming showed that seeds of sugar beets, maize, leek, onion and partly carrots were surprisingly tolerant to the heat. This implies that crop sowing might be integrated with steaming so that steaming and sowing can be done in the same pass provided that crop sowing is done after steaming.

Technical studies have focussed on ways to distribute the steam as evenly as possible in the soil volume to be steamed with the aim to reach the desired maximum soil temperature all over the volume. Test-driving with a prototype band steamer in the field revealed that this might be difficult to achieve in the very topsoil layer and that technical modifications were necessary for further improvements. The test-driving also showed that a maximum soil temperature of 90°C was necessary in the field situation for sufficient weed control and that a fuel consumption of approx. 350 litres of fuel oil ha^{-1} was necessary to achieve that temperature.

A major concern about steaming the soil is the lethal effects on other soil organisms than weed seeds. Thus, many non-target organisms are most likely killed, and the time it takes for the soil to recover is not known. Some of these aspects were studied in 2003, and the results indicated that the recovery process is rather slow. Bacteria responsible for oxidation of ammonium-N were significantly inhibited and the population had not recovered after 90 days. Also fungi and enzyme activities were reduced significantly, but physical and chemical soil conditions such as water content, pH, nitrate content, water-soluble carbon and *in situ* respiration activity were not affected. However, it is not clear whether these effects will affect crop growth negatively or whether some may even be beneficial. Thus, further studies are needed to describe the effects of steaming on soil organisms and other soil properties and how it may affect crop growth.

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Thermal weed control by steaming in vegetable crops

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Thermal weed control by steaming was performed in two different series of experiments in vegetable crops in 2001-2003.

The first series of experiments was deep steaming down to about 20-30 cm soil depth in carrots. The steam, delivered by a separate aggregate via a drag pipe, was injected by vacuum into the soil by a new prototype of tractor-mounted equipment. One of the objectives was testing the weed effect of the new technology.

The second series of experiments was shallow steaming, by a self propelled machine, called 'Regero', injecting the steam by pressure down to about 7 cm soil depth in different kinds of lettuce. The objective was testing of a technology already on the market. To optimise the use under Norwegian conditions five different steaming intensities were compared.

The results show that deep steaming (6 minutes or more at 99-100) significantly reduced both the density (to about 5,3 % of untreated) and the percent cover (3,3 %) of weeds, and the seed bank (to about 9,0%) in the soil compared with untreated area. The yield increase was not consistent. At 10 cm soil depth the attained temperature was minimum 70 C in 6-9 minutes. At 20 cm soil depth the temperature not always was satisfied.

Shallow steaming in different salads and Chinese cabbage (about 2 minutes or more at 99-100 C) significantly reduced the weed density (4,0%) and the seed bank (to about 1% of untreated). The yield was significantly increased. At 2 cm soil depth it was achieved 70 C or more in minimum 10 minutes. At 5 cm soil depth only a few times the temperature was not satisfied.

According to the literature the letal temperature for weed seeds is about 60-80 C (Melander *et al.*, 2002; Mariska *et al.*, 2003). The experiments showed that it is possible to save fuel on the steaming machines, and still get significant weed control.

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A device to kill weed seeds captured during crop harvesting.

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The harvesting of annual crops provides an opportunity to remove or kill the seed of weed species when mature and within the crop canopy. Petzold 1956, discussed the dispersal of seeds by modern harvesters and concluded that the harvesting process would distribute several important weed species more widely. Crops that are either direct headed or windrowed before harvest have possibilities for destruction of remaining weed seed at harvest. *Lolium rigidum* (annual ryegrass) is the major weed of interest in Australia because of widespread herbicide resistance. Management of such ryegrass depends upon physical and non-selective chemical control methods.

A device has been developed to kill seeds by utilising the waste heat from the exhaust gases of the harvester motor. An Australian provisional patent application number 2003905285 has been granted.

Table 1. Germination of ryegrass from seedkilling treatment, mean of 10 replicates.

treatment	Germination % (SD)
Treated ryegrass	0.8% (1.09)
Untreated ryegrass	86% (1.41)

The device consists of an enclosed steel cylindrical cyclone into which the exhaust gases are introduced via a tangentially located inlet duct at one end. The device was tested in a standing wheat crop infested with annual ryegrass. Ten replicate samples of treated seed were collected from the field. The germination of the treated ryegrass was almost completely inhibited by exposure to the hot exhaust gas Table 1. Limiting seed return to the soil is a potential method to reduce both population size and spread of weeds within a field. In field trials with seed removal, seed return was reduced by 86% in barley crops and by 78% in wheat crop (Matthews 1992). Another positive outcome of non-herbicide methods of ryegrass control is the tendency for regression or loss of herbicide resistance from resistant populations when selective herbicide use is stopped (Matthews 2002). There is potential to kill nearly all weed and retained crop seed during the harvesting process.

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Effect of crop rotation and tillage on infestation of *Cirsium arvense* in organic farming systems

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Canada thistle (*Cirsium arvense*) is still difficult to control in organic farming systems. Since low competitiveness of most of the crops and limited possibilities for direct control measures, *C. arvense* is stated as a main problem by organic farmers.

Therefore, it was the aim of a two-year-project to survey the recent situation on organic farms in Germany. In 2003 detailed interviews of 156 organic farmers were run throughout Germany sampling data on weed infestation, cultivation practices and measures of weed control. Most of the farmers (93%) stated to have problems with *C. arvense*. On average, 33% of the arable area grown organically is highly infested but farmers appraised that the problem will not arise in the next future. Evaluation of the data clearly shows that low abundance of *C. arvense* is correlated to a high portion of mulching crops, especially clover-grass or alfalfa-grass mixture. A moderate control effect is achieved by winter annual crops whereas undersown or row crops do not have any influence. According to the survey a high portion of cereals within the crop rotation is intensifying problems with *C. arvense*.

As a result of the survey soil tillage is widely based on turnover soil tillage by a conventional plough, probably because of its well-known beneficial weed control effects. The most common equipment for stubble tillage is the wing share cultivator followed by the disc harrow and other types of cultivators. There is no clear farmer's estimation on the control effect of these machines. The so called Arado plough appears to reduce *Cirsium* populations but it is very rarely used in practice. Obviously the control of *C. arvense* does not depend on the type of the equipment but is more affected by the time and frequency of treatment. Finally the site- and time-specific use of the equipment combined with high competitive crop rotation plays an important role in weed management.

In addition field experiments on effects of crop rotation and soil tillage have been conducted at the BBA trial area for organic farming. Since conversion to organic farming in 1996 *C. arvense* has spread continuously over almost this field. This increase was mainly caused by growing summer crops in the first years and reduced frequency of stubble tillage. Since changing the experimental design in 2001 by separating the area into 8 plots with a more mixed crop rotation the spatial distribution could be decelerated. Growing and frequently mulching of grass-clover showed good control of *C. arvense*. Using a wing share cultivator 2-3 times could also reduce the density of *C arvense*, especially when tillage follows a crop with high competitiveness. These findings show the clear interactions between crop and tillage management and the need to use both tools for effective control of *C. arvense*.

Due to current economic conditions there might even be an increasing force for reducing soil tillage or more simplified crop rotations. This possible development of organic farming systems is not compliant to the needs of a preventive weed control. Therefore farms with a cereal-based crop rotation should use also other options to increase crop competition, e.g. cultivar choice, sowing methods or fertilizing practice.

Response of *Sonchus arvensis* to mechanical and cultural weed control

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Perennial weeds are an increasing problem in Finland, particularly in organic farming. *Sonchus arvensis* L. (perennial sowthistle) is among the most common and harmful perennial weeds. Controlling it using physical weed control methods is not an easy task. However, crop competition and cultural practices like mowing, hoeing and bare fallowing provide some possibilities for management of *S. arvensis*.

In order to study the biology and physical control of *S. arvensis*, a 3-year field experiment was established in 2001 at Vihti, southern Finland. The experiment was sown on a clay soil (containing 6–12% organic matter) field under organic production, infested heavily with *S. arvensis*. The experimental design was randomised blocks with five replicates. The experimental field was fertilized with pig slurry (plant available N 60–100 kg ha^{-1}) at cereal sowing time.

The treatments consisted of various crop plants and cultural practices, including fibre hemp, spring cereal (barley in 2001, oats in 2002) with or without inter-row hoeing, bare fallow and ley (timothy + red clover) with mowing. In 2003 the whole field was sown with spring wheat. Prior to cereal harvest, plant samples from two 0.5 m × 0.5 m quadrats were cut at the soil surface. The growth stage and height of each *Sonchus* shoot were assessed, as well as the number of shoots and dry mass per quadrat.

Statistical analyses were performed with the SAS statistical package. The plot-wise pooled numbers of *S. arvensis* shoots were square root transformed and the biomass log-transformed before subjecting to statistical tests with the MIXED procedure with the Tukey adjustment.

In 2001 *S. arvensis* was most abundant in fibre hemp and first year's timothy + red clover ley, and rather abundant also in cereals without inter-row hoeing. Bare fallowing reduced the density and dry mass of *S. arvensis* most. Also inter-row hoeing reduced *S. arvensis* density compared to hemp or ley. Highest *S. arvensis* dry mass was observed in hemp plots. Fibre hemp is known to be a competitive plant, but in this field it grew poorly in both years.

Also in 2002 the density and dry mass of *S. arvensis* were highest in hemp plots and in oats plots with no mechanical weed control. The density and dry mass of *S. arvensis* were lowest in the bare fallow treatments. In plots where oats was grown after previous summer's bare fallow, the dry mass of *S. arvensis* was significantly smaller than in hemp, oats, or hoed oats plots.

The rating of the treatments according to the control effect was: bare fallow > ley > cereal with inter-row hoeing > cereal > fibre hemp.

The results suggest that the following measures could be implemented in order to suppress *S. arvensis* infestation: A crop which is competitive in the conditions of the given field should be chosen. Bare fallow is an effective way to reduce *S. arvensis*, but it's a costly method which may impair soil structure, in case of ample precipitation. Mowing the ley seems to have effect on *S. arvensis*; it would be profitable to have a perennial, regularly mown green fallow or silage ley included in crop rotation.

Mechanical control in crop stand is also possible; inter-row hoeing in cereals seems to impede *S. arvensis*, if it is done 2–3 times during the growing season. Inter-row hoeing is effective between cereal rows, but it can't control the weeds within the crop rows. The subsequent effect of different treatments, assessed in spring wheat in 2003, will be published later.

Participatory organic weed management: *Rumex* spp. control a farmer perspective

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A new DEFRA funded project began in August 2002, taking a new approach to weed management in the UK. This is a participatory project where farmers, researchers and other organic stakeholders identify, prioritise, trial and develop solutions to weed problems. Organic farmers were surveyed and asked 'What are your main weed management problems?' and over 60% (n=152) responded that docks caused them the greatest concern. An open meeting was held in December 2002 where interested parties met and discussed organic weed management. Problems were prioritised and the project will focus on three main topics 'Perennials', 'Systems approaches to weed management' and 'Knowledge collation and dissemination'. The research direction is steered by focus groups comprised of farmers, researchers and advisors.

In terms of *Rumex* spp. (docks) this project is aiming to collate all published literature both 'scientific' and 'grey' information on organic dock control and also document current farmer management practice. Farmer weed management interviews have been undertaken and written into case study information from different farming systems. Some basic monitoring of dock populations has been undertaken on 12 farms. These populations will be monitored over the course of the four-year trial to quantify the efficacy of different control methods. Research trials will be established to compare control techniques. Work is also underway to investigate the potential of biological control with the beetle *Gastrophysa viridula*.

Information will be presented here from the literature review of dock management and the current farmer opinions and practice in the UK. Dock management trials that farmers are taking part in will also be discussed.

Population dynamics of weeds affected by time and type of tillage

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Introduction

Type and time of tillage can affect different stages of a weed's life cycle: dormancy status of the seeds, germination, emergence, control of established plants and thus the seed production. As a part of two projects concerning tillage and plant protection in spring cereal production financed by the Royal Ministry of Agriculture, one field experiment was conducted at Ås from 1994 to 2000. The aims were to study the population dynamics of certain weed species with various tillage systems and to develop population dynamic models for each species.

Materials and methods

Four tillage treatments were performed: Mouldboard ploughing (simulated by hand spade) to 18 cm in autumn or spring, or harrowing (by rotary cultivator) in autumn (6-8 cm depth) or spring prior to sowing (ca. 5 cm depth). Plots with ploughing or autumn harrowing were harrowed in spring too. No herbicides were applied. To ensure establishment of eight weed species, including the four species mentioned in this study, seedlings were transplanted to the field after emergence of the cereals at start in spring 1994. The spring cereals grown in all years were barley, except for oats in 1995 and 1999. From start in 1994 for Galeopsis tetrahit, Matricaria perforata and Sonchus asper and from 1998 for Chenopodium album the number of weed plants and seed production during the growing season, and the seedbank before tillage in the autumn were assessed each year. Twenty soil samples per plot, 2.5 cm in diameter, were taken to 18 cm depth, bulked and the seedbank estimated by a one-year greenhouse germination procedure as described by Tørresen (1998). The number of plants when the cereals had 3-4 leaves and the seedbank were assessed for all species present.

Results and discussion

During the experimental period the total number of weeds and the seedbank in the upper 18 cm soil depth increased in harrowed plots compared to ploughed plots. Only a few percentage of the total seedbank emerged to new plants.

There was a good correspondence between number of plants in early summer, seed production and the weed seedbank for *M. perforata* and *C. album*. *M. perforata* had most plants, largest seed production and seedbank with harrowing in autumn or spring. *C. album* had most plants and seeds produced in plots with harrowing in autumn. *C. album* had more plants and larger seedbank than the three other species on ploughed plots. The number of plants, seed production and the seedbank of *G. tetrahit* and *S. asper* were little compared with those of *M. perforata* and *C. album*. The emergence of *G. tetrahit* was favoured by spring ploughing.

These data were used to develop simple population dynamic models of the species. We plan to validate the models with independent data from an adjacent field experiment conducted in 1994-2000.

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Spot ploughing and population dynamics of weeds

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A tillage practice of 'complete inversion' of soil i.e. overturning of the soil block in 180° was defined and proposed, a simulation was conducted to evaluate its effect on weed control, and a 'spot plough' was developed and tested to accomplish such specific task. A simple linear matrix model of population dynamics of annual weeds was employed for the simulation, where four layers were set to describe the population of weed seeds, and the tillage practices were expressed by probability matrices of the complete inversion with the spot plough and 'complete mixing' with a rotary harrow. The simulation showed that alternately changing the depth of ploughing year by year had significant effect on weed control, and the effect was greater when a lower survival rate of the seeds was assumed. The spot plough was designed as a tool for the complete inversion that was accompanied by least lateral displacement of soil. It had the working width and depth of 360 mm and 100 - 180 mm, respectively, and was designed to operate at a speed of 1.9 m s-1 to utilise the inertia of the soil slice to securely rotate itself. A field experiment of the spot plough was conducted in a fallow land to evaluate its performance. The complete spot inversion required an operating speed of at least 1.6 m s-1; setting the speed lower than that resulted in a portion the soil block left half-inverted, and further reduction led to considerable lateral displacement of soil. The displacement in forward direction was also minimal (50 – 90 mm) as well as in lateral direction, implying that the spot ploughing is suitable for potential application and verification of the demographical model in the field basis.

Weed population dynamics by influence of crop rotation in 40 years period

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Weed population size and diversity of their communities are shaped by a number of biotic, abiotic and anthropogenic factors. Agricultural cropping systems, which are typical anthropogenic factor, incompletely utilize resources for growth and reproduction available in those habitats. These unused resources are a “niche-vacuum” within which weeds have adapted over short and long time periods.

Properly planed crop rotations offer benefits to the soil, allow weed control and promote biodiversity. Crop rotations are central to the holistic approach to crop production, which provides opportunities to implement management strategies that enhance diversity: they limit the buildup of weed populations and prevent major weed species shifts.

To verify adjudgements published in scientifical literature in the beginning of 20 th century and to find optimal indices for local agroecological conditions there were in the oldest in Latvia Plant breeding Station (Priekuli) in 1958 a long term crop rotation experiments established. Since beginning of experiments one of the main task was to find manners that promotes the health and vigour of the crop plants to reduce weed pressure without using of pesticide. Acquired dates lets to deduce of dynamic of weed populations in a long-term period.

The experiment is located on a soddy podzolic light loam with the following characteristics in the year of establishing: organic matter content 2.1 %, soil pH_{HCl} 5.8 to 6.1, P_2O_5 80-100 mg kg^{-1}, and K_2O 100-120 mg kg^{-1}, and includes 11 different crop rotations, and five different fertilizations systems.

The normal mean temperature varies from -6.2 ^{0}C in January to 16.7 ^{0}C in July. The mean annual rainfall is 691 mm. Measurements of soil nutrient content and of crop yield was performed every year. Herbicides were not used. Weeds have been controlled by ridging in the potatoes and sharing of stubble surface after harvesting of cereals.

Starting dates showed that in the period first ten years after establishing of experiments the weed infestation at the experimental site was relatively evenly distributed. Total weed densities in all crop rotations spiral from 129 to 275 weed seedlings. Dominant weed species were: *Chenopodium spp.*, *Vicia hirsuta* S.F.Gray*, Barbarea vulgaris* L.*, Raphanus raphanistrum* L.*, Matricaria spp., Spergula arvensis* L.*, Mentha arvensis L., Cirsium spp., Sonchus arvensis L., Tussilago farfara* L.*, Equisetum arvense* L.

Results show that during a more than 40-years' period by influence of crop rotation and fertilizing there were in investigations field essential changes of weed populations. In average the amount of weeds species in this period were decreased. Amount of fixed weed species varies from 23 to 34.

Combining physical and cultural weed control with biological methods – prospects for integrated non-chemical weed management strategies

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We aim, through this paper and discussions during this workshop, to promote greater integration of activities between the Physical and Cultural Working Group and the Biocontrol Working Group of the European Weed Research Society. This process started at the 2002 EWRS Symposium at Wageningen, where papers offered from both working groups were combined into one session 'Integrated Weed Management, Physical Control, Biological Control and Allelopathy', and led to the authors reviewing examples and possibilities for integration between these weed control methods (Hatcher & Melander, 2003). It was clear that there were only a few examples of combining physical/cultural and biological weed control methods in the literature, and no review had been undertaken before.

In this talk we will present our conclusions on circumstances where we think physical and biological weed control can be combined, or is worthy of further investigation, and situations in which we think this combination would not be successful.

We considered four physical and cultural methods for weed control: mechanical, thermal, cutting, and intercropping, and reviewed how they affect factors that are important to biocontrol agents, for example: soil moisture; disturbance; soil surface cover; plant nutrient and allelochemical status; and age of plant material.

We conclude that it will be easiest to combine biological control with fire and cutting in grasslands; within arable systems it would be most promising to combine biological control (especially using seed predators and foliar pathogens) with cover-cropping, and mechanical weeding combined with foliar bacterial and possibly foliar fungal pathogens. However, some combinations cannot be recommended. For example, changes to the soil brought about by mechanical and thermal weeding in arable crops may be particularly harmful to insect biological control agents, which are already difficult to introduce into these habitats.

We stress also the need to consider the timing of application of the combined control methods in order to cause the least damage to the biological control agent, along with maximum damage to the weed and to consider the wider implications of these different weed control methods. For example, weeds also interact with pests and diseases of crops by acting as alternate hosts for them and their predators, and the effects of physical and cultural control methods may change this relationship (Norris & Kogan, 2000; Hartwig & Ammon, 2002).

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EWRS Working Group: Germination & Early Growth
An overview of working group activities and opportunities

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A better understanding of the emergence behaviour of weed species in relation to cultural and meteorological events presents a number of opportunities. For example, the magnitude and relative timing of a flush of emergence will influence the size and competitive pressure of a weed population hence impact on subsequent crop weed interactions and population dynamics. This combined information could be used to target the timing of cultivation and maximise the efficacy of control strategies (physical and chemical), or indeed to help the development of new strategies that build on this improved knowledge.

In recent years there have been significant research developments to understand and predict the emergence patterns for a number of important weed species. Since the autumn of 1999, a number of members of the EWRS Germination and Early Growth Working group have collaborated in a simple joint experiment to gain a better understanding of this early stage of the life cycle of weeds. The experiment has formed the focal point of the working group's activities. The aim has been to produce a weed emergence dataset for weed seeds collected from different countries and subsequently buried in contrasting climatic locations. So far the study has explored some of the differences between the study populations in their emergence behaviour. The resulting dataset has also been used to illustrate a simple emergence model and hence to test some of the assumptions that are frequently made when models are applied to a wide range of environments and weed populations. The working group plans to initiate other simple collaborative experiments in the future and through annual workshops, the working group also provides a forum for discussion and the exchange of ideas.

Crop-weed interaction research; its link with physical and cultural weed control

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The EWRS Working Group 'Crop-Weed Interactions' focuses on the interactions between crop and weed plants. Attention is given to a fundamental understanding of processes governing crop-weed interactions, as well as the utilization of this knowledge for improved weed management. One of the main objectives is to bring fellow scientists together to exchange information and promote discussion on the Working Group topic.

At the time of establishment of the Working Group, research related to crop-weed interactions focused on the construction of robust damage relationships to support rational decision-making on the use of herbicides. Multi-location trials were laid out by the Working Group members (from Finland to Spain and from Italy to the UK and Canada) to evaluate the yield-loss weed density model of Cousens (1985) and the relative leaf area model of Kropff & Spitters (1991). The evaluation confirmed the good descriptive ability of both models (Lotz et al., 1996). At the same time, predictive ability of both models was found to be poor and suggestions for improvement were made.

In the last decades, interest in weed management strategies that are less dependent on herbicides has increased. Alternative control measures, like mechanical control received increased attention. At the same time, agronomic measures to manipulate crop-weed interactions, like competitive cultivars, crop spatial arrangement, timing, level and placement of fertilizers and intercropping practices were explored, opening new scope for research in the area of crop-weed interactions. Furthermore, the time horizon of interest of systems that aim at a reduced reliance on herbicides is not restricted to a single season. Main emphasis should be given to the long-term management of weed populations. In this situation, the effect of the crop on the weed, particularly on weed seed production, becomes increasingly important. Consequently, research on crop-weed interactions merges with research on weed population dynamics. In line with this, the interest of the WG has extended, of which the development of decision support systems that model the consequences of cropping systems on the population dynamics of weeds is just an example.

These new developments encourage a further collaboration with closely related working groups. Competitive relations between crops and weeds are largely determined early on in the cropping season, reason why the activities of the WG 'Germination and Early Growth' are of interest to the Working Group. There is also a close link with the WG 'Physical and Cultural Weed Control'. The shared interest in cultural control measures is just one aspect. Selectivity and efficacy of intra-row mechanical control measures is closely related to size differences between crop and weed, and thus to competitive relations. At the same time, an improved crop competitive ability might help to suppress weeds that have escaped mechanical control. Obviously, options for further collaboration among Working Groups should be further explored.

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EWRS Working Group Education and Training

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Introduction

Weed science has changed in last decade. New weed management concepts and new technology in chemical and non-chemical weed control are developed, scientific approaches have diversified and methodology is continuously improving. Knowledge management and exchange are hot items and networking is considered the future motor of modern research and development. In this context education and training is of critical importance. The Scientific Committee of EWRS decided therefore to work out a new concept for a EWRS Working Group Education & Training.

Mission

The mission of the EWRS Working Group Education and Training is to facilitate the transfer of knowledge in all aspects of weed science for students and professionals at all levels of training.

Objectives

The overall objective of our working group is to develop a permanent, constantly updated, source of information in weed science that can be freely shared with instructors, teachers, professionals, students and fellow weed scientists to learn and/or teach weed science.

Activities

Through our web portal (Weed Portal) we provide teaching and training material and a training network bulletin board. The Weed Portal is financially supported by the EWRS and can be accessed at http://www.ewrs-et.org/ for teaching and training purposes.

The type of teaching material offered is diverse, ranging from short introductory paragraphs to in-depth and comprehensive textbook chapters or documents. The scope of the topics covered can range from general, with broad views, to specialised, in depth and focused on specific problems. Other types of materials are also presented, such as pictures, references and links to similar or complementary material.

The content of the Web Site and its comprehensiveness will depend on your contribution. You will find a comprehensive directory on weed science topics ready to be filled with content. You will find a discussion platform to exchange information and ideas. The more you contribute the more you can profit.

Collaboration

The EWRS Working Group Education and Training works together with other EWRS Working Groups, with organisations and universities all over the World and of course with you. You are invited to visit our web site to download material and to contribute with your own work. How many of us did prepare lectures, scripts and presentations on weed science, technology and management? Sharing this work will help to disseminate weed science, the work of EWRS and its members.

With your help we will continue to improve our activities. We consider Education and Training a core activity of EWRS and we will enhance Education and Training to a core competence of EWRS.

Guidelines for physical weed control research: flame weeding, weed harrowing and intra-row cultivation

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A prerequisite for good research is the use of appropriate methodology. In order to aggregate sound research methodology, this paper presents some tentative guidelines for physical weed control research in general, and flame weeding, weed harrowing and intra-row cultivation in particular. Issues include the adjustment and use of mechanical weeders and other equipment, the recording of impact factors that affect weeding performance, methods to assess effectiveness, the layout of treatment plots, and the conceptual models underlying the experimental designs (e.g. factorial comparison, dose response).

First of all, the research aims need to be clearly defined, an appropriate experimental design produced and statistical methods chosen accordingly. Suggestions on how to do this are given. For assessments, quantitative measures would be ideal, but as they require more resources, visual classification may in some cases be more feasible. The timing of assessment affects the results and their interpretation.

When describing the weeds and crops, one should list the crops and the most abundantly present weed species involved, giving their density and growth stages at the time of treatment. The location of the experimental field, soil type, soil moisture and amount of fertilization should be given, as well as weather conditions at the time of treatment.

The researcher should describe the weed control equipment and adjustments accurately, preferably according to the prevailing practice within the discipline. Things to record are e.g. gas pressure, burner properties, burner cover dimensions and LPG consumption in flame weeding; speed, angle of tines, number of passes and direction in weed harrowing.

The authors hope this paper will increase comparability among experiments, help less experienced scientists to prevent mistakes and essential omissions, and foster the advance of knowledge on non-chemical weed management.

Computer model for simulating the long-term dynamics of annual weeds

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A simulation model of the population dynamics of annual weeds and how it is affected by crop rotation, cultivation practices and weed control was presented by Rasmussen et al. (2002). The model aims to predict the development of a certain weed species in order to plan crop rotation and cultivation practices to minimise the risk of proliferation. The model does not predict the exact number of weeds expected to be found in a certain year or crop, but rather the general development over a number of years. It included the most important processes of the weed life cycle: seed survival in the soil, seed placement in soil after tillage, seed germination depending on soil depth, time of year and tillage and weed physiological development. The component describing the number of weed seeds resulting from a certain density of emerging seedlings was however rudimentary.

In Rasmussen & Holst (2003) a simple model to predict seed production from seedling density was presented, and its six parameters for *Chenopodium album* and *Papaver rhoeas* estimated from literature data, supplemented with field data on *P. rhoeas* seed production in Denmark. Parameter values were specified by their expected ranges rather than just point estimates, which enabled us to determine the expected ranges of seed production at given seedling densities. The model has been incorporated into the model framework presented earlier for a more complete description of annual weed seedbank dynamics in a crop rotation.

While the model needs to be validated, parameters for the two selected species were readily estimated from available literature and more species can be easily added.

In Rasmussen et al. (2003), the model was extended to include volunteer oilseed rape. The model was compared with an alternative model, and the pros and cons of both models was discussed.

The model can be freely downloaded from the Internet at
http://www.agrsci.dk/plb/nho/Fieldweeds.htm.

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Designing crop rotations for organic plant production with low livestock density, combining weed control and nutrient supply

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Introduction

Due to official regulations, Norwegian agriculture is divided into cereal cropping areas with very little animal husbandry, and areas with high livestock density in the coastal and mountain regions. Stockless organic farming requires a good management of green manure crops. Available green manure species as well as the amount of nitrogen (N) that is fixated, are restricted due to climatic conditions, with short growing seasons and cold winter climate. Crop rotations on stockless organic farms may be composed by a combination of subcropping legumes in cereals, mulching of vegetables with chopped plant material (Brandsæter & Riley 1999; Riley et al., 2003) and growing leys rich in legume to produce the mulch or nourish a subsequent cash crop. In the climatically best regions, production of legume or grass seeds is a further option.

Crop rotations

Rotation 1 is designed for a full-time farmer with good access to cultivated land. 66% of the land is used for cereals and rapeseed, and 34% for green manure. Rotation 2 is designed for a part-time farmer with less farmland who wants to keep the land in shape and produce some cash crops, but can not manage to cultivate all the farmland intensively. 44% of the land is then used for vegetables and herbs, and 56% to produce mulch or green manure crops.

	Rotation 1		Rotation 2
1.	Green manure	1.	Cereal or lettuce + est. of ley
2.	Barley with subcropped legume	2.-5.	Ley
3.	Oats and peas	6.	Potatoes
4.	Green manure/winter rye	7.	Green manure
5.	Rye, then ryegrass-clover	8.	Cabbage with early mulch
6.	Late planted rapeseed	9.	Carrots with late mulch

Weed regulation

The main bottlenecks to achieve satisfactory yields and income in these cropping systems will be the nutrient availability, weed regulation and amelioration of soil structure (Etun et al 2002). Green manure and mulch leys must be cut regularly to control perennial weeds.

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Crop growth stage susceptibility to rotary hoe cultivation in narrow row and wide row soyabean cropping systems

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The objectives of this project were to investigate soyabean response to row spacing management systems, to evaluate the effect of tractor wheel tracks on soyabean yield in a narrow row system and to determine the susceptibility of various growth stages of soyabean to physical damage caused by cultivation with the rotary hoe in drilled and row planted soyabeans in a weed free situation. This three year experiment was conducted from 1999 to 2001. Soyabeans were systematically cultivated with a rotary hoe from the pre-emergence to the third trifoliate leaf stages in order to determine their susceptibility to cultivation. Two and three cultivations were done on a combination of growth stages. Selective herbicides were used to keep fields weed-free to avoid confounding effects between weed interference and cultivation. Within this project, narrow rows (17.6 cm spacing, planted with a drill seeder) production systems were compared with conventional rows (76 cm spacing, planted with a row planter) production systems.

Row spacing management systems

Soyabean density, yield, grain humidity at harvest and 1000-grain dry weight were significantly greater in the treatments seeded with the row planter. Soyabean densities represented only 28 and 73 % of the seeding rate with the drill seeder and with the row planter, respectively. This difference is probably due to the absence of press wheels on the drill seeder and to the increased emergence (through soil cracking) of the row planted soyabean. However, a soyabean population 290 % greater in the crop seeded with the row planter only increased yield by 5 %, indicating that soyabean is very plastic and could have a lower seeding rate. These differences are most probably a reflection of the type of seeder used rather than a difference in soyabean response to row spacing.

Tractor wheel tracks

Soyabean population was reduced only on the wheel tracks when cultivation was done at the 3rd trifoliate leaf stage. Soyabean yield decreased significantly on the wheel tracks when cultivation was done later than the 1st unifoliate leaf stage. Grain humidity at harvest varied between 12.4 and 13.3 %. It was not significantly different among cultivation treatments but was slightly lower (less than 1 %) on the tractor wheel tracks in the treatment that was cultivated at pre-emergence, the 2nd trifoliate leaf stage and in the non-cultivated control than between tracks. Yield losses due to wheel tracks increased as cultivation was done later, indicating that soyabean cannot compensate for late physical damage.

Growth stages susceptibility

For all the variables tested, there were no significant differences in susceptibility between the various growth stages of soyabean to physical damage caused by cultivation with the rotary hoe. These results were true both in drilled and in row planted soyabeans. Soyabean population tended to be greater in the non-cultivated control but differences were not statistically significant.

Criteria for optimised weed harrowing in cereals including development of experimental equipment for weed harrowing trials

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The objective in a recently initiated project is to add new knowledge as a fundament for improving weed harrowing in organic cereal production as well as using weed harrowing as a alternative for the use of herbicides in conventional farming. The project has two main objectives: (a) Develop new experimental equipments for weed harrowing trials, and (b) Develop criteria for whether a farmer shall harrowing or not, and how to optimise the harrowing operation. The last objective includes also new knowledge of how to combine the use of harrows and subcropping legumes in cereals. One important aspect in the project is to study whether harrowing recommendations, build on experiments carried out in other countries with lighter soils, are suitable also on heavier soils and in stony conditions, which are typical for the cereal growing areas of Norway.

Developing new experimental equipments includes the use of narrow (1.5 meter) fingerweeders which have the same tines and specification as a broader one. The narrow fingerweeders are combined with the use of tractors with an increased gauge (ca 1.75 meter), to avoid tracks in the experimental plot. It is important to drive a fingerweeder with a certain speed. Normally you need a broad headland between each experimental plot to accelerate. With this system you can drive over the neighbouring plot with the harrow lifted and with right speed, and just put down the harrow at the start of the plot and lift it again at the end without stopping. By this methodology size of experimental plots can be reduced and more plots and treatments can be included in each trial. With a small experimental area also soil uniformity and weed distribution will be more homogenous. The strength of the harrowing operation is defined by cereal coverage before and after harrowing, using a software program analysing digital pictures.

Yield, as well as weed control parameters, from the first field experiment will be presented. This experiment includes different fingerweeders, harrowing at different cereal growth stages and different harrowing strength (aggressiveness), obtained both by different speed and by harrowing at different working depths.

The Swiss pocket knife concept for crop nursing

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Numerous tools and implements for physical weed control have been developed and optimised in the last decade including innovative techniques for selective weed control. However, various tools will have to be applied to control weeds in different crops, growth periods and conditions. Due to lack of standardisation between implements and laborious adjustment operations for the tools producers are forced to buy a wide range of machinery which, particularly for small farms, cause unbearable investment costs. For small structured farms with a large variety of crops a light, flexible and easy to use crop nursing system would be ideal. Therefore a project was started at Agroscope FAW Wädenswil with the objective to develop a sophisticated crop nursing system.

Components of this so called Swiss pocket knife concept for crop nursing are a light weight and inexpensive tool carrier and a user guide which enables practitioners to optimally apply commercially available tools and implements under there site specific conditions. Multifunctionality, flexibility, and easy to use are key requirements of the Swiss pocket knife concept. The tool carrier FOBRO-Mobil of the Bärtschi-FOBRO AG company, Hüswil (CH) was used as a basis. Advantages are its lightweight, the task specific engine power, its economics and the low initial costs. Size and hydraulic power transmission makes it a very manoeuvrable and benefits the ergonomic design. As a Swiss pocket knife, the tool carrier is multifunctional. Weed control is mechanically and/or thermally possible in and between crop rows. At the same time cover crops can be drilled and/or fertilizer be applied with high precision. The combination of carrier and tools is very flexible to use because it can easily be adapted to specific conditions such as soil type, crop stage, weed stage and population, climatic and topographical conditions. The tools are clearly arranged, easy accessible and controllable. A hydraulic guidance system allows to adjust the tools online during the work, potentially with optical guidance devices.

In close cooperation with the machinery industry and vegetable growers new tools were developed. Tools and guidance system are extensively tested in various vegetable crops and under a wide range of field conditions. One of these new developments is an actively vibrating hoe which allows a very shallow and precise soil treatment close to crop plants. Results and experiences from practical use of the tools are now used to work out an decision support system. Based on this decision support system a user guide will provide all necessary information for the farmer to find the most suitable tool and adjustment for the current crop, weed and field situation.

As there is not one Swiss pocket knife, there are many combinations of tools which can be combined to specifically meet the requirements of a vegetable grower. Although, the concept is designed for small farms its adaptability and the guide which helps the farmers to take the right decisions for technology and timing of weed control makes it likewise interesting for large farms. The tool carrier and most of the tools are commercially available but there is more work to do to improve tools and to optimize treatment combinations. The users guide for an efficient and labour saving use of mechanical and thermal weed control will be available in early 2005. Hopefully it will then help to promote the use of non-chemical weed control techniques in vegetable production.

Techniques for green manure cutting: Energy requirement and ley recovery

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A green manure ley needs to be mowed several times every season to control the weeds. From a resource perspective, the number of mowings should be reduced to a minimum in order to save fuel. Additionaly, the farmer needs an economical and practical solution to the task.

Materials and methods

Two trials were carried out on grassland and clover ley respectively, where ley regrowth, evenness of spreading and evenness of cutting was measured after different mowing machines. Those included two flail mowers, bar cutter, rotary mower with conditioner and a pasture topper. One additional trial was carried out where fuel consumption was measured in clover ley by use of a tractor computer. From this, energy consumption per hectare was calculated. The clover leys used where quite thick, with an estimated dry matter yield of at least 5000 kg/ha. The grassland being a grazed pasture yielded approximately 1000 kg/ha. Yields were not measured.

Results

The flail mowers very much cut the plants to pieces with 70% of mass in pieces less than 5 cm of length. The rotary mower and the cutter bar left more than 90% of the mass uncut.

Flail mowers required a relatively high transmission effect which was increased considerably with the mass flow. The disc mower with conditioner required the highest transmission effect, but this increased comparably slowly with the masses of plants passed through. The effect required for the transmission of the pasture topper and the cutter bar were negligible. The cutter bar used least total energy per hectare, followed by the disc mower.

The cutting capacity was decidedly highest for the disc mower and lowest for the cutter bar with comparably small differences between the other machines. The cutter bar was the only machine leaving the grass in a clear windrow.

The clover ley regrowth, measured by coverage and plant height, was more rapid after machines cutting up the plants. The grassland showed no differences except for the cutter bar whose swath hindered the regrowth to some extent.

Discussion

All machines tested could be used for the purpose. The choice will, however, totally depend on yield, farm size and what other chores there might be for mowers.

Clearly, machines may not make much of a windrow.

The regrowth was obviously favoured by cutting the plants into pieces. However, cutting on a somewhat earlier date could have been a good choice considering the reduced time and energy consumption. This would have been favourable for all machines, but most notably for the rotary mower which would have increased the capacity most while probably reducing crop hindrance.

We do not know to what degree the slow down of regrowth in these cases affects the leys competitiveness against weeds or not. Further trials on this will be carried out.

Water-jet cutting of potato tops – some experiences from Sweden 2003

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In Swedish potato production, the haulm is generally controlled before harvest. This operation can be carried out either by a chemical treatment with karfentrazonetyl or dikvat, or by crushing in combination with flaming. Chemical defoliation of potato tops is a standard method for most producers but there is an increased use of crushing and flaming, especially in potatoes intended for crisps. The "crushing and flaming-method" is considered as a more environmentally friendly method, but requires more working time compared to chemical defoliation since it generally only can cut four rows at a time.

A competitive physical method needs high cutting capacity, i.e. high driving speed and possibility to cut 8-12 rows at a time which, in turn, requires lower weight and less input of fossil fuel.

An interesting approach would be to use water-jet cutting for defoliation. The method is an industrial technique to cut plastics, metal and wood, blasting of metal constructions before painting, concrete demolishing. Water-jet cutting uses water with extreme pressures (2000-3000 bar) but has generally low water consumption (5-25 litres min^{-1}). Basically, the method uses a high-pressure pump, high-pressure pipes/hoses and a nozzle made of synthetic sapphire. Water-jet cutting can be used either stationary for robotized cutting, or as a mobile unit operated by hand .

In August 2003, a commercial mobile unit mounted in a 10-feet container (Hammelmann high pressure pump unit HDP 114/Aquajet 11) with an operating pressure of 2350 bar was tested in potatoes to investigate the potential for cutting of potato haulm.

Different types of nozzles and water pressures were tested in field by the use of hand-held lance. Worker safety problems and potential development of the machine was identified.

It was concluded that a water pressure of 1000 bar was sufficient to cut the tops using a nozzle with 1.0 mm diameter. A water flow of 23 litres min^{-1} can supply about 20 nozzles with sufficient pressure and flow to cut potato tops. It was not possible to test cutting speed in field, but earlier studies have shown that cutting can be carried out by a speed of 18 km h^{-1}.

Further experiments and a field prototype of a water-jet potato cutter will be developed in mid 2004 in cooperation with a Swedish manufacturer.

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Achieving an optimal balance between machine vision capability and weed treatment effectiveness using competition models.

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To achieve greater precision in the detection and subsequent removal of weeds, an automated mechanical weeding device has been developed (by Silsoe Research Institute) that is guided by machine vision. Firstly it was necessary to test the algorithm of the detection system for its robustness over a range of different crop species. Secondly, the algorithm was tested for its ability to correctly classify crops and weeds during the early stages of crop establishment when physical weed removal would be typically implemented in the field. The detection system was linked with a competition model developed at Horticulture Research International. Using the competition model it was possible to demonstrate, in terms of final yield, the critical balance between increasing the sensitivity of the detection system *vs.* the possibility of, in doing so, misclassifying some crop plants as weeds and inadvertently removing them. A number of competition scenarios indicated that the detection system parameter settings to achieve optimum yields were particularly sensitive to the competitive ability of the weed species. For example, in the presence of a relatively uncompetitive weed, such as *Veronica persica,* crop yield was more sensitive to accidental crop removal than from weed competition. In contrast, yield loss was more attributable to weed competition than crop damage when in the presence of *Tripleurospermum inodorum*. Combining the detection system and the competition model in this way it was possible to simulate numerous scenarios. These simulations were used to demonstrate that optimum yield may not necessarily be achieved through simply maximising weed removal or minimising crop damage. Instead, optimum yields are more likely to be achieved through a "trade-off" strategy balanced for a specific crop and weed species combination. At present, the detection system may be able to achieve good classification of crop and weed material with operation speeds that are generally fast enough for real-time operation. However, if the accuracy of the actual removal method were relatively coarse then the whole system would become limited by this stage of the process. Therefore, development of this technology will ultimately depend on the associated weed removal technologies also being considerably more sophisticated in their ability to target and remove individual plants than at present.

Seed mapping of sugar beet to guide weeding robots

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Individual plant care in agriculture will lead to new opportunities in crop management. Not only the weeding operation is in focus here but it will be more in general for individual chemical or physical treatments of individual weed or crop plants. For the application of fertilizers and chemicals in small dose rates and accurately targeted advanced sensor information e.g. based on spectral responses can be used to consider the individual plant needs ('the speaking plant'). This will have a significant effect on the reduction of inputs and increase the general efficiency rates of agricultural means.

The objective of this project was to provide high accuracy seed position mapping of a field of sugar beet to allow subsequent physical weeding as inter- and within-row treatments. By knowing where the seeds were placed the assumption was that the plants will show up close by. This information about where the individual plants are can be used to show where the crop rows are. Therefore, this can be used as an appropriate information for guiding tractors and/or implements. At least for steering operations for inter-row weeding this procedure can be sufficient.

A high accurate, cm-level, RTK GPS, optical seed detectors and a data logging system were retrofitted on to a conventional sugar beet precision seeder to map the seeds as they were planted (Nørremark et al., 2003). The average error between the seed map and the actual plant map was between 16 mm and 43 mm depending on vehicle speed and seed spacing (Griepentrog et al., 2003). Both parameters influenced the plant position estimates significantly. The seed spacing was particularly important because of its influence on the potential of seed displacements in the furrow after passing the seed detecting sensors.

The results showed that the overall accuracy of the estimated plant positions were acceptable for the guidance of vehicles and implements for weeding purposes as well as for individual plant treatments. This research is contributing to the ongoing Danish research project Robotic Weeding as a cooperative research project of The Royal Veterinary and Agricultural University (KVL), Frederiksberg and the Danish Institute of Agricultural Sciences (DIAS), Horsens.

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The design of an autonomous weeding robot

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An autonomous weeding robot is designed using a phase model of the design process as design method. In this phase model the design of a product is represented as a process consisting of a problem definition phase, alternatives definition phase and a forming phase. The results of the different phases are solutions on different levels of abstraction. In this paper we present an outcome of the design method for an autonomous weeding robot and we will discuss the difficulties in applying such a method to the actual case of an autonomous weeding robot.

The problem definition phase starts with defining the purpose of the design, which is formulated as 'replacement of hand weeding in organic farming by an automatic autonomous device on field level'. In this problem definition phase also the program of requirements is established. An important requirement is that the weeding robot has to be able to work in sugar beet as a 'model crop'. This implies that the weeding robot could be working also in crops comparable to sugar beet with respect to planting distance and regularity of the planting distance. The last part of the problem definition phase consists of the definition of the functions of the robot. A function is an action that has to be performed by the robot to reach a specific goal. Important functions are intra-row weed detection and intra-row weed removal. The functions are grouped in a function structure, which represents a solution on the first level of abstraction.

The function structure consists of several functions which each can be accomplished by several alternative principles. For example, alternative principles for the function "intra-row weed removal" are mechanical, laser, flaming, etc. The alternatives definition phase lists possible alternative principles for the various functions in the function structure. By selecting one alternative for each function and by combining these alternatives, concept solutions can be established. Using a rating procedure, one of these concept solutions is chosen as the solution at the end of the alternatives definition phase.

In the forming phase the chosen concept solution is worked out to the final solution.

The advantage of the approach is that it provides a good overview of the total design. Also, the design method forces the designer to look at alternative solutions. Because of the structured sequence of design activities, it is easy to keep track of the progress of design. A problem when using this approach for research is that it is not always clear whether a potential alternative will really be able to fulfil the function sufficiently. Some possible alternatives to fulfil a function represent rather a research direction than a possible solution.

Lay-down working cart improves efficacy of hand weeding

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Hand work on (organically managed) horticultural fields is often unavoidable. Hand planting, hand weeding, and harvesting of strawberries and cucumbers are examples of tasks which are hard, if not impossible, to mechanize. Manual weed control is often the major limiting factor for organic vegetable production on a farm level.

We have developed a Crawler, a wagon designed to support and transport a worker on the field. Our construction is a three-wheel, electically powered transporter. We aim to quantify labour-saving and labour-easing effects of the Crawler.

During the summer 2000, we did different hand works on horticultural fields in different farms. In each time, work output of 30 min periods with and without Crawler were recorded. Several people, varying from experienced Crawler users to beginners, have been measured. Measurements include transplanting, hand weeding and picking of strawberries. Only data on hand weeding is presented.

The familiarity of the worker with the Crawler had a major effect on the efficiency of the Crawler. Whereas the experienced Crawler users improved their work performance on an average by 32 %, no effect was noticed when beginners worked with the Crawler.

Although many farmers argued, that with a low weed density (and therefore fast weeding) the Crawler helps more than with slow moving on the field (connected to high weed density), measurements did not support their observations. However, the variation between the measurements was large.

Most of the farmers who have used the Crawler considered the 30 min measurement as too short. According to their opinion, lower exertion to knees and back enable longer working days and weeks, thus improving the working capacity and well-being in a long run. This is difficult to measure and hard to calculate in economical terms.

Finger weeder for cabbage and lettuce cultures

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Finger weeder has changed weed control strategy in many organic vegetable farms, where hand weeding or hand hoeing of planted vegetables has been nearly completely replaced by machine work. To replace herbicides in conventional farming, finger weeder must have acceptable efficacy compared to herbicides. For lettuce growers, however, no herbicides are registered in Finland. Still there has been doubts, whether plants get soiled through finger weeding, thus making the quality of the product commercially unacceptable.

Summer 2002 we compared finger weeder against net harrow and herbicides in cabbage. Field trial 2003 was dedicated to lettuce: we compared different intensities of finger weeding in two different lettuce cultivars. Trials were performed at Uusimaa Rural College as randomized block experiment with two replicates, plot size 1,6 x 20 m. Elomestari Weed Master was used as a tool carrier for goosefoot hoe and finger weeder.

Finger weeder, net harrow and herbicide treatments were compared in cabbage plots. For mechanical control, hoeing was done twice, using goosefoot hoe between the rows (inter-row) and either finger weeder or net harrow within the row (intra-row). Herbicide treatment program was planned and realized by Berner Oy, Helsinki and no hoeing was done. Measurements included plant density and yield, both crop and weeds.

All weed control treatments significantly increased the cabbage yield, whereas between mechanical and chemical control there was only small differences. Additional hand hoeing slightly improved the mechanical weed control, but was not necessary for acceptable result.

In lettuce experiment, two intensities for finger weeding was compared to simple inter-row hoeing: gentle, where fingers are appr. 1 cm distance from each other, and intensive, where they overlapped appr. 2 cm. Besides crop and weed yield, also soiling of the lettuce was scored.

Very few weeds emerged at lettuce plots and no differences between the treatments were observed. Finger weeder had no effect on lettuce quality, even intensive treatment left the crop undamaged.

Finger weeder proved to be an effective weed control tool for planted cabbage and lettuce. Even in conventional farming it is a realistic alternative to chemical control.

Steaming soil in narrow strips for intra-row weed control in sugar beet

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The objective was to study the weed control effect and the energy use when soil was steamed in narrow strips before sowing. The experiment was carried out on a sandy soil on an organically cultivated field in the southern part of Sweden (Österlen). The field was sown with sugar beet a couple of hours after the treatment. Annual weeds were predominant in the experiment, with the main species observed being *Senecio vulgaris* (L.), *Chenopodium album* (L.) *Solanum nigrum* (L). and *Solanum physalifolium* (Rusby).

Treatments were performed using tractor-drawn steaming equipment from Regero (France) with a 700 kW diesel boiler to heat the water. The hot steam was conveyed to nine applicators (9 rows). Each applicator heated a section of the soil 0.14 m wide and 0.04-0.05 m deep. The total working width for the equipment was 5.10 m. The amount of steam applied per hectare was adjusted by varying the tractor travel speed. Dose-response relationships were described in order to estimate the effective energy use and effective travel speed of steam treatment.

The soil temperature was 70 °C to 80 °C during the treatment. Preliminary results indicate that steam treatment can control *S. vulgaris* and *C. album.* It was not possible to show a significant weed control effect on *S. nigrum, S. physalifolium and Fallopia convolvulus* (L.) at the energy doses studied. One explanation for the insignificant effect may be that the soil temperature did not reach 70-80 °C in all parts of the treated soil volume, i.e. in the central part of the volume. The energy dose required to achieve a 90% reduction in plant number (LD_{90}) was 850 L diesel ha^{-1}. The steam-applicators used in the experiment were prototypes, i.e. there can be a great potential to decrease the energy use by technical development of the applicators.

The steam treatment made it possible to reduce the working-hours for manual weed control (hoeing) from approximately 110 h ha^{-1} to 60 h ha^{-1}.

The cost to treat one hectare is estimated to 7500 SEK (830 €, 2003 price level) with the equipment from Stockholmsgården, under following circumstances. Investment 300 000 SEK, 79 L diesel oil h^{-1}, 4 SEK L^{-1} diesel oil, driver 150 SEK h^{-1}, tractor 100 SEK h^{-1}, capacity 0.1 hectare h^{-1} and 20 hectare $year^{-1}$. Decreasing the treated strip to half of the width will double the capacity and decrease the cost to approx. 4900 SEK $hectare^{-1}$.

Thermal weed control by water steam in bulb unions

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Data of six year field experiments carried out at the Lithuanian University of Agriculture shows that thermal weed control by humid water steam is effective and can be widely applied, however, it needs special equipment. At the same time a number of factors, influencing the process of thermal weed control, should be evaluated. As cultural plants differ in their sensitiveness to thermal impact every crop requires special technology of weed control by water steam (Lazauskas & Sirvydas (2002); Sirvydas et all (2002)).

In the period of 2000-2003 experiments (6 variants with 6 replications) were carried out in laboratories and Experimental Station of LUA to investigate weed control by water steam in onions. Experiments of four years completely revealed the advantages and imperfections of weed control by humid water steam, which should be considered improving weed control technology and equipment improvement.

It's expedient to make thermal weed control by humid water steam two times during vegetation period in the crop of onion seedling. The best effect of thermal weed killing by humid steam is received when this method is applied in the entire field without protecting onions against impact of the steam. If germination of onions and weeds starts in the time of the first weed killing period, an open type disperser with two steam outflow canals should be used. Steam outflow through two channels enables to weaken wind influence on dispersion of steam flow and to prolong the retention time. During the second weed killing period the use of an open type humid water steam disperser with one outflow channel is expedient. The onions are a little bigger and their leaves create the shelter, which stops the influence of wind on steam dispersion.

Theoretical, laboratory and field experiments allow to state that weed control should be started when they are in the stage of seminal leaf-first leaf. In this phase of growing retention time of 1 second is suficiently enough to decimation the weeds. However, weed killing degree can be limited by local microclimatic conditions. 0.5 sec retention time is enough to kill weeds under laboratory conditions. In killing of bigger weeds (7-10 cm) the retention period of 2 sec is required. If weeds are not killed in the germination phase and thermal impact is aimed at onion plants, the retention period of 2 sec should be used for decimation weeds by humid water steam in the onion crop.

Application of thermal weed control by humid water steam results are not only successful weed control but also gives material increase of onion yield. The investigation data show that in case of weed control by steam the obtained average yield is 424 kg/ha (9.5 percent) higher than that in the control variant where weeding has been applied three times. In comparison with manual weeding additional yield in 95 percent probability level was rather stable in all years of investigations - 8.4 percent (in 2000), 10.2 percent (in 2001), 9.9 percent (in 2002). At the same time quality of the production improved. Comparison with the manual weeding shows that increase of yield completely covers the expenses of thermal weed control by water steam.

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Thermal desinfection of soil by water steam

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During soil sterilization by water steam the soil mass heats to the water steam condensation temperature 100 ^{0}C. This temperature is sufficient to kill weed seeds, soil fauna and pathogen micro organisms (Davies et all 1993; Melander & Rasmussen (2001); Sirvydas & Stepanas (1997)).

Engineering and biological soil analysis show that soil sterilization efficiency is determined by the intensity of 100 ^{0}C temperature field formation and character of its distribution in the layer of sterilized soil.

Mobile technical equipment for soil sterilization by water steam has been developed on the basis of the experimental results. It is composed of the group of perforated pipes moving in the soil. The perforations in the pipes are 5 mm diameter, ranged in groups in 120 degrees angle.

The shields located above the steam supply holes to prevent the latter from obstruction with soil. As mobile sterilization equipment moves the shields form channel in the soil. The diameter of these channels is bigger than that of perforated pipe, therefore, the contact area of water steam and sterilized soil increases. Increased contact of steam and soil intensifies the heat exchange and output of the equipment. Inside conidial shape of the shields is 120 degrees. According to thermodynamics, movement direction of the outgoing steam flow is parallel to the axis of perforated pipe. The outgoing steam flow maintains and does not destroy the form of the channel that has been formed in the soil. Additionally water steam is supplied to the channel through area between the perforated pipe and stopper. Its length can be changed by changing length of the rope. Investigation shows that thanks to the formed channel soil heating to the sterilization temperature shortens down to 20 degree. Parameters of the mobile equipment for soil sterilization are based on the investigation results. The presented construction of the mobile equipment for soil sterilization ensures equal and intensive formation of 100 degree C temperature field in the sterilized layer of the soil. For reducing heat loss to the environment and slow down the cooling of the surface of the soil, it is covered with textile. Thermal sterilization of the soil is effective but expensive way. 30-50 kg of water steam is used sterilization of 1 square meter of the soil. Used amount of steam changes according to the thickness, dampness of the soil layer, as well as perfection of the used mean for soil disinfection.

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Weed seeds control by steam and substances in exothermic reaction.

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A new system for soil disinfection (including weed seeds control) by means of steam injection after the incorporation in the soil of varying amounts of compounds (KOH, CaO, etc.) that causes an exothermic reaction was developed and improved in the five years period 1998-2003 by the Celli firm in co-operation with the researchers of the Sezione Meccanica Agraria e Meccanizzazione Agricola of the DAGA of the University of Pisa.

A specific experiment was carried out in 2003 in controlled conditions in order to evaluate the effects of the application of this system on seeds of both microthermal and macrothermal weeds.

The experiment was carried out on plastic "chests" (with parallelepiped shape, square base with side of 30 cm and height equal to 50 cm) in which steam was injected at a depth of 15 cm by means of a specific dispenser. The amount of steam was the same used when the treatments are performed by means of the operative machines in open ground. Four doses (corresponding to 1000, 2000, 3000 and 4000 kg ha-1) of two substances in exothermic reaction (KOH and CaO) were used and compared to an only steamed control and an untreated control. The compounds were mixed to a sandy soil until the depth of 15 cm, while weed seeds were put in specific permeable small plastic sacks (100 seeds/250 cm3) resistant to high temperatures and chemical reactions, that were placed at 7.5 cm of depth. The effect of the treatments was evaluated on seeds of three microtherm (Alopecurus myosuroides Hudson, Matricaria chamomilla L., and Raphanus raphanistrum L.) and four macrotherm (Amaranthus retroflexus L., Echinochloa crus-galli L., Fallopia convolvulus L. and Setaria viridis L.) weed species.

After the treatments the soil contained in the sacks was put in plastic pots and watered each day until plants finished to emerge from all the viable seeds. The effects of the different treatments were determined in terms of both number of emerged plants and weed density reductions with respect to the untreated control.

During all the tests the trends of soil temperature were monitored at 7.5 and 15 cm of depth by means of PT100 sensors 4 cm long that send a voltage signal to data loggers from which data are acquired and recorded on a personal computer using specially designed software.

The temperatures were measured for three hours and after divided in four "classes" ($T<40°C$; $40\leq T<60°C$; $60\leq T<80°C$; $T\geq 80°C$). The time of persistence in the soil of each class and the highest, the average and the final (after three hours) values of temperature were taken into account in order to compare the effects of the different treatments.

A completely randomised experimental design was used to compare the nine treatments and the untreated control, while a factorial design was used to compare the effect of the two substances and the four different doses.

Although data processing is still in progress, the first results analyzed seem to evidenziate a clear effect of compound doses in weed seeds control (increasing control for increasing amounts of both the compounds), while eventual differences in the efficiency of the two substances in exotermic reaction are not so clear. However, a better control seems to be connected to the use of KOH for microthermal weed seeds and CaO for macrothermal weed seeds.

Flaming for intra-row weed control in Globe Artichoke

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The cultivated artichoke is *Cynara scolimus* L. a member of the Asteraceae (Compositae), the family that also includes lettuce, sunflower, aster, endive, chicory, thistles, and other cultivated and weedy species. The artichoke is a perennial plant and today is mainly cultivated for the production of the edible flower buds.

Although the artichoke is grown on all the world's continents, it is above all a Mediterranean crop. Nearly 85% of the world's artichokes are grown in the countries bordering the Mediterranean Sea.

Italy is the largest producer as well as the largest consumer of artichokes. Nearly half of the world artichokes are grown in Italy; in this country it represent for spread the third horticultural crop after tomato and potato.

Artichoke fields generally are maintained in perennial culture for 2 to 10 years and the cultivation cycle reaches up to 300 days. For this reason artichoke, that is very strong crop, has in weed control one of the greater problems especially in organic farming.

Non-chemical intra-row weed control is carried out with hand hoeing that is a very long and hard work; it is not possible to use hoeing-machine because of plant morphology.

The present study aimed to investigate the possibility to change hand hoeing with flaming for intra-row weed control.

Trials were conducted in 2002 and 2003 at the experimental station of the Division of Horticulture and Floriculture of the University of Pisa (43°40' lat. N, 10°19' long. E). Artichoke (*Cynara scolimus* L. cv. Terom) was grown according to the standard cultural practices in the study area, at a density of 0,7 plants m^2 with an inter-row spacing of 1,40 m.

The experiment compared two different intra row weed control techniques during the cultivation cycle, hand hoeing and flaming, and an unweeded control.

Flaming was performed with a knapsack flamer. The experiment was laid out in a randomised complete block design with four replicates. Size of elementary plots was 60 m length by 1.40 m width. For any treatments were measured or calculated operative time, working capacity, and LPG consumption per hour and hectare. Weed density was sampled by species just before weed control treatment. Artichoke yield was determined at different times (as soon as the bud were ready for harvest) by complete harvest of each plot.

In 2002 intra-row weed control was performed with one treatment of hand hoeing and two of flaming. The working time was of 180.2 h/ha for hoeing and 129.3 h/ha for flaming in all. The LPG consumption was 99.9 kg.

In 2003 the number of treatment was the same than in the previous year and the time needed was 238.1 h/ha for hand hoeing and 160,0 h/ha for flaming with a LPG consumption of 115.2 kg.

In the two years trials artichoke yield (bud/ha) was not different for the two different intra-row weed control technique and lower for the unweeded control.

At the end of cultivation cycle the time to remove the weeds (standard cultural practices) was not different between the two techniques and higher for the control.

These first results indicate that flaming is efficient for intra-row weed control in artichoke. To improve the performances of flaming it is naturally needed to develop a specific flame machine for artichoke.

Terminating ley with mid-summer bare fallow controls *Elymus repens*

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Perennial weeds, especially *Elymus repens* (L.) Gould (common couch), become often a problem in long-term leys. They cause problems also in the succeeding crop, particularly in organic farming, where chemical weed control is not used. The objective of this study was to find such ways for terminating long-term leys, which are more effective in suppressing *E. repens* than traditional autumn or spring ploughing. In addition to controlling perennial weeds our aim was to accelerate the nitrogen release from the ley in order to increase the availability of nitrogen to barley in the early summer.

The field experiment with four replicates was placed in medium fine sand soil field at Juva in eastern Finland. The ley was 3-year old in 2000, consisting of timothy and red clover. The percentage of red clover was about 50%. In the first experimental year, the timothy-clover ley was terminated using various types of cultivation with different timing.

Treatments in terminating ley:

A1 Stubble cultivation (three times during about one month) after harvesting one forage yield, catch crop and autumn ploughing in October ("mid-summer bare fallow" treatment)

A2 Stubble cultivation after second forage yield, no catch crop, autumn ploughing in October

A3 Plain ploughing in September, shortly after second forage harvest

A4 Aftermath was grown, plain ploughing in October, just before winter

A5 Plain ploughing in spring

The effect of different treatments on *E. repens* was assessed in 2001. In spring the whole experimental field was sown with barley. In early July, the number of shoots of perennial weeds was assessed on 2 × 0,25 m² at both ends of each plot. In statistical analyses, the number of *E. repens* shoots and barley yield in different treatments were compared to the "ploughing in October" treatment (A4), which was considered as the standard practice when terminating ley.

The alternative methods reduced *E. repens* infestation when compared to ploughing. After plain ploughing (A3, A4, A5) the density of *E. repens* varied from 147 shoots m^{-2} to 182 shoots m^{-2}, none of the ploughing treatments being superior to the other. The "mid-summer bare fallow" treatment (A1) reduced significantly *E. repens* (having only 27 shoots m^{-2}). Stubble cultivation in Autumn after harvesting second forage yield seemed to reduce *E. repens* (to 94 shoots m^{-2} in barley stand) when compared to plain ploughing, but the difference was not statistically significant.

The grain yield and hectolitre weight of barley were highest, 2390 kg ha^{-1} and 61,6 kg $hectolitre^{-1}$, respectively, after combination of stubble cultivation and a catch crop (A1). The second highest grain yield was harvested after late plain ploughing (A4). However, none of the yields differed significantly from the yield in treatment A4. The availability of nitrogen was affected by the treatments. There was 40 kg ha^{-1} soluble nitrogen on the top soil (0–30 cm) in May, in the year after the mid-summer bare fallow (A4). The lowest content of soluble nitrogen was after springtime ploughing.

The results of this study suggest that mid-summer bare fallow is a relatively effective way to reduce the amount of *E. repens* when terminating ley. Early started stubble cultivation is also less sensitive to moist weather, leaving more time for exhausting the rhizome reserves of *E. repens*. Stubble cultivation and catch crop do increase the costs but not as much as bare fallowing for the whole summer would do. Additionally, mid summer bare fallow allows harvesting one forage yield prior to bare fallowing.

Temporal sensitivity of *Cirsium arvense* in relation to competition, and simulated premechanical treatment.

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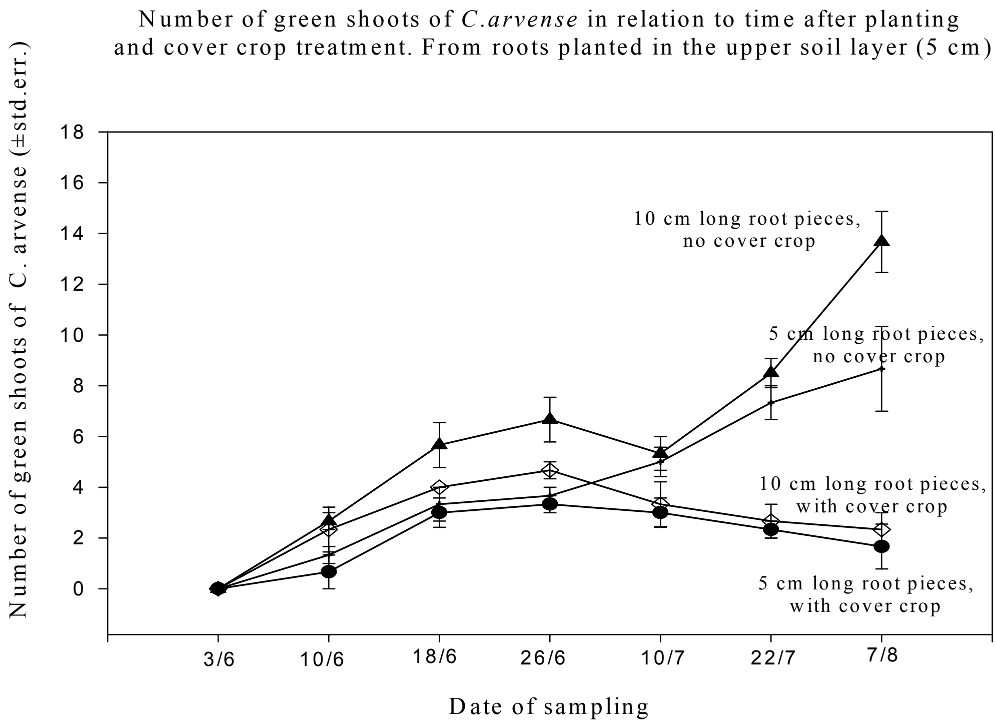
Cirsium arvense is regarded as one of the ten worst weeds in Europe and N. America. In Canada infested land increased from 20.000 Ha in 1975 to 200.000 Ha in 1997. Yield reductions in winter wheat in the range of 28 – 71% have been recorded. *C. arvense* is highly tolerant to mechanical treatment of upper plant parts. Combined actions to regulate growth of *C. arvenes* in organic farming are necessary. This includes crop rotation, soil cultivation, crop density, cultivar selection and mechanical control. The aim of the following study was to assess the effect of pre-mechanical treatment in spring, given as length and depth of burial of the roots. This was combinated with or without a one season green manure crop. The effect of cutting date was also evaluated. The experimental design was a randomised complete block in a split-split plot-design with three replicates. Totally there were, 2 root lengths (5 and 10 cm) x 2 planting depths (5 and 15 cm) x 2 cover crop treatments (±) x 3 replicates x 7 sampling dates giving, 168 subplots. Content of nonstructural carbohydrates as a qualitative measure on the critical nutrient level in the *C. arvense* roots will be measured. The cover crop consisted of a mixture of *Phacelia tanacetifolia* (5 kg/Ha), *Vicia sativa* (80 kg/Ha), *Trifolium pratense* (5 kg/Ha) and *Lolium multiflorum* (10 kg/Ha).

Preliminary results show that the cover crop, strongly reduced above ground and below ground growth of *C. arvense.* Cover crop in combination with short root pieces had a strongly negative effect on growth and dryweight of *C. arvense* roots.



Puccinia punctiformis as mycoherbicide on *Cirsium arvense*

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Cirsium arvense, Creeping or Canada thistle is an increasing problem for farmers. Several attempts to use biological control have been studied. As pathogen to *C.arvense.* Rostrup (1873) noticed the increased number of infected plants by *Puccinia punctiformis* with increased density of the weed and in 1923 this pathogen was tested in laboratory and in fields. In contrary to other pathogens *P. punctiformis* is an obligate parasite to *C.arvense*. The pathogen is ubiquitous, easy to distinguish and to extract and thus suitable as mycoherbicíde.In spring, 2002, we transplanted 120, apparently healthy, plantlets of *C.arvense* at 8-10 leaf stadium were in tubes, containing surface soil, with 10 plants in each tube. The dimension of the tubes was150 cm long, Ø 40 cm.

In late June, *P.punctisformis* infected thistle were collected outside the trial area. About 50 leaves were swilled in 1 l of water for 1 hour, with a drop of detergent. The suspended spores were harvested by sieving and centrifugation at 7000 rpm for 10 min and applied to the test plants in 9 tubes by household atomizer. The application was repeated once in mid-July. In August, all treated plants had developed uredosori. All adventitious shoots were heavily infected by the pathogen and died off before end of season. In October, the roots were harvested and stored at 3°C for 6 weeks. 25-30 cm pieces of roots, from the superficial part, were laid out in buckets in sterilized soil. The buckets where kept moist at 10-12°C in 16 hour light. In February, the plants and roots in the buckets were harvested. Green shoots and emerging shoots, the number of healthy or infected shoots, numbers of shoot buds, healthy or diseased, and degree of root infection, was assessed.

Shoots emerging in buckets showed both pycnium and uredium to a various degree. The two forms appeared on shoot from the same root piece. This suggest that the fungus can become systemic after a secondary infection. Roots from *P.punctisformis* infected plants exhibited increased sprouting compared to roots from non-infected plants. Increasing infection in root increased also senescence of shoots and shoot bud.

Conclusions

•*P.punctiformis* enhances early sprouting from roots.
•Early sprouting will enhance effect of mechanical weed control measures in spring.
•Increased sprouting will deplete energy reserves in root and thus reduce delayed sprouting after spring farming.
•*Puccinia puntiformis* can be utilized as an agent for biological control of *Cirsium arvense*.

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Cover crops in cauliflower production:
Implications for weeds, insects, beneficial arthropods and yield

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Cover cropping systems may help to improve agroecosystems, through decreased soil erosion, improved soil fertility, promotion of beneficial insects and reduced weed competition. If these benefits are realized they can improve the sustainability of the system, as cycling, diversity, stability and capacity are enhanced. These changes bring the system to more closely resemble natural systems.

Within three experimental years, hairy vetch (*Vicia villosa* Roth.), fall rye (*Secale cereale*L.), yellow sweet clover (*Melilotus officinalis* L.) and white clover (*Trifolium repens* L.) were grown as cover crops with cauliflower (*Brassica oleracea* L. var. *botrytis*), and compared to monoculture cauliflower. In an effort to reduce competition between the cauliflower and cover crops, the cover crops were either mowed or rototilled prior to transplanting the cauliflower. The effects of the cover crops on weeds, allelopathy, cabbage and turnip root flies (*Delia radicum* L.and *D. floralis* Fall.), beneficial arthropods and cauliflower yield were investigated.

Monoculture and rototilled hairy vetch plots showed the highest number of weeds throughout the experiment. Mowed plots showed the lowest weed densities. None of the experimental treatments tested (rototilled hairy vetch, yellow sweet clover and white clover and mowed white clover) showed significant allelopathic potential. In 2000, the number of cabbage and turnip root fly eggs was not significantly different between the treatments. In 2001 however, fewer eggs were collected in cover crop plots, compared to the monoculture plots. In 2002, hairy vetch plots showed the largest number of eggs, but also had the largest abundance of beneficial insects, including spiders, carabids and staphylinids. Within week 28 and 29 of 2002, cabbage and turnip root fly egg registration was greatest. As well, carabid and staphylinid populations were largest during these two weeks, indicating that the populations were possibly influenced by the eggs. The resultant yields in the plots showed that rototilling of the cover crop prior to planting improved cauliflower yield, compared to mowing. The rototilled plots generally had the most weeds, but presumably the increased nutrient availability and reduced competition from the cover crops resulted in improved cauliflower yields, compared to mowed plots. Mowing of the cover crop decreased weed numbers, but most likely the higher level of competition and lower nutrient availability resulted in smaller cauliflower yields. Cover cropping systems have the potential to improve the sustainability of vegetable cropping systems, but more knowledge is required to establish and maintain ecological benefits, while still producing yields acceptable to farmers.

Mulching compared to physical weed control measures in organically grown vegetables

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Mulching vegetables with chopped plant material both supplies nutrients and suppresses weeds. In order to compare its effectiveness with other non-chemical means of weed control, a trial was performed with inter-row harrowing (twice), flaming (twice) and rotary brushing (three times) in white cabbage and beetroot. A control treatment that was weeded manually was included in the trial. The plots to which mulch (chopped cocksfoot, *Dactylis glomerata*) were applied were flamed once before mulching. A treatment in which the mulched plots were hand-weeded was included, in attempt to distinguish between nutrient and weed control effects. Highly significant yield effects were found in both vegetable crops. Relative to the control treatment, beet yields were 135% and 123% after mulching, with and without hand-weeding, respectively, whilst cabbage yields were 124% and 118%. Yields after inter-row harrowing were 79% for beet and 83% for cabbage, relative to hand-weeding. Comparable figures for brushing were 65% and 86% of the control, whilst the poorest yield results were obtained with flaming (40% and 62%), due to heat damage of the crop plants, particularly in the case of beetroot. As well as increasing crop yields, the use of chopped mulch also gave the greatest degree of weed control. Weed control on mulched plots was satisfactory throughout the growing season, probably due to the slow decay of the grass. Flaming gave the next best degree of weed control, while harrowing and brushing gave poorer weed control in this trial. As well as effects on total weed biomass, the different treatments also strongly influenced the weed flora composition. For instance, *Erodium cicutarium* dominated flamed plots, probably because of heat tolerance of this species, while the weed flora was more diverse in other plots. As mulching may be more expensive than other weed control methods, it is an important requirement that the benefits of mulching compensate for their additional cost. This study showed that chopped plant material prevents weed growth as well as supplying nutrients.

The effects of different cover crops on weed control and yield in organic potato and tomato production

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Introduction

Cover crops can have many beneficial effects on the cropping system, such as the improvement of the soil structure and the prevention of erosion and loss of nitrates, and the increase of soil organic matter and nutrient content when used as a green manure (Brandsaeter *et al.,* 1999). Cover crops can be also good weed suppressors (Boydston *et al*., 1995) and integrate the effect of other weed control methods in organic or low input systems.

This study aimed to evaluate the effect of different legumes and non-legume cover crops on weed control and yield of potato and tomato in an organic rotation with chick-pea as the preceding crop.

Materials and methods

A field experiment started at Viterbo in winter 2001/2002 with a 3-year rotation in space and time, where a cover crop was grown in the interval between two main crops (chick-pea /cover crop / potato / cover crop / tomato). In the first year, chick-pea opened the rotation. In the second year, on 13 September 2002, the following five cover crops were sown in sub-plots following chick-pea: hairy vetch (*Vicia villosa*), snail medick (*Medicago scutellata*), rapeseed (*Brassica napus* var. *oleifera*), italian ryegrass (*Lolium multiflorum*) and subterranean clover (*Trifolium subterraneum*). A sub-plot without cover crop (fallow) was also included. Some months later, one week before the planting of the following potato (12 March) and tomato (23 April), the cover crops were cut and incorporated into the soil by disk-harrowing after biomass sampling to measure dry matter production and nitrogen content. Weed biomass was also sampled, counted and dried per species. The fallow sub-plot was splitted in two sub-sub-plots, one managed with no N fertilisation (no N control), and the other fertilised with 200 kg ha^{-1} mineral N (mineral N control). In the other sub-plots, the following potato and tomato received only the green manure as nutrient source. In potato and tomato, weeds were controlled by 1 inter-row hoeing and hilling up, and 2 inter-row hoeing + 1 intrabine hoeing, respectively. In each sub-plot, a sample area kept weed-free was also present.

Results and discussion

Compared to mineral N control, cover crops resulted in clear weed suppression in the following potato (on average 66 g m^{-2} of weed DM *vs* 111 g m^{-2}, $P < 0.05$). Compared to mineral N control, potato following cover crops had also a lower yield reduction in the weed presence for respect to weed-free conditions (8.3 *vs* 16.9 %, $P < 0.05$). In weed-free conditions potato yielded more when following legume cover crops and in mineral N control than when following rapeseed and italian ryegrass and in no N control (on average 50.6 *vs* 46.0 t ha^{-1} tuber FM, respectively, $P < 0.05$).

Compared to mineral N control, italian ryegrass and snail medick were more weed suppressive in the following tomato (on average 266 g m^{-2} of weed DM vs 409 g m^{-2}, $P < 0.05$). Compared to mineral N control, tomato following these two cover crops had also lower yield reduction in the weed presence for respect to weed-free conditions (on average 15.2 *vs* 28.6 %, $P < 0.05$). Hairy vetch gave low yield reduction in the weed presence (16.9 %) but did not have relevant weed suppression effect. This was probably due to a complementarity effect with late emerging weeds (mainly *Amaranthus retroflexus*) in the use of nitrogen. In weed-free conditions, tomato yielded more when following hairy vetch and in mineral N control, and least in no N control (61.6 *vs* 46.2 t ha^{-1} fruit FM, respectively, $P < 0.05$).

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Physical weed control in organic spinach production.

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A two years experiment (2002-2003) is being carried out on the possibility to perform the physical weed control of spinach in the typical cultural and environmental condition of the Serchio Valley (that is one of the most important area of spinach production in Italy), in order to obtain a "biological" product.

Firstly, the strategy of physical weed control of spinach in the Serchio Valley was defined and included the realization of the false seed-bed technique, a flame treatment before crop sowing and two mechanical (precision hoeing) interventions in post-emergence.

False seed-bed technique was performed by means of a specific spring tine harrow 1.5 m wide, while flaming was performed by means of a new operative machine realized at the University of Pisa equipped with five "open flame" rod burners 25 cm wide.

A specific precision hoe with seven units (inter-row of about 18 cm) was built, tested, improved and set up to perform weed control both between (by means of a rigid tine supporting a 9 cm wide orizontal blade) and in rows (by means of vibrating teeth or torsion weeders). During summer 2003 was built also a specific basket weeder (fit to operate in the typical conditions of biological spinach cultivated in the Serchio Valley), in order to improve weed control in post-emergence.

During the testing period the evolution of weed flora (both presence and biomass) was monitored and spinach leaves yield was recorded. Moreover work chains characteristics, manpower use and physical weed control costs were determined.

The results were quite good and put in evidence that physical weed control in biological spinach cultivated in the Serchio Valley can be performed, obtaining relevant and high quality yields, without the need of too many hours of manual labour and with fully acceptable costs, taking also into account that in Italy the market price of "biological" spinach is quite high.

Pre-planting and tree row treatments in organic apple production

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Our objective was to study the effect of some pre-planting and tree row treatments on weed control, tree growth, fruit yield and damage caused by diseases and pests in organic apple production.

Choice of an efficient pre-planting procedure is important for weed control before establishing an organic apple orchard. We tested mechanical fallowing by milling cutter and a hairy vetch (*Vicia villosa*) ground cover in comparison with continuous grassland in the year before planting apple trees. Mechanical fallowing gave the best weed control after planting. The effect was particularly notable on couch grass (*Elymus repens*) density. A significant reduction in weed density was also found as a result of using a hairy vetch ground cover.

Different tree row treatments after planting were studied in two experimental apple orchards. Our results from the first three years after planting indicated that the best control of weeds in the tree row was when either using a milling cutter or a plastic mulch. Lowest yields were recorded on trees with a mulch of chips made from fruit tree wood. In plots with a ground cover of *Trifolium repens*, competition from the cover crop seemed to reduce the fruit yield. The use of a cover crop in the tree rows, combined with milling, needs further development before we can recommend such methods.

Diseases as well as harmful and beneficial insects were recorded per tree in this trial, and fruit samples were checked for diseases and insect-related damage. By this approach we aim to detect effects of tree row treatments on diseases and pests. So far the only significant difference discovered is an increased problem with green apple aphid (*Aphis pomi*) on trees with plastic mulch.

Destruction of O*robanche ramosa* seeds with a new soil drench and control of emergence by herbicides.

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Destruction of weed seeds in the soil is an objective that has rarely been achieved, especially by environmentally safe methods. *Orobanch*e species pose serious weed problems perpetuated by high numbers of long-lived seed so destroying seeds allows the prospect of eradication. A new and isolated outbreak of *Orobanche ramosa* was positively identified in South Australia in 1989. An area of about 4900 km^2 is under strict quarantine. Eradication of this weed is contemplated because of the restricted distribution but eradication requires methods that totally prevent germination or emergence or seed production, or kill seed in the soil.

A novel soil drench "Seed Inhibitor 041202" from Certified Organics NZ (Certified Organics Ltd., PO Box 74 382, Market Road, Auckland, New Zealand. Email, info@certified-organics.com: WWW.certified-organics.com) was tested in a water dilution *in vitro* and in one-litre pots of field soil and in field trials, (table 1). Plant back trials showed that wheat or vetch establishment was not affected 21 days after treatment.

Table 1. Germination of seeds following "Seed Inhibitor" treatment on ryegrass, canola and *O. ramosa*, mean of 3 reps.

	Application and dilution rate	Effectiveness (% control)
In vitro	100mls 20%	100%
Canola and ryegrass		
	100mls 10%	100%
Pot trials	1L field soil wet to 10% w/w	100%
Canola and ryegrass	10%	
	5%	100%
Field trials *O. ramosa*	20,000L/Ha 10%	93%
	20,000L/Ha 5%	64%

Previous research has shown most members of the group of herbicides that inhibit acetolactate synthase or amino acid synthesis to be effective against *Orobanche species* (Plakhine 1997; Garcia-Torres 1991). Further work was undertaken in an alkaline, calcareous soil in a 260mm rainfall environment. Most of these herbicides gave 100% control of *O. ramosa* at reduced application rates in this environment.

The use of Seed Inhibitor 041202 has great potential to kill weed seeds in the soil prior to establishment of high value crops or in eradication programs.

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Integrated weed control methods in winter and spring sown lentil (*Lens culinaris*)

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Sowing dates and weeds are two considerable factors in diminishing lentil production. In order to assess the effectiveness of sowing time and various weed control methods in lentil an experiment was laid out in randomized complete block design in a split plot arrangement with four replicates at research farm of College of Agriculture, Tehran University, Karaj (Iran) during 2001-2002. Treatments comprised two sowing dates viz. winter or "Entezari" and spring as whole plots and eleven weed controls treatments as subplots. These treatments comprised of pre-plant application of trifluraline (960 gr. a.i./ha); pre-emergence application of pendimethalin (1.32 kg. a.i./ha); post-emergence applications of cyanazin (1 kg. a.i./ha), pyridate (1.2 kg. a.i./ha) and oxyfluorfen (480 gr. a.i./ha); six different combinations of the first two herbicides with pyridate / oxyfluorfen plus one hand weeding; finally a weed free and a weed infested plot also included as check. The results showed that lenil's seed and biological yield; pods per plant; grain numbers per pod; thousand seed weight; main stem height and harvest index were significantly affected by sowing dates ($p < 0.01$) however, branch numbers per plant was not significant ($p > 0.05$). Similarly, these traits showed significant difference ($p < 0.01$) under weed control treatments except the main stem height. The interation effects was only observed for seed yield ($p < 0.01$). In Entezari sowing date the seed yield and other yield components, except 1000 seed weight, were significantly higher as compared to spring sowing. The combinations of pendimethalin + pyridate, pendimethalin + one hand weeding and ttrifluralin + one hand weeding compared with check (weed infested plot) proved to be among the best treatments for weed control in Entezari and spring sown lentil.

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Composition of weed floras in different agricultural management systems within the European climatic gradient

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Arable ecosystems are mainly threatened by the loss of species, the unification of species inventories, the introduction of alien species, shifts within the community structure and limitations within the regulation ability. Significant decreases in flora diversity on arable land have been observed throughout Europe in the last three decades [Andreasen et al. 1996, Hilbig et al. 1992; Toth et al. 1999]. Despite the obvious losses in weed flora diversity, there exist only a few protection measures for arable land apart from some field-edge programs. The occurrence of many of the weed species depend on specific farming systems to maintain suitable habitat conditions. To balance ecological effects against economic restrictions on arable land, comparative studies about the interactions between environmental conditions (e.g. changing climate) and different levels of land use intensity are lacking. One of the most important open questions in agriculture is the assessment of the value of species diversity for its own sector.

Current paper presents the first results of field investigations on weed flora compositions along a climate gradient from South to North Europe. The field investigations have been carried out between 1999 and 2003 in eight regions situated in a climate gradient which reached from South Italy, via Hungary, Germany and Sweden up to Finland. The investigations on the weed flora were designed to characterise i.) the regional differences in the weed flora composition along the climate gradient, not only in terms of species diversity and weed flora composition but also for the dominance structure and some functional groups within the weed flora and ii.) to analyse the influence of different land use types on it. For identifying the impact of land use, we have included weed surveys on three types of arable fields within every region: i.) cereals under conventional/ integrated farming; ii.) cereals under extensive use/ ecological farming and iii.) fallow fields / set aside fields.

We have found at all nearly 700 weed species in the eight selected regions. The number of weed species decreased from more than 400 in South-Europe to 130 in Northern Europe. Species richness on fields under extensive use/ ecological farming was in average higher by 50-70 % than on fields under conventional/ integrated use. Beside the differences in diversity, we have observed different patterns of species response on climate conditions. One group of them, probably one of the most problematic from the land users point of view, were species occurring according the whole length of the climate transect. This group was mainly related to cereal fields under conventional/ integrated land use. Species of special interest for nature protection or for use as plant genetic resource could also been found. But those species were mostly restricted to particular regions or fields of extensive/ ecological land use type. Differences from the general trends, as well as some interpretations on functional groups will be discussed.

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Do control technologies substantially alter the large-scale patterns of weed occurrence?

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The association between physical and chemical weed control technologies and temporal changes in weed communities is both logical and well documented. There is a generally held belief that technologies selectively filter community composition from an environmentally determined species pool. We report on a landscape-scale survey in which we explore redefinition of the concept of agricultural system to include farmer attitudes and constraints. We hypothesize that, in practice, the performance of control technologies can substantially differ from theoretical optima for reasons that have nothing to do with the technologies themselves. In order to address our hypotheses, we collected data on weed seedbank composition, margin floral diversity and the farmer's decision-making process. Field margin floral composition, which we use as a surrogate measure of the diversity of the local species pool, was collected from 70 sites in 6 counties spanning the breadth of the corn-producing portion of the state of Wisconsin. Field margins were surveyed in 2002, and adjacent field seedbanks were sampled from 30 fields in 2003 using elutriation techniques. In addition to information about soil, weather, and production history of the fields, farmers were asked to complete an extensive written survey that examined their attitudes about weeds and the use of cultural, physical and chemical weed control technologies. This survey shared many questions with a much more extensive statewide survey to ensure that the representativeness of sociological component of the sampled fields was representative of a larger group within the state of Wisconsin.

Anywhere from 11 to 33 agriculturally significant weed species were recorded in margins that ranged from 200 to more than 3300 meters in perimeter. The shapes of the field, which in some instances could strongly impact the realized efficacy of control technologies, had corrected perimeter-area ratios of 1.12 to 2.40. Particular life-history characteristics were associated with the land-use and structure directly adjacent. In particular, adjacent to forested land, many large-leaved perennials traded resources for physical protection from control measures. Over fifteen weeds had large-scale spatial distributions that were cosmopolitan; occurring in over half of fields sampled.

Even when accounting for the sizeable uncertainty in the seedbank sampling procedure, it was clear that weed communities were not regulated by efficacy of physical and chemical control technologies alone. While the logic that the type and efficacy of control technology exerts a selective influence on the weed community is unassailable, it is unclear how important the hypothetical selection pressure is in practice. For the case of Wisconsin production systems, implementation of control practices was sufficiently variable to allow for the prolonged persistence of a large set common agricultural weeds. Our study begs the question of whether we should consider technologies divorced from the socio-political milieu in which they will be used. We suggest that an understanding of environmental and ecological impact of technologies will require addressing this hidden dimension.

Competitive ability, a cultural tool for weed management in wheat

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The aim of this presentation is to present some of the results from the research on use of competitive ability of wheat in management of some annual weeds. Research has been conducted on crop and weed ecology, and cultural factors affecting the crop weed competition and efficacy of this cultural method.

Crop competition against weeds can be improved by the choice of more competitive crop cultivars, which may reduce the need for weed control. The main characteristics of crop competitiveness are plant height, growth rate, root/ shoot ratio and canopy architecture or spatial distribution of the canopy foliage. To determine the effects of weed competition on wheat, two experiments were conducted in Ferdowsi University of Mashhad, Iran, in 2001(field study), and Guelph University, Ontario, Canada, in 2002(growth cabinet study). In field study ,the treatments included three Cruciferous weeds, wild mustard(Sinapis arvensis), turnip weed(Rapistrum rugosum) and flix weed(Descurainia sophia), at five density (0, 4, 8, 16 and 32 plant/m2 for wild musturd and turnip weed, and 0, 16, 32, 64 and 128 plant/m2 for flix weed). Randomized complete block design with four replications in an additive series technique was employed as the experimental design. In growth cabinet study, we used a model system of annuals to examine how canopies of species having differing morphologies differed in architectures and light-interception abilities, and how different species performed when grown in these canopies. Wheat, Wild mustard and Flix weed were grown as "targets", surrounded by neighbors of a single species. Neighbors could be any one of the target species. Plants were grown in pots, with one target plant and three neighbors plants. Wild mustard and turnip weed significantly affected plant height, leaf area, leaf distribution, dry matter accumulation and grain yield of wheat. Wheat and flix weed had a more open canopy than the other species and were weak competitors. Increasing weed density, reduced height, leaf area, number of tiller, harvest index and grain yield of wheat. In addition, in comparison with control, leaf area of wheat was located more at the top of plant. Other weeds also showed similar effects. Wheat biomass was highly correlated with a measure of target light interception. In comparison with control red to far-red ratio and wheat root to shoot ratio were decreased with increasing weed density.

Cultural weed control in organic pigeon bean (*Vicia faba* L. var. *minor*) through optimisation of crop spatial arrangement

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Introduction

Pigeon bean, an important crop for organic systems in Central and Southern Italy, has a high phenotypic plasticity, i.e. it is able to adjust its growth habitus and photosintate allocation in plant organs to different sowing densities and/or inter-row spacing. Consequently, this crop can potentially be grown either in narrowly-spaced or widely-spaced rows. The latter is a potentially interesting technique in low-external input and organic farming systems since it can allow inter-row hoeing. This experiment aimed to evaluate the effect of different crop spatial arrangements and mechanical weed control treatments on crop growth and yield and on weed density and biomass in order to find the best cultural "package" for pigeon bean grown in organic conditions.

Material and methods

A field experiment was carried out in 2001-02 and 2002-03 at S. Piero a Grado (Pisa, Central Italy) within a large scale long-term experiment comparing conventional and organic systems. Three pigeon bean spatial arrangements and four direct weed control treatments were arranged in a split-plot design. Crop spatial arrangements (main plots) were: narrowly-spaced rows (NSR), i.e. 14 cm inter-row distance; widely-spaced rows (WSR), i.e. 42 cm inter-row distance; paired rows (PR), i.e. 14 and 42 cm distance between the rows in the pair and between pairs, respectively. Weed control treatments (sub-plots) were: spring-tine harrowing with different tine adjustments (-15°, 0° and +15° in NSR, only +15° in WSR and PR; the value is the angle between the upper tine part and the perpendicular to the soil surface), precision hoeing with or without a torsion weeder (in WSR and PR), and an untreated control (in all main plot treatments). Total seasonal (Nov-Jun) rainfall and T was similar in the two years but the March-June sub-period was warmer (+0.3/0.8 °C min/max T) and much drier (-58% of total rainfall) in 2003 than in 2002, which resulted in very low crop yield. Crop and weed densities were measured before and after mechanical weed control. Crop growth parameters as well as crop yield, yield components and total weed biomass were measured at pigeon bean harvest. Data were subjected to ANOVA and means compared by LSD test.

Results

In 2002, most of the significant differences among treatments came out from the NSR *vs* WSR *vs* PR comparison. In WSR and PR crop density just before mechanical weed control (MWC) was 49% and 71% that in NSR, respectively. However, this difference in crop stand did not affect total weed density. Lack of significant differences in weed density or biomass among crop spatial arrangements persisted until pigeon bean harvest. In contrast, no difference in crop stand density due to spatial arrangement was found in 2003. As in 2002, total weed density and biomass were not influenced by crop spatial arrangement at any stage and no significant interaction was observed. Unlike 2002, in 2003 total weed density after MWC was on average 37% lower in the spring-tine harrowed plots than in the unweeded control, but total weed biomass at harvest did not differ. The precision hoe + torsion weeder was the only tool that significantly reduced total weed biomass at harvest (by 36%). In 2002 pigeon bean reacted to the narrowing of inter-row width by increasing plant height and the insertion height of the first pod on the stem, but not in 2003. No significant differences among crop spatial arrangements were observed in grain yield per unit area in both years, but in 2003 yield was usually higher in the spring-tine harrowed plots. Precision hoeing did not exert the same effect, regardless of the presence or absence of the torsion weeder.

Effects of plant density and nitrogen fertilizer on the competitive ability of canola (*Brassica napus* L.) with weeds

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Effective weed control usually arises from a combination of cultural, mechanical and chemical applications. The cultural exercises comprise adequate soil fertility; optimum crop stands (proper seeding rate) and optimum sowing date. In due respect, an experiment as a factorial complete block design with 4 replications was conducted to determine the optimum plant density and nitrogen fertilizer levels in order to increase competitive ability of canola (*Regent* × *Cobra*; an inbred variety) with weeds. The treatments included four levels of plant density viz. 150, 190, 230, and 270 plants m^{-2}, and four levels of nitrogen fertilizer viz. 0, 46, 92, and 138 Kg ha^{-1}.

The results showed that the different levels of plant density and nitrogen fertilizer (N) had significant effects on canola's leaf area index (LAI) and dry matter accumulation, as well as on weed's dry matter at three stages of plant growth viz. rosette, stem elongation, and 50% flowering. Addition of N fertilizer resulted in increasing plant LAI and decreasing weeds dry matter. The density treatments of 150 and 270 plants m^{-2}, along with 138 Kg N ha^{-1} showed the highest LAI at rosette and stem elongation stages. The LAI at different plant growth stages was an important factor in enhancing the competitive ability with weeds.

There were significant differences between different plant density and N fertilizer levels for traits such as plant height, pod bearing stem length, biomass and seed yield. Increasing plant density significantly decrease pod bearing stem length, and total pod numbers per plant (i.e. pod numbers in main and sub-branches), but increased plant height. The highest seed yield resulted at 190 plants m^{-2} along with 138 Kg N ha^{-1}. Finally, it is concluded that the increasing plant density as well as N fertilizer may increase the competitive ability of canola to suppress weeds.

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First results on the competitive ability of lentil (*Lens culinaris*) genotypes

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Introduction

Cultural means such as the growing of more competitive genotypes can enhance the effect of partially weed suppressive means like mechanical or reduced-rate chemical control (Lemerle *et al*., 1996). More competitive genotypes have been detected in barley (Didon, 2002), bread (Lemerle *et al*., 2001) and durum wheat (Paolini *et al*., 2002), but other crops need to be characterized by this point of view. Lentil (*Lens culinaris* Medik.) is an important protein source for human consumption. In Italy the growing of lentil declined in the last decades owing to the low yield potential and the tendency to lodging of locally grown populations. Erect, higher yielding genotypes have been recently developed, which may renew the interest for the crop. This study aimed to test the competitive ability of some of these genotypes, eligible to be registered as new varieties and introduced in sustainable cropping systems.

Material and methods

A field study started at Viterbo in winter 2003, where in a split-plot design with three replicates in randomized blocks the following factors were applied: a) 10 lentil genotypes (plots); b) 2 levels of a natural weed infestation: absent or present (sub-plots). A weed stand in the crop absence per block was also grown. Lentil was drill-sown on 17 January to have a density of 200 plants m^{-2}, and fertilized with 100 kg P_2O_5 ha^{-1}. Sub-plots allocating the "weed infestation absent" level were kept weed-free. Beginning of flowering, insertion angle of the secondary branches to the main stem, plant height, percent of fertile and sterile pods, grains per pod, above-ground biomass and grain yield were determined on the crop at harvest. Beginning of flowering, plant height and biomass total and per species were determined on the weeds. The ratio of crop and weed relative biomass [.i.e. (B_{cw}/B_{wc}) /(B_c/B_w), with B as the biomass per unit area of crop or weeds competing with each other (*cw* or *wc)* or of the weed-free crop (*c*) or of the weed stand in the crop absence (*w*)] was log transformed to the *competitive balance index* C_b. Higher C_b values mean higher crop competitive ability.

Results and discussion

Seven genotypes out of ten resulted to be less competitive than weeds ($C_b < 0$), mostly represented by *Polygonum aviculare, Chenopodium album, Fallopia convolvulus, Cirsium arvense, Atriplex patula* and *Fumaria officinalis* in order of abundance. Instead, three genotypes were more competitive than weeds ($C_b > 0$) and more competitive than the others as well. The same genotypes also showed the least yield decrease in the weeds presence (ranging from 4.5 to 7.1 % compared to an average of about 25.4 % for the others) and, given the extremely low precipitation during their whole growing cycle (105 mm), a reasonably good grain yield in the weed absence (ranging from 1.13 to 0.89 t ha^{-1} DM). Crop competitive ability resulted to be mainly related to the earliness of flowering, which likely gave to lentil a higher competitive advantage against late emerging species (*C. album* and *A. patula*). Results suggest an interesting variability in the competitive ability of genotypes. In our conditions, earliness of flowering and an erect plant habit seemed to be the traits most related to crop competitive ability.

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