PROCEEDINGS OF THE

5th WORKSHOP OF THE EWRS WORKING GROUP:

CROP - WEED INTERACTIONS

In collaboration with

COST action 860

Working group 4: Plant-plant interactions

12-15 September 2006
Rothamsted, UK

Conference Centre Rothamsted Research
Harpenden, UK

Organizers:
Jonathan Storkey (Local Organizer-Rothamsted Research)
Peter Lutman (Local Organizer-Rothamsted Research)
Lammert Bastiaans (WG Coordinator-Wageningen University)

Content

Preface

The 5th workshop of the EWRS Working Group Crop-Weed Interactions was held at the Conference Centre of Rothamsted Research, Harpenden, UK, from 12-15 September 2006. The workshop was a joined meeting with members of Working Group 4 of COST action 860 (SUSVAR; http://www.cost860.dk). In this COST action the focus is on sustainable low-input cereal production, and particularly on how crop diversity (e.g. variety mixtures) can be used to ensure stable and acceptable yields of good quality under low input, especially organic, conditions. In WG4 the attention is on plant-plant interactions, which involve the interaction between the varieties that constitute a mixture, as well as the interaction between the variety mixture and weedy plant species. This specific interest was reflected in the workshop program, which consisted of four main sessions. A total of 28 researchers attended the workshop.

In the first session, attention was given to the enhancement of weed suppressive ability of crops. Both competition and allelopathy were addressed. Methodological issues with regard to selection and determination of the potential contribution of an enhanced weed suppressive ability to overall weed management were presented. Finally, the current and future role of crop-weed competition modelling in research and weed management were discussed.

In the second session diversity was the central theme. Do variety mixtures improve the ability of the crop to suppress weeds? Experimental results on barley variety mixtures were presented, followed by a discussion on how to analyse and interpret the results of these kinds of experiments. From the other end, options for toleranting weeds for ecosystem services were discussed. Mechanistic crop-weed competition models were used to estimate the consequences for crop yield. The models were also used to characterise those weed species that are less harmful for crop production.

The third session dealt with cultural weed control. A broad overview of crop husbandry measures that contribute to weed management was presented. In addition, a mathematical framework for evaluating the effectiveness of cultural weed control was put forward and discussed. Also the role of cover cropping in weed management was elucidated. These presentations were complemented with a lecture on mechanical weed control.

In the fourth session weed management was discussed in a cropping systems context. The role of crop and soil management factors was discussed based on the results of a long term farming systems trial. Problems with initiating such an experiment were also brought up. What should be done if you want to study weed management in a crop rotation, but weeds don’t show up during the first year of experimentation? In a final presentation the relation between intercropping and parasitic weeds was discussed.

In between the presentations a visit was brought to the renowned long-term experiments at Rothamsted Research: Broadbalk winter wheat, established in 1843, and Park Grass (1856). Peter Lutman guided us along the experiments and treated us with all kind of interesting, peculiar and fascinating facts. Peter, together with Jonathan Storkey, was also responsible for our very well cared-for stay at Rothamsted. Once again, many thanks for this kind hospitality.

During the last two days of the Workshop a short-course on modelling plant-plant interactions was provided to a selected group of interested participants. The course started of with a lecture on descriptive crop-weed competition models and a comparison between descriptive and mechanistic modelling (Lammert Bastiaans). This was followed by lectures on the principles of modelling competition for light (Jonathan Storkey) and water (John Cussans). Participants were also given the opportunity to make their own simulations using the crop-weed competition model INTERCOM. The course was ended with demonstrating some of the applications of crop-weed competition modelling that have been developed in recent years. In this session Laurence Benjamin kindly contributed with a demonstration of the Decision Support System ‘Weed Manager’.

The integration of the weed research community, represented by the members of the EWRS-WG Crop Weed Interactions, with members of COST-action 860 was considered very fruitful. It resulted in a fine mix of scientists with interests ranging from fundamental to more applied. In the final discussion of the Workshop it was considered valuable to meet again. April 2008 was selected as an appropriate moment and Jose Maria Urbano of the University of Seville kindly offered to host this meeting.

Lammert Bastiaans
Wageningen University, The Netherlands
Coordinator EWRS-Working Group Crop-Weed Interactions

Workshop Program

<u>Tuesday 12 September</u>

8.30 - 9.00 **Registration of participants**
9.00 – 9.30 **Workshop opening**
SUSVAR-Cost action 860
Hanne Oestergaard
EWRS and the working group Crop-Weed Interaction
Lammert Bastiaans
Objectives and format of the workshop

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

9.35 Cereal competition against weeds
Steve Hoad
10.00 Development of chlorophyll imaging technique for assessment of competitive ability of cereal genotypes
Karel Klem
10.25 Allelopathy as alternative, complementary tool for weed management: potential and limitation
Helena Gawronska

10.50 Break

11.15 Applications and extensions of the Benjamin-Aikman plant competition model
Andrew Mead & Bastiaan Brak
11.40 Understanding crop-weed competition – where have we got to and where are we going?
Peter Lutman
12.05 Discussion

12.30 *Lunch*

Session 2 14.00 – 17.00
Topics:
- ***Increased diversity and crop competitive ability***

14.00 Is it possible to influence competition by increased diversity in barley?
Ulla Didon
14.25 Performance of six variety mixtures of spring barley selected for weed competitiveness and weed suppression
Hanne Oestergaard
14.50 Natural selection for weed control and inter-cropping
Martin Wolfe
15.15 Options for tolerating weeds for ecosystem services
Jonathan Storkey

15.40 Break

16.10 Weed diversity in semi-natural agro-ecosystems

Eveline Stilma

16.35-17.15 Discussion on options for weed management through increased crop competitive ability and increased diversity.

17.30-18.30 Future of Susvar WG 4

19.30 *Dinner*

<u>Wednesday 13 September</u>

Session 3 9.00 – 10.40

Topic:

- ***Cultural and direct weed control measures***

9.00 Agronomic strategies to enhance competitive ability in organic wheat
Roberto Paolini

9.25 Mechanical weeding in cereal crops
Peter Mercer

9.50 A mathematical frame-work for evaluating the effectiveness of cultural weed control
Lammert Bastiaans

10.15 Threshold-Based Cover cropping strategies: Implications for Managing Weed Seedbanks
Steven Brian Mirsky

10.40 Break

10.50 Visit to the long term experiments of Rothamsted Research

12.30 *Lunch*

Session 4 14.00 – 16.00

Topic:

- ***Weed management in a cropping systems context***

14.00 Enhanced tolerance to weed competition: Effects of crop and soil management in a long-term farming systems trial.
Matthew Ryan

14.25 Weed competition in the second year of dryland farming in Southern Spain
Jose Maria Urbano

14.50 Reduction of *Orobanche crenata* infection in faba beans and peas when intercropped with cereals.
Monica Fernandez

15.15 Discussion

15.45 Break

Session 5 16.15 – 17.00

Topic:

- **Closure of general workshop**

16.15 Next EWRS WG-meeting

16.25 WG4-Susvar project – discussing the next steps.

<u>Thursday 14 September</u>

Short course on modelling plant-plant interaction -
Contributors: Jonathan Storkey, John Cussans, Laurence Benjamin and Lammert Bastiaans

Session 6 9.00 – 12.00

- ***Systems analysis and modelling***
  Descriptive models on crop-weed competition
  Descriptive versus Mechanistic modelling

Session 7 14.00 – 17.00

- ***Modelling competition for light***
  Early growth
  Competition for light
  Using a plant-plant interaction model

<u>Friday 15 September</u>

Session 8 9.00 – 12.00

- ***Modelling competition for below-ground resources***
  Competition for water
  Interpretation of results

Session 9 14.00 – 17.00

- ***Applications***
  Examples of model applications

ABSTRACTS

Session 1
Enhancing crop competitive ability: genetic aspects and mechanisms

Cereal competition against weeds

Steve Hoad

SAC Crop and Soil Systems, West Mains Road, Edinburgh EH9 3JG
steve.hoad@sac.ac.uk

Competitiveness against weeds can be described by a combination of plant growth habit and other crop characteristics. Characteristics that are generically desirable for a competitive crop are: (1) high, and even, plant establishment, (2) high tillering ability, (3) high crop ground cover, (4) increasing plant height and (5) a planophile leaf habit. An early prostrate habit (at the start of tillering) combined with a moderate to high leaf area index (either through rapid leaf development or good crop establishment) was a good indicator of crop competitive ability. Rapid early growth allows the crop to maintain a light interception lead over the rapidly growing weeds, and with the right habit, shade newly emerging weeds. Other competitive characteristics such as nutrient and water competition are suspected to play an important part, as may allelopathy. Ground cover at early tillering was strongly correlated with weed suppression throughout the season. High tillering capacity, through tiller production and/or retention, is important in creating and maintaining a high level of crop ground cover. High tillering also buffers against adverse situations that may lead to delayed or poor emergence. Although plant height was not always linked to competitive ability, very tall varieties would appear to be competitive at moderate to good plant population densities. Height can compensate for an erectophile leaf habit. Tall varieties may also have an advantage over some very tall grasses and scrambling weeds. The best weed suppressors were often the better yielding varieties. The balance between plant and crop characteristics for weed suppression will determine the value of a variety for early, late and season-long weed control. A continuous planophile leaf habit has a clear advantage for weed suppression over the erectophile type at a given plant or shoot population density, but there are also benefits of early and late planophile habits depending on the relative establishment of crop or weeds during the season. Selection for variety types should be considered in relation to climatic factors that affect both crop and weed growth. Where breeding lines are exclusively of erectophile types, then it should be possible to improve weed suppression through shading by increasing LAI with increased height and leaf size.

Development of chlorophyll imaging technique for assessment of competitive ability of cereal genotypes

Karel Klem

Agrotest Fyto, Ltd., Havlickova 2787/121, CZ 767 01 Kromeriz, Czech Republic
klem@vukrom.cz

Nineteen morphologically different winter wheat genotypes were grown in field trials, each in weed free and weedy variant randomized in three replications. The weed infestation was established by artificial sowing of the following weed species: *Apera spica-venti, Galium aparine, Tripleurospermum maritimum, Papaver rhoeas, Stellaria media* as most important weed species in the Czech Republic. During spring vegetation, the crop development was periodically assessed by recording chlorophyll fluorescence images. Until canopy closure, the images were analyzed using image analysis software to obtain relative crop coverage, distribution of crop cover across rows and rate of crop cover development. After canopy closure, the images were analyzed for intensity histograms as a parameter describing vertical leaf cover distribution in canopy. The leaf area distribution across rows were fitted using waveform sine function $y=A\ sin\ (\pi\ (x-x_c)/w)$ where A is amplitude, w width and x_c center of the wave. Yield losses caused by weeds were correlated with individual parameters obtained from fluorescence images (crop cover, parameters of horizontal crop cover distribution, rate of crop development, vertical leaf cover distribution). Highest correlations were found out from rate of crop cover development during tillering stage, horizontal distribution of leaf cover (across rows) at the end of tillering and leaf cover in the top third of canopy at the end of stem elongation. The correlation coefficients for individual parameters did nod exceed R=0.55. Using artificial neural networks as multivariate method with several input parameters, the correlation between predicted yield losses and observed values increased to R=0.95. The results show that competitive ability is an integration of crop development during tillering and morphology of crop canopy at the end of stem elongation. In the year 2006 the assessments during vegetation were extended by measurements of PAR transmission through canopy after heading using newly developed instrument TransmiPAR and by measurement of canopy reflectance in the red band (650-690 nm), red edge band (700-750nm) and near infrared band (750-800nm). The data analysis from year 2006 is in progress.

Allelopathy as alternative, complementary tool for weed management: potential and limitation

Gawronska H., Ciarka D., Gawronski S.W.

Laboratory of Basic Sciences in Horticulture
Faculty of Horticulture and Landscape Architecture, Warsaw Agricultural University
Nowoursynowska 159, 02-776 Warsaw, POLAND
helena_gawronska@sggw.pl

In sustainable and especially in organic farming agriculture the major treat and extremely challenging task is weed control. Recently it has been suggested in several papers, that allelopathy holds great prospect for finding alternative strategy for the weed management because it is considered to be: 1) cheaper, 2) friendly to the environment and 3) socially acceptable to be applied in practice. Additionally cost of high technology agriculture is not everywhere acceptable, appearance of herbicide resistant biotypes, and increasing awareness of the environmental pollution by pesticides increase interest in allelopathy. There is no doubt that plant's biologically active substances possess allelopathic mode of action both stimulatory and inhibitory with the latter, as having the potential of application, being much more often reported. Allelopathic effects are observed at both heterotrophy and autotrophy growth stages of the receiver plant and on every level of biological organization including agro-ecosystem. There are examples of using crops (rice, rye, buckwheat, black mustard or sorghum-sudangrass hybrid and sunflower) for the satisfactory weed suppression with minimal or none herbicide use. Theoretically several ways of utilizing of allelopathy can be considered: (i) cultivation crops of high allelopathic potential that: 1/ efficiently will suppress weeds in neighborhood, 2/ as pre-crop for green manure, for production of biologically active mulch 3/ as a main crop in rotation with other species (residues after yield harvest left as a source of allelocompounds); (ii) cultivation for isolation of allelocompounds to be used for spray, and (iii) isolated from plants allelocompounds may serve as templates for synthesis of "natural herbicides" with new and varying mode of action. Unfortunately, allelopathic compounds released into environment might and often do have negative impact also on cultivated crops and this effect is not easy to control because of the very complex interaction between allelochemicals and all components of the environment including weather conditions. This is especially true for the underground part (physical and chemical properties of the soil, nutrients availability and microbial population and activity) contributing to allelochemicals transformation. Despite that our knowledge on allelopathy has extremely increased in last decades, we are not yet at point to propose farmers ready to use technology for allelopathy-mediated weed prevention and control. In fact, it is not expected that there will be a universal strategy for weed management based solely on allelopathy. Rather, there will be an outline of combinations of elements recommended for a given site, since some agricultural problems are local. Therefore, recommendations would probably be of local value covering adaptation to a specific climate and soil conditions together with cultural practices preferred by farmers at this site. Moreover, they will not be a status-quo type of recommendations and some readjustments would be necessary to be made based on the current changes of weather and other local agro-ecological conditions.

Nevertheless, the results on field and under controlled conditions studies together with great genotypic variation in crops allelopathy show that there is potential and chance for exploitation allelopathy, as a complementary to other cultural practices, in the weed management. In our opinion future research on allelopathy should focus on:

- continuous assessment of available in germplasms genotypes for selecting and breeding for increased allelopathic activity,
- screening crop *cvs*. for higher tolerance to negative impact of allelochemicals,
- in-depth study on the interactions between released allelochemicals and all components of environment contributing to allelochemicals transformation (especially underground part),
- determining growing conditions for enhanced allelopathic activity (stress induced)
- elaborating cultural practices in the weed management with allelopathy for a specific sites and crops to be applied, (for example shallow green manure, biologically active mulch or crop residues incorporation *vs.* layering on surface, selecting *cvs* of high relative growth ratio to reduce length of pre-crop cultivation, etc.)
- interaction between components of mixtures,
- assessment of the ecological effects of allelopathy on agro-ecosystem and on neighboring ecosystem(s) in both short (crop life cycle) and long-term (between life cycles) in order to examine effects on all components of the environment operating in joint action,
- examining the role of volatiles in bioregulatory signaling between plants-plants, plants-microrganisms and between plants and the 2^{nd} and 3^{rd} trophic levels - a novel avenue attributed to allelopathy,
- explore of anti-pathogens and anti-insects activities of allelochemicals for their usefulness in biocontrol,
- searching for gene(s) involved in biosynthesis of allelocompounds to be used for constructing GMO for enhanced production of allelochemicals, and on
- using of biotechnology tools for constructing GMO with genes of interest and possible employing crop plants as bioreactors for allelochemicals production.

Applications and Extensions of the Benjamin-Aikman plant competition model

Andrew Mead & Bastiaan Brak

Warwick HRI, University of Warwick, Wellesbourne, Warwick, CV35 9EF
andrew.mead@warwick.ac.uk

The Benjamin-Aikman plant competition model was first described in 1994, and models plant growth allowing for competition for light by the use of potential and restricted crown zone areas. A powerful feature is that the model parameters are obtained for each species grown separately, and that competition between species is an emergent, rather than modelled, property of the model.

Following a brief description of the Benjamin-Aikman plant competition model, we will describe a number of recent and current applications of the model:

- Within Bastiaan's PhD he is currently working on incorporating the plant competition model with models describing other aspects of weed population dynamics. One interesting development is the identification of the need to separately model physiological development alongside biomass growth.
- Models relating seed production to plant biomass have been combined with the plant competition model to consider the impact of different weed control strategies on the total seed production.
- The plant competition model has been used to evaluate the efficacy of mechanical weeding controlled by machine vision, and to identify the appropriate balance between weed control and crop damage. One important extension as part of this study was to validate the plant competition model for multiple weed cohorts (different emergence times).
- Work on pest control has shown that growing a cabbage crop in an under-planting of another plant species can reduce pest numbers. The plant competition model has been used to quantify the interaction between crop-weed competition and the potential for control of cabbage root fly during the critical early weeks of crop growth.

Two limitations of the current version of the Benjamin-Aikman plant competition model are the lack of allowance for any explicit spatial arrangement of plants (the model is based purely on the density of each plant cohort), and the lack of any allowance for between-plant competition for below-ground resources (nutrients, water). Embryonic approaches to addressing these limitations will be briefly discussed.

Understanding crop-weed competition – where have we got to and where are we going?

Peter Lutman

formerly *Rothamsted Research, Harpenden, Herts, AL5 2JQ, UK*
peter.lutman@bbsrc.ac.uk

Understanding the impact of weeds on crop yield has been a key activity of weed science, and of applied plant ecologists for over 50 years. As far as the UK has been concerned, this work focussed on describing the yield loss resulting from aggressive weeds such as *Avena fatua* and *Galium aparine* including quantifying thresholds. In recent years, this work has been extended to include less competitive species.

Weed density / yield loss relationships, based on hyperbolic relationships were calculated but it was realised that such relationships could exhibit much site to site and year to year variation. This led to two areas of work: i) endeavours to assess the weather and other abiotic and biotic drivers of this variation, ii) realisation that weed density was possibly not the best predictor of yield losses (although practically it was the most amenable attribute of weeds that could be recorded). Mechanistic models from Wageningen linked crop and weed green area accumulation to yield response and this led to more empirical relative leaf area prediction models (see papers by Kropff and Lotz). Intuitively, leaf area models were thought to be more reliable predictors of crop yield losses but in reality our experience has been that this has not always been the case. Over the last few years the Rothamsted research on competition has concentrated on three areas:

1. Improving the mechanistic models of competition so that they are more relevant to winter wheat
2. Developing a hybrid predictive system for our weed DSS, based on a mechanistic calculation of early growth and leaf area expansion with an empirical calculation of yield loss based on the leaf area at canopy closure
3. Assessing the reliability of density/based predictions.

This work has been done under the influence of:

- increased economic pressure on farmers and the increased need to target weed control more carefully, to minimise variable costs of production
- increased awareness of the ecological services provided by weeds, and of the need to reduce the impact of weed management on the agro-ecosystem.

We are now faced with a series of issues and challenges that impact on weed management and on the need for information on weed competition.

1. Although we can predict with reasonable accuracy yield losses from weeds in winter wheat, we need to improve quantification of likely variability and need more data for other crops.
2. Can we persuade farmers for ecological and economic reasons not to aim to kill every weed in crops, but to target only yield threatening populations?
3. Can we use our enhanced understanding of weed population dynamics to convince farmers that allowing weeds to survive in one crop will not jeopardise the success of following crops?
4. Is it true the ecological services from weeds can be delivered by appropriate off field vegetation management?

Session 2
Increased diversity: crop competitive ability and ecosystem services

Is it possible to influence competition by increased diversity in barley?

Ulla M E Didon

Department of Crop Production Ecology, Swedish University of Agricultural Sciences, P.O. Box 7043, SE-750 07 Uppsala, Sweden, Tel + 46 18 67 28 80
Ulla.Didon@vpe.slu.se

The potential weed suppressive ability of a variety mixture is essential for the yield and yield stability of the crop. Opinions differ on what constitutes the perfect mixture, but one theory is that it is important to have niche differentiation or complementarity between varieties in a mixture. Niche differentiation is predicted to result in reduced levels of intraspecific competition, increasing the opportunities for individuals to perform well and to compete better as a plant stand against weeds. Detailed information about how mixtures influence the weed competitive ability is currently lacking, but in some studies fewer weeds have been found in mixtures than in pure lines.

A greenhouse trial was performed to investigate whether mixtures of barley varieties could suppress weeds better than barley grown in pure stands, and whether the weed suppressive effect differed between the various mixtures. The barley varieties used differed in three specific characteristics, namely allelopathic activity, root length development and shoot length in the first growth stages. Two weed species, *Brassica rapa* and *Lolium perenne*, were chosen as the model weed flora.

The results indicate that the competitive effect on weed biomass was dependent on the composition of the barley variety mixture. There was also a tendency for mixtures to have a better competitive effect on weeds than pure stands of barley varieties, but this effect depended on the varieties contained in the mixture. Contrasting allelopathic activity and shoot development characteristics between the varieties in the mixture increased the competitive effect. The weed suppressive effect was lowest in a mixture containing varieties differing in root development but with low shoot development and high allelopathic activity.

Performance of six variety mixtures of spring barley selected for weed competitiveness.

Hanne Østergård

Risø National Laboratory, 4000 Roskilde, Denmark
hanne.oestergaard@risoe.dk

In a variety mixture, competition between component varieties as well as differences in performance of the components may lead to changes in the proportion of component varieties between seed sown and seed harvested. This will imply that farm saved seeds of variety mixtures will constitute an evolving population. Can the characteristics of the component varieties predict the performance of the mixtures and how much changes are found over a short period of years and in different environments?

In 2002, six 3-component variety mixtures of spring barley were constructed based on altogether 14 mostly high-yielding varieties with focus on variation in straw length and expected weed competitiveness. The six mixtures and derivatives of these were included in the large Danish BAR-OF variety trials in the years 2002-2005 taking place in organic and conventional environments. Each year mixture plots were sown with seeds being 1) seeds from conventional multiplication of the component varieties in equal weight proportions taking into account differences in seed germination or 2) seeds harvested from the mixture at the same location the previous year, resembling the use of farm saved seeds; the smallest seeds were removed before sowing to decrease the load of seed borne diseases. By means of DNA markers, changes in the proportions of the different components in each mixture were estimated.

In general, the grain yield of a mixture was higher than that of the average of its component varieties. Further, there was a trend of a better weed suppression of the mixture. However, no clear rules for prediction of the success of a mixture could at present be made. The mixture composition was found to change over years and between locations for some of the mixtures. The selection imposed by the agricultural practise for farm saved seed will be discussed. Further, the potentials for constructing optimal mixtures for varying environments will be dealt with in relation to work on combining cereal variety mixture data in different meta analyses within the SUSVAR network.

Natural selection for weed control and inter-cropping

M S Wolfe, K Hinchsliffe, Z Haigh and H E Jones

Elm Farm Organic Research Centre, Hamstead Marshall, Newbury, Berkshire RG20 0HR UK
martin@wakelyns.demon.co.uk

For organic farmers, there are few varieties available that have been bred under organic conditions with selection for characteristics relevant to organic production. For this reason, we started a programme of production of composite cross populations in wheat. The composite crosses are based on all possible combinations of crosses of nine high yielding varieties (Y composite: 36 crosses), 12 high quality varieties (Q composite: 66 crosses) or of 20 varieties including all of the high yield and high quality varieties (YQ composite: 185 crosses). A duplicate set includes crosses of all varieties with naturally occurring male sterile lines. Population samples have now been exposed in the field for three seasons at four sites, two organic and two conventional. The aim so far has been to allow natural selection to differentiate the populations at these sites and encourage adaptation separately to organic and conventional soils and management.

We now intend to modify the selection, for example, by selecting for larger grain size in each of the populations. The purpose of this is first, to follow the assumption that plants that are susceptible to seed-borne diseases are likely to produce small grains. Selection for large grains should therefore ensure that the frequency of grain from healthy plants is increased. Second, if we assume that, generally, larger grain are likely to produce larger and more vigorous seedlings, then we can follow Weiner's principle of size-asymmetric competition by increasing the relative competitiveness of the populations against annual weeds. In other words, selection for larger grain may simultaneously provide two advantages.

Selection for weed control may also lead to increased frequencies of plants with allelopathic effects. This would be of particular value with the respect to the three major perennial weeds, couch (*Elymus repens*), docks (*Rumex spp*.) and creeping thistle (*Cirsium arvense*), for which size-asymmetric competition often works to the advantage of the weed.

At the same time as selecting for weed control, there is considerable interest in selecting the populations for effective inter-cropping with legumes (white clover and related species) to try to obtain simultaneous crop production and fertility building. Previous experience suggests that white clover is highly competitive with modern varieties of wheat, reducing their productivity, and that the positive effects of fertility building may not be felt until the next stage in the crop rotation. Selecting the populations for performance in inter-cropping could therefore have a positive value. A major question however, is how to balance selection for strong competition against a wide range of weed species, with selection for a degree of mutualism with legume species: is it feasible, and what is the simplest approach?

Options for tolerating weeds for ecosystem services

Jonathan Storkey

Plant & Invertebrate Ecology Division, Rothamsted Research, Harpenden, UK
jonathan.storkey@bbsrc.ac.uk

The recent declines in the flora and fauna adapted to arable environments have resulted in a change of emphasis of weed research in the UK. Whereas previously research was driven by the deleterious effects of weeds on crop yields and quality, increasingly they are being viewed as an important resource for higher trophic groups. This presents the challenge of reconciling the negative effects of weeds on the crop with their positive benefits for the farm ecosystem. The paper addresses two important questions that need to be addressed within this context. Firstly, what weeds can be tolerated in the cropped area of the field – can weeds be classed as being especially injurious or beneficial? Secondly, what represents an 'acceptable' weed density that strikes the appropriate balance between crop yield loss and biodiversity gains? To answer the first question, a matrix of the eco-physiological traits of a range of weed species was compiled. Multivariate analysis was then used to group weeds according to their plant traits. The groups had a similar competitive ability and value to higher trophic groups. Two 'beneficial' groups of weeds were identified that combined a relatively low competitive ability with high biodiversity value. A simulation model of crop weed competition was combined with a population dynamics model to investigate possible systems for managing a weed population at a density that is both sustainable in terms of crop yield and the provision of resource to higher trophic groups.

Weed diversity in semi-natural agro-ecosystems

Eveline Stilma[1,2], Paul Struik[2] , Hein Korevaar[1], Ben Vosman[2]

(1) Plant Research International b.v., P.O.Box 16, 6700 AA Wageningen
(2) Crop and Weed Ecology group, Wageningen University, P.O. Box 430, 6700 AK Wageningen
eveline.stilma@wur.nl

The aim of this study is to design sustainable agricultural production systems that are biodiverse and have a high aesthetic landscape value. Until now cropping systems have been developed for maximal productivity. High inputs of herbicides and pesticides increased productivity. However, such production systems have consequences for the environment and for maintenance of biodiversity. The importance of biodiversity is more and more being acknowledged. Biodiversity is decreasing by human intervention; farming is the single greatest threat to biodiversity on the planet (Altieri et al., 1987; Green et al., 2005). Therefore bringing back biodiversity in agriculture is a good means to solve the problem of biodiversity loss. Diversity of weed communities in cropping systems is increasingly brought to attention (Legere, 2005; Poggio, 2005). In this study biodiverse production systems are designed with high diversity between species and within species (genetic diversity). A three-year field experiment is carried out under low input with mixtures of cereals (rye or barley) and pea in association with re-introductio of wild flowers. The resulting four combinations for each cereal are: cereal monocrop, cereal intercropped with pea, cereal with introduced herbs and cereal intercropped with pea and introduced herbs. Each treatment was replicated four times, both on a sandy soil and on a clay soil. Genetic diversity was created in the cereal crop; for barley by a mixture of 11 varieties; for rye by a single variety because its cross-pollinating nature originates a genetic variation within one variety. The cereal seeds harvested in one year were used as sowing material for the next growing season. The weed community was establishing itself. However, the following wild flowers were introduced: *Papaver rhoeas, Centaurea cyanus, Chrysanthemum segetum, Misopathes orontium, Matricaria recutita (sandy soil)/Matricaria inodora (clay soil).* The biodiverse production systems have time to develop into sustainable agro-ecosystems. Weed populations can form unique communities dependent on the main crop and soil type through three years of development. During the growing seasons, functionality of biodiverse production systems was being assessed. Measurements were done to determine the amount and quality of the yield, the aesthetic value of production systems, ecological diversity (nematodes, carabid beetles, fungi/ bacteria in the soil), change in genetic diversity of the cereal and weed dynamics. This part of the study is about weed dynamics. Four times in during the three growing seasons the weed species present were assessed as well as the number per individual weed species on 1 m^2 per plot. Weed dynamics during one growing season were simulated. Changes in weed diversity were calculated. Preliminary results show that weed suppression during one growing season were depending on the main crop. Soil type or location strongly influenced weed population and its dynamics. Weed diversity was different between crop treatments.

Session 3
Cultural and direct weed control measures

Agronomic strategies to enhance competitive ability in organic wheat

Roberto Paolini

Department of Crop Production, University of Tuscia, Via S. Camillo de Lellis s.n.c.
01100, Viterbo, Italy
rpaolini@unitus.it

The basic strategies to enhance crop competitive ability and achieve satisfactory weed control efficacy in organic wheat are discussed.

After briefly outlining pre-requisites for a competitive, good yielding organic crop, the potential of cultural means (any husbandry choice enhancing crop competitive ability) in wheat (crop genotype, crop density, rate of organic fertiliser, mixture of varieties) is discussed, with emphasis to the conditions for their exploitability and to the interactive effects (genotype x environment x management) which determine their efficacy. In this context, the effects of the environment, of the type and degree of weed infestation and of the sowing time (winter/spring crop) are mainly focussed.

The potential of integrating cultural and mechanical means in wheat is then discussed, with emphasis on choices and conditions allowing the best performance of this type of integrated non-chemical weed control strategy.

Wheat/grain legume intercropping is also discussed as both a further strategy to increase crop competitive ability and a choice to obtain yield advantages and higher residual effects to the benefit of the cropping system. In this context, advantages, disadvantages and limitations are also considered.

Finally, research needs to improve the exploitation of crop competitive ability in organic wheat are outlined.

Mechanical weeding in cereal crops

Peter Mercer and Julie Morgan

Agri Food and Biosciences Institute, Agriculture and Food Science Centre, Newforge Lane, Belfast BT9 5PX, UK
peter.mercer@dardni.gov.uk

Arable organic agriculture is at present a small part of the general organic industry in N. Ireland, but organic cereals are needed for winter feed for organic livestock. From 2003 – 2005, field trials showed that the most significant problem was weeds, which could be reduced by increasing sowing density of the crop, although the effect on yield was not high. In 2006, preliminary trials were carried out on mechanical weeding on commercial and experimental sites. To ensure consistency of treatment, a spring tine harrow, pulled by a quad, was taken to each of six sites. A core set of treatments consisted of untreated and single and double runs of the tiner over the crop at around GS 14. Further treatments, including slower or faster speeds, lower ground pressure and a comparison with a farmer's harrow were included at individual sites. Crops were assessed for tiller, grass and broad-leaved weed numbers at the beginning of July and August and samples were taken mid-August for crop and weed biomass and grain yield.

Results to date indicate that overall the number of tillers was significantly increased by a single run of the tiner compared with the untreated, although there was no significant effect on crop biomass. Both tiner treatments reduced the amount of grass weeds, especially the single run. Although there was a tendency for lower numbers of broad-leaved weeds with a double run of the tiner, this was not translated into a significantly reduced biomass.

Development of a mathematical framework for evaluating the effectiveness of cultural weed management

Lammert Bastiaans

Crop and Weed Ecology, Department of Plant Sciences, Wageningen University, P.O. Box 430, Wageningen, The Netherlands
lammert.bastiaans@wur.nl

Weed management is an essential part of any farming system. In organic farming systems, direct weed control methods are often laborious and therefore expensive. Consequently, cultural control, like the use of more weed competitive cultivars, increased seeding rates or a more homogeneous spatial arrangement of crop plants, seem an appealing alternative. An important question that remains is whether cultural control is really able to provide a substantial contribution to weed management. Are the effects significant, or do the measures only have a marginal effect? As cultural control does not necessarily focus on weed seedlings, but might also be directed towards tackling other life cycle stages of the weed, it is also relevant to find out how beneficial it is to focus the efforts on specific life cycle stages.
To be able to address these kinds of questions, a mathematical framework was constructed for evaluation of the short and long term contribution of cultural control practices to weed management. For this purpose, a weed population model was constructed, with crop-weed competition accounted for. The level of detail was chosen such that the framework provides sufficient opportunities to account for the effects of cultural control on both crop-weed competition and weed population dynamics. At the same time, the parameter requirement of the model was kept modest. The model can be used to estimate the expected results related to tackling specific life cycle stages. It also allows the results of short-term field experimentation to be put in a long-term perspective.

Threshold-Based Cover Cropping Strategies: Implications for Managing Weed Seedbanks.

S.B. Mirsky, D.A. Mortensen, and W.S. Curran

The Pennsylvania State Univ., University Park.
sbm138@psu.edu

Reduced reliance on herbicidal weed control often results in additions of seed to the soil seedbank. Lower weed seedbank densities are critical to the success of non-chemical weed management practices. While weed management efficacy (mortality) has not been demonstrated to be density dependent in cropping systems using non-chemical methods for weed control, clearly the relationship between initial weed seedbank size and efficacy of weed management has important implications for ecologically-based weed management (EBWM). Effects of varying initial weed seed population levels on efficacy of weed management in diversified cropping systems were tested. Weed seedbank fluxes from recruitment, mortality, and fecundity were measured in a diverse (cover) cropping systems study. Seedbanks of *Chenopodium album*, *Abutilon theophrasti*, and *Setaria faberi* were established at four densities (0, 60, 450, and 2100 m^{-2}) in a cropping systems trial in central Pennsylvania in 2004 and in 2005. Cover crops, tine weeding, and inter-row crop cultivation comprised the integrated weed management systems. Seedbank population size was monitored by taking ten (6 x 10 cm) soil cores and growing them out in a greenhouse. Initial background populations of *Chenopodium album* and *Setaria faberi* (1418 and 1339 seeds m^{-2}, respectively) prohibited us from establishing the density relationships that were targeted for in the field for 2004. However, there was a strong relationship between seedling recruitment and initial seedbank density in 2004 for *Abutilon theophrasti* and for all three weed species in the 2005 year site ($r = 0.91$). A curvilinear relationship between initial seedbank densities, post management weed densities and weed fecundity were observed in the soybean cash crop (inverse density dependence) and oats/clover (density dependence) cover cropping system. The decrease in efficacy of weed control with increasing weed seedbank densities has tremendous implications for EBWM. The potential for density dependent feedback loops with EBWM strategies can result in regional persistence as a function of localized high density seedbank patches.

Session 4
Weed management in a cropping systems context

Enhanced Tolerance to Weed Competition: Effects of Crop and Soil Management in a Long-Term Farming Systems Trial.

M.R. Ryan[1,2], D.A. Mortensen[1], L. Bastiaans[3]

[1]*The Pennsylvania State University, University Park, USA*
[2] *The Rodale Institute, Kutztown PA, USA, and*
[3]*Wageningen University, Wageningen, The Netherlands.*
mrr203@psu.edu

Long-term farming system trials provide unique opportunities to examine crop-weed interference relationships in crops that are not only managed differently, but are also grown in soils that have differentiated over the life of the experiment. The Rodale Institute's Farming Systems Trial (FST) was initiated in 1981 and compares a conventional corn-soybean rotation with two organically managed farming systems. Over the 26 year history of the FST, the conventional and organic-livestock systems produced similar corn yields while the organic-legume system averaged approximately 10% lower yield (7460, 6718, and 7439 kg ha^{-1} for the organic-livestock, organic-legume, and conventional systems respectively). At the same time the two organic systems averaged 4-5 times greater weed biomass than the conventional system. To explore the apparent increased weed tolerance in the organic systems, an experiment was conducted to determine if differences exist in crop-weed interference relationships in corn across systems. Density of mixed weed species was manipulated to achieve four levels ranging from weed free to a heavy infestation. Weed density and biomass at peak accumulation was used as a measure of weed infestation, and the rectangular hyperbola model was fitted to data from each system. Corn yield loss as a function of mixed weed density was significantly higher in the conventional system. Further analysis indicates differences exist in the competitiveness of individual weed species across systems. *Chenopodium album* was more competitive in the organic-livestock system compared to the conventional system. *Ambrosia artemisiifolia* and *Amaranthus retroflexus* were more competitive in the conventional system compared to the organic systems.

Weed competition in the second year of dryland farming in Southern Spain

J.M. Urbano, F. Perea, G. Pardo

University of Seville, Seville, Spain
urbano@us.es

Organic farming has already become in an important part of the Spanish agricultural producion, with and rapid increase in the last 10 years. In the period 1995-2005 organic farmig acreage has multiplied by 33 and the number of farmers involved by 20, with more than 800.000 hectareas which means more tha 11% of the total farming acreage of the country. Cereals and other annual crops account for about 30% of this organic acreage, mainly in the less productive regions (wheat yields below 2 tons/ha), but the lowering trend in grain prices and the new Common Agricultural Policy allow to foresee that organic acreage is going to increase and that more productive farms will go organic.

It is widely accepted that weeds are a major problem in organic farming and also that weed management skills have to be tested for each enviroment. Until now most studies about thresholds and weed control in organic farming have been carried in Spain in low yielding regions and have showed that weed competence is very limited and different techniques of mecanical control have been proposed.

In november 2005 an organic trial was initiated in a farm that can be considered representative of 4 tons/ha of dryland wheat production and we want it to become a long term trial. A plot of 4 has was divided to stablish the following rotation cycle: wheat - sunflower - peas - faba bean (green manure), assigning 1 ha to each crop. In the previous year, sunflower was sown and no checmicals were added, so this agricultural year 2005/06 can be considered as 2nd year of organic farming.

In the wheat and peas plots, experiments have been stablished to get information about thresholds, and critical periods (weed free and competence critical periods). The results obtained this year have been conditionated by the very low weed density, showing that weeds are not a problem in the second year of dryland organic farming when the initial seedbank is very low. *Helianthus annus* (previous crop) had the highest density, followed by *Picris echioides*, *Phalaris paradoxa*, *Anagallis arvensis* and *Polygonum aviculare*. Total weed densities were about 0,3 plants/m^2 and thus no influence in the yield was detected. Nevertheless, 14 aditional species also appeared in the experiment although anecdotically.

The goal of this presentation is to open a discussion and to look for advices about issues as: a) alternatives included in the rotation; b) way to study the weed competence; c) how to handle the problem of such lo weed infestation; d) etc.

Reduction of *Orobanche crenata* infection in faba beans and peas when intercropped with cereals

Mónica Fenández-Aparicio[1], Josefina C. Sillero[2] and Diego Rubiales[1]

[1]*Institute for Sustainable Agriculture, CSIC, Apdo. 4084, E-14080, Córdoba, Spain*
[2]*CIFA Alameda del Obispo, IFAPA-CICE, Córdoba, Spain*
monfapru@yahoo.com

Intercropping is regarded as an ecological method to manage pests, diseases and weeds via natural competitive principles that allow for more efficient resource utilization. Many African farmers traditionally intercrop maize or sorghum with legumes to increase crop production achieving better returns on fertilizer, pesticide, energy and manpower resources. These intercrops reduce also the infection by *Striga hermonthica*. However, there was no such evidence of beneficial effect of intercropping reducing the infection of *S. gesnerioides* (infecting cowpea) or *Orobanche* species infecting legumes.
Orobanche crenata is a parasitic weed that causes huge damage to legume crops. Control strategies have centred around agronomic practices and the use of herbicides, although success has been marginal. Our field experiments show by the first time that *O. crenata* infection on faba bean and pea is reduced when these host crops are intercropped with oat. A tendency for reduction of infection was also observed in intercrops with triticale and barley, but differences were usually not statistically significant. The number of *O. crenata* plants per host plant decreased when the ratio of oat increased in the intercrop. Pot experiments confirmed the reduction of infection in faba bean intercropped with oat and barley. Also glass plate experiments confirmed a significant reduction of infection in faba bean intercropped with oat. An in vitro test showed that oat and triticale roots were unable to stimulate germination of *O. crenata* seeds, but on the contrary, significantly inhibited germination of seeds that were previously stimulated to germinate by exogenous application of GR24.

List of participants

Aassveen, Mauritz (NO)
The Norwegian Crop Research Institute (Planteforsk)
mauritz.aassveen@planteforsk.no

Bastiaans, Lammert (NL)
Crop and Weed Ecology, Department of Plant Sciences, Wageningen University, P.O. Box 430, Wageningen, The Netherlands
lammert.bastiaans@wur.nl

Brak, Bastiaan (UK)
Warwick HRI, University of Warwick, Wellesbourne, Warwick, CV35 9EF
b.h.brak@warwick.ac.uk

Benjamin, Laurence (UK)
Rothamsted Research, Harpenden, Herts, AL5 2JQ, UK
laurence.benjamin@bbsrc.ac.uk

Champion, Gillian (UK)
Broom's Barn Research Station, Higham, Bury St Edmunds, Suffolk, IP28 6NP
gillian.champion@bbsrc.ac.uk

Cussans, John (UK)
Rothamsted Research, Harpenden, Herts, AL5 2JQ, UK
john.cussans@bbsrc.ac.uk

Didon, Ulla (SE)
Department of Crop Production Ecology, Swedish University of Agricultural Sciences, P.O. Box 7043, SE-750 07 Uppsala, Sweden
Ulla.Didon@vpe.slu.se

Fernandez, Monica (ES)
Institute for Sustainable Agriculture, CSIC, Apdo. 4084, E-14080, Córdoba, Spain
monfapru@yahoo.com

Gawronska, Helena (PL)
Laboratory of Basic Sciences in Horticulture,Faculty of Horticulture and Landscape Architecture, Warsaw Agricultural University,Nowoursynowska 159, 02-776 Warsaw
helena_gawronska@sggw.pl

Haigh, Zoe (UK)
Elm Farm Organic Research Centre, Hamstead Marshall, Newbury, Berkshire RG20 0HR UK
zoe.h@efrc.com

Hamad, Abeer (GR)
Laboratory of Weed Science, School of Agricultural Sciences, University of Thessaly, Volos, Greece
hamad@uth.gr

Hinchsliffe, Kay (UK)
Elm Farm Organic Research Centre, Hamstead Marshall, Newbury, Berkshire RG20 0HR UK
kay.h@efrc.com

Hoad, Steve (UK)
SAC Crop and Soil Systems, West Mains Road, Edinburgh EH9 3JG
steve.hoad@sac.ac.uk

Jones, Hannah (UK)
Elm Farm Organic Research Centre, Hamstead Marshall, Newbury, Berkshire RG20 0HR UK
hannah.j@efrc.com

Klem, Karel (CZ)
Agrotest Fyto, Ltd., Havlickova 2787/121, CZ 767 01 Kromeriz, Czech Republic
klem@vukrom.cz

Krcmova, Radka (CZ)
Na Proseku 14/78, Prague 9, CZ-19000
lacertaster@gmail.com

Lutman, Peter (UK)
formerly: Rothamsted Research, Harpenden, Herts, AL5 2JQ, UK
peter.lutman@bbsrc.ac.uk

Mead, Andrew (UK)
Warwick HRI, University of Warwick, Wellesbourne, Warwick, CV35 9EF
andrew.mead@warwick.ac.uk

Mercer, Peter (UK)
Agri Food and Biosciences Institute, Agriculture and Food Science Centre, Newforge Lane, Belfast BT9 5PX, UK
peter.mercer@dardni.gov.uk

Mirsky, Steven Brian (USA)
The Pennsylvania State Univ., University Park.
sbm138@psu.edu

Oestergaard, Hanne (DK)
Risø National Laboratory, 4000 Roskilde, Denmark
hanne.oestergaard@risoe.dk

Paolini, Roberto (I)
Department of Crop Production, University of Tuscia, Via S. Camillo de Lellis s.n.c. 01100, Viterbo, Italy
rpaolini@unitus.it

Rubiales, Diego (ES)
Institute for Sustainable Agriculture, CSIC, Apdo. 4084, E-14080, Córdoba, Spain
ge2ruozd@uco.es

Ryan, Matthew (USA)
The Pennsylvania State University, University Park, USA, and The Rodale Institute, Kutztown PA, USA
mrr203@psu.edu

Stilma, Eveline (NL)
Crop and Weed Ecology group, Wageningen University, P.O. Box 430, 6700 AK Wageningen
eveline.stilma@wur.nl

Storkey, Jonathan (UK)
Plant & Invertebrate Ecology Division, Rothamsted Research, Harpenden, UK
jonathan.storkey@bbsrc.ac.uk

Taab, Alireza (SE)
Department of Crop Production Ecology, Weed Biology Group, Swedish University of Agricultural Sciences, Box 7043 SE-750 07 Uppsala, Sweden
alireza.taab@vpe.slu.se

Urbano, Jose Maria (ES)
University of Seville, Seville, Spain
urbano@us.es

Wolfe, Martin (UK)
Elm Farm Organic Research Centre, Hamstead Marshall, Newbury, Berkshire RG20 0HR UK
martin@wakelyns.demon.co.uk