Session 2C

Organic Production

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Platform Papers: 2C-1 to 2C-4

Poster Presentations: P2C-5 to P2C-8

Plant protection in organic agriculture: a systems approach for above-ground disease management

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Besides plant nutrition, the most important challenge for organic farmers is plant health management. Measures and strategies available in organic farming are crop rotation, biological control, varietal choice, and diversification and resistance management strategies. Clearly, crop rotations are related to the three other strategies. While the presence of a pathogen is required to cause disease, the absence of a pathogen is not necessarily required for a healthy crop. Rather, the balance between beneficial and detrimental organisms usually determines the outcome. This is one of the fundamental principles of the organic approach: to manage the system to reach a natural balance allowing for successful production in the absence of chemical pesticides.

Biological control is often understood as the application of beneficial organisms while in a wider definition host resistance is taken as part of biological control. Application of biocontrol agents is particularly successful in many greenhouse operations. For example, the use of suppressive composts in the planting substrate can drastically reduce damping-off and other diseases.

Also, under the controlled climatic conditions and within the containment of a greenhouse, the release of beneficial micro-organisms (including hyperparasites, plant growth promoting rhizobacteria (PGPR), mycorrhiza and Rhizobia) is by now routine in many operations. While hyperparasites are of interest for the direct control of soil and foliar diseases, PGPR may indirectly improve plant health by enhancing their overall resistance.

Under field conditions, the approaches to biological control include, for example, the introduction and establishment of exotic biocontrol organisms as has happened in some historical cases and the application of the so-called inundation practice. Both these approaches are usually successful if highly specialized interactions occur between pest or pathogen and the biocontrol agent and if the climatic conditions allow for the permanent or temporal establishment of the biocontrol agent. For the inundation approach, in addition, the organizational infra structure and educational level of the applicants also have to be taken into account. Very successful examples exist in Cuba and elsewhere.

The most important, albeit also least spectacular approach to biological control in the field is the enhancement of often less specialized natural enemies and beneficial microorganisms through habitat management. This is the basis for most disease management strategies in organic farming. Crop rotation, varietal choice, and diversification and resistance management strategies all are part of the overall habitat management strategy in an agricultural system and all can be managed to enhance biological control.

With respect to foliar diseases, there are a number of possible approaches ranging from soil management to micro-climate management to the management of the plant genetic resources. Crop rotations are fundamental in improving crop health in various ways.

The most important are:

- the reduction of pathogen propagules in the soil or on crop residues over time:
- the enhancement of soil microbial activity;
- possible direct suppressive effects on certain pathogens and also weeds.

The third mechanism is important and deserves much more attention in future research, if ecological methods such as no or reduced tillage to reduce erosion are to become more prominent in organic agriculture. Recent research on alternatives to the use of methyl bromide has added much knowledge about possible disease suppressive effects of various crops (see Finckh and Wolfe (2006) for more details).

Besides the simple choice of resistant varieties as far as available, diversification and resistance management strategies are of paramount importance in habitat management. Multiple diseases, insect pests and weeds need to be accounted for when deciding on the appropriate varietal and species choice. Multiple mechanisms contribute to disease reduction in diversified systems (see Finckh and Wolfe (2006) for details), the main ones being distance and barrier effects and induced resistance.

Depending on the type of crop and disease diversification approaches may differ fundamentally. To illustrate this, organic potato production (with respect to late blight management) and organic cereal production will be contrasted and a variety of possible approaches to make better use of diversification strategies in modern agriculture will be presented:

- Strategies in genetic resources development, e.g. the selection for inducibility of resistance and competitive ability as well as an evolutionary breeding approach leading to highly adaptable plant populations (modern landraces);
- Local and regional management strategies: Possibilities for growers to use diversification strategies on-farm with the existing equipment;
- Technical solutions: These are integral to the future use of diversification strategies and they reach from more or less simple adjustments to machinery for planting and harvesting to separation devices of the harvested goods.

Finckh M R; Wolfe M S (2006). Diversification strategies, pp 269-308. In: *The Epidemiology of Plant Disease*, edited by BM Cooke; D G Jones; B Kaye. Springer.

Promoting plant health through organic systems: soil health and root disease suppression

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Introduction

A healthy soil is defined as a stable soil with high biological diversity, low soluble C and N content, and disease suppressiveness. The stability of a system can be measured by its resistance and resilience to a disturbance (van Bruggen & Semenov, 2000; van Diepeningen *et al.*, 2006). Soil microbial populations generally fluctuate, and start to oscillate regularly in response to a disturbance, such as addition of organic material to soil. The amplitude of the waves in microbial populations (measure of resistance), their frequency, and the time needed to return to initial conditions before organic amendment (measure of resilience) may be used as indicators for soil health (van Bruggen & Semenov, 2000). Organically managed soils commonly have a higher diversity of bacteria, mycorrhizal fungi, nematodes, earthworms, insects and arthropods than conventionally managed soils (Mäder et al., 2002; van Diepeningen *et al.*, 2006). Also a higher microbial activity and microbial biomass have been found in organic soils (Mäder *et al.*, 2002). However, some authors found no differences in microbial diversity between organically and conventionally managed soils, so that these differences are still disputed. Soils with a higher biological diversity, such as natural or organically managed agricultural soils are frequently more suppressive to soil-borne diseases than conventionally managed agricultural soils (Hiddink *et al.*, 2005; van Bruggen & Termorshuizen, 2003), but exceptions have been found (Messiha *et al.*, 2007). The aim of this study was to compare stability and resilience after a disturbance and disease suppressiveness in organic and conventional soils.

Methods

Thirteen pairs of arable soils from conventional and organic farms (Experiment 1) were compared with respect to various chemical and microbiological characteristics. Bacterial diversity was estimated from DGGE banding patterns. Resistance of the microbial community to a disturbance (drying-rewetting) was assessed from the amplitude in soil respiration immediately after the disturbance. Daily microbial dynamics was monitored after a disturbance of organic and conventional greenhouse soil (amended with dried and shredded grass-clover material). Oxygen use in the greenhouse soils was measured by Oxitop. Disease suppressiveness was also studied for organic and conventional greenhouse soils (Experiment 2 and 3). The pathosystem was *Fusarium oxysporum* f. sp. *lini* on flax.

Results and discussion

In 13 pairs of soils from organic and conventional farms, soil health was better in soil under organic management with respect to nitrate concentration, microbial diversity, and resistance to disturbance (Table 1). In soils from organic and conventional greenhouses, oxygen consumption was higher and relative peak height of bacterial populations in amended compared to non-amended soil was lower in the organic soil. Fusarium wilt in flax was less severe in organic soil. These results suggest that bacterial diversity, activity and response to a disturbance can indeed serve as indicators for soil health, including disease suppressiveness. Cultural practices that may contribute to soil health and disease suppression will be discussed.

Table 1. Bacterial diversity, respiration, relative peak height of oscillations in bacterial CFUs, microbial oxygen use (Oxitop), and severity of Fusarium wilt on flax in organically and conventionally managed soils; field soils in Experiment 1, and greenhouse soils in Experiments 2 and 3.

Experiment	Variable	Organic	Conventional	Signif. t-test
1	Bacterial Diversity S (# bands)	49.8	43.4	0.001
1	Basal respiration (µg CO_2/g soil/hr)	6.3	3.7	0.047
1	Response amplitude after disturbance (drying-rewetting) (µg CO_2/g soil/hr)	6.7	8.0	0.026
2	Relative peak height of bacteria after disturbance (grass-clover / unamended)	34	133	0.001
3	Oxygen use (mg O_2 / kg dry soil / h)	5.6	4.1	0.05
2	Area under disease progress curve	8.3	25.3	0.001
3	Area under disease progress curve	36.9	56.8	0.01

Acknowledgements
We thank A D van Diepeningen, E Kaku and S Karfopoulos for carrying out the experiments and V V Zelenev for harmonics analysis. AM Semenov was funded by NWO-Russia grant 047.017.011.

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Weed community dynamics in mixed ley-arable organic rotations

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Context

Weed community dynamics are a key issue in organic agriculture. For producers, weeds are often the major biotic limitation to yield and economic performance, having greater impact than either pests or diseases. At the same time, the stability of yield and quality in organic systems is probably reliant on the damping effect of system diversity on the population sizes of nuisance organisms, and so a healthy weed community is a vital part of the system because of the role of plants as the primary producers in the foodweb. It is essentially this role which policy makers recognize in setting a high utility on organic farming. In an informal sense, the presence of weeds in organic farming can be seen from a policy-maker's perspective that the farming system is delivering the goods. Clearly then, for a variety of reasons, it is important to understand the dynamics of weed communities in organic systems not least because producers need to have an intuitive feeling of how to balance the competing objectives of maintaining a livelihood while providing non-market goods.

In principle the task of elucidating the rules of weed management for organic production is simple enough. Ideally, one would infer a target community structure (so that it will fulfill all of the key ecological functions required) and size (to balance ecological effectiveness with economic impact) and then select control measures so as to achieve the required balance between population (and hence overall community) growth and decline over time. In practice, of course, the task is far from easy, not least because the relevant data are rarely available and problematic to interpret when they are. One of the main limitations is that data are required over a sufficiently long time series to allow community dynamics models to be elucidated and validated (note that such models can be either formal mathematical models, or less formal models derived from expert opinion, but the issues of elucidation and validation are common to both). In this paper we present some initial results from on-going work to model the behaviour of weed communities in long-term organic rotation experiments in Scotland and link the dynamics to assessment of weed community utility for biodiversity.

Concepts

At low overall weed population densities, such as are commonly found in agriculture, natural density-dependence can be ignored and the inter-annual dynamics are determined by the balance between processes which increase population size (reproduction and immigration; (r+i)) and those which decrease it (death and emigration; (d+e)). In theoretical treatments of population dynamics it is often assumed that both i and e can be ignored (by assuming that the population is closed) or treated as if they are small and constant.

For present purposes, we simply assume that the net effects of positive (r,i) and negative (d,e) processes are reflected in the observed population sizes, but note that for many organic production systems, the usual assumptions about insignificant i and e may well not be safe as a result of the import/export of manures.

We can express the ideas in the ideas in the paragraph above formally in a difference equation: $N_{t+1} = (r+i)N_t - (d+e)N_t$, where the subscript, t, denotes year (corresponding to rotation phase). Writing $g = (r+i)$ and $f = (d+e)$ clears away some of the process detail and allows us to draw some general expectations about the dynamics of weed community size and utility before confronting our hypotheses with the test of agreeing with observations. First, we see (as already mentioned) that population size in the next rotation phase is determined by the net effects of positive (g) an negative (f) factors on the population in the current phase of the rotation; and by extension, the effects of a whole rotational sequence (G and F, say) on the population is given by the net result of g and f effects for the rotational sequence. A couple of important results are, now fairly easy to see. For G>F the population will increase over the rotation, for G<F the population will show a net decrease, and for G=F there will be no net change. Within a rotational sequence we should expecto see population oscillations as the balance shifts between g and f. Finally, the perceived utility of a rotation will be sensitive to the phase(s) in which it is sampled because of inter-specific variations in g and f. It is quite easy to see that sampling a rotation with an overall negative impact on weed community size (G<F) might lead to the conclusion that the rotation was beneficial to biodiversity, if, in the sampled phase, the g value in the previous phase for a particularly highly valued species had led to a transiently high population density.

Observations

Data from three years (1991, 1994 and 1999) for different ley-arable rotation experiments at two sites in north-east Scotland, Woodside and Tulloch were available for analysis. Population sizes of the readily germinable fraction of the seedbank were assessed for these years for replicate samples of 200ml of soil. At both sites both the mean and variance in population sizes and the number of species present increased from 1991 to 1994 and then declined between 1994 and 1999. For example the overall means (variances) in plant numbers at Woodside were: 1991, 0.47(4.05); 1994, 1.55(65.49); 1999, 0.63 (8.54). At Tulloch the corresponding values were: 1991, 1.56(10.26); 1994, 2.00(40.88); 1999, 1.31(21.62). The number of species present at each of the sites in 1991, 1994 and 1999 were 16, 25, 19 at Woodside and 12, 17 and 13 at Tulloch. The sampled years do not correspond exactly to complete circuits of the rotations at either site, but it can be seen that the net effect of the practices at Woodside was to reduce weed seed abundance slightly from 1991 to 1999 while at Tulloch the net effect was a growth in weed seed numbers. At both sites a conspicuous peak in plant and species abundance occurred in 1994. We note that this peak provides support for our theoretical expectation that seedbank dynamics will be oscillatory in organic rotations, while also highlighting the potential pitfalls of relying on individual year sample data to estimate the impact of farming system practices on biodiversity. The underlying mechanisms for the observed results at the level of individual species and rotational sequences are currently under investigation using numerical simulations based on the observed data.

Acknowledgments

SAC and SCRI are Main Research Providers for the Scottish Executive.

Diversity in arable systems for production stability

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Conventional UK wheat crops are composed of monocultures of individual varieties selected for production under high inputs. Consequently, when grown under low input conditions such varieties have considerable yield and quality shortfalls (4 to 5 t/ha modal range). This reduced productivity is the result of the interaction between varieties that have not been selected for production under low-input conditions, and the field environments that are often highly variable in the absence of a range of inputs. Most importantly, the predictions for increased climatic variation, together with higher prices for inputs will place additional demands on the crops we grow in all systems.

One possible avenue by which climatic variation can be buffered and oil use offset is to increase the diversity within the varieties or breeds that are grown. In the case of cereal varieties, improved yield stability has been recognised from growing mixtures. Nevertheless, recent work has demonstrated that these potential benefits can be unreliable in organic systems, possibly a result of too little diversity among the cereal components of the mixture relative to the environmental variation present in organic growing conditions.

A more complex, but potentially more robust and resilient solution is to use composite cross populations as in the 'evolutionary breeding' concept proposed by Suneson (1956) for barley. Wheat populations, created from two-way crosses between all parents, can produce thousands of unique genotypes, and have the potential to evolve under specific field conditions through successive seed saving and re-sowing.

In the Defra funded project AR 0914 six wheat composite cross populations (CCPs) were developed from a total of 20 parent varieties: Y and Yms (nine high yield parents without and with male sterility), Q and Qms (12 high quality parents, without and with male sterility; one of these parents was also included in the high yielding group) and YQ and YQms (all 20 parents without and with male sterility). The CCPs, and their equivalent physical mixtures, are now at F_6, being the fourth generation of selection in the field at two organic and two non-organic sites.

The performance of the CCPs compared to their physical mixtures, and the individual stands of the parent varieties has demonstrated across a range of environmental conditions that the CCPs consistently yield higher than the mean of the parent varieties. Within a single year, the performance of the physical mixtures is as good as the populations, but early indications suggest that across years CCPs have a greater stability than mixtures.

Furthermore, across the two organic and two non-organic trial sites Finlay-Wilkinson analyses revealed that the CCPs have higher stability compared to the majority of the parents; older varieties were found to perform relatively well in low yield potential environments, and the inverse was true for modern varieties. The CCPs ranked highly across all growing environments suggesting that the genetic diversity within the crop acts to buffer variation in field conditions.

Trial results from the 2007 harvest will be presented. Further data from phenotypic analyses of the populations will provide insights into the value of evolutionary breeding for the development of crops for low-input conditions.

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Effects of *Phytophthora infestans* on potato yield in organic farming as influenced by nutrient status

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Introduction

Late blight, caused by *Phytophthora infestans* is commonly thought to be the factor most limiting yield in organic potato production. However, empirical evidence from a large survey study in Germany (Möller, 2001) and a rough modelling study based on results from three years experiments (Finckh *et al.*, 2006) suggest that the limited nutrient availability in organic farming may be an overriding factor limiting yields. These results suggest that because yields in organic farming are potentially much lower than in conventional farming the effects of *P. infestans* might be overestimated. In organic farming systems, nutrient availability is governed by N mineralization processes in the soil in spring which are strongly dependent on temperature and humidity. Therefore, the model of Finckh et al. (2006) pointed to the need to include climatic data and N-dynamics in any yield loss model. In the presented study, detailed data on yield development, soil nitrogen dynamics, plant N-uptake, climate, and late blight development from four years experiments under organic conditions were used in an attempt to build an empirical yield model for organic potatoes.

Materials and methods

The interactive effects of N-availability in the soil, climatic conditions and late blight were studied in the presence and absence of copper from 2003-2006. All trials were arranged as split-plots with four replications at a planting density of 40,000 ha^{-1}. The variety Nicola from the middle early maturity group with early bulking was used throughout all the experiments. Weather data were recorded with the aid of a fixed weather station at the experimental site and temperature sum was calculated as sum of effective daily mean temperatures above 0 °C from emergence to defoliation. The mineral nitrogen content of the soil was analysed at three different growth stages (emergence, onset of flowering and end of flowering) by using a Continuous Flow Analyser (CFA Evolution II, Alliance Instruments, Frepillon, France). Growth, nitrogen uptake and tuber formation of the plants were examined at different developmental stages: Three sequential harvests were conducted at 75, 85, and 95 days after planting (DAP) in the different years. Fresh and dry mass of leaves and tubers were determined and total N was measured with the quantitative Dumas method (Macro-N; Foss Heraeus Analysesysteme, Hanau, Germany).

Percent diseased leaf area (DLA) was assessed once or twice weekly in each sub-plot from the first appearance of late blight to defoliation. Both the area under the disease progress curve (AUDC) and the relative AUDC (rAUDC) at 50 -, 60 -, 75 – and 100 % DLA were calculated from these data. The rAUDC was computed as the relation of AUDC of a single sub-plot and the maximum AUDC reached for the respective stage of DLA per year.

A multivariate stepwise linear regression analysis maximising R^2 was conducted with a subset of the data and validated with a second subset, to identify the most important yield determining factors. As yield response to several factors is not linear the variables were transformed to comply with the linear regression approach. The final model selection was based on a low Akaike`s information criterion considering in addition the adj. R^2 and the residual MSE and the residual distributions of the construction and validation dataset.

Results and discussion

A model including disease severity at different stages, disease reduction, N-uptake by the plants and soil mineral nitrogen content at the end of flowering explained up to 86 % of the observed yield variation in the construction dataset and about 73 % for the validation set. Adjusted to the whole data, the adjusted R^2 achieved was 0.82. The residuals were normally distributed as tested with the Kolmogorov-Smirnov-Test.

The regression indicates obvious positive yield effects of soil mineral nitrogen content and total N-uptake by the plants at the time of the first and second sequential harvest,. The influence of *P. infestans* development on yield was less straightforward as the modelling process resulted in a model including multiple disease related parameters (AUDC at 75% DLA, Log (AUDC at 50% DLA), $AUDC^2$ and $(rAUDC\ at\ 75\ \%\ DLA)^4$) . This was due to large differences in disease development and the growing conditions of the plants among years. In 2003, the disease severity did not exceed 40 % by the time the plants reached maturity and the temperature was high during the vegetation period so that plant development was fast and there was no influence of disease on yield (Regression of AUDC on yield: adj. R^2 = 0.00). Also, in 2005 and 2006 the epidemics began at a high accumulated temperature sum (950, 1136 °D) and stagnated at a low level for a long time before plants were defoliated by the disease resulting in a high total temperature sum (1563, 1584 °D) and no significant effects of disease on yield (2005: adj. R^2 = 0.122; 2006: adj. R^2 = 0,068). In contrast, in 2004 the temperature sum from emergence to the first occurrence of late blight and total defoliation of the plants was 855 and 1278 °D, respectively, i.e. much lower than in the other years resulting in a highly significant effect of disease on yield. However, even in 2004, only 35% of the variation in yield (adj. R^2 = 0.355) could be explained through disease severity while the effect of N-uptake was much stronger.

Conclusions

Overall, yield of potatoes grown under organic agricultural management appears to be much more influenced by growing conditions (temperatures and nutrient availability) than by late blight. To predict yield losses under organic growing conditions due to late blight or other diseases or calamities (e.g. hail), disease or leaf area loss assessments should be coupled with data on nutrient dynamics that allow for the prediction of the potential yield. Total N-uptake by plant foliage at given developmental stages coupled with disease severity assessments might be a useful parameter in this context.

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Impact of farming practices on stem-base diseases of wheat

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Summary
The stem-base diseases of wheat such as eyespot, sharp eyespot and brown foot rots were assessed by molecular methods to evaluate the impact of organic and conventional farming practices on their incidence. The most frequent pathogens on stem bases of wheat were *Gibberella coronicola* and *Monographella nivalis* in the 2006 experimental season. The occurrence of *Oculimacula yallundae, Oculimacula acuformis, Ceratobasidium cereale* and *Gibberella avenacea* was very low. Species such as *G. zeae, F. culmorum, F. poae* and *Gaeumannomyces graminis* were not found at all.

The comparison of organic and conventional farming practices did not result in large differences in occurrence of stem-base pathogens; nevertheless, a higher frequency of positive detection was recorded for *O. acuformis, O. yallundae* and *M. nivalis* under conventional farming.

Introduction
Organic farming differs fundamentally from conventional farming in soil fertility, weed, pest and disease management, and makes higher demands on product quality and yield stability. Organic farming systems aim at resilience and buffering capacity in the farm-ecosystem by stimulating internal self-regulation through functional agro-biodiversity in and above the soil, instead of external regulation through chemical protectants (van Bueren *et al.,* 2002).

A number of aspects of organic *vs.* conventional farming practices have been studied *e.g.* grain yield and quality. Lower yield under organic than under conventional farming was found by Baeckstrom *et al.* (2006) and explained by a lower amount of plant available N. Dry matter content in grain was significantly lower under organic than under conventional farming. Grain protein content was a quality parameter which was negatively influenced by organic farming and volumes of organic loaves of breads were significantly lower than those of corresponding conventional ones (Carcea *et al.,* 2006). Comparison of the two farming systems regarding disease incidence is also relevant.

In the study of Hiddink *et al.* (2005), take-all severity on roots of barley and wheat, caused by *Gaeumannomyces graminis* var. *tritici*, was significantly lower in organically-managed than in conventionally-managed soils. The higher microbial activity found in the organically-managed sandy soil combined with the significantly lower take-all severity suggest that microbial activity plays, at least in part, a role in the take-all suppressiveness in the organically-managed sandy soil. Similarly, another study (van Bruggen & Termorshuizen, 2003) showed that in well-managed, long-term organic farms, soil-borne diseases need not be a problem.

In this study, farming system (organic and conventional) was evaluated as a factor affecting incidence of stem-base diseases.

Materials and methods

Four winter wheat cultivars (Sulamit, Ebi, Drifter and Bill) were cultivated in small-plot field experiments after a cereal crop in conventional farming and in an eight-course crop rotation following red clover in an organic system. In total 224 bulk samples of stem bases were taken from both farming systems. Four varieties were sampled at four growth stages: tillering, jointing, heading, and waxy maturity. Fungal species (*M. nivale vars nivale and majus, O. acuformis, O. yallundae, C. cereale, G. coronicola, G. zeae, G avenacea, F. culmorum, F. poae, G. graminis* var. *tritici)* were detected by molecular techniques through the use of species-specific primers. Differences in the frequency of positive or negative DNA detections in samples were evaluated using the Chi-square test.

Results and discussion

The most frequent species detected in samples of stem bases of wheat was *G. coronicola* (62.50 % of samples). Further, high number of samples contained DNA of *M. nivale,* at approximately balanced proportions of both varieties, *nivale* and *majus* (50.88 % and 53.98 % samples, respectively). *R. cerealis* was positively detected in 3.54 % of samples. *O. acuformis* and *O. yallundae* were rarely present in our samples (2.21 % and 1.77 %, respectively). Only 1.30 % of samples contained DNA of *F. avenaceum. F. graminearum, F. culmorum* and *F. poae* were not found at all.

The comparison of organic and conventional farming practices did not show large differences in occurrence of stem-base pathogens; nevertheless, a higher frequency of positive detection was recorded for three species under conventional farming. The incidence of *M. nivale* var. *nivale* was more frequent under conventional farming than organic $\chi^2 = 12.50$ (P=0,023). *O. acuformis* and *O. yallundae* were detected in conventional but not organic farming systems.

Acknowledgment

This work was supported by GACR project no: 522/06/P103.

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Weed management in organic cereals by the use of legume intercrops and over-winter green manures

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Introduction

Weeds are often cited as being one of the most important constraints to cereal production in low-input and organic production systems, despite a large volume of published information on general weed management. One suggested reason for this is that successful weed management in the long-term requires the issue to be addressed at the level of the cropping system. In this study we investigated how increasing the complexity of the crop environment through the use of intercrops and green manures affected weed communities over the first two years of cereal production in an organically-managed cropping sequence in Scotland. Specifically, we addressed the hypotheses that; 1) intercrops reduce weed biomass in the current growing season; 2) over-winter green manures reduce weed biomass and alter the species composition of the weed community in a second-year cereal crop.

Methods

An intercrop experiment investigating mixtures of cereals and legumes with different over-winter treatments was established in the spring of 2006. The experiment was located at SAC Aberdeen (57.2°N, 2.2°W), on a site which had been in grass/clover and grazed by sheep for the previous four years. The field was ploughed approximately one month before the plots were power harrowed, sown and rolled on 25 April, 2006. The treatments (Table 1) were arranged in three randomised blocks and each plot was 4 m × 1.5 m. The crops sown were barley (var. Westminster), oats (var. Firth), peas (var. Zero4), white clover (var. Alice) and oilseed rape (hybrid var. Elan). Plots were combined on the 11 September, 2006 to evaluate yield. After harvest, the plots destined to have an over-winter green manure of rape were shallow rotovated, the seeds broadcast by hand and the plots rolled. No manure, fertiliser, herbicide or other agrochemicals were applied to the plots at any stage. Herbage was removed from a 50 × 50 cm area of each plot during 2006 (nominally at GS60/61 and just prior to cereal harvest). The herbage was separated into the different crop fractions and weeds, and the biomass of each fraction was measured.

Table 1. Combinations of cereals, intercrops and green manures used in the experiment together with, in parentheses, seed rates (kg ha^{-1})

Cereal	Intercrop	Over-winter green manure
Barley (200) or Oats (250)	None	None
	Clover (5)	Clover
Barley (100) or Oats (125)	Peas (125)	None
	Peas(125)	Oilseed rape (6)

In spring 2007, after ploughing and power harrowing, the whole site was sown with oats (var. Firth, 250 kg ha^{-1}), followed by rolling, on 16 April, 2007, and the previous year's plots were re-marked for future assessments within the crop (as for 2006). Weed species counts were made at the start of stem extension (GS 30/31, 13 June, 2007) in the second-year oats using one 50 × 50 cm quadrat per plot.

Results

The weed biomass in cereal/clover intercrops was considerably less than in sole-cropped cereals (Table 2), and there was a slight but non-significant indication that plots with barley had fewer weeds than those with oats. In contrast, pea/cereal intercrops typically had about twice as much weed biomass as the sole-cropped cereals. The early-season weed biomass in a second-year oat crop was reduced by an over-winter green manure of clover but not with oilseed rape (Table 3).

Table 2. Weed biomass (relative to respective cereal sole-crops) in barley and oats intercropped with either clover or peas.

Cereal	Barley		Oats	
Intercrop	Clover	Peas	Clover	Peas
GS60/61	0.57	2.0	0.79	1.7
Harvest	0.57	5.2	0.85	2.1

Table 3. Weed biomass (g m^{-2}, ± S.E.) in second-year oats at GS30/31 in plots that had contained either barley or oats, followed by an over-winter fallow or green manure (GM).

2006 Crop	Post harvest 2006	Barley	Oats
Cereal monocrop	Fallow	6.3 ± 5.6	4.5 ± 2.2
Cereal + clover	Clover (GM)	3.5 ± 1.5	2.6 ± 0.4
Cereal + pea	Fallow	3.7 ± 1.9	4.2 ± 1.8
Cereal + pea	Oilseed rape (GM)	3.9 ± 1.7	5.2 ± 3.3

The most common weed species across all treatments (expressed as % of total weeds) were chickweed (*Stellaria medica*, 35%), annual meadow-grass (*Poa annua*, 32%), knotgrass (*Polygonum aviculare*, 16%), spurrey (*Spergula arvensis*, 5%) and forget-me-not (*Myosotis arvensis*, 5%). The abundance of these did not change significantly as a result of the different over-winter treatments, although there were indications that the abundances of annual meadow-grass and chickweed were reduced by the presence of clover, and the abundance of spurrey was increased by an over-winter fallow. These trends will be examined in more detail by further measurements in the summer of 2007.

Conclusions

Intercropping can be a useful technique to manage weeds during the cereal cropping phase of an organic rotation but the choice of intercrop species affects the degree of weed control obtained. This appears to be achieved by a reduction in the biomass of individual weeds rather than by a reduction in weed numbers or a change in the weed community composition. Other potential benefits of intercropping systems, such as yield enhancement, must be taken into account when assessing the efficacy of weed control strategies.

Acknowledgements

We thank G Dubouchaud, S Karl, A Milne and D Simpson for field assistance.

Does farm worker health differ between conventional and organic horticultural systems?

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Abstract
Self-reported health status of farm and pack house workers on conventional and organic farms in the UK was assessed using four standard, validated survey instruments. There were no significant differences between organic and conventional farm workers for three of the four health instruments used but the Short Depression Happiness Scale showed organic farm workers were happier. This was explained by the number of different work related tasks performed rather than any relationship to pesticide use.

Introduction
Organic farming under the stewardship of the International Federation of Organic Movements (IFOAM) is in the process of redefining the aims of the organic movement based upon four core principles. The first of these principles proposes that the maintenance and enhancement of physical, mental, social and ecological well-being should underpin good organic farming practice. If the farm worker physical and mental well-being status is a measure of the difference between organic and conventional farming practices then it is reasonable to assume that organic farm workers will display higher levels of good health than their conventional counterparts. Whilst many workers in UK horticulture are economic migrants from eastern Europe who work in a hazardous environment, little or nothing is known of their health. This study evaluated the self-reported health status of field and pack house workers in UK vegetable horticulture and was premised on the null hypothesis that there is no significant difference between the health status of organic and conventional farm workers.

Methods
The health of seasonal field and pack house workers, was measured through the use of four standard health instruments (Short Form 36, EuroQol EQ-5D and the Visual Analogue Scale and the Short Depression Happiness Scale). Population norms exist for the first three of these questionnaires which permits comparisons between groups with reference to a fixed population mean (EuroQoL Group, 1990; Ware, 2000). The SF-36 comprises eight scales and two component scales (Physical Functioning, Role Physical, Bodily Pain, General Health, Vitality, Social Functioning, Role-Emotional and Mental Health).

Two further scales summarise the aggregate scores of relevant scales. These health scales aggregated to give separate and unique scores for physical health scores (Physical Component Summary (PCS)) and mental health scores (Mental Component Summary (MCS)). Five translated versions of the questionnaire were made available to the respondents (English, Latvian, Lithuanian, Polish and Russian).

Results and discussion

Questionnaires were distributed on eight farms in England and Wales employing between one and 1,500 workers. The sample population comprised 395 males and 210 females representing approximately 1% of the UK total for seasonal or casual employment in agriculture and horticulture. More than 95% of the workers were aged between 18 and 34. The following results refer to this age group only.

There were no significant differences between workers on conventional and organic farms for health scores derived from the SF-36 scale and component summary scores, the EQ-5D and the Visual Analogue Scale. However, five of the eight SF-36 scale scores and one component summary score of the SF-36 for workers on conventional farms were significantly lower than the age specific population norm (Role Physical *df* 901, p=0.001, Bodily Pain p=<0.00001, General Health p=0.002, Social Functioning p=<0.00001, Mental Health p=0.0001, Physical Component Summary p=0.0002), whilst for organic farm workers only three of the component scores were significantly lower than the population norm (Bodily Pain *df* 444 p=0.0046, Social Functioning p=0.0002 and Mental Health p=0.0392). The VAS 18-34 age group mean score for males (79.67) was close to the norm score expected for males aged 55-64 (78.99) whilst the female mean score (75.6) was closer to the mean score for the 65-74 age group. Workers on organic farms scored significantly higher than conventional farm workers for the SDHS (Mann Whitney U test n=334, p=<0.012). The contributing factors to SDHS scores were explored by entering the independent variables farm, farm size, farming method, number of tasks per day, wages, age, gender, nationality, marital status and children into a stepwise backwards model. A significant model emerged ($F_{,3,306}$=9.986 p=<0.001 adjusted r^2 =0.08). Significant variables were farm (β= -0.171p=0.002), farm size (β= -0.159 p=0.01) and number of tasks per day (β= 0.128 p=0.036). The mean scores for the SDHS for respondents performing one to five different tasks per day were 11.77, 12.30, 13.07, 12.84 and 13.27 respectively. A best fit line for the means of each SDHS score by task number gave an r^2 value of 0.84.

Owing to the labour intensive nature of organic farming the creation of employment in this sector is heralded as further evidence of the benefits that accrue to society through organic farming (Morison *et al.*, 2005). There are important ethical implications to be considered by exposing farm workers from Eastern Europe to a working environment that erodes their health status. If organic farming increases employment opportunities and these vacancies are filled by migrant workers then there is a reasonable likelihood that more people will experience declining health than before. One possible and cost effective avenue to explore is that of increasing the range of tasks. Workers on organic farms already perform a greater range of tasks than on conventional farms (Jansen, 2000; Morison *et al.*, 2005) and it may be more cost effective for organic farms to extend and deepen this practice.

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