PROCEEDINGS OF THE

4th WORKSHOP OF THE EWRS WORKING GROUP:

CROP - WEED INTERACTIONS

10-12 April 2003
Viterbo, Italy

Congress Hall, Faculty of Agricultural Sciences, University of Tuscia
Via S. Camillo de Lellis 01100 Viterbo

Organizers:
Roberto Paolini (Local organizer-University of Tuscia)
Lammert Bastiaans (WG Coordinator-Wageningen University)

Content

Preface

The 4th workshop of the WG Crop-Weed Interactions was organised at the University of Tuscia in Viterbo, Italy from 10-12 April 2003. The workshop consisted of 4 sessions and was attended by 29 participants.

In the first session attention was given to the enhancement of crop competitive ability, either by genetic improvement or through management. Parameters to express competitive ability and practical ways to select for competitiveness were discussed. Also studies on the influence of crop spatial pattern were presented.

In the second session presentations were given on the activities within the WG Germination & Early Growth and the WG Physical and Cultural Weed Control, to increase the awareness of what exactly is going on in other WG's. Commonalities and areas were the WG's complement one another were identified. This session further included general presentations on Integrated Weed Management.

The third session dealt with the intercross between population dynamics and crop-weed competition and particularly focussed on the development of decision support systems that include both aspects. In principal these systems should be able to evaluate long-term weed management strategies. Apart from technical obstacles, the parameter requirement of these systems was discussed. In this regard the relation between plant dry weight and weed seed production of various annual weed species received special attention.

In the fourth session studies on weed suppression and biodiversity were presented. The role of intercropping as a weed management tool was discussed. Furthermore, opportunities for increasing on-farm biodiversity by tolerating low-competitive weeds that have tangible benefits for farm wildlife were debated. Are there specific criteria to identify these species and what are the best options for maintaining these species, while at the same time controlling the more harmful weeds?

On Thursday afternoon the Experimental Farm of the University was visited. Competition seemed a key-word in many of the experiments, including experiments on competitive cultivars, cropping systems research and a demonstration plot of cover crops. Apart from this agricultural trip, a visit was brought to the medieval quarters of Viterbo, where a lunch was taken at the Town Hall with its historical rooms. All of this was a perfect illustration of the wonderful hospitality that we received from the local organizers prof. Roberto Paolini, Christina Mirabelli and Fabio Faustino.

Lammert Bastiaans
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Coordinator EWRS-Working Group Crop-Weed Interactions

Workshop Program

<u>Thursday 10 April</u>

8.15 - 9.15 **Registration of participants**
9.15 **Workshop opening**
9.25 Developments in weed management and crop-weed competition research
Lammert Bastiaans

Session 1 9.35 – 12.30
Topics
- ***Enhancing crop competitive ability: genetic aspects and management***

9.35 Opportunity of measuring competitive ability by a competition index in crop/weed associations.
Roberto Paolini, F. Faustini & C. Mirabelli
10.00 WECOF: Developing enhanced weed management in winter wheat through improved crop and plant architecture.
Ken Davies, Steve Hoad, Philip Maskell
10.25 Maize competitiveness under different crop densities.
Milena Simić, L. Stefanović

10.50 Break

11.15 Crop spatial pattern and weed suppression in spring wheat.
*Lars Kristensen, J. Olsen, J. Weiner & H.W. Griep*entrog
11.40 Influence of crop spatial pattern on weed suppression in different weed species.
Jannie Olsen, L. Kristensen, J. Weiner & H.W. Griepentrog

12.30 *Lunch*

Session 2 14.15 – 17.00
Topics:
- ***Related working groups***
- ***Integrated Weed Management***

14.15 Working Group Germination & Early Growth
Andrea Grundy
14.40 Working Group Physical and Cultural Weed Control
Bo Melander
15.05 Collaboration and integration among EWRS-working groups
Paolo Barberi

16.00 Sustainable weed management in sugar beet
Giovanni Campagna, G. Rapparini
16.25 Physiological, molecular and morphological traits of Italian *Lolium* spp. populations susceptible and resistant to diclofop-methyl.
Giovanni Dinelli, A. Bonetti, I. Marotti, M. Minelli & P. Catizone

17.00 Visit to the medieval quarters of Viterbo
20.30 *Dinner*

Friday 11 April

Session 3 9.00 – 11.15
Topic:
- ***Crop – weed competition and population development (Decision support)***

9.00 Critical period of weed competition in French bean
F. Stagnari & F. Tei
9.25 The challenges and compromises in the application plant competition models
Laurence R. Benjamin
9.50 Modelling of the long-term effects of cropping systems on the population dynamics of weeds.
Alban Collard
10.15 Seed production by annual weeds in winter wheat and other arable crops
Peter Lutman

11.30-12.15 Working group issues

12.15 *Transfer to the Town Hall*, *lunch and visit to the Historical Rooms*

14.30–17.30 Visit to the nearby Experimental Farm of the University (competition experiments on potato, chickpea, lentil, tomato and cover crops)

Saturday 12 April

Session 4 9.00 – 11.30

- ***Increased biodiversity and weed suppression***

9.00 Legume-cereal intercropping as a weed management tool
Henrik Hauggaard-Nielsen, B. Jørnsgard & E.S. Jensen
9.25 Clover as cover crop in full field vegetable culture: suitability and species characteristics.
Nick den Hollander & L. Bastiaans
9.50 What is a 'good' weed?
Jonathan Storkey

…… Concluding remarks and closure

12.30 *Lunch*

ABSTRACTS

Working Group Crop-Weed Interactions

Developments in weed management and crop-weed competition research

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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 decade, interest in weed managment strategies that are less dependent on herbicides has increased. As a result, agronomic measures to manipulate crop-weed interactions, like competitive cultivars, crop spatial arrangement and timing, level and placement of fertilizers, have opened new scope for research in the area of crop-weed interactions (session 1). The same holds for the introduction of intercropping practices to suppress weeds (session 4). 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 major interest to our Working Group. Their is also a close link with the WG "Physical and Cultural Weed Control". Not only does this WG focus on cultural control, the selectivity and efficacy of intra-row mechnical control measures is closely related to size differences between crop and weed, and an improved crop competitive ability might help to suppress weeds that have escaped mechanical control. Options for further collaboration among Working groups will be explored and discussed in session 2.

In systems that aim at a reduced reliance on herbicides, the time horizon of interest is extended and main empasis is given to 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 weed population dynamics. In line with this, decision support models are being developed that model the consequences of cropping systems on the population dynamics of weeds (session 3).

References

Cousens, R., 1985. An empirical model relating crop yield to weed and crop density and a statistical comparison with other models. J. Agric. Sci. 105, 513-521.

Kropff, M.J. & C.J.T. Spitters, 1991. A simple model of crop loss by weed competition from early observations on relative leaf area of the weeds. Weed Res. 31, 97-105

Lotz, L.A.P. et. al., 1996. Prediction of the competitive effects of weeds on crop yields based on the relative leaf area of weeds. Weed Res. 36, 93-101.

Session 1
Enhancing crop competitive ability: genetic aspects and management

Suitability to measure competitive ability by an index of competition in various crop/weed associations

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Detecting more competitive crops (e.g., due to variety, fertilisation, crop density, etc.) represents an important tool to implement integrated weed control. However, the use of competitive indexes (e.g., the competitive balance index C_b) is time and work consuming (as the growing of weed pure stands and their sampling is also required) and, at least in some cases, likely statistically inefficient, as ratios of ratios concurr to the means that have to be compared, with problems of high error MS and difficulties to evidence statistically significant differences. Ranking competitive ability seems to be definitely more simple by ranking crop biomass or grain yield decrease (if the harvest index is not affected) in the weed presence. However, this does seem reliable only in some cases, particularly when crops compared for their competitive ability do not complement with weeds or complement to the same extent [i.e., when the RBT (relative biomass total) of the various crop/weed mixtures is 1 or, even if higher, does not significanlty change for the various mixtures]. When crops to be compared complement with weeds to a different extent, ranking competitive ability by an index of competition is correct, while ranking competitive ability by crop biomass decrease is not, and similar biomass decreases can even result in very different competitive ability. Examples concerning different crop/weed associations are given of these different conditions of reliability in measuring competitive ability in the two above mentioned alternative ways.

WECOF: Developing enhanced weed management in winter wheat through improved crop and plant architecture

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Weed management is one of the most significant problems facing organic arable production. Organic farmers generally rely on using direct control measures such as mechanical weeders, but other than rotation, many indirect measures are less widely implemented. The EU funded WECOF (Weed Control in Organic Farming) project puts an emphasis on optimising the natural competitive relationships between the crop and the weeds in reducing potential weed growth and competition. The WECOF partners are led from the Institut fur Organischen Landbau, University of Bonn, with SAC, Edinburgh, Warsaw Agricultural University and Instituto Madrileno de Investigation Agraria y Alimentaria, Madrid, providing the agronomic research, with micro- and macro-economic analysis provided by Dipertimento di Biotecnoligie Agrarie e Ambientali, University of Ancona. WECOF also includes work on allelopathy and photocontrol. The project started in October 2000, using winter wheat as a model crop. The project concentrates on organic systems, but the results are expected to be of value to all integrated crop management (ICM) systems.

Crops are characterised by ranking the relative importance of key plant and crop factors in shading weed growth. A series of core trials have been established in Germany, Scotland, Poland and Spain comparing plant structure by the use of different varieties and crop architectural factors by the use of different sowing row widths and direction. Variety trials have also been established in Scotland with constant row width and sowing direction to give more detailed varietal comparisons. Results from the first two seasons of trials in Scotland are described. There are clear varietal differences in weed suppression; row-width has a bigger effect than sowing direction. Key growth stages and architectural features are being resolved. Results are being used to develop models to assist breeders in producing improved crop ideotypes for organic production, and in production of a decision support system to assist farmers and advisers in variety selection and management for improved weed suppression.

Maize competitiveness under different crop densities

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A successful development of the integrated weed management system, which consists of a combined application of several management practices, requires detailed information on crop : weed interactions. The crop density is one of factors which can improve crop competitiveness and may be manipulated for weed suppression at a relatively low cost. Its application in maize as a broad-cast, spring crop, in the combination with herbicide application, can, to a great extent, contribute to weed suppression.
The 4-replicate trail was set up according to the RCBD at the Maize Research Institute, Zemun Polje (Central Serbia) in 1996 and conducted till 1999. Effects of three different maize densities on weed fresh weight (g m^{-2}) and the leaf area index of two maize hybrids were observed under conditions with and without herbicide application. Data were processed by ANOVA.
The increased maize density significantly reduced ($P<0.05$) the weed fresh weight. At the same time the maize leaf area index very significantly increased with the crop density increase (from D_1 to D_3). These two parameters significantly differed over variants with and without herbicide applications. The crop density x herbicide application interaction resulted in very significant differences in the weed fresh weight. The lowest weed fresh weight (117.4 g m^{-2}) was determined in the highest crop density on the area treated with herbicides. Obtained results point to the fact that maize growth in higher densities with herbicide application can successfully control the level of weediness.

Crop spatial pattern and weed supression in spring wheat

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Crop density and spatial arrangement are important for crop competition with weeds. Sowing seeds in uniform grid pattern decreased weed biomass in spring wheat by 30% compared to normal sowing practice (Weiner et. al, 2001). From a practical point of view, highly uniform sowing can be difficult to achieve due to technical constraints. It is therefore important to investigate other spatial patterns in addition to normal practice and a uniform grid arrangement. In field experiments we compared weed and crop biomass and grain yield in weed-infested spring wheat grown under (1) normal sowing practice (12 cm rows), (2) uniform grid arrangement and (3) spatially random distribution of seeds at different seeding densities. The spatial distribution of individual plants is analysed by the use of Voroni polygons (Mead, 1966). The uniform grid pattern and the random distribution, i.e. treatments that have a less clumped distribution than normal crop rows, perform equally well, showing higher degree of weed suppression, as well as higher crop biomass, than normal crop rows. These preliminary results suggest that a high degree of uniformity may not be necessary for optimizing crop competition with weeds, as long a given level of spatial non-clumpedness (evenness) has been achieved.

References

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Influence of crop spatial pattern on weed suppression in different weed species

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Increasing interest in reducing the use of herbicides in agriculture has increased interest in alternative methods of weed management. One approach is to increase the ability of the crop to itself suppress weeds by altering the crop density and spatial distribution. We hypothesize that by increasing the crop density and by sowing the crop in a uniform grid pattern instead of traditional rows, weed suppression can be substantially increased because crop plants start competing with weed plants before they start competing with other crop plants and the competition between crop and weed begins before the crop loses its initial size advantage. A field experiment was conducted in spring 2001 to determine the effect of three densities (204, 449 and 721 plants m^{-2}) and two spatial patterns (normal rows and a uniform grid pattern) of spring wheat (*Triticum aestivum* L. cv. Leguan) on interspecific competition between spring wheat and six weed species (*Sinapis alba, Lolium multiflorum, Papaver rhoeas, Chenopodium album, Matricaria perforata* and *Stellaria media*). The different weed species were sown in high densities to obtain high weed pressures. The biomass of the target weed and other weeds was measured in early July. The experiment was repeated in spring 2002 with four of the weed species (*Sinapis alba, Lolium multiflorum, Chenopodium album* and *Stellaria media*). The biomass of the weeds decreased with increasing crop density. There were strong and highly significant effects of both crop density and spatial distribution on weed biomass in all cases. Overall, the total weed biomass was 30 % (2001) and 20% (2002) lower when the crop was sown in a uniform grid pattern than when the crop was in rows. A combination of high density and uniform sowing resulted in a 65 % (2001) and a 45 % (2002) decrease in total weed biomass in comparison with normal sowing practices.

Session 2
- Related Working Groups
- Integrated Weed Management

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 aid 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.

Working Group Physical and Cultural Weed Control

The importance of crop competition in physical and cultural weed control strategies

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Most physical and cultural weed control methods for arable crops do not provide complete weed control. Some weeds will escape the treatments and the numbers depend strongly on the successfulness of conducting the treatments. Moreover, current mechanical weed control methods, that work the intra-row area of the crop, generally operate with low selectivity whether it is cereals grown at narrow row spacing or typical row crops (e.g. maize, sugar beets, and many vegetables) at wider row spacing. Low selectivity means that a high weed control level might be associated with severe crop damages, particularly if large weeds are to be controlled satisfactorily.

Thus, seeking for complete weed control can be very risky or more likely impossible. Since realising that, a number of investigations have then focussed on the tactical use of mechanical intra-row methods, particularly how they can be combined with cultural methods that mainly improve crop competitiveness and crop tolerance to withstand mechanical impact (uprooting and soil covering) from the weeding tools. Some promising weed control strategies in e.g. spring barley, onion, and pulse have been achieved from this work (e.g. Rasmussen & Rasmussen, 1995; Melander, 1998; Melander & Rasmussen, 2001; Rasmussen, 2002). Examples will be given here including results from very recent studies with mechanical and cultural weed control strategies in winter cereals. In these investigations, the prospects of cultural factors, such as crop species, row spacing, crop seed rate, and fertiliser placement, to improve the suppression of escaping weeds were studied.

Crop competition also seems to play an important role in the development of new technologies for intra-row weed control in row crops. Timing of laser cutting, or other cutting devises, and the duration of the effect of soil steaming are both methods, where information on crop/weed interaction appears to be essential for practical implementation of these techniques (Heisel, 2001; Melander et al., 2002). Such aspects will discussed as well.

References

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Sustainable weed management in sugar beet

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Recently, the public opinion has been implemented towards food healthy and techniques of minimum environmental impact cultivations. Organic cropping has had large success, in particular as far as fruit and vegetable productions are concerned. Over the last two decades, experimentation and research on integrated weed management and non-chemical control techniques received great impulse all over the world. Presently, these problematics are also studied on large-scale crops like sugar beet.

This presentation discusses results of a study where traditionally grown (recommended-rate chemical weed control + mineral N fertilisation), low input [integrated chemical weed management (i.e. reduced-rate herbicide treatments + non-chemical means) + mineral N fertilisation] and organically grown sugar beet (non-chemical weed control + organic fertilisation) were compared, particularly as far as weed control was concerned.

Several problems arises where herbicides were not applied, with a yield decrease not balanced by a higher price of the product. Early sowing resulted in root yield increase, while late sowing favoured weed competition by late or relatively late emerging species. Good results were obtained with reduced herbicide rates integrated by agronomic and mechanical means, in line with the sustainable agriculture. Moreover, no use of insecticides favoured the diffusion of *Gastroidea poligoni*, a native Coleoptera able to feed on main weed species such as *Polygonum aviculare* and *Fallopia convolvulus*. The minor costs and the good productions obtained with the sustainable technique could have a next success.

Tecniche di coltivazione della barbabietola da zucchero a minore impatto ambientale

In questi ultimi tempi si è registrata una notevole sensibilizzazione dell'opinione pubblica verso tecniche di coltivazione a minore impatto ambientale e ad alimenti più sani. Grande successo hanno riscontrato le coltivazioni biologiche, in particolare per i prodotti orticoli e frutticoli. Grande impulso ha avuto a livello mondiale la sperimentazione e la ricerca di tecniche naturali per il contenimento delle avversità e delle malerbe. Attualmente ci si sta ponendo questa problematica anche nei confronti di colture estensive come la barbabietola da zucchero.

In questo contributo sono state poste a confronto la tecnica tradizionale di contenimento delle malerbe con riduzione dell'imput chimico e solo con mezzi agronomici e meccanici come in una coltivazione biologica.

Notevoli difficoltà sono state riscontrate con quest'ultima tecnica, con perdite produttive non compensate da una maggiore valutazione del minor prodotto raccolto. Un miglioramento delle produzioni si è ottenuto con semine eseguite con un certo anticipo, mentre in quelle più tardive si è avuto una minore infestazione, ma di malerbe a sviluppo estivo più competitive nei confronti della coltura. Buoni risultati sono stati ottenuti con la riduzione dell'impiego di erbicidi, che prevedeva l'integrazione di mezzi agronomici, in linea con gli obiettivi di un'agricoltura sostenibile. Il rispetto degli insetti utili ha favorito inoltre la diffusione di Gastroidea poligoni, in grado di alimentarsi selettivamente delle diffuse Polygonum aviculare e Fallopia convolvulus. A fronte dei minori costi sostenuti, si è potuto ottenere una produzione simile a quella ottenuta con la tecnica tradizionale.

Physiological, molecular and morphological traits of Italian *Lolium* spp. populations susceptible and resistant to diclofop-methyl

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In the last ten years the appearance of herbicide resistance among weeds has been continuously growing, sometimes with a worrying frequency. Worldwide, one of the most relevant cases of herbicide resistance involves *Lolium* genus. Some Lolium biotypes exhibited cross-resistance to eleven herbicide chemical classes characterized by seven different modes of action (Preston et al., 1996). The resistance to aryloxyphenoxypropionate herbicides was reported for some Italian *Lolium* spp. populations, sampled in a wide area of Central Italy (Bravin et al., 2001). In pot experiment, the populations Roma94 (RM) and Tuscania97 (TU) were up to 7 times more resistant to diclofop-methyl than the susceptible population Vetralla94 (VT). A research program was set in order to: 1) identify the physiological resistance mechanism to diclofop-methyl; 2) taxonomically characterize the three Italian *Lolium* populations by ISSR (Inter Simple Sequence Repeat) molecular markers; 3) evaluate morphological and vegetative traits as well as their possible role in resistant response to diclofop-methyl.

As regards the first research item, both resistant (R) and susceptible (S) *Lolium* spp. populations were target-site sensitive, since the enzyme ACCase (ie., the metabolic target of –fop herbicides) is inhibited by low concentrations of diclofop-methyl. No difference in diclofop-methyl absorption by shoots of R and S biotypes was observed. A relatively higher rate of metabolism was found in one R biotype (RM). The radioactivity distribution was slightly different in the S biotype with respect to R biotypes. Approximately 8% less of radiolabel was found in culm and root of the S biotype (VT) than in those of the R biotypes (RM, TU). Therefore it seems unlikely that the detected physiological differences could completely account for the resistance levels observed at the whole plant level.

As concerns the second research item, together with five *Lolium* species (*L. perenne, L. multiflorum, L. rigidum, L. boucheanum, L. hybridum*) and four *Festuca* species (*F. rubra, F. ovina, F. pratensis*, *F. arundinacea*) as reference groups, the three ryegrass biotypes were investigated for genetic variation and phylogenetic relationship by means of ISSR (Inter Simple Sequence Repeat) markers. Hierarchical cluster analysis of 84 polymorphic loci among bulked DNA samples revealed that resistant and susceptible biotypes formed a discrete group between the *Festuca* and the *Lolium* groups. As a consequence the investigated populations were not unambiguously classified: the three ryegrass biotypes are mixed populations made up of individuals belonging to different botanical species and, to a large extent, of intrageneric and intergeneric hybrids. Data from bulked DNA analysis from weed populations evidenced 11 markers of all *Festuca* reference species. Since ISSR markers are inherited in a dominant fashion (Welsh et al., 1991), data suggest hybridization with *Festuca* species or the inheritance of *Festuca* genome from a common ancestor. The mean number of putative *Festuca* loci found in R populations was higher than that found in the S biotype. Percentage of *Festuca* genome in the weed populations was 7.4% for susceptible VT, 13.8% for resistant TU and 15.6% for resistant RM. It has been demonstrated that *Lolium* spp. can hybridize with *Festuca* species and the natural maintenance of the foreign genome in a progeny of hybrids between *Lolium* and *Festuca* has been shown (Zwierzykowski, 1996). The absence of F1 hybrids in three weed populations suggests that in previous generations hybridization with different *Festuca* species could have been occurred, and subsequent backcrosses with *Lolium* species or hybrids could have led to introgression of *Festuca* DNA in weed populations. Even if mechanism of spread of

Festuca genome is still unclear, influence of *Festuca* genome on resistance to diclofop-methyl could be hypothesized.

Finally, for the third research item the response to different diclofop-methyl doses (16 and 40 □g ai plant^{-1}) and application techniques (drop and spray application), quantified as percentage of survival and tillering rate of survived plants (response to chemical disturbance) was investigated. In addition, the response of the three ryegrass biotypes to different mowing techniques (mowing under the first leaf insertion on culm and mowing at soil level), quantified as dry matter production (response to mechanical disturbance) was studied. At low herbicide pressure (low diclofop-methyl dose and/or spray application) RM biotype was the more resistant population, whereas at high herbicide pressure (high diclofop-methyl dose and/or drop application) the TU biotype exhibited a higher resistance level than RM biotype. The tillering was significantly higher in the TU biotype than in the other accessions. However, both R accessions (RM, TU) showed better vegetative traits (dry matter production and tillering) than the S biotype (VT). These vegetative traits are probably correlated with the diclofop-methyl response of R biotypes, indicating for these biotypes a higher competitive capability. In particular, the tillering response observed in R biotypes could be a plastic adaptation (selected by the herbicide), which allows the plants to escape to the diclofop-methyl control.

As a conclusion, the obtained results suggest that multiple mechanisms involving both physiological (metabolism, translocation) and morphological (tillering, competition) responses accounted for the observed level of resistance to diclofop-methyl.

Session 3
Crop-weed competition and population development

Critical period of weed competition in French bean (*Phaseolis vulgaris* L.)

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A field experiment was carried out in central Italy in order to evaluate the effect of weed-infested and weed-free periods on French bean yield. Results showed that in order not to exceed a 5% yield reduction the critical period of competition occurred from 10 to 33 Days after Emergence corresponding to 87 and 323 Growing Day Degrees after Emergence (Tbase = 10°C). Weed competition decreased the number of pods $plant^{-1}$, whereas did not affect the number of crop plant m^{-2}, pod length and pod diameter.

The challenges and compromises in the application plant competition models

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A decision support system (DSS) is being developed for weed control in winter wheat in grown in the UK. The project is a consortium of several partners who are responsible for different aspects of the DSS software. Rothamsted Research is tasked to develop the biological model which will estimate (i) the winter wheat yield loss given the presence of weeds of specified density and (ii) follow the population dynamics of specific weeds over a six year crop rotation that includes winter wheat.

The model for estimating wheat yield loss is based on INTERCOM, but the need for compatibility with models to optimise herbicide usage, and to ensure practicable run times have necessitated major modifications to the INTERCOM approach. The INTERCOM approach and the modifications that have been adopted will be described, along with examples of the model outputs.

Modelling of the long-term effects of cropping systems on the population dynamics of weeds

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A model of weed population dynamics was developed, describing the weed life-cycle and the impacts of cropping system on this life-cycle. It allows simulating on the long-term the cumulative effects of cultural practices and crop rotation on both qualitative and quantitative changes in weed infestation.
To account for variability in cultural practices, the model has a daily time-step. It is plurispecific in order to be used in practical field situations, with a complex flora. It is explanatory and deterministic. Input variables are the cropping system (herbicide, soil tillage, crop rotation), the initial composition of the seed bank, the time course of Leaf Area Index of the crop, the soil type (texture and pH) and the air and soil climate.
The model is a succession of sub-models, describing one of the weed life-cycle stages. 7 different stages were developed, from the soil seed bank, to seed shedding. Cultural practices can affect differently weed plants from each of those stages.
Modelling options were determined from literature reviews and discussions with experts in weed biology. The decision rules for modelling choices were that (i) the model must be sufficiently accurate to adequately describe the effect of cropping system on weed population dynamics but that (ii) it should be simple enough to be easily used in a broad range of field situations. In consequence, parameters should only be found in the literature or estimated by experts. Therefore, for some complex and poorly known processes like for instance seed dormancy, we had to restrict ourselves to simple descriptive modelling options
In the current version of the model, *Alopecurus myosuroides* is the only species parameterised.

A first validation attempt was performed by comparing observed data of a field experiment to simulated data. The model produced levels of weed population far too high, absolutely not in accordance with field reality. Nevertheless, the life-cycle of *A. myosuroides* was generally respected with germination and emergence periods corresponding to observations. Periods of dissemination took place approximately one month earlier than what is commonly observed.
A second set of simulation was performed to evaluate the impact of the introduction of winter pea in a cropping system. Simulated results were similar to the ones of the first simulation, with unrealistic population levels. However the ranking of cropping systems according to their effects on *A. myosuroides* population dynamic was coherent with what was expected.

Reasons for the inability of this first version of the model to produce satisfying results from a quantitative point of view are discussed. Two main hypotheses are put forward. First, simulated germination is too high because soil water potential data may be inexact and because seed confinement in soil is not well accounted for. Second, seed production by weed plants must be too high because the dynamic of competition, and especially crop-weed competition in early stages, is not taken into account. Finally, possible ways to improve this first version are discussed.

Seed production by annual weeds in winter wheat and other arable crops

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As farming systems in the UK and elsewhere in Europe move away from prophylactic weed control towards more targeted approaches to weed management, the need for a better understanding of weed population dynamics increases. If weeds are not to be fully controlled, either for economic or environmental reasons, there is a need to assess the consequences for subsequent crops. The fundamental parameters required are the levels of seed production and the longevity of the seeds. This paper addresses the issue of seed production by arable weeds. This is a laborious task and one of the main aims of our work, apart from quantifying seed production is to explore the allometric relationship between seed production and plant dry weight. Plant dry weight at maturity is often recorded in experiments and if this value could be used as a surrogate for seed numbers, this would simplify the estimation of seed production.

Over the past 5 years (and even earlier) we have recorded seed production and plant dry weight for 16 different annual arable weeds. Data is more extensive for some species than others. Methodological problems have made seed assessment for some species very difficult. The robustness of the relationship between plant weight and seed number has been tested by collecting data from several seasons and sites, and by exploring the effects of changing crop agronomy e.g. crop seed rate, and crop nutrition. Much of the work has focussed on weeds in winter wheat but some studies have included weeds growing in other crops or on their own. Although the work has focussed on seed production by individual plants, some data have also been collected from plants sampled on a per unit area basis.

Overall, there is a strong linear relationship between plant weight and seed number. In general, the relationship for individual weeds does not seem to vary greatly between crops but there is evidence that weeds growing in the absence of the crop do behave differently. The strongest relationship in the research seems to be between $\log_{10}$ plant weight and $\log_{10}$ seed numbers. This transformation is particularly useful where there are large differences in production between, for example, plants growing alone and those growing in a competitive crop such as winter wheat.

Results from a sample of the 16 weed species will be presented and some of the ‘problems’ discussed.

Session 4
Increased biodiversity and weed suppression

What is a 'good' weed?

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Sustainable weed management systems aim to increase farm biodiversity by conserving residual weed populations in arable fields while maintaining yield. These systems need to address three questions: 1) Which species should be conserved; 2) How many individuals can be tolerated and 3) What is the appropriate agronomy to achieve these objectives. This presentation mainly addresses the first of these questions.

Weed species need to be categorised on the basis of their potential benefit to higher trophic groups and their impact on crop yield. A 'good' weed can be defined as a species which combines tangible benefits for farm wildlife with low competitive ability. It is likely that weed species which meet this criteria will share similar plant strategies for growth and reproduction in the crop canopy. The aim of the current project is to categorise weeds in functional groups on the basis of the eco-physiological traits which determine these strategies.

A screening programme is underway to parameterise a number of eco-physiological traits for 23 weed and three crop species. These traits include seed size, seedling growth rate, height, rate of photosynthesis, time of flowering and partitioning parameters (specific leaf area, root : shoot ratio, leaf area ratio). The data will be entered into a matrix of species x plant trait and a multi-variate analysis performed to identify groups of species with similar eco-physiological profiles. The intention is to group weeds outside of the database on the basis of existing botanical information. Initial data from the first growing season is presented at this meeting.

Legume-cereal intercropping as a weed management tool

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Legumes benefit the farming system via symbiotic N_2 fixation and by their effect as break-crop for cereal diseases in rotations (Jensen, 1996). However, most legumes are known to have a weak competitive ability towards weeds (Jørnsgaard et al., 2001).

Weed density and biomass is often markedly reduced in intercrops (IC) compared to the respective sole crops (SC) (Hauggaard-Nielsen *et al.*, 2001a). Liebman and Dyck (1993) explained such IC-weed control advantages by either (i) Weed-suppression; a more effective use of resources by IC or suppressing weed growth through allelopathy compared to SC or (ii) Weed-tolerance; use of resources that are not exploitable by weeds or convert resources to harvestable material more efficiently than SC.

Calculation of pea-barley IC Land Equivalent Ratios (LER) showed that plant growth factors were used up to 30-40% more efficiently by IC than by SC (Hauggaard-Nielsen *et al.*, 2001a; Jensen, 1996). LER indicate a more complete exploitation of environmental growth resources probably influencing the weeds competitive ability. This is supported by another study showing that pea-barley IC caused a deeper barley root system and a faster lateral root development by both species as compared to SC (Hauggaard-Nielsen *et al.*, 2001b) indicating a potential improvement in the search of soil water and nutrient sources. Utilization of soil N sources was shown to influence weed biomass production. In a field study weeds accumulated about 55 kg soil N ha^{-1} in aboveground plant parts during spring in a pea SC compared to around 20 kg soil N ha^{-1} in a pea-barley IC (Hauggaard-Nielsen *et al.*, 2001a). Furthermore, 46 days after emergence about 30 kg more inorganic soil N ha^{-1} was found under pea SC compared to pea-barley IC supporting weed growth.

A higher degree of interspecific competition combined with a certain complementarity between intercropped species improves the crop stands competitive ability towards weeds. The weed-suppression approach from Liebman and Dyck (1993) are the most likely to explain the present pea-barley IC findings.

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Clover as cover crop in full field vegetable culture:
Suitability and species characteristics

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Full field vegetable culture often suffers from severe weed infestations resulting in yield loss. Farmers choosing to produce without the use of herbicides are in need of alternative weed control measures. Covering the bare soil between the crop rows during the growing season with a non – crop plant may be a tool to reduce the number of weeds. Germination of weeds can be prevented once the soil is covered and already established weeds may be reduced in biomass and seed production. Clover offers excellent potential as a weed suppressing cover crop while it possesses a number of additional advantages (N – fixation, disease and pest suppression). Previous experiments however showed that clover often was too competitive towards the crop.
Understanding which characteristics of clover are responsible for its competitive ability is necessary when choosing a suitable clover species for use as a cover crop. A screening of 8 clover species has been carried out in which information on relevant species specific features was gathered while competitive strength was measured using a test plant (leek) and by doing weed counts. Further experiments were carried out using 3 contrasting clover species selected from the first screening trial. White clover appeared to be most promising, persian clover seemed the best weed suppresser but strongly reduced yield of the main crop. Subterranean clover seemed least promising but its features in relation to its competitive capacity need to be studied further to gain a better understanding of characteristics of clover in relation to competitive strength.
One of the main questions that rose was on the relative importance of below and above ground competition for clover. Subterranean clover in particular appeared to reduce the biomass of a test plant (leek) as much as other clover species in spite of its limited ability to compete for light. N analysis of the leek plants showed a significant reduction of total N content of the leek plants grown together with subterranean clover indicating competition for nutrients.
A pot experiment was carried out in the 2002 growing season in which the following hypothesis was tested: Subterranean clover allowed to compete above and below ground (full competition) will perform better then subterranean clover allowed only to compete above ground (only light competition). The experiment was carried out using three clover species (subterranean, white and persian clover) and two test plants (annual ryegrass and spinach). Clover was sown in the centre (∅ 7cm) of the pot while the outside ring of the pot (∅ 21cm) consisted of either the same clover species, a test plant or bare soil. A piece of plastic pipe (∅ 7cm) was placed from the surface to the bottom of the pot in half of the pots preventing below ground competition. Above and below ground biomass was harvested, dried and weighed 8 weeks after sowing.
Subterranean clover did not have an increased biomass in the full competition situation compared with only-light-competition situation. Subterranean clover however was able to reduce biomass of rye grass in the full competition situation compared to the only-light-competition situation. Rye grass growing together with white or persian clover showed no decrease nor increase in biomass under different competition situations. N analysis of clover and test plants and a repetition of the experiment including different N levels of the soil will have to give further clarification of the results found so far.

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