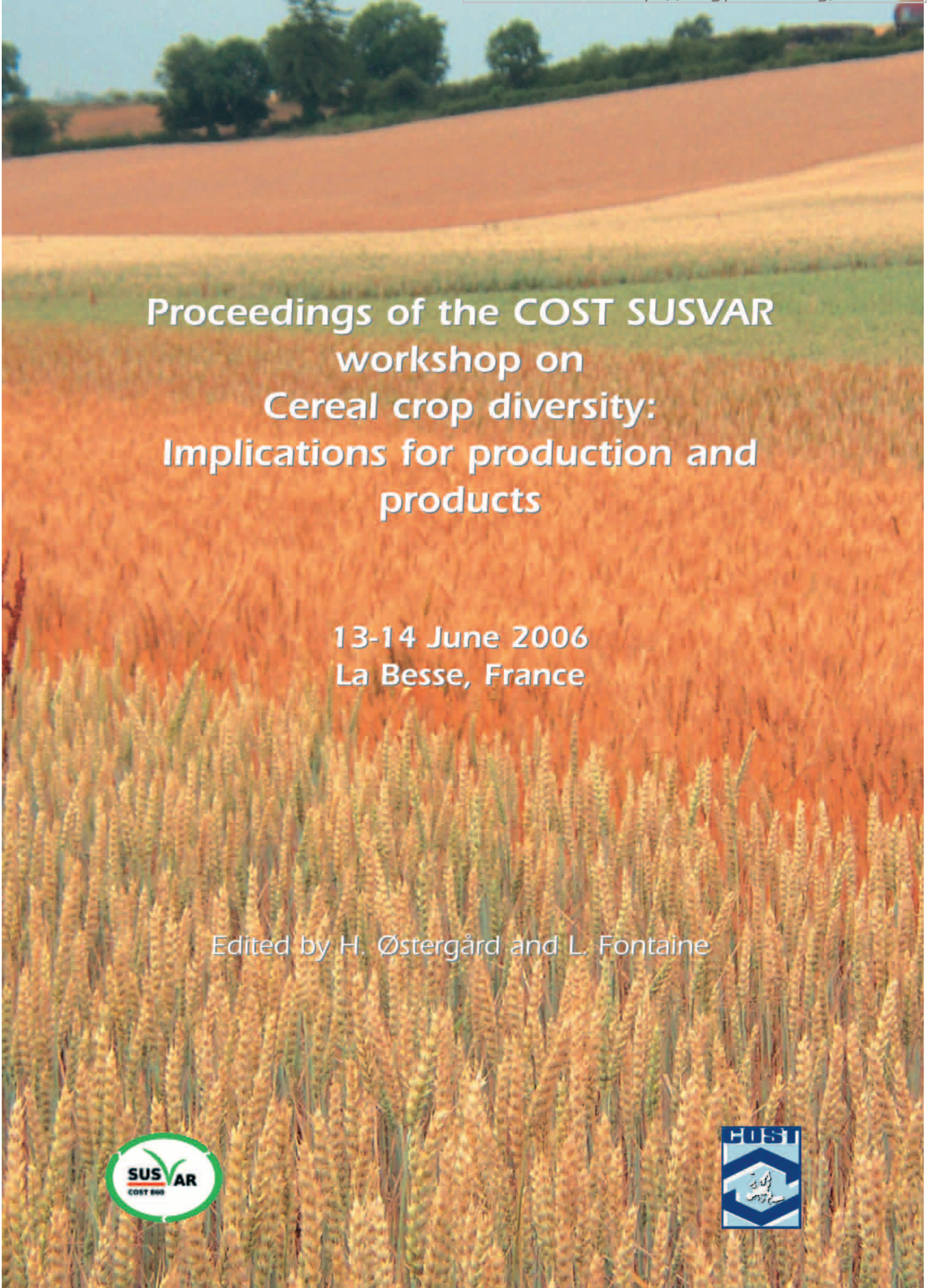

Proceedings of the COST SUSVAR workshop on Cereal crop diversity: Implications for production and products

13-14 June 2006
La Besse, France

Edited by H. Østergård and L. Fontaine

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Hanne Østergård, Laurence Fontaine (Eds), 2006.

Proceedings of the COST SUSVAR workshop on Cereal crop diversity: Implications for production and products, held in Domaine de La Besse (Camon, Ariège), France, 13-14 June 2006.

ITAB, Paris, France, 153 pages.

Printed on recycled paper.

Photos: L.Fontaine, ITAB, M. Haefliger, Biocivam.

ISBN 2-9515855-7-8 9782951585577

This workshop was organised in France by Biocivam de l'Aude, INRA (Institut National de Recherches Agronomiques), ITAB (Institut Technique de l'Agriculture Biologique), RSP (Réseau Semences Paysannes). Organiser of the program: Hanne Østergård, Risø National Laboratory, Denmark. This workshop was supported by COST, ONIC, Conseil Général de l'Aude. The publication of proceedings was supported by COST.

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Preface

This proceeding comprises papers based on oral and poster presentations at the COST860 - SUSVAR workshop on cereal crop diversity held in La Besse, France, 13-14 June 2006. The support by COST is acknowledged.

SUSVAR stands for 'Sustainable low-input cereal production: required varietal characteristics and crop diversity' and COST is an intergovernmental framework for European co-operation in the field of scientific and technical research. The SUSVAR network, initiated spring 2004, now includes researchers from more than 100 institutions in 28 European countries.

The main aims of the SUSVAR network are to ensure stable and acceptable yields of good quality for low-input, especially organic, cereal production in Europe. This will be achieved by developing ways to increase and make use of crop diversity, by establishing methods for selecting varieties, lines and populations taking into account genotype-environment interactions and by establishing common methodology for variety testing where appropriate. The present workshop focused on ways to increase and make use of crop diversity from the production to the product. As crop diversity often is argued to be an advantage for the grower but a problem for the end user of high quality grain products, the six introductory oral presentations (Topic 0) gave introduction to farmer's conception of diversity and examples of practical applications of variety mixtures for baking and distilling quality. The remaining part of the workshop was open for poster contributions reflecting the ongoing research within the SUSVAR network on crop diversity. The posters were grouped into four topics: Growing variety mixtures (Topic I), Evolutionary processes in diverse crops (Topic II), Genetic diversity (Topic III) and Variety and species mixtures, diseases and soil (Topic IV). The posters were introduced by a moderator and their contribution is included as an introduction to each topic.

Cereals are an important contribution to food production and the economy in Europe. As a consequence, reduced inputs of pesticides and chemical fertilisers are of general interest, and increasing the area grown under organic conditions receives much public support. The presently available crops and varieties may not be the best to ensure stable and acceptable yields under low-input conditions since most cereal varieties for the last 50 years have been developed to produce high yields under potentially unlimited use of pesticides and synthetic fertilisers. In many countries, national projects are in progress to investigate the sustainable low-input approach. These projects are coordinated in the SUSVAR network by means of exchange of materials, establishing common methods for assessment and statistical analyses, and by combining national experimental results. The network comprises scientists from many disciplines to investigate the complex interactions between the crop and its environment, in order to be able to exploit the natural regulatory mechanisms of different agricultural systems for stabilising and increasing yield and quality. The results of this cooperation will contribute to commercial plant breeding as well as official variety testing, when participants from these areas disperse the knowledge achieved.

I hope that this proceeding will be a useful inspiration for those involved with plant breeding and plant production of cereals as well as other crops by presenting methodologies for studying genetic diversity and genotype-environment interactions in cereals as well as practical applications of crop diversity: variety mixtures, composite crosses and intercropping.

Hanne Østergård, Risø National Laboratory, Denmark
Chair of COST860-SUSVAR

Topic 0

Crop diversity and quality of end product – Involving farmers and end users

Papers are based on invited oral presentations. Papers are listed in alphabetical order of first author which is not necessarily the presenting author.

Introductory considerations on crop diversity

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Key Words: Organic Farming, cereals, biodiversity, varieties, mixtures

Abstract

Modern society faces decreased biodiversity in nature caused by increased uniformity in agriculture, and health related problems with nutrition caused by industrialisation in food production. Conversion to organic farming increases biodiversity, because of diversification in crops and decreased intensity in control of weed and pests, and increase biochemical diversity within food products because of decreased nitrogen application in field. The author argues that the positive effects of in organic farming can be further improved by improved genetic diversity within the crop. Inter-cropping and variety mixtures are already used by some farmers, but diversity within the crop can be further improved by development of composite cross populations, composition of new stabilized populations, and reintroduction of historic varieties and populations.

Introduction

Biodiversity has been decreasing during the last century all over the world, including Europe, and for the last two decades a number of international treaties and conventions has requested actions to improve biodiversity, eg. Convention on Biodiversity (Rio 1992), The Global action plan (1996) and The International Treaty on Plant Genetic Resources for Food and Agriculture (FAO 2003). One of the main reasons for the decreased biodiversity in Northern Europe is the homogenization in agriculture, especially the shift towards increased cereal production.

Cereal production

Cereals is today the dominating type of crop in European agriculture. In 2005 in Denmark, small grain cereals covered 56% of the grown agricultural area, and more than one third of the total surface area of the country (Statistics Denmark 2006). The way these crops are grown is therefore of considerable impact on the whole natural ecosystem in countries, where cereals are the dominating crop in an industrialized agriculture. All small grain cereals except rye are self pollinating species. Pure line varieties of these crops are therefore extremely homogeneous. In principle, all plants of each variety are exactly identical, and identical in both gene pair alles. Cereals and other self pollinating grasses does exist in nature and does occur in populations with these grasses as the dominating species. In some cases even as dense as a weed infected monoculture grown in an agricultural system. Growing cereals and similar grasses as a dominating crop in a mixture or in some cases in a monoculture is therefore not *per se* unnatural. However, growing cereals or any other grasses without any genetically variation between plants is never seen in nature.

Crop diversity and pesticides

In order to control weed, pests and diseases, and to supply crops with nutrients, organic farms grows crops in rotation with other crops. Conventional farms can control weed and most diseases chemically and fertilize the soil with artificial fertilizers. Therefore, crop rotation on conventional farms can be less complex, as it is mainly driven by subsidies and marked demand. Where cereals covers 56% of the conventional cropping area in Denmark, cereals only covers 28% of the organic cropping area (Plantedirektoratet 2006).

The use of pesticides reduces the diversity and amount of weed species, insects and mycoflora. The use of pesticides therefore also reduces the biodiversity of the agroecological system in general, not only of the target organisms it aims to control, but also the biodiversity of organisms feeding on them, or in other ways having symbiotic interacting with them.

It has been sown in many studies that the more complex crop rotations on organic farms, and the absence of chemical pesticides, courses increased biodiversity in terms of birds, mammals, insects etc. compared with conventional farms (Hole *et al.* 2005).

It has been a goal for organic farming to increase biodiversity in the agroecological system. Even though biodiversity is in general greater in organic compared with conventional farming, it is of permanent relevance to discuss how the biodiversity in the system can be further improved to mimic an even more natural system.

Hence, organic farming is more diverse on the farm level, and manage the crops in favour of biodiversity also on the field level, but if we focus on the genetic level within the crops, the differences are minor or absent. Organic farms us in general single line varieties, and the varieties are in general the same used in conventional farming.

Cereal breeding

To finance a breeding program, income for the breeder comes from the royalty of successful varieties, and the more seed is sold, the higher the income. Therefore, it is more profitable to develop a variety suited for a large area, rather than a variety specialised for a specific local niche. The competition for the marked for unspecialised varieties is therefore very intense, whereas niche markets is less profitable.

Some organic farms grow cereals at a high fertilisation level, e.g. some dairy farms, whereas others apply no fertilizers to their cereals. In some locations one plant diseases is important and a specific resistance is crucial, whereas the disease is absent in other locations and other resistances more relevant. These differences makes the demand for varieties for organic farming very diverse, whereas the market for varieties for conventional farming is much more homogeneous, as specific differences in fertilisation, pests and diseases can be regulated with chemical input.

Simple breeding technologies like crossing and back crossing has made it possible to transfer genes from one variety to another. Huge effort has been put to insert resistance genes against mildew, rust and other diseases into the most successful varieties, and the result is that practical all varieties on the European market are more or less related with each other, as they are bred for the same purpose and market, and have used the same genetic sources. For example, the MLO gene against powdery mildew was introduced into most barley varieties within only decade.

New breeding technologies including GMO makes it possible to incorporate genes from non-related species into cereals, and in general makes it possible to speed up the breeding process. In principle, these technologies could increase the genetic diversity in crops, but most likely it will speed up the process of spreading desired characters to other varieties. Therefore, it will change the genetic composition of the cereals, but will not necessarily increase the diversity.

Lack of diversity in cereal production is a problem not only for biodiversity in nature, but may also be hazardous for human health. If for example a gene turn up to be allergenic, it may take more time to find out than it takes to incorporate the gene into the majority of varieties on the market. Many health problems in Europe are related direct to lack of diversity in human nutrition in modern industrial food production. Through cooking we may make food taste differently, but if all major ingredients are genetically identical, there will be no diversity in the nutritional value. Since cereals are the major ingredients in most modern foodstuff, genetic diversity in cereal production may have crucial impact on human health as well.

To have a variety approved, the seed legislation request the varieties to be uniform and stabil (EU-regulation 1994) and improve performance compared with other varieties over a range of different environments. In this way, the seed legislation sustain the development in the genetic composition of cereal varieties towards homogeneity.

Diversity – an organic approach to cereal breeding

Only few breeding programmes for organic cereals exists, and where they do, the income mainly comes from public and private support rather than from royalty from marketing of organic varieties. The likely explanation is that organic farming is not one seed market, but a range of different seed markets, much more diverse and more dependent on local conditions than conventional farming. The improved yield from a successful variety from a specific breeding program for a specific niche within organic farming will therefore only in few cases be able to pay the expenses for the programme for that specific niche, because each niche within organic farming is too small. Even though specific breeding for organic farming may develop new profitable varieties better suited for some conditions of organic farming, the effort will not solve the fundamental problem that organic farming is more diverse, and should be more diverse to reflect the environment it exists in. The principles for organic farming is formulated by IFOAM (2005). It would be more in line with these principles of organic farming to find crops able to adapt to the different environments, rather than manipulating the environment with inputs of fertilizers and control agents to fit a variety basically unsuited for that niche.

Many studies of variety field trials conclude that in average, the same high yielding varieties from conventional breeding programmes are also (or often) highest yielding in organic farming. However, in many of these studies, an interacting between variety and environment are observed, and this interaction seems to be more conspicuous in organic systems (Østergård *et al.* 2006). This means that in some environments, one variety is the best, whereas in other environments another variety is the best. Even though the generalized varieties in average is the best, it also shows that the strategy aiming for one variety for all environments is less fit for organic farming than for conventional farming. Since breeding for a single line variety in organic farming *per se* contradicts the aim for biodiversity, it is therefore relevant to look for other strategies in the supply of seed for organic farming.

Variety mixtures has often been proposed as a way to stabilize yield. Most variety trials are conducted on relatively common environments and with relatively homogeneous varieties. The positive effect of diversity may therefore be less pronounced than in cases, where the difference between varieties are greater and performed on more extreme environments where the varieties are less suited.

Mixtures of species (e.g. barley and pea) have shown positive effects on diseases, nutrient efficiency and yield (Kinane and Lyngkjær 2003; Hauggaard-Nielsen *et al.* 2001). Half a century ago, the cropping of species mixtures were used more frequently, but in all European countries the frequency of crop mixtures is reduced during the last 5 decades.

Landraces are populations of crops with a diverse genetically background grown in specific sites during history. The landraces are therefore populations selected for adaptation for the niche where they are grown. Landraces possess some of the characters aimed for in organic farming, but landraces are not bred for the use in modern organic farming, where ploughing depth, fertilization practice and a many other things have changed since agriculture left the use of landraces a century ago. Also, land races lack the improvement achieved by plant breeding during the last 100 years such as straw strength, disease resistance, backing quality etc.

Composite cross population (CCP) are populations based on crosses of several different varieties, where the crosses are multiplied without pre-selection (Wolfe *et al.* 2006). Composite cross populations have a very high degree of diversity both in the population and genetically within each plant in the first generations after crossing.

A cross between composite cross populations and variety mixtures are mixtures of a diverse range of varieties grown during several generations in the same location (farm, region or similar uniform niche), where the cropping under special conditions selects the varieties best suited for the conditions.

Hence, there are ways to improve crop diversity within organic cereal production, but in practice these methods are rarely used, and except for variety mixture and species mixtures little research is invested to investigate the potential in agriculture and in organic farming in particular.

Bottlenecks for crop diversity

There are many reasons for the farmer not to optimize crop diversity in practice.

Before the lase reform of the Common Agricultural Policy in EU, different subsidy were given to each crop. Therefore, one hectare with barley and one hectare with peas received more subsidy than two hectares with a barley/pea-mixture. This were one of the reasons for the farmers not to chose mixtures of crops, and when the farmers don't use a technology and politicians don't encourage it, the researchers are less reluctant to develop the technology further. Only few scientific publications advocate for crop diversity during this subsidy period even though the positive effect on yield and diseases is well documented.

In many countries it is not legal to market seed in variety mixtures, and in countries where it is legal, only certain mixtures are approved, where the varieties in the mixture are uniform in appearance, and with only few varieties (often 3-4) included. In practice, most research and marketing of variety mixtures have concentrated on the control of diseases such as mildew, and yield effect of the mixture compared with the included few varieties.

Most cereal crops in modern industrialized agriculture are sold to a miller, malt house, feed processor or others, normally with a wholesaler in between. These industrial processors demand a uniform supply, but will normally need to bye grains from a number of producers. To improve uniformity in the supply, most industrial consumers prefer single line varieties, and gives a reduced price for mixtures. In some cases, there is a need to separate a mixture after harvest, which causes extra cost.

On this background, little is done to improve diversity in cereal production in practice. To solve these obstacles is crucial for improved biodiversity in agriculture and related systems.

Conclusion

Diversity is an aim organic agriculture, and a number of benefits can be obtained by the use of crop diversity such as improved yield, reduced weed, diseases and pests. However, legal and logistic problems counteracts the diversification of crops.

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A Participatory Approach to Variety and Mixture Trials: Methods, Results and Farmer Opinions

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Key Words: Organic Farming, winter wheat, varieties, mixtures, seed borne disease, participatory research

Abstract

A participatory research methodology was used to compare the performance of UK wheat varieties under organic conditions. Plots of three breadmaking winter wheat varieties (Hereward, Solstice and Xi19) and a mixture (1:1:1) of the varieties were grown at 19 UK farms in two seasons (2003/04 and 2004/05). Measurements were taken of growth habit, yield and grain quality. The results from the two years of trials illustrated the variability of organic systems; grain yield, protein concentration and Hagberg falling number results showed greater variation among sites than among varieties. However, seed health status was generally high over all sites. Although the trials were successful, some of the participating farmers felt there were some limitations in the process. These included a lack of ownership of the research trials on their farms and a desire for more researcher visits. It was clear that a greater time investment was needed at the start of the project to help with farmer understanding and ownership. However, despite the negative comments, farmers appreciated their involvement. Farmer participation is essential for systems-level research and this project helped to develop a small core of trained farmers and researchers.

Introduction

The current source of comparative information about cereal varieties for UK farmers is the Recommended Lists of cereals (Anon., 2006). However, these lists are of limited value to organic farmers. Firstly, the data relates to crops grown under conventional management and although ‘untreated yields’ are available, these only refer to fungicides, with all other inputs being applied according to best management practice. Secondly, information about characters important in organic production such as weed suppressive ability and resistance to seed borne diseases is not included. Finally, no information is supplied about varietal mixtures, the use of which may be advantageous in organic systems by buffering the spread of diseases, and reducing the number of insect pests and weeds present in a crop (Wolfe, 2001).

A number of organic variety trials have been carried out in the UK. For example, NIAB carried out trials in 2000, and the results were published in the 2001 Cereals Variety Handbook (Anon., 2000). However, these trials were restricted to just three sites.

In order to produce meaningful data on the relative performances of organically grown varieties, the range of trial sites would have to be extended significantly. Unfortunately, this is beyond the resources of the current research system. For this reason, a farmer-participatory method was developed, to not only reduce the resource burden but also to develop a better understanding of variety testing with farmers. The project was designed also to determine the risks associated with saving seed on organic farms

Farmer participation in agricultural research and development is now used extensively throughout the world to help define and resolve the research needs of farmers. Such approaches have proved useful in solving problems in complex and diverse farming systems, characteristics typical of organic farming. However, there is limited experience of participatory farming methods within the United Kingdom, in contrast to the extensive work carried out in developing nations (e.g. Okali et al., 1994). Close collaboration between industry and research in the UK has been recognised as important to address some of the demands within agricultural systems (Anon, 2002).

Methodology

The project was advertised at farm events to promote participation, as well as by using existing farmer contacts of Elm Farm Research Centre (EFRC). At project initiation, participating farmers were contacted with a letter detailing the project methods, aims and objectives.

Seed (25 kg) of the UK bread-making winter wheat varieties Hereward, Solstice, Xi19 and a mixture (1:1:1) of the three varieties was distributed to 19 UK farmers in September 2003 and 2004. Farms were scattered between the east and west of England; most farmers participated in both years, however not all sites were the same and different fields were used between years. Participating farmers sowed the seed in large marked plots (average 125 m2) using their standard methodology within a field containing wheat.

During the growing season researchers gained information from each of the farmers about their farming system (e.g. number of years organic, farming enterprises), the trial field (e.g. soil type, previous cropping) and the trial (e.g. drilling date, row width) using both telephone and written questionnaires. The farmers were interviewed in July or August (prior to harvest) each year to assess their views of the trial, as well as their own experimental activities and learning methods.

Prior to harvest, but when the crop was ripe (Growth stage 92 (Zadoks et al., 1974)), each farm was visited and measurements taken from four places within each variety plot. At each location weed incidence, crop height and ear numbers were measured and ears taken from 1 m2. These were subsequently threshed, grain yield, thousand grain weight (TGW) and specific weight was measured and samples taken for protein and Hagberg Falling Number (HFN) determination.Samples of grain for each variety at each site were sent to NIAB, Cambridge, for seed borne disease testing. Grain from other producers and seed merchants was also tested.

Dissemination of results was achieved with quarterly newsletters, presentations at two farm open days per year, magazine articles (EFRC publication) and telephone contact.

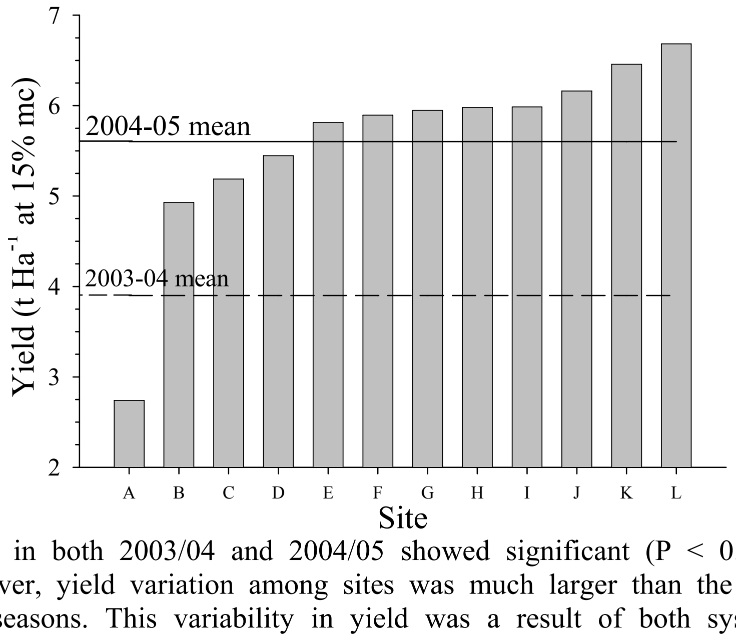
Results and discussion

Agronomic data

Grain yields

The overall average yield in 2004/05 (5.60 t ha^{-1}) was higher than in 2003/04 (3.9 t ha^{-1}) (Figure 1).

Figure 1. Average 2004/05 yields of the three varieties and mixture at each site (LSD = 0.66) and the means of all yield data in 2004/05 and 2003/04.



Yield results in both 2003/04 and 2004/05 showed significant (P < 0.05) site by variety interactions. However, yield variation among sites was much larger than the difference between varieties in both seasons. This variability in yield was a result of both system and site level interactions.

Growth habit

The results from 2003/04 revealed an East-West split across the country; the wheat in the west was shorter but higher yielding compared to the taller and lower yielding wheat in the East. In contrast, in 2004/05 the wheat grown on the western sites was significantly ($P < 0.001$) taller than those in the east (77.6 cm and 70.1 cm in the west and east, respectively), although the differences weren't as large as in 2003/04. The eastern sites also seemed to be lower yielding than the western sites, but this was due to the low yields at site A (Figure 1), which affected the overall average for the eastern sites.

Grain quality

Although there were no significant differences among the HFN results of the varieties in either year, on average HFNs were higher in 2004/05 than the previous season (Table 1). The low HFN results in 2003/04 can be attributed to the wet summer which caused grains to sprout and HFNs to drop.

Table 1. Grain quality results of varieties and the mixture in 2003/04 and 2004/05.

	HFN (s)	**Protein (%)**	**TGW (g)**	**Specific weight (kg/Hl)**
2003/04				
Hereward	245	11.8	50.3	72.9
Solstice	227	11.7	48.7	72.2
Xi 19	212	12.3	49.9	70.2
Mixture	222	12.0	50.4	72.3
Mean	**226**	**12.0**	**49.8**	**71.9**
l.s.d.	11.4	0.56	2.53	0.72
2004/05				
Hereward	240	10.2	44.8	79.5
Solstice	256	9.5	45.1	79.7
Xi 19	279	9.5	47.3	76.3
Mixture	248	9.7	45.3	78.7
Mean	**256**	**9.7**	**45.6**	**78.5**
l.s.d.	49.2	1.54	0.22	0.92

Unlike the HFN results, the average percentage protein was lower in 2004/05 than 2003/04 (Table 1). However, if the protein harvested per hectare is calculated using the yield results, it can be seen that, in fact, the yield of protein per hectare increased by 16 % (0.06 t Ha-1) between 2003/04 and 2004/05. The carbohydrate in the grain increased by a greater proportion (47 %). Therefore, it can be seen that the weather difference between years affected more the carbohydrate producing potential of the crop rather than the protein producing potential because the latter is much more dependent on available soil-bound nitrogen.

Most of the varieties in 2004/05 achieved the milling requirement for HFN (>250s) and all made the requirement for specific weight (>76 kg/Hl); an improvement on the previous season where neither of these requirements were met by any of the varieties. However, none of the varieties met the protein level required for a milling premium (>13%) in either season.

Seed borne diseases

There was no evidence that seed borne diseases occurred at higher levels in organic production, and the health status of all seed was generally good across all sites and varieties. In both years, variation among the varieties proved much smaller than the variation among sites and years. The trials confirmed, on a large scale, that the genetic variation available among a small sample of modern wheat varieties is inadequate for the variability among organic farming systems. Interestingly, all varieties proved similarly plastic in their environmental response in that, in 2003-4, the trials grouped into short, high yielding in the west and tall, low yielding in the east. This tended to the reverse in 2004-5, but, again, all varieties and the mixture responded in the same way.

Questionnaire and interview feedback

This project used one possible method for participatory research, which provided some valuable insights for future trial designs. Interviews with farmers were designed to be open discussions and also explored the farmer's own experiments and activities. By necessity, these interviews were carried out at harvest, and were thus limited by other time demands on the farmers. Better feedback could have been achieved at farmer meetings and field days, or when farmers were less busy.

The farmers who were interviewed generally considered informal discussions at farm walks and research institutions, as the most useful for gaining valuable business information. However, the turnout for events advertising this research project and related work was poor.

Farmers' views

a) Some farmers valued the variety performance data and the effects of variability, which required data from many trials under different conditions. Indeed, some pointed out that even the extended trial set that was used did not cover adequately the wide range of variables that can be expected. This underlines the need for greater and more relevant genetic variability within and between crops.

b) Farmers were requested to assess the trial plots for establishment, early and late ground cover, disease cover, the number of ears, size of ears, and straw length plus criteria of their own choosing. However, in all but one case there was a reticence to complete these assessments: farmers felt the need for greater researcher-led assistance (full sets of field assessments were carried out by researchers prior to harvest). Concern for more researcher involvement raises the questions of the understanding by farmers of the participatory approach (or of the ability of the researchers to explain it) and of the level of ownership of the project by the farmers.

It was clear in relation to this project that the 'balance of power' between farmers and researchers favoured the researchers. However, an imbalance in one direction or the other is inevitable and dependent on the nature of the project. For example, in a sister project on weed control in organic farming systems, also DEFRA-funded (Project OF0315), it was clear that for some aspects, the project was much more dependent on farmer rather than research inputs.

c) A number of farmers appreciated the detailed comparisons of the varieties in that it helped them to recognise the difficulty of trying to reconcile the appearance of varieties in the field with their final performance. This was a valuable lesson in relation to interpretation of farmer's own trials. The overall variability also helped farmers to appreciate the problems involved in trying to incorporate further new varieties into successive trials.

Researchers' views

The researchers became increasingly aware, throughout the project, of the importance of the investment of time into the participatory approach at all stages (see Methodology section). The timing of the interactions between researchers and farmers was vital; interviews must take place if possible when the workload is at a minimum. Also, the 'open' interview technique is easily disabled by interruptions. A number of farmers requested previous year's trial results prior to drilling in the subsequent year; a rapid turnaround of trial data is necessary to ensure the information is of greatest value to the grower.

Conclusions

The participation of farmers in agricultural research ensures that the outputs are of direct relevance to farmers. The level of participation can vary however (Biggs, 1995) depending upon the research objectives, and partner expectations. For the individual farmers, the data provided a reference for their own farming systems. Innate curiosity about the abilities of others has been described before as a driving factor for benchmarking in agriculture (Kragten & de Snoo, 2003).

New and valuable information, to both researchers and farmers, was produced that could not have been produced in any other way. The two years of trials demonstrated the large variability of organic systems and the difficulty in selecting a single variety suitable for organic farms. However, seed borne disease results showed that seed health status was generally high over all sites. It could also be seen that although it is possible to meet most quality requirements for milling, achieving protein quality is very difficult.

Disappointingly, the project failed to engender a sense of ownership with most of the farmers, clearly demonstrated by the disappointment in the relative contribution of researchers and the desire to have a 'standard' trial design at each site. The solution is firstly, to spend more time in introducing the project and its objectives and in discussing and developing the trial design. Secondly, it is important to recognise and recruit farmers, and researchers, who have a high willingness and ability to participate. Initial meetings should ensure that a common understanding is reached between farmers and social and field scientists. The meeting should take place at an off-peak time of year, and include inducements such as other presentations. However, the project did develop a useful set of working relationships (farmer-researcher; farmer-farmer and researcher-researcher) which should be exploited in further project development.

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The effect of growing cultivar mixtures on baking quality of organic spring wheat

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Key Words: Cultivar Mixtures, Spring Wheat, Baking Quality, Organic Farming

Abstract

Growing cultivars in mixtures is a valuable disease management practice in organic agriculture. In order to apply this in wheat for Dutch organic farmers it is important that mixing varieties in the field does not negatively influence baking quality. For four years, we have analysed yield, performance in a baking test, protein content, Zeleny-sedimentation value, Hagberg falling number and hectolitre weight of two-way and three-way mixtures of five modern spring wheat cultivars. We have found a small positive mixture effect on loaf height. Yield and the other parameters did not differ from the calculated mean of the pure-line cultivars, except for one particular combination which showed a positive effect on both yield and protein content. This involved a combination between the only variety in the trial which was susceptible to brown rust and the standard variety. Contrary to what is commonly believed among Dutch organic farmers, we found no evidence that growing varieties in mixtures has a negative influence on baking quality. It may even slightly improve quality, with yield equalling the average of the individual components.

Introduction

The beneficial effect of growing wheat cultivar mixtures on the reduction of a number of diseases is well documented (e.g. Garett & Mundt, 1999; Finckh et al., 2000, Wolfe, 2000). Besides achieving efficient disease management, producing wheat with good baking quality is also important for Dutch organic farmers. The reason for this lies in the fact that organic wheat production is only profitable when farmers receive the premium price for baking wheat. Traders determine the premium price on the basis of the parameters protein content (>11,5%), Zeleny sedimentation value (>35 ml.), Hagberg falling number (>250s.) and hectolitre weight (>76 kg.). For millers and bakers, also the baking test results are important in the assessment of baking quality.

In the literature, studies dealing with the effect of mixing cultivars on baking quality mainly look at protein content and Zeleny-sedimentation value. In Argentina, Sarandon & Sarandon (1995) found a positive mixture effect for protein content in a two-component mixture: in a proportion of 2/3 of the variety with lower protein content and 1/3 of the variety with higher protein content, when grown without fertilizer. Mixtures followed the mean of the individual components after application of 90 kg nitrogen/ha. Gallandt et al. (2001) studied six varieties and all 15 possible two-way combinations at 13 diverse locations in the USA. They concluded that the protein content in mixtures correlated well with the mean of the individual components. A French study by Mille et al. (2006) reports positive mixture effects for 3 of the 31 two-component mixtures studied, while the other 28 did not show a statistically significant difference from the mean of the individual components. In the same research project, the Zeleny-sedimentation value followed the mean of the individual components.

Dutch organic farmers experimented with wheat mixtures in the early nineties of the last century to deal with diseases such as rusts (*Puccinia recondita, Puccinia striiformis)* and Septoria leaf blotch (*Septoria tritici*). Most of them claim that mixing had a negative effect on baking quality, and therefore the majority of these farmers stopped growing mixtures. Also, Dutch traders and millers responded negatively when consulted on the baking quality of mixtures. However, farmers who still grow mixtures find a positive effect on quality.

At the beginning of our research project, in 2000, organic farmers heavily depended on only one spring wheat cultivar, Lavett. This was the only commercially available variety, which combined good performance in organic fields with a level of baking quality that was accepted by the milling industry. However, organic farmers dislike reliance on only one variety, because this makes the cropping system vulnerable to the outbreak of diseases, in the event of a breakdown of one of the cultivar's resistance genes. In this research project, we studied whether we could diminish reliance on one single variety by growing mixtures of Lavett with other commercially available varieties, without compromising on yield and baking quality. To that end, we compared the performance of the mixtures with Lavett. In addition, we analysed the question whether mixtures performed better than expected on the basis of monocrop means with respect to the individual components.

Methodology

Variety and mixture choice

The experiment was initiated upon request and in close collaboration with the farmer of the research location. He was mainly interested in continuing with the most promising varieties and combinations. For that reason each year a number of varieties and mixtures were replaced by new ones (Table 1). Also, at his request, all mixtures tested contained the cultivar Lavett. During the research period, Lavett was the only commercially available spring wheat variety suited for the production of baking wheat under organic growing conditions. In the first year, two-way and three-way combinations with Lavett and the varieties Baldus, Melon, Sunnan and Vinjett were made. In the second year, Baldus and Vinjett were replaced by Echo and Pasteur.

All varieties were classified as baking wheat in official variety tests. Melon and Pasteur were included because these were the varieties available at that time producing the highest yield. Pasteur and Sunnan were also chosen because of their high protein content. Lavett, Baldus, Vinjett, Sunnan and Echo were known to perform well in baking tests.

Table 1: Varieties and mixtures in the research.

	Year				Number of years in trial
Mixtures	2000	2001	2002	2003	
Lavett-Echo-Pasteur (LEP)				X	1
Lavett-Sunnan-Melon (LSM)	X	X	X	X	4
Lavett-Melon-Pasteur (LMP)		X	X	X	3
Lavett-Echo (LE)			X	X	2
Lavett-Pasteur (LP)			X	X	2
Lavett-Melon (LM)		X	X		2
Lavett-Echo-Melon (LEM)			X		1
Lavett-Sunnan-Pasteur (LSP)		X	X		2
Lavett-Sunnan (LS)	X	X	X		3
Lavett-Sunnan-Vinjett (LSV)	X				1
Lavett-Sunnan-Baldus (LSB)	X				1
Lavett-Baldus (LB)	X				1
Varieties					
Lavett	X	X	X	X	4
Melon	X	X	X	X	4
Pasteur		X	X	X	3
Echo			X	X	2
Sunnan	X	X	X	X	4
Baldus	X				1
Vinjett	X				1

Trial set-up

From 2000 to 2003, field trials were conducted on an arable farm which had been managed organically since 1984. The farm was situated on young fertile clay soil in Flevoland province, the Netherlands. Crop husbandry was practised in accordance with normal farmers' practice. Spring wheat plots were fertilized with 25 tons/hectare of composted cow manure in the autumn, and weeds were managed by frequent tine harrowing after sowing up to the moment of stem elongation. Onion was the pre-crop in the first three years and sugar beet in the last year.

For the experiment, a completely randomized block design was used for sowing, with two replicates in 2000, and three repetitions from 2001 onwards. Furthermore, to standardize inter-plot interference, objects were distributed in a “check board” pattern, with each object flanked by buffer plots of the standard variety. Sowing was done with farm machinery, with harvesting taking place with a field plot harvester.

Baking quality assessment

The harvested grains were analysed for protein content (with Near Infrared Reflectance), Zeleny-sedimentation value, Hagberg falling number and hectolitre weight in a milling factory, in accordance with standardized laboratory protocols. Baking tests were conducted by a test baker from a specialized organic wheat milling company. The samples were milled with a laboratory Bühler mill. Also for mixing and rising, laboratory equipment was used. The miller’s standard baking recipe was used, consisting of only whole wheat meal, yeast, salt and water. The baker also carried out the final evaluation of the results. To prevent any bias during baking and evaluation, the grain samples he received were randomly numbered. The test baker was not informed on the names of varieties and mixtures until after he had filled in his evaluation forms.

Statistical analyses

The overall performance of varieties and mixtures was compared with the variety Lavett with the help of regression analysis and calculating the probability of the differences between each object.

To test whether mixtures perform better than expected on the basis of the average mean of the individual components, the difference between the observed value and expected value was calculated for each plot and year. It was hypothesized that these differences were >0, which was tested with a t-test for all calculated differences (independent of the specific mixture) and for specific mixtures.

Results and brief discussion

How do the mixtures compare to the standard variety Lavett?

The principal requirement is good performance in a baking test, otherwise varieties will not be accepted by the milling industry. Figure 1 shows the average performance of varieties and mixtures which were tested more than one single year. Of the pure varieties, only Lavett and Echo produced an acceptable loaf of bread in a baking test. In Figure 1, the results of height measurements (in cm) are given. Echo and the Lavett-Echo mixture even outperformed Lavett. The loaf height of the other mixtures was not significantly different from Lavett. In the last three years of the research loaf volume (cm^3) was also measured. In our research loaf height correlates well with the loaf volume and so the results of loaf volume were similar to results of the height measurement. In this paper we only present height measurement data, because these cover the whole four years of research.

For protein content, Lavett scored among the lowest. Single varieties Sunnan and Pasteur outperformed Lavett, as well as the two two-way mixtures between Lavett and either Sunnan or Pasteur and the three-way mixture of these varieties. For Zeleny-sedimentation value differences between objects were low. Lavett scored among the highest and Melon and all three mixtures containing Melon scored significantly lower than Lavett.

For hectolitre weight, differences between varieties and mixtures were also small and therefore this trait will not be discussed any further here. Hagberg falling number did show differences for objects, but varieties and mixtures showed large variability for this trait. This is because Hagberg falling number is largely influenced by environment and weather. Hagberg falling number can have a negative influence on baking quality, but only when it drops below a certain threshold level (about 200 seconds). All samples remained above this threshold and therefore Hagberg falling number did not influence the results of the baking test. Due to its variability, this trait will also be left out of the discussion here.

The varieties Pasteur and Melon outperformed Lavett for yield, while Echo and Sunnan produced significantly less. Pasteur also gave a better yield than all the mixtures. The differences for yield between mixtures and Lavett were not statistically significant.

These results show that bread made from mixtures is just as good as the best baking variety in the mixture, despite the presence of components with inferior baking quality. This suggests that for loaf height there is a mixture effect: i.e. that cultivars grown in a mixture perform better that the average of the individual components when grown in a monocrop. This will be analysed further in the next paragraph. The results in Figure 1 indicate that for the other parameters - yield, protein content and Zeleny-sedimentation value – performance of most of the mixtures equals the mean of pure-line cultivars. Whether this is actually the case will also be analysed further in the following paragraphs.

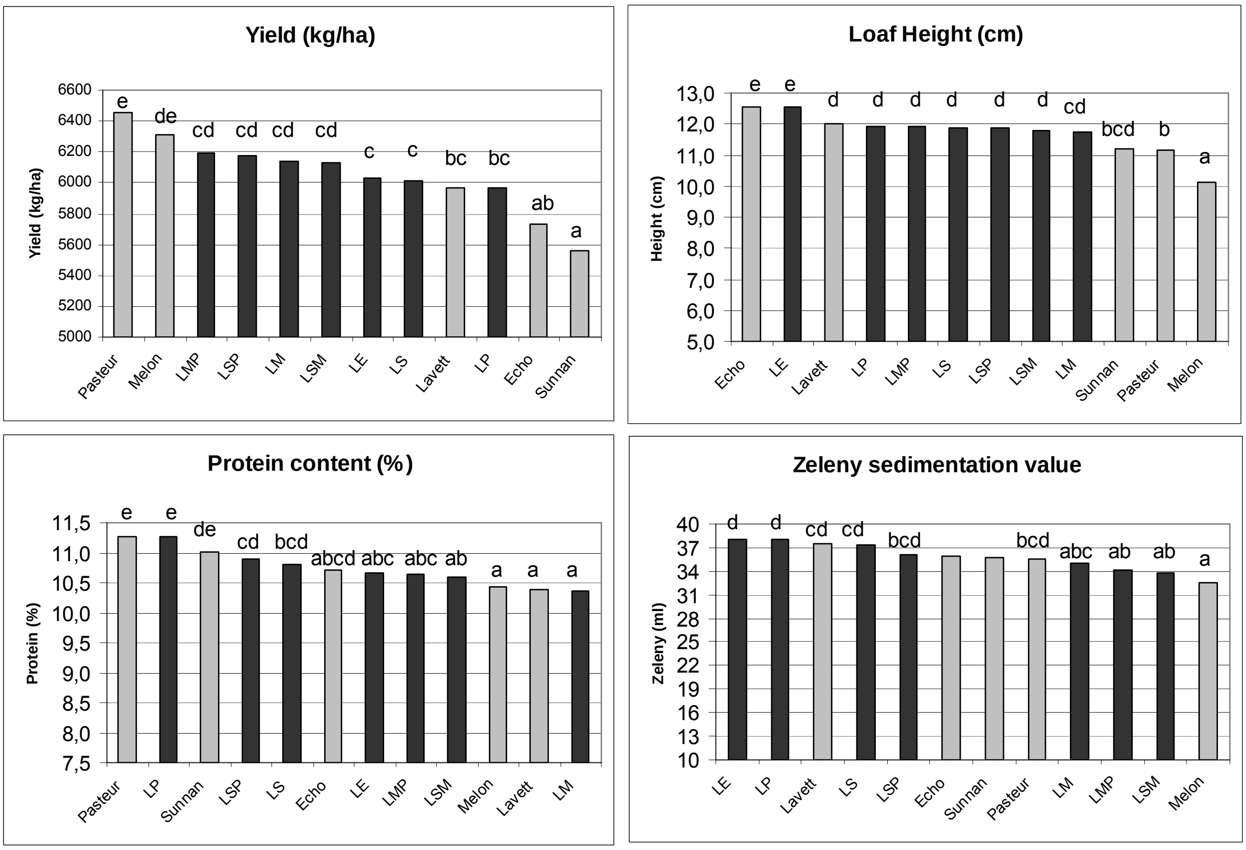

Figure 1: Differences in yield, loaf height, protein content en Zeleny sedimentation value between mixtures and cultivars (when letters above the bars are different, differences are statistically significant p<0.05)

How does mixture performance compare to the average of its pure-line components?

Due to the fact that the yearly baking tests were not carried out in repetitions, the dataset was too small to test performance statistically for each individual mixture. However, the pooled data of all mixtures of all years show that 21 of the 23 samples tested performed better than the average mean of the individual components. The mean difference of 0,5 cm (an increase of 4,4% of the mean loaf height) was significantly different from 0 (t-test; P=0,95) (Figure 2).

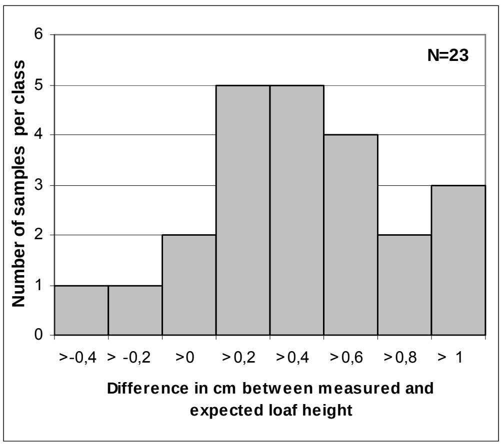

Figure 2: Distribution of the difference (in cm) between measured loaf height and expected loaf height, based on the mean of the individual components

The above analysis does not take differences between years into account. We found a bigger mixture effect in the first two years of the research project than in the last two years (Table 2). These differences cannot easily be explained. The set of varieties and mixtures changed from year to year and the measured effect obviously varies with the varieties in the trial. However, this does not offer a complete explanation, because the Lavett-Sunnan-Melon mixture - which was tested for four years - showed a similar decrease for loaf height as in the table. Another difference between the first and last two years is that latter two were relatively hot years. The year 2003 was especially hot during a prolonged period in July/August. Recent research at Wageningen University shows that baking quality of Lavett in particular is susceptible to heat stress. Indeed, in 2003 Lavett performed well in the baking test, but relatively less well than in the other years. Thus, heat stress may well be an explanation for the disappointing results in 2003.

Table 2: Difference between years for the mixture effect on loaf height

Year	Mixture effect for Loaf Height (% of mean loaf height)
2000	+5,9%
2001	+5,9%
2002	+3,9%
2003	+1,4%

For yield, protein content and Zeleny-sedimentation value, the dataset was large enough to test whether individual mixtures showed a positive mixture effect. Only the Lavett-Echo mixture performed better than expected on the basis of the individual pure line components for both yield and protein content. Echo is an older variety which is susceptible to both brown rust and lodging. Indeed, we found a suppression of brown rust in the mixtures (unpublished data). This would probably explain the mixture effect for yield and protein content. Also, lodging was suppressed in the mixtures, which may also be an explanation for the mixture effect. However, this is less likely than the susceptibility to brown rust, because lodging in the pure stand of Echo was not strong enough to cause yield loss.

Performance of the other mixtures for yield, protein content and Zeleny-sedimentation value was equal to the mean of the individual varieties.

Conclusions

In baking tests, mixtures of the five cultivars studied in this research project performed better than the mean of the individual components. This mixture effect was small - an average 4,4% increase in loaf heigth - and varied over the years.

For yield, protein content and Zeleny-sedimentation value, mixture performance was equal to the mean of the pure-line components. Nevertheless, there was one exception. The mixture of Lavett and Echo showed a positive effect for both yield and protein content. Echo was the only variety which was susceptible to brown rust as well as lodging. Our research shows that mixing is an effective management practice against both problems.

Differences in hectolitre weight between varieties and mixtures were small, and therefore the effect on mixing could not be analysed for this trait. The effect on Hagberg falling number was also impossible to calculate because this trait showed high variability between years. This parameter only negatively influences baking quality when it falls below 200s. None of the harvested samples came below this value, and so the Hagberg falling number did not influence performance in the baking trials.

These results show that the currently available spring wheat varieties can be grown in mixtures, without a negative effect on baking quality and yield. In most cases, mixing even results in slight improvements in bread quality.

Acknowledgements

Mr. L. Kruit, organic farmer, inspired the author to conduct this research project, offered his farm as a research site, nursed the crops and collaborated in the research set-up. Mr. M. Krijger of Krijger Molenaars analysed the harvested grain and Mr H. Donker and C. Pool of BD Graan were involved in the baking tests. The students F. Schaap and D. Kroeze helped in gathering data as part of their thesis research. For this article, Mrs S. Burgers, statistician of Biometris-WUR, collaborated in the analysis of the data. Finally, Mrs. L. Kuipers of Taalcentrum-VU improved the English text. The author wishes to thank all of them.

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Values of organic producers: results of a focus group study in Switzerland

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Key Words: organic producers' values and motives, organic farming principles, value conflicts

Abstract

The article summarises eight focus group discussions, conducted in 2004 and 2005, about values among established and recently converted organic producers (mountain and lowland area) and other stakeholders in Switzerland. The analysis identifies positive and negative first associations with the term 'organic', background and the motives for conversion of organic producers and the range of values held.

The discussions covered personal values as well as those that the participants consider to be important for the sector as a whole, with particular attention to all the possible meanings associated with them and related value conflicts between organic and societal values. In the analysis the values were contrasted with the four new principles of organic production of IFOAM (International Federation of Organic Agriculture Movements). Ecological sustainability (economic, environmental, and social) and recycling were a strong and dominant issue among Swiss organic producers, related to the principle of ecology. The maintenance of soil fertility is perceived differently by newly converted farmers (soil conservation) then by experienced ones (soil fertility). The concept of a healthy ecosystem (soil, plant, animal, human beings) was considered very important, whereas landscape conservation and plant biodiversity were more relevant, especially to mountain farmers. Fair trading conditions were seen for many participants as a core issue. The producers did see a secure livelihood, the maintenance of their family farm and the farm succession as well as major issues.

The major conflicts were seen to arise from conventionalization and globalisation of the organic agriculture sector. Many farmers were against an industrialisation of agriculture and against a too strong commercialisation of their products. Another central discussion point was the overregulation and inspection: standard/rules should be more comprehensive and the inspection work less bureaucratic. The results are contrasted with other findings, in particular with other surveys on the values of organic consumers.

Introduction

The recent development of organic agriculture is characterised by fast growth, large-scale production, involvement of large conventional companies, and global trade. This fast growth may threaten the effectiveness of organic agriculture to function as an alternative, a more sustainable development path and as a source of inspiration for mainstream agriculture and for the development of environmental and rural development policies. There is, therefore, renewed interest in values and principles that can guide the future development of organic farming.

In Switzerland organic farming has a long tradition, starting with the first Swiss biodynamic farm, founded in 1928, followed by Minna Hofstetter, who started to publish on organic gardening. After the Second World War, Hans and Marie Müller developed the bioorganic movement, working together with the soil scientist Hanspeter Rusch. They helped to establish the first farmers' marketing cooperative in 1946. By the 1970's, farming practices similar to modern organic farming had evolved (Vogt, 2000). In 1980, five regional organic farmers' organizations decided to adopt common guidelines for organic production. Today, these are known as the standards of BIO SUISSE, the umbrella organisation of all organic farmers' organizations in Switzerland. Over the last ten years, the number of organic farms has increased almost five-fold, but growth is currently stagnating at only 2.3% per year. In early 2005, 11.2% of farms were organic (6,420 farms) on 10.5% of the land area (112,000 ha). The majority of these farms is in the mountains and hills. These farms produce milk and meat, while fruit, berry, vegetable and wine production are under-represented due to production difficulties. The average size of organic farms is still small at between 15 and 20 ha, although there is a strong tendency to grow. The Swiss Federal Government has supported organic farming with direct payments since 1993. Organic farmers achieve price premia of 20% to 100% compared to conventional farm products. Together with the subsidies, this results in incomes for organic farmers similar to those of conventional farmers (Rudmann and Willer, 2005).

One of the first sociological studies of motives for conversion was carried out in Switzerland. Fischer interviewed 100 pioneer organic farmers in 1982 and concludes that although the motives and opinions of organic farmers varied considerably, they shared common basic characteristics. Decisions by farmers to change to an organic system were motivated principally as follows: *i.* external factors, such as negative experiences in applying conventional methods, disease in humans and animals on the farm, and contacts with successful organic farmers; *ii.* internal factors, such as psychological predisposition, or the search for a new way of life. Fischer also notes that some of the farmers believed that organic farming systems would become widespread in a short time because of the required change of occupational consciousness. However, it appears now that economic motivation to convert has become much more important with the development of markets and conversion aid.

The focus group research study, which was conducted as part of the EU funded Organic Revision project (www.organic-revision.org, Nr. FP6-502397) aims to provide an overview of values held among organic farmers and stakeholders, as well as of similarities and differences among the various national and private organic standards.

Methodology

Five focus groups discussions, conducted from November 2004 until January 2005, were involving 36 mostly full-time producers from the German speaking part of Switzerland, representing a wide range of enterprises (livestock, arable crops, and horticultural crops) and a range of farm sizes. The farmers have mainly been recruited with assistance of regional organic farm advisors. A few farmers were also found through an article in an organic farming magazine. The groups were formed of producers who had converted their farms either before or after 1993, the year when nationwide grants were introduced in Switzerland, established and newly converted organic farmers accordingly. In the mountain area, one group came from a village, which converted in an early stage as a whole cheese cooperative to organic farming. A sixth group included the staff of the nationwide umbrella association of the producer organisations and logo owner (Bio Suisse), and a seventh consisted of agricultural university students, who were relatively new to the subject of organic farming. The pre-test was held among the staff of the research institute for organic farming, FiBL in Frick.

There was a common discussion guide for the focus group meetings. The discussion started with the warm-up phase, in which participants were asked to write down a few keywords to identify positive and negative associations with the term ‘organic’. The discussion continued with participants’ own ‘organic farming history’, which means with their personal motivation for organic agriculture. This led on to a discussion of values important for the organic sector, potential value-conflicts, and prospective values of organic farming in the future. Each focus group was fully recorded and transcribed. The transcripts were coded using a common codebook. The values were contrasted with those represented in the four new IFOAM Principles of Organic Agriculture, which were recently approved by the IFOAM General Assembly.

Results and brief discussion

First association with the term ‘organic’

In total there were mentioned: 160 positive associations split into 45 different keywords and 133 negative associations split into 46 different keywords. The following table summarises the main positive and negative associations.

Table 1 Spontaneous association of the Swiss focus groups with the term „organic”

Spontaneous association	Prio-rity	In which of the 8 groups was this relevant?
Negative associations		
- Too many rules, too bureaucratic	1	All
- More labour, high workload	2	All, mainly farmers lowland area
- „Conventional „ market development	3	Mainly farmers
- Decreasing or insufficient trust	3	Mainly students
- Too high selling price for consumers	3	Mainly students, partly all groups but less in mountain farmers groups
- problematic crop inputs (e.g. copper)	3	Mainly students and mountain farmers
Positive associations		
- Health, product quality	1	All groups, mainly early converters and students
- Natural farming	2	Mountain farmers, experts BIO SUISSE and students
- Quality of life, professional pride	2	All groups, hardly by mountain farmers
- Animal welfare	2	All groups, mainly students and experienced mountain farmers
- No synthetic crop inputs	3	Mainly students and farmers from lowland area
- Careful soil management	3	All groups except established/early converted farmers in mountain area
- Sustainability	3	All groups, mainly experts from BIO SUISSE
- Closed (nutrient) circles	3	Experienced farmers, mountain farmers, students

Priority ranking: highest 1: > 15 associations; high 2: 10-14 associations; medium 3 6-9 associations.

The own 'organic history' and further development

Personal motives were predominant like personal conviction, the guarantee for the origin of the self-produced food, and doubts about the conventional agriculture. These motives were less predominant for mountain farmers. Furthermore mainly early converters were very much influenced by the personality of pioneer farmers.

The health of the ecosystem was seen as important and fundamental, mainly from farmers in lowland area which recently converted and from stakeholders such as experts of Bio Suisse and students. Related to this issue were often mentioned the healthy environment (the circle of "healthy soil – healthy plants – healthy animals – healthy humans") as well as the ecological sustainability:

> *„My personal consciousness told me that I cannot go on with a lot of spraying and afterwards eating the residues of it." (Established mountain farmer).*

Social justice and fair conditions were mentioned mainly by mountain farmers. It was mentioned several times that it is important to build up another relationship, a „social quality", between consumers and the market partners, which is relying on fairness, trade relationships which are socially just and trust as well as a common comprehension.

Organic farming was and still is seen as a strategy to survive and a possibility to earn a living, mainly by mountain farmers. The direct payments and the better prices were seen as very helpful to improve or at least maintain the farm income.

For mountain farmers it was generally a rather small step to convert to organic farming with little investments as they have farmed already rather naturally.

Mainly farmers in the lowland area mentioned professional pride and meant that to convert to organic farming was a new challenge for them.

Health and product quality were mainly important for lowland farmers and students. Here the focus was mainly on the production of high quality food without harmful residues.

Range of values collected and prioritized

The values mentioned in each group and the results of the "voting" in three groups are summarized in table 2. The values are grouped following the four proposed principles of organic agriculture by IFOAM, but include other terms covered by the producers that were included as own headings in previous drafts of IFOAM principles.

Table 2 Motives and Values and their importance as voted by the participants (3 votes per person)

	CH 1 cF, LL	**CH 2 eF, LL**	**CH 3 eF, LL**	**CH 4 cF, M**	**CH5 eF, M**	**CH 6, P**	**CH 7 St**	**CH 8 R**
Principle of ***health***								
Health in general		**3**	**3**		**3**			x
Food quality		x					**5**	
Human health			x					x
Healthy food	2							
Principle of ***ecology***								
Use of renewable resources							**4**	
Ecosystem health						x	1	
Ecological sustainability	**4**		**6**		**4**	**7**	**6**	2
Lower energy use							2	
Bio-diversity promotion				**4**	x			1
Landscape diversity				**3**	1			
Cycling principle		x		1	x			
Principle of ***fairness***								
Social sustainability			**4**					x
Economic sustainability			**3**					
Fair direct payments				1				
Rural employment				**3**				x
Family farm				**8**				
Livelihood		1			**5**			
Social justice						**3**	2	x
Fair price		1			2			x
Self-reliance/Independence	x	1	1					x
Principle of ***care, precaution***								
Avoidance of residues								x

Where cF stands for converting Farmers, LL for Low Land area, eF for established Farmers, M for Mountain area; P for Bio Suisse experts, St for Student, R for researchers (pre-test). Numbers show how often this value/motive was did get on of the 3 priority points, x this issue was discussed, but did not get a priority point.

We can see that for converting farmers the ecological principle (Bio-diversity promotion and ecological sustainability) is an important motive, although "the farm should be managed in such a way to sustain a family economically" (Converting mountain farmer). On the other hand for established farmers health, biodiversity, livelihood and ecological sustainability represent also important values.

Organic values and IFOAM principles

In the majority of the discussion groups the principle of cycling and recycling was discussed. The aspects mentioned dealt with the cycling approach and animal management within the farm, with closed nutrient cycles ("*Sustainability in organic farming means closing the cycles*", male researcher) and with the use of resources. However some experts from BIO SUISSE complained about the way some farmers practice organic farming: producers seem to ignore basic ecological principles.

Genetic diversity and landscape diversity was mainly mentioned by mountain farmers and researchers. Other issues such as mixed farming or minimising the use of energy however were not mentioned. Only recent converted farmers from the mountain area mentioned the maintenance of old varieties as a motivation for organic farming. To newly converting mountain farmers species richness is very important and in particular diversity means better/nicer meadows for the cattle. One newly converted farmer underlined the effect of landscape amenities on tourism: "*Tourists can enjoy uncontaminated flora of the Alps*". The main issues were the cycling principle and for mountain farmers biodiversity and landscape amenity in particular with regard to tourism.

Generally the principle of care was not often mentioned. Taking care of nature was however the most occurring issue within this principle, whilst avoidance of residues was slightly mentioned. GMO was not a major issue. The most important link was made between care and taking responsibility for future generations. Respect and protection of nature are attributes linked to this surveyed value. This is corresponding with the sustainability concept. The use of synthetic chemicals interferes with food quality (residues) and was seen as negative. Only for established organic farmers soil fertility was a major issue. One remarked his concern and his sense of responsibility towards long term soil fertility, as individual motive for converting his farm. The conservation of stable and better soil structures was seen as important for a sustainable preservation of the environment from the newly converted farmers.

In general, sustainability involves all three major dimensions of the society, which are economic, social and ecological, which according to one participant's statement should be kept and developed together. It is "*strategically successful to keep the three dimensions togethe*r" when farming organically (established mountain farmer). Several participants from almost all group sessions recalled the concept of picturing organic agriculture as a whole (holistic principle). For instance one farmer described organic cereal production as involving/implying "*healthy soil, healthy animals and healthy food*" (established mountain farmer).

All major fairness value dimensions have been mentioned in the majority of the groups; in particular securing farm income has been very largely discussed and articulated as three main issues (farm income, price, subsidies). Among the reasons for converting there is the financial motive. To earn adequately with farming was the main and strongest motive for converting to organic farming. In the mountain area in particular it represents a chance to survive as a farmer. For established organic farmers farming organically does not seem to give any guarantee for a secure existence. Similarly some newly converted organic farmers expressed the need to complement the family income with a second job (e.g. as bus driver), although being satisfied with the farm activity. On the size of the farm both groups of farmers seem to agree that farms becoming larger succeed in reaching higher production outcome at a higher price, in this way organic farming seems to assure a more stable income (established organic farmers). Several established low land farmers underline that conversion to organic was often stimulated by better price, rather than by conviction: "*Pioneers of organic farming have started for ideological reasons. They had neither better prices nor direct payments. They just said that it must be possible to farm otherwise*" (newly converted farmer).

Newly converted organic farmers showed more hope for more price fairness: "*In order to guarantee a fair income for the farm, so that the family can live with and develop farm activities as well, the price should be fair and represent real production and processing costs charged to farmers*" (newly converted farmer).

The third issue concerning fairness and livelihood deals with the availability of subsidies. This is seen as controversial, since subsidies are necessary, but they should also be distributed in accordance to real farmed land and to real needs.

For farmers of all groups to keep on farming over generations was an important issue. Telling about his personal history into organic, one established mountain farmer underlines that his convincement was transferred by the father who was a pioneer in organic horticulture. For the son now farming organically is the only imaginable way and motivation for farming.

Conflicts and synergies

More positive interactions were found then conflicts (e.g. a healthy soil is promoting healthy animals). Conflicts were mainly seen interfering from outside, between the values of organic agriculture and societal values and less inside the organic agriculture movement.

The majority of farmers in the discussion groups see the main threat for the organic movement mainly as result of the current world-wide economic development. This does result in more centralization in a globalized market, higher price pressure and cost-efficiency, bigger and more anonymous trade structures (with stronger dependency from powerful buyers). The (re)cycling principle or fair prices are getting more difficult to achieve.

Another external conflict was seen between the consumer behaviour and the values of organic agriculture: the current trends with regard to the consumer lifestyle and eating habits, in particular the trends to more convenience food and fast food as well as the trend to cheap or discount price, makes it difficult to maintain a high product quality profile for organic produce and fair prices.

Other external conflicts mentioned dealt with food miles in contrast with the ecological principle; the burden stemming from inspection and certification which conflicts with the social principles.

On the other hand as internal conflicts participants identified the three dimensions of sustainability: the necessity of an economic sustainability leads to a stronger specialisation; larger farm structures bring a higher workload, which conflicts with the social sustainability as well as with the cycling principle (opening of nutrient cycles) and/or with the ecology principle (reduction of biodiversity on farms). The main conflict between ecology and organic farming values is that the diversification of the production raises the labour burden.

General conflicts with organic values deal with the decision whether to specialize and thus reduce the workload or to diversify the production (and thus have more income sources). The globalisation enters in conflict with the respect of natural growth and the product attribute of seasonality that is much valued by consumers of organic food products.

Conclusions

Almost all participants were engaged in organic agriculture based on a certain believe or because they just like organic farming. Not only farmers had strong concerns with regard to the current development. The discussion about the basic values and the over-arching principles of organic agriculture were seen as very positive and a move in the right direction.

Fair trading conditions were seen for many participants as a core issue. The producers did see the maintenance of their family farm and the farm succession as major issue. Many farmers were against an industrialisation of agriculture and against a too strong commercialisation of their products. Several farmers and several groups mentioned the problem of the lack of solidarity between farmers. Solidarity should get more importance in the future. Several farmers wished that there will be better cooperation between farmers and market actors as well as a better common strategy with a clear concept. Financial sustainability (maintaining income) is important to many producers, but should not dominate over all other values. Facing conventionalization of organic sector and bureaucracy, the survey revealed the need for more cooperation and solidarity, for better communication and for the reflection about the political role of organic agriculture in the future.

The four IFOAM principles of fairness, health, ecology and precaution appeared to be met by the values of organic Swiss farmers. The results are contrasted with other findings, in particular with other surveys on the values of organic consumers. Further details see http://www.organic-revision.org/values/D21.html (Padel, 2005).

Acknowledgement

The authors of this paper are very grateful to the European Commission and the Swiss Government for funding this research work. Furthermore the authors thank to Mrs. Susanne Padel from the University of Aberystwyth/Wales for developing the guidelines for the focus group discussions and the final cross-country report in the EU Organic Revision project and for giving feedback to the article.

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Grain quality characters in complex mixtures of soft wheat and acknowledgement by farmers and distillers

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Key Words: Wheat Mixtures, grain quality, whisky distilling

Abstract

Six wheat varieties, 15 four-component and 6 five-component mixtures were included in a trial harvested in 2004. There was little disease observed and the mean yield of the six varieties did not differ significantly between fungicide treated and untreated plots. For untreated plots, the mean yield of the 4-component mixtures was significantly higher than that of the varieties, but there was no further increase observed in the 5-component mixtures. Spirit yields were predicted from protein and extract data and there were differences between varieties, with Consort giving the highest value. No significant differences were observed, however, between the means of the varieties and the mixtures, from either treated or untreated plots. There were no differences between the varieties for starch content, but, for turbidity, Consort had the highest levels. This did not, however, have a significant effect on complex mixtures as there were no significant differences between mixtures for turbidity. Treated plots were, however, higher than untreated for starch content and turbidity in 4- and 5-component mixtures. Complex mixtures may increase field yield with no adverse effect on distilling quality and thus provide an opportunity to extend the commercial life of good distilling varieties or to include mixture components, with high spirit yields, that have not been recommended as individual varieties for agronomic reasons.

Introduction

Around 90% of Scotch whisky is sold in the form of blends between malt and grain whisky, of which the latter forms the larger component. Consequently, grain distilleries produce nearly 60% of Scotch whisky and also distil neutral alcohol, which forms the basis of beverages such as gin and vodka. In the initial stages of the distilling process, cereal starch is degraded enzymically (for Scotch whisky, the enzymes must be from the malted barley that is included in the mash) and the sugars produced are fermented by yeast.

From the 1980s, wheat replaced maize as the cereal of choice, largely for economic reasons. Soft wheat varieties are preferred, for ease of processing, and the variety Riband was used extensively as it gave a higher yield of alcohol, per tonne of grain, than other varieties. Swanston *et al.* (2005) assessed the use of 3-component mixtures for distilling and were able to obtain good combinations of grain and spirit yield. These authors also reported that a mixture had been successfully incorporated into a batch of grain distilled commercially.

Until 2003, only 4 varieties were accepted by distillers, so choice of mixture components was limited. The addition of 2 further varieties to the UK Recommended List (HGCA, 2003) therefore made it possible to consider more complex mixtures to determine whether the improvements in yield and disease resistance, observed in barley with increased component number (Newton *et al*. 1997), would also be obtained in wheat.

Methodology

The 6 wheat varieties Riband, Claire, Consort, Deben, Wizard and Robigus were included in a trial sown at the Scottish Crop Research Institute (SCRI) Dundee in October 2003 and harvested in September 2004. Also included were all 15 four-component and 6 five-component mixtures possible from these varieties. Each entry was replicated six times with three replicates receiving a fungicide treatment, to protect against foliar pathogens, and the other three replicates untreated. Plot dimensions were as previously described (Swanston *et al*. 2005).

Following harvest, grain was dried and plot yields were corrected to 12% moisture content. Samples were cleaned and grain retained by a 2.2mm sieve was used for subsequent analysis. Protein and hot water extracts were determined as described by Swanston *et al.* (2005) with spirit yield then predicted using the formula developed by these authors. Starch content was determined by an enzymic method (McCleary *et al.* 1994) and turbidity (a measure of the starch released into suspension) measured as described by Koliatsou & Palmer (2003) with the modifications noted by Swanston & Smith (2006).

Results and Discussion

Very little disease occurred in the trial and there was no significant difference between treated and untreated plots for yield (Table 1). There were differences between varieties with Riband Robigus and Wizard giving the highest yields and Claire the lowest. In the previous season, Riband had given lower yields than Deben when untreated and had not significantly outyielded Claire (Swanston *et al*. 2005), so there was a change in yield rankings between seasons. For the mixtures, there were no significant differences for yield, either between treatments or between mixtures. The mean yield of all the 4-component mixtures was higher than the mean yield of all the varieties, although only significantly so for the untreated plots (Fig. 1). The 5-component mixtures did not, however, show an additional yield increase in this trial, in contrast to results observed previously in barley (Newton *et al*. 1997).

Table 1. Analysis of variance for yield and quality characters in six varieties of wheat

Between		**MS**				
	Df	**Plot Yield**	**Protein**	**Extract**	**Starch**	**Turbidity**
Reps	2	0.22	0.47	4.35	38.26	0.00
Genotypes	5	0.48***	1.62*	15.32	20.03	47.38**
Treatments	1	0.22	0.39	2.14	15.44	1.16
Gen.xTreat.	5	0.05	0.13	16.77	24.73	4.92
Residual	22	0.06	0.48	12.11	23.71	14.59
Total	35					

* - significant at the 5% level, ** significant at the 1% level, *** significant at the 0.1% level

There were significant differences between varieties for protein content, but not extract (Table 1) and there were no differences between treatments for either character. Consort and Wizard had the lowest protein levels, with Consort predicted to give the highest spirit yield. There were no significant differences between the mixtures for either protein or extract. However, in the 4-component mixtures there was a slight increase in protein and a significant increase in extract between treated and untreated plots. Small increases in treated compared to untreated were also observed in the 5-component mixtures, although, in this case, it was the protein results that were statistically significant. There were, however, no significant differences in predicted spirit yields, between the means of the varieties and the means of the mixtures, either treated or untreated (Fig.2).

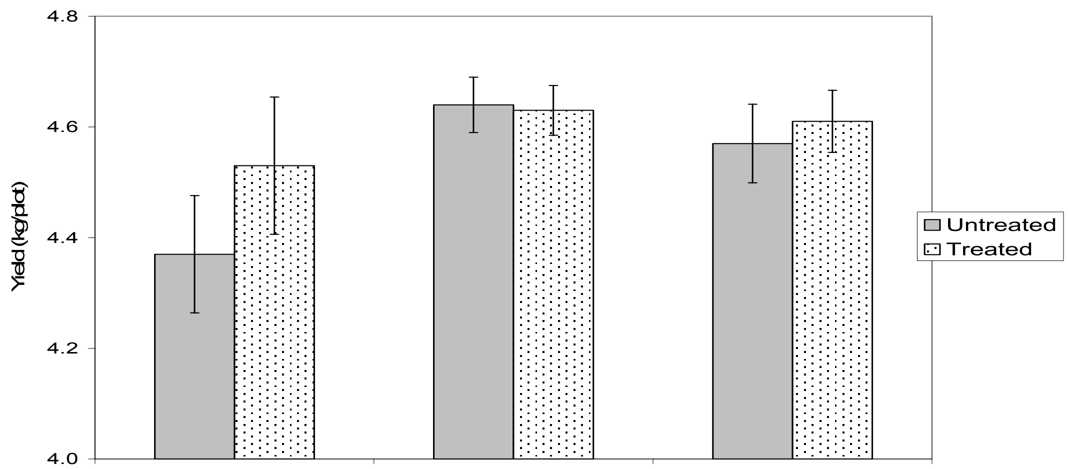

Fig. 1. Mean plot yields of varieties, 4-way and 5-way mixtures, with and without fungicide

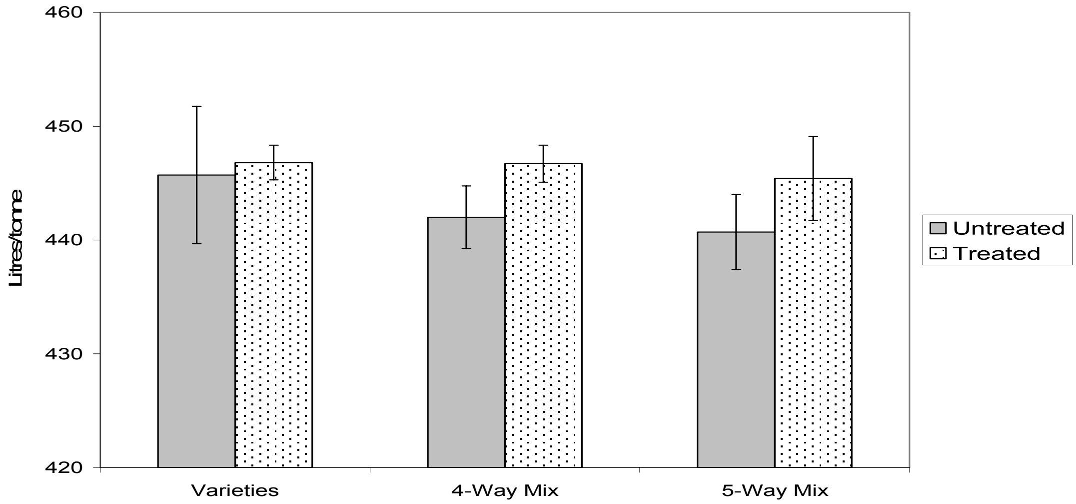

Fig. 2. Mean predicted spirit yields (litres/tonne) of varieties, 4-way and 5-way mixtures, with and without fungicide

For the varieties, there were no significant differences between treatments for either starch content or turbidity, but there were differences between varieties for turbidity (Table 1). Consort had the highest turbidity, with Robigus the lowest. For the 4-component mixtures, there were significant differences between treatments for both characters (Table 2), while, for the 5-component mixtures, there were slight differences between treatments for turbidity and higher, significant differences for starch content. Although neither character was shown to correlate closely with spirit yield over a range of varieties and environments, high values may be valuable attributes in certain varieties (Swanston *et al.* in press). Fungicide treatment may delay leaf senescence and thus increase the duration of grain filling, even in the absence of disease, so this could account for differences in grain composition, between treated and untreated mixtures. However, it would also be expected to result in increases in grain size and yield as observed in 2003 (Swanston *et al*, 2005).

Table 2. Mean values of treated and untreated 4- and 5-component mixtures for starch and turbidity. Values indicated by a different letter are significantly different at the 5% level.

Mixture Type	**Turbidity (arbitrary units)**		**Starch (%)**	
	Treated	Untreated	Treated	Untreated
4-Component	61.5[a]	58.1[b]	67.8[a]	64.1[b]
5-Component	60.5[ab]	58.9[b]	67.7[a]	64.1[b]

Distillers are prepared to accept wheat mixtures so long as they are made up from accredited seed and produce grain with acceptable specific weights (Baxter, *pers. commun.*), but a more positive encouragement of mixtures could bring advantages to both distillers and growers. Soft wheat varieties entered into Recommended List Trial in the UK are assessed for distilling quality, but varieties are merely listed for suitability, with no ratings or data provided. The distilling industry moved from maize largely because wheat was considerably less expensive, although maize was a superior raw material (Walker, 1986). Cost is thus a major factor and it is unlikely that distillers will pay premium prices, to justify farmers growing the best distilling varieties if they have lower yields or other agronomic problems, such as weak straw or disease susceptibility.

Conclusions

The capacity exists to incorporate wheat varieties with highest spirit yields, but with agronomic problems, into mixtures, where the other components will compensate for their weaknesses. This would also permit the commercial life of varieties to be extended or varieties not achieving recommended status to be utilised in agriculture. Slight differences in quality between mixture components appear to have little effect in wheat (Jackson & Wennig, 1997), (Swanston *et al*, 2005) compared to malting barley, so the distilling quality should not be compromised. In addition, the inclusion of a larger number of components should increase yield and may, therefore, dilute grain protein composition. This would give an additional enhancement of distilling quality due to the strong negative correlation between spirit yield and grain nitrogen (Riffkin *et al* 1990).

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Baking quality of variety mixtures of organic wheat and acknowledgement by farmers and millers in Germany

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Key words: variety mixtures, baking wheat, baking quality, organic farming

Abstract

Using mixtures can give you the option of improving baking quality, yield stability or yield. Another strategy of improving baking quality is transferring the millers' knowledge of "fitting" varieties to the farmers. But we don't know whether this will work with many important varieties in organic agriculture having well-balanced quality on high level.

Introduction

Deficiency of nitrogen causes lower contents of protein, celeny, gluten and baking volume in baking wheat under organic standards in Germany. So the most important problem for organic farmers and millers is to get sufficient baking quality. Although general strategies for the production of baking wheat (sawing time, density, rotation) are followed results are often not satisfactory. Using variety mixtures could be one step to improve or stabilize baking quality. Although basic principles of mixtures (available varieties, maturities, at least three varieties, in some cases two varieties) should be followed the expected result is different to other crops. Improving yield is less important because yield and baking quality are in a negative correlation. The more important expectations are:

- improving quality, especially baking volume
- improving quality stability compared to the theoretical average
- improving yield stability compared to the theoretical average
- being able to use varieties which have a "flaw" (yield, quality, disease acceptability, low weed suppression, lodging)
- occupying a place in relation of yield and quality which is not occupied by another important variety.

Methodology

13 organic variety trials 2003 - 2005, exact, small scale (12 m²)

Results

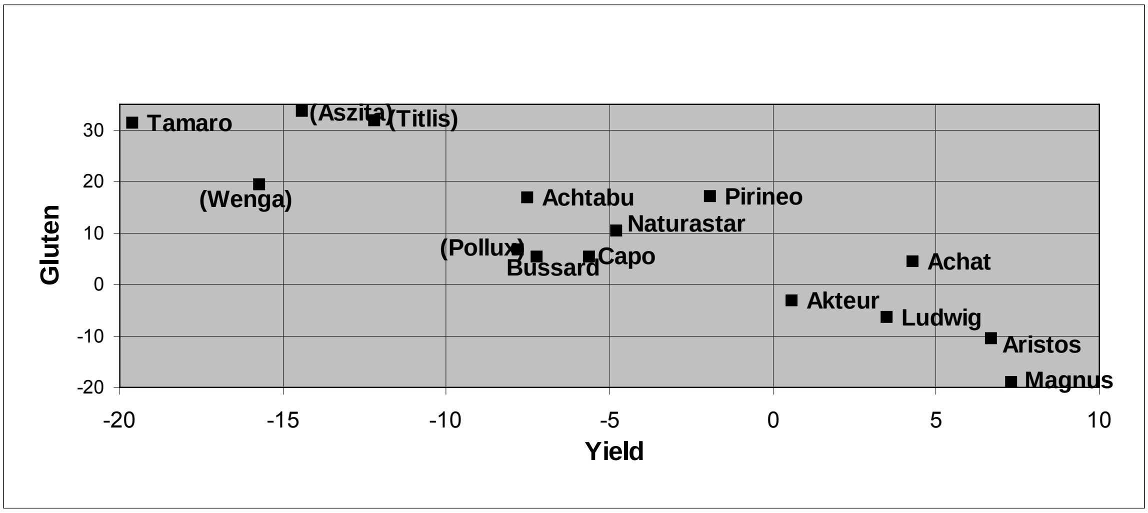
The winter wheat variety mixture Achat + Tamaro + Bussard (Vogt-Kaute, 2003 – 2005) shows a positive influence mixture effect on gluten (1,9%), falling number (1,9%) and baking volume (1,5%). The influence on yield, protein and celeny is neutral or negative.

Table 1 Winter wheat variety mixture AchTaBu

	Yield rel %	Protein %	Celeny	Falling number	Gluten %	Baking volume ml
AchTaBu	94,6	11,6	33,5	320	27,2	676
Theor. Average	94,7	11,6	38,2	314	26,7	666
Difference in %	- 0,1	0,0	- 9,7	+ 1,9	+ 1,9	+ 1,5

Yield stability is increased, but quality stability is not increased. The three relatively similar components themselves show a high stability which is difficult to enhance. A reason why stability does not improve could be the lower stability of the mixture Achat + Tamaro without Bussard. Bussard seems to be necessary as a "re-stabilization". The fact that a AchTaBu-mixture is successful under German organic condition is that a place regarding yield and quality that is not occupied by another variety can be established.

Table 2 Yield and quality (gluten) of important wheat varieties in Southern Germany 2001-2005 (varieties in brackets are tested but not available, Pirineo only 3 results)



The AchTaBu-mixture with its high quality component Tamaro realizes an increase of 2 – 3 percent of gluten compared to the standard organic baking wheat varieties Capo, Bussaard, Achat and Naturastar without loosing yield. The AchTabu-mixture is grown commercially on about 500 ha organic land and is the most successful baking wheat variety mixture in Germany at the moment. Some farmers with good experience with AchTaBu- mixture have begun to develop their own mixtures.

Testing 6 different mixtures Völkel (2005) also showed the strongest effect on gluten and baking volume.

Other trials (Finckh 2003, France 2004) using very different varieties or using varieties with disease problems showed higher effects on yield than on quality.

There is a tradition of using variety mixtures in wheat in some countries. The Austrian strategy of registration as one variety in the 70s and 80s (Perlo, Amadeus) is probably not legal under EU-rules anymore. Swiss advisers recommend variety mixtures - probably because of disease aspects.

There is a good knowledge in conventional mills in Germany for mixing varieties inside mill. The purpose is to be able to buy cheaper varieties of lower quality classes. The baking volume of the mixture is higher than the theoretical average mixing a good quality variety with hard gluten to a bad quality variety with soft gluten. Only one trial was made under organic conditions (Apel, 1992). Baking volume could even be increased above the level of the high quality component. In the 90s this result could not be transferred into organic farms because of several reasons.

- Knowledge of varieties was still low,
- mills only could use the best quality varieties because of lower protein level
- the well known "fitting" varieties did not show their higher yield under organic conditions so it wasn't economically interesting for an organic farmer to produce them.

But why not transferring the knowledge from the mills to the farmers now and let the farmers produce mixtures? The mills would have to fulfill some conditions and would be difficult to find. They have to be interested in a quality strategy farmers participate in.

The good effects of mixtures shown could have some limits. They were shown under quite low baking volume levels. Can they be repeated on higher levels and with high quality varieties? This could be more difficult because many good quality varieties show well-balanced baking quality themselves.

Conclusion

There are some good results with variety mixtures for improving baking quality of organic wheat. There seems to be a tendency that a mixture of more different varieties tends to a higher yield but not to a higher quality. Several results with mixtures composed for improving baking quality show a positive mixture effect on gluten and baking volume between 1 and 6%. But is this sufficient for the millers' expectations? Or do we have to find better mixtures?

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Essai réalisé par Arvalis / Institut du Végétal à Pludual (22) en 2004 : Etude des variétés de blé en conduite biologique

Topic I

Growing variety mixtures

Papers or abstracts are based on posters presented at the workshop. They are listed in alphabetical order of first author which is not necessarily the presenting author. At first is presented the introduction by the poster moderator.

Growing variety mixtures: Introduction

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Keywords: variety mixture, weeds, yield, diseases, cereals, pure lines, populations, conventional, organic

Abstract

This paper introduces Topic 1, Growing variety mixtures, followed by brief comments on the seven presentations that constitute this session. Taken together, the posters indicate the current broadening of interest in variety mixtures, both geographically and in terms of the aspects being studied. Nevertheless, the most frequent positive gains are still found in relation to the delay in epidemic progress in disease in mixtures. Currently this is the most useful aspect for application in conventional agriculture to help reduce the use of oil-based inputs over a wide range of cereal species. In organic agriculture, where disease is generally less of a problem, there is interest in mixtures for more general application including, for example, weed competition and improved nutrient use efficiency. However, more general use of mixtures in agriculture will need a better understanding of, and more information on, the specific and general mixing ability of available varieties and, ideally, the introduction of more relevant varieties and populations. Such understanding should help in the future design of appropriate mixtures.

More generally, it is important to recognise, for practical application, that pure lines, mixtures and segregating populations represent a range of useful tools which could be used in various combinations, depending on availability and need.

Introduction

a) Historical

The concept of variety mixtures tends still to be regarded as something novel. However, this is true only in the restricted sense that 'varieties', bred by man for use in agriculture, are new. If we think of variety mixtures as combinations of self-pollinating genotypes, then it is highly likely that this is the way in which most cereal species evolved, both prior to, and following, domestication. Large stands of non-domesticated cereals are generally found to consist of numerous patches of mixed genotypes, where each patch represents an ecosystem which may differ in only small and subtle ways from its neighbours. This principle was common throughout agriculture until roughly one hundred years ago. Even Charles Darwin, in the Origin of Species, noted how farmers commonly grew variety mixtures because of their better performance than single varieties, and that there was experimental proof for this:

> *'It has been experimentally proved that if a plot of ground be sown with one species of grass, and a similar plot be sown with several distinct genera of grasses, a greater number of plants and a greater weight of dry herbage can thus be raised.' (Charles Darwin: 'The Origin of Species by Means of Natural Selection' ch.4).*

Darwin's studies, of course, formed a major basis for the revolution in the understanding of evolution and genetics, which in turn led to the major advances in plant breeding, led, for example, by scientists such as Sir Rowland Biffen in the early part of the twentieth century. These pioneering studies led to the development of pure line variety breeding – with varieties of the major cereals that could be relied upon to breed true in each generation. Initially, this was seen by breeders and others as a way of protecting farmers. If they bought seed of one of the newly selected varieties, they, the farmers, could be guaranteed that the variety would appear and perform in exactly the same way in each field and every year.

The appeal of this almost mechanical biological system led to the development of an increasingly complex bureaucratic and legal system for registering and maintaining pure line varieties. More recently, this provided the opportunity for a new initiative from the breeders, to develop the idea of Plant Breeder's Rights and the notion of charging royalties for seed of pure-bred varieties. In this way, the system developed from one with a main objective of protecting farmers, to one that, arguably, now has a main function of protecting breeders. This shift in emphasis has made it more difficult, over the years, to move away from large-scale monoculture of single, pure line varieties.

During this period, the area cultivated with different forms of variety and species mixture in cereals declined steadily, particularly in the more developed countries. More recently, the same process accelerated rapidly in the less developed countries, particularly following the 'Green Revolution'.

A parallel change occurred in plant science: early in the twentieth century, there was considerable interest in the production of species mixtures, but this was replaced rapidly by the influence of the rapid advances in modern plant breeding. By the middle of the century, there were very few cereal scientists working with variety or species mixtures, the notable exceptions including, for example, Artie Browning and Ken Frey at Iowa State University. In the 1950's and 60's they developed a particular interest in oat 'multilines', the idea of producing a series of lines that were all identical except for differences in genes for resistance to crown rust. In other words, a multiline variety would look and behave like a modern true breeding monoculture, except in relation to crown rust, where the diversity of resistance genes would delay the development of the disease epidemic.

Other small scale studies were also being undertaken, but, at the end of the 1960s, I had the good fortune to be joined by John Barrett, an evolutionary geneticist. Our interest developed in both fundamental and field studies of barley variety mixtures, using pure line varieties that differed for many characters including disease resistance (and included early discussions with Hanne Østergård). The concept was taken up commercially in the UK at the end of the 1970s. Initially the farmed area of mixtures of barley and wheat increased exponentially until the amount of harvested grain grew to an amount that began to be noticed by the maltsters and millers. These end-users would not buy mixtures and so commercialisation failed. Meanwhile, the German Democratic Republic took up the idea of barley variety mixtures from the work at Cambridge and developed a large scale application – 350,000 ha of malting barley, which represented the whole of the spring barley crop by the end of the 1980s. However, in this case, pathologists, breeders and maltsters all worked together to ensure that the mixtures grown by farmers were both disease resistant and acceptable for malting. This proved highly successful – until the Berlin Wall came down!

During this whole period, another American scientist, Chris Mundt, who had been a Ph D student of Artie Browning, also developed many valuable lines of study both in the science and in the application of variety mixtures. This was achieved to a large extent through other PhD students, one of whom was Prof. Maria Finckh.

b) The current work on variety mixtures

Now we are seeing a broadening of the concept, with different groups looking at a wider range of the effects of mixtures and of populations. This is developing under both conventional and organic conditions, which is helping to deepen our understanding of plant-plant interactions under varying environments. This is exemplified by this morning's programme with four different sessions looking at the biological value of diversity within crops, against the predominant trend of the twentieth century. The reasons for starting this new trend were sound biological and ecological arguments. However, the pressure to move in this direction is now increasing because of rising oil prices, which are causing large increases in the prices of oil-based inputs, together with global climate change which increases the need for crops that are able to withstand large and unexpected variations in weather and climate. In other words, there is an increasing need to replace and improve technological control of the crop environment by naturally occurring biological mechanisms, which we are only just beginning to understand and exploit.

Brief comments on the seven presentations

Husked and naked oat varieties and mixtures for organic farming systems. H. Jones et al.

The set of two-way mixtures allowed some assessment of the mixing ability of different component varieties. The variety Expression appeared to be both the highest yielder and the best mixer. Was this because it suppressed other varieties in mixtures, leading to a higher average yield? Or was it because it was highly competitive with itself so that in mixtures it was able to yield even more than in pure stand? Scott Phillips (EFRC, 2004) found a similar case in potato, where the variety Cara had high general mixing ability because individual plants of Cara yielded more if they were grown apart from each other. Again this was in an experiment with two-way mixtures, useful for testing for mixing ability.

Evaluation of spring barley cultivar mixtures in Ireland. R. Hackett et al.

Different complexities of mixture were used in this study, organised in a simplex design which could be valuable also for other studies on mixing ability among different varieties.

Cultivar mixtures in Spanish durum wheat. F. Martinezet al and *Results of traits with mixture of cereals. G. Vasilevski et al.*

Two general comments were made. The first was that it was good to see work on variety mixtures being expanded to Spain and Macedonia. The second concerned the small plot sizes used in the two studies, which could affect the results obtained. It is certainly possible to use small plots, but it is particularly important that they should be surrounded by a relatively large 'guard' area. For example, work by Jenkyn at Rothamsted in the 1970's looked at spatial effects on plots. The field trials compared a 'conventional' trial design with all plots neighbouring each other, against an 'exploded trial', where the plots were well separated and each was surrounded by another species. Jenkyn found that the plots performed significantly better for disease delay and yield in the 'exploded trial' which better simulated a series of separate fields. Similarly, Scott Phillips (EFRC 2004) showed, with potato, that arranging the same total area of four varieties as a large number of small plots delayed blight development compared with different layouts with larger plots. In other words, there is a strong tendency for inter-plot interactions among neighbouring small plots even without the use of variety mixtures.

Does root development of component varieties play a significant role for yield of the mixtures? N.-O. Bertholdsson et al. and *Designed mixtures of barley varieties – influence on weeds. U. Didon et al.*

These presentations were related to each other and to the earlier presentations on competition and mixing ability. The first, on root and shoot development, provided an intriguing insight into the importance of the earliest stages of development in relation to final field performance of varieties. The second poster carried this concept through into the area of competition with weeds. The two presentations raise the fascinating question of the degree of self-competition among the plants of a single variety and the extent to which this may or not be related to the ability of those plants to compete with plants of the same (mixtures) or different, species (weeds). Particularly in the latter case there is the added dimension of allelopathy, but this could even be problematic in variety mixtures.

Meta-analysis is a powerful tool to summarize variety mixture effects - exemplified by grain yield and weed suppression of spring barley. L. Kiær et al.

The final presentation described the first stages of a new project which promised to be very interesting in utilising large amounts of existing data to search for new insights into the performance of variety mixtures relative to their components.

Two summary points related to general questions. The first was the question of whether or not we should be growing mixtures. The answer may be related to the agricultural system. In conventional production, there is an increasing value in designing mixtures for disease control (and possibly weed control) because of the increasing prices of pesticides. The change from monoculture to simple variety mixtures is relatively straightforward provided the question of quality can be taken care of, as discussed in earlier sessions. The answer for organic production may be somewhat different, partly because disease is less important and partly because the required genetic variation and adapted varieties are not available. This is why our own programme is now focussing on the development of composite cross populations.

The second summary point relates to our attitudes as scientists, who often think in categories for convenience and clarity. In this case, I am thinking of the classes of pure lines, mixtures and segregating populations. For practical purposes, we should not be rigid in our categorisations, particularly where there are limitations within those categories. So, for example, there could be situations where effective cropping may be achieved by mixing seed of a small number of productive pure lines into a relevant segregating population to provide a range of genetic variation appropriate to a range of organic farms.

Does root development of component varieties play a significant role for yield of the mixtures?

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Key Words: Organic Farming, roots, grain yield stability, spring barley

Abstract

The knowledge how to select varieties for the mixtures is still rather limited in general and for root traits in particular. Should root development be accounted for when making mixtures? To answer this question field data and early growth data of roots and shoots from 6 barley 3-component variety mixtures and their components have been compared. The data used comprise of grain yield results from 20 organic and conventional trials during 4 years and root length, root-and shoot weight of 14 days old plants grown in hydroponics.

In pure varieties there were positive relationships between grain yield and root weight, grain yield and shoot weight and grain yield and root length. There were similar positive relationships between the grain yield and the mean of the component varieties root weight, shoot weight and root length in the variety mixtures. The regression coefficients were, however, much higher in mixtures than in pure lines indicating some special features of mixtures relative to pure lines in the relation to the early vigour traits. A stability parameter calculated as the mean square deviation from the highest yield showed that the mixtures were more stable than most of the pure varieties. There were a positive relationships between yield stability and root length, root weight or shoot weight, even if not significant. There were also a tendency of positive relationships between the mixture effects, i.e. the differences in yield between mixtures and the mean yield of the component varieties, and the variance in shoot or root growth of the components varieties.

It is concluded that varieties in general should have high early root-and shoot growth (early vigour), but in mixtures, early root and shoot growth should differ to some extent between the component varieties.

Acknowledgements

The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas), The Danish Research Centre for Organic Farming (DARCOF) and the project members of BAR-OF.

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Designed mixtures of barley cultivars – influence on weeds

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Key Words: Cultivar mixtures, weed competition, barley cultivars

Abstract

A greenhouse trial was performed to investigate whether mixtures of barley cultivars could suppress weeds better than barley grown in pure stands, and whether the weed suppressive effect differed between the mixtures. Three barley cultivars (Hydrogen, Henni, Thetford) were grown as pure lines, all possible two-cultivar blends and one three-cultivar blend. The barley cultivars chosen were selected because they differ in three specific characteristics, namely allelopathic activity, root length development and shoot length in the first growth stages. Two weed species, *Brassica rapa* cv. Agat and *Lolium perenne* cv. Helmer, were chosen as the model weed flora. The experiment was run until the barley cultivars reached the beginning of the ear emergence stage.

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

Introduction

Cereal cultivar mixtures have so far been studied mainly in relation to their influence on control of single diseases and mostly under high-input farming conditions. The potential weed suppressive ability of a mixture is essential for the yield and yield stability of the crop. In cultivar mixtures, the interactions between the crop plants based on their competitive ability interfere with their ability to compete with weeds. The way in which cultivars should be selected to simultaneously interact positively with each other while also outcompeting weeds is unclear. If there is complementarity between cultivars in a mixture, this may result in reduced levels of intraspecific competition, increasing the opportunities for individuals to perform well and to compete better together against weeds as a plant stand.

The aim of this study was to investigate whether mixtures of barley cultivars could suppress weeds better than barley grown in pure stands, and whether the weed suppressive effect differed between the mixtures.

Methodology

The experiment was carried out in 35 cm x 45 cm boxes in a greenhouse, with three two-rowed spring barley (*Hordeum vulgare* ssp. *vulgare* L.) cultivars grown as pure lines, all possible two-cultivar blends and one three-cultivar blend. The barley cultivars used (Hydrogen, Henni, Thetford) were chosen because they differ in three different characteristics, allelopathic activity, root length development and shoot length in the first growth stages. These cultivars have been investigated previously in the Danish project BAR-OF (Characteristics of Spring Barley Varieties for Organic Farming) funded by FØJO/DARCOF (Østergård & Jensen, 2005). The varieties have also been tested for allelopathic activity and root and shoot length of 14-day seedlings (Nils-Ove Bertholdsson, Svalöv Weibull AB, Sweden, unpublished). Cv. Hydrogen has high allelopathic activity, medium root development and low shoot development. Cv. Henni also has high allelopathic activity but rapid root development and low shoot development, while cv. Thetford was chosen because of its low allelopathic activity, medium root development but high shoot development. Two weed species, turnip rape (*Brassica rapa* cv. Agat) and perennial ryegrass (*Lolium perenne* cv. Helmer), were chosen as the model weed flora. The experiment was run until the barley cultivars reached the beginning of the ear emergence stage. At harvest the barley, ryegrass and turnip rape plants were counted, cut at ground level, dried and weighed. The vegetative and reproductive parts of the turnip rape plants were weighed separately. To avoid edge effects, no plants were taken from the outer 5 cm of the boxes.

Competitive effect (CE) of barley on weed biomass was calculated as: CE = 1 – (ZB/ Z), where ZB and Z represent the biomass when the weeds were grown with and without the barley cultivars, respectively. Competitive response (CR) of crop biomass was calculated as: CR = 1 – (Yw/ Y), where Yw and Y represent the biomass when the barley cultivars were grown with and without weeds, respectively (Goldberg & Landa, 1991).

Results and brief discussion

The cultivar mixture with cvs. Hydrogen and Thetford (HyTh) had the greatest competitive effect (CE) against the weed biomass, while cv. Hydrogen grown in pure line had the lowest CE. The HyTh mixture had also the lowest amount of reproductive parts of turnip rape plants compared to the other mixtures and pure lines. The mixture with all three cultivars did not increase the CE compared to the mixtures with two cultivars. The weed suppressive ability increased when two cultivars (HyTh) with contrasting characteristics in allelopathic activity and shoot development were combined. The mixture HyHe, with cultivars that differ in root development, did not increase the weed suppressive ability. This could be due to both Hydrogen and Henni also having low shoot development and thus lower CE.

The competitive response (CR) of the crop biomass was lowest for cv. Hydrogen and greatest for cv. Thetford. Cv. Thetford showed a greater decrease in the aboveground biomass in the presence of weeds than when grown in mixture with Hydrogen (HyTh) or the mixture with all three cvs. (HyHeTh), as shown by a higher CR value. The mixture of cv. Thetford and cv. Hydrogen (HyTh) was not so influenced by competition from the weed flora compared to the mixture cv. Thetford and cv. Henni (HeTh), as shown by a lower CR for HyTh than for HeTh. As in the case of CE, the mixture with contrasting characteristics in allelopathic activity and shoot development strengthened the barley plant stand resistance against the weed flora.

Conclusions

The result indicate that the competitive effect on the weed flora biomass was dependent on the composition of the barley cultivar mixture. There was also a tendency for a higher competitive effect on weeds of mixtures compared to pure stands of barley cultivars, but this depended on the combination of cultivars present in the mixture. Contrasting characteristics between the cultivars as regards allelopathic activity and shoot development increased the competitive effect. The weed suppressive effect also differed between the mixtures. A mixture where both cultivars had low shoot development and high allelopathic activity but contrasting root development decreased the weed suppressive effect.

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Evaluation of spring barley cultivar mixtures in Ireland

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Key Words: Spring barley, cultivar mixtures, simplex design.

Abstract

In Ireland most cereals are grown using single cultivar stands. Cultivar mixtures can have advantages over crop monocultures. Much of the work to date on cultivar mixtures has focused on the benefits of cultivars mixtures in terms of reductions in disease. The aim of this project is to determine if yield benefits can be obtained by using cultivar mixtures of spring barley under Irish conditions in the absence of disease effects. In 2005 two, three and five-way mixtures of six cultivars varying in height and to a lesser extent in crop maturity were grown and maintained free of significant levels of disease using fungicides. Three levels of fertiliser N and seeding density were used to simulate different environmental conditions. A novel experimental design was used that allowed the number of plots required to be kept to manageable numbers. In general there was no significant positive effect on grain yield detected. The work is continuing in 2006.

Introduction

Most of cereals in Ireland are produced using single cultivar stands with high levels of inputs. However, single cultivar stands can be subject to significant variation in yield as a result of abiotic (i.e. light and nutrient conditions) and biotic stresses (i.e. pathogens). Some studies have shown that mixtures of cereal possess some advantages over cultivar monocultures. Increasing crop genetic diversity can reduce fungal disease levels (Mundt *et al.,* 1994), increase yield (Newton *et al.,* 1997) or produce greater yield stability over seasons (Bowden et al., 2001). Using cultivar mixtures to increase the stability and efficiency of cereal cropping systems is a potential method of reducing synthetic input requirements of current cropping systems.

Much of the work to date on cultivar mixtures has concentrated on their effects on fungal disease and consequent yield benefits (Finckh et al., 2000). However cultivar mixtures may exploit above- and/or below-ground resources more efficiently than cultivar monocultures which could lead to increased yields in the absence of disease effects or reduce the requirements for fertiliser inputs. In order to out-yield a single cultivar stand, it is likely that component cultivars of a mixture must be sufficiently different in their resource requirements or ability to withstand stresses (biotic and abiotic) in order to be complementary. A key requirement in formulating successful cultivar mixtures is correct choice of component cultivars. However cultivar mixtures to date have been formulated largely on an ad-hoc basis and criteria for selecting suitable components of mixtures are lacking. Little work has been carried out on determining the characteristics component cultivars should have in a successful mixture. The objectives of this study are to determine whether cultivar mixtures are advantageous in terms of yield in the absence of fungal disease under Irish conditions. Initial work has focused on varying canopy structure within mixtures to determine if yield benefits can be obtained.

A simplex design which is an experimental design that allows testing for synergism and antagonism among multiple species is being used (Cornell, 1990). This design is similar to functional response curve designs of competition experiments and can address multispecies interactions as well as two – species interactions. Contrary to previous designs addressing the relationship between species diversity and ecosystem function, it takes into consideration the initial abundance of species in the species mixtures. Initial abundance can influence species performance in mixtures considerably (Connolly et al., 2001), and is therefore an important factor in species interactions. This design can reduce the number of field plots normally required when working with cultivar mixtures.

Methodology

An experiment was planted at the Crops Research Centre Carlow, Ireland in April 2005 that included six cultivars of spring barley (Riviera, Lux, Cocktail, Frontier Westminister and Doyen). The experiment was designed to give detailed information on mixtures of Riviera (tall-strawed), Cocktail (medium-strawed) and Lux (short-strawed) and less detailed information on mixtures containing Westminster, Frontier and Doyen. A simplex experimental design was used. The structure of the experimental treatments is outlined in Table 1.

Three seed rates (200, 350 and 500 seeds/m^2) and three fertiliser nitrogen levels (80, 120 and 160 kg N/ha) were included to simulate different crop structures and environments. For mixtures and monocultures including Westminster, Doyen or Frontier the high seed rate and high fertiliser N rate were not used.

Three applications of fungicides were made to prevent fungal diseases from becoming established in the crop. Herbicides and insecticides were applied according to standard farm practice. Grain yield was measured at harvest.

Table 1. Structure of treatments used to examine spring barley mixtures at Oak Park in 2005.

Crop type	Proportions	Repetitions	No. plots
Mixtures and monocultures that included only Riviera, Cocktail, Lux			
Monoculture	100	3 x 3 seed rates x 3 N rates x 3 replications	81
2-way mixture	50:50	3 x 3 seed rates x 3 N rates	27
3-way mixture	33:33:33	1 x 3 seed rates x 3 N rates x 3 replications	27
	45:45:10	3 x 3 seed rates x 3 N rates	27
	80:10:10	3 x 3 seed rates x 3 N rates	27
Additional mixtures and monocultures including Westminster, Doyen or Frontier			
Monoculture	100	3 x 2 seed rates x 2 N rates x 2 replications	36
3-way mixture	33:33:33	19 x 2 seed rates x 2 N rates	76
5-way mixture	20:20:20:20:20	6 x 2 seed rates x 2 N rates x 2 replications	48

Results and brief discussion

There was generally no significant grain yield benefit from the use of mixtures compared to the mean of the component monocultures. One mixture did exhibit a tendency to outyield the mean of its component cultivars and is being further investigated. However only a limited range of cultivars was used in this experiment and it was a single site experiment.

Conclusions

Initial work indicates that in the absence of disease effects there was no effect on yield from using cultivar mixtures of spring barley under Irish conditions. However only one seasons work has been completed and only a limited number of cultivars were included in the work.

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Husked and naked oat varieties and mixtures for organic farming systems

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Key Words: Oat, organic, husked varieties, naked varieties, sustainable

Abstract

Old oat varieties performed well, and in some cases out-yielded newer varieties in trials of naked and husked oats under organic conditions. In the first year of trials, variety height was found to be an important characteristic for oats grown under organic conditions; tall oat varieties out-yielded the dwarfs. This effect is likely to have been the result of taller plants having an increased ability to compete against weeds.

A comparison between the husked and naked varieties revealed that husked varieties had relatively higher yields; this may have been the result of poor establishment in the naked varieties. This data will be verified in the second year of replicated trials for harvest 2006, which will include the best performing husked and naked varieties, and a mixture of superior IGER-bred F2 breeding lines.

Introduction

Plant breeding involving the incorporation of phenotypic assessments with molecular marker technologies is likely to enable more effective, targeted selection of traits for crop breeding programmes. However, these key traits from varietal selection do depend upon the end market.

The OatLINK project focuses on varietal selection based on characteristics that are suitable for: human consumption; livestock feed; and more sustainable production system including organic agriculture.

This paper discusses the results of the first year of trials that aim to identify and evaluate important traits of existing and novel oat varieties for organic production.

Methodology

Two trials, one of husked, and the other naked oat varieties were established at Wakelyns Agroforestry, Suffolk, in October 2004. The husked oat trial involved 4 current varieties (Buffalo, Gerald, Kingfisher, Penderi) and 2 new varieties from IGER, Tardis and the provisionally named Brochan. The naked oat trial included 3 current varieties (Expression, Grafton, Hendon) and a new high oil variety, Racoon, along with all their two-way mixtures. Half the trial plots were then under-sown with clover in March. Twelve F2 lines supplied by IGER were also sown in small plots (1m x 1m). The trials were of a replicated split-plot design with 2.4m x 10m plots. Variety assessments included crop emergence and establishment, early crop and weed cover, pest and diseases, crop height, lodging and canopy cover, and grain yield. The grain quality analyses were carried out by IGER.

Results and brief discussion

Husked oats

The husked oat experiment established well. There was a highly significant ($P < 0.001$) difference among the varieties in the number of plants that emerged, but the number of plants that actually established did not differ (Table 1). Therefore there were differences ($P < 0.05$) in the percentage of plants that survived, with Tardis having the highest plant survival percentage, and Buffalo the lowest.
Crop ground cover in April differed ($P < 0.001$) among husked varieties (Table 1). Penderi had the lowest crop cover with only 43.5%. However, despite varieties differing in crop cover, the percentage of weed cover was not affected by variety.

Table 1. Establishment, early crop cover, height and yield of husked varieties at Wakelyns

Husked Variety	Establishment (Plants/ m^2)	Early crop cover (%)	Crop Height (cm)	Yield (t ha^{-1} @ 15%mc)
Gerald	189	50.6	82.8	8.48
Tardis	166	54.9	80.6	8.28
Penderi	164	43.5	70.4	8.19
Kingfisher	171	60.8	96.6	8.05
Brochan	177	62.3	79.8	7.78
Buffalo	184	55.6	54.6	7.53
SED (33 df)	**10.6**	**3.82**	**1.59**	**0.200**

There were significant (P < 0.001) differences in yield among the husked varieties (Table 1). Gerald and Buffalo yielded the highest and lowest, respectively, with the new variety, Tardis, doing well. However, the relative yields of the varieties could not be explained by how the varieties established or the crop cover earlier in the season, rather yields could be partially or wholly attributed to the shortness of the variety (Table 1) which affected a variety's competitiveness against weeds.

Naked oats

The naked oats took longer to emerge than the husked varieties and did not establish as well leading to fewer plants per m2 (Table 2). In contrast to the husked material, there were no differences in emergence counts between varieties or variety mixtures, but there were significant differences in the number of plants established (Table 2). However, this was not due to any significant differences in the plant survival percentage.

Table 2. Emergence, establishment, plant survival and early crop cover of naked varieties at Wakelyns

Naked variety/ mixture	Emergence (Plants/m^2)	Establishment (Plants/ m^2)	Plant survival (%)	Early crop cover (%)
Expression	132	95.3	81.1	34.5
Grafton	171	100.0	65.5	45.8
Racoon	138	95.5	72.8	49.9
Hendon	121	81.8	88.6	29.1
Grafton/ Expression	154	117.0	79.4	52.4
Expression/ Racoon	139	106.8	78.4	50.0
Hendon/ Expression	124	82.8	69.7	36.8
Hendon/ Grafton	133	96.8	74.4	41.8
Grafton/Racoon	130	92.5	74.5	51.1
Hendon/Racoon	136	87.8	65.2	39.9
SED (54 df)	**19.3**	**9.59**	**12.71**	**6.65**

Largely because of the lower emergence, the percentage ground cover of the naked oats (Table 2) was generally less than that of the husked oats (Table 1). Nevertheless, the crop cover of the naked oats did differ among varieties (P < 0.001). For example, Hendon had a particularly limited ground cover at only 29.1% (Table 2). It can also be seen that the crop cover of the variety mixtures were as high as, and usually higher, than the component varieties.

The naked varieties (Table 3) yielded less than the husked varieties (Table 1), which may have resulted from the relatively poor establishment. As with the husked oats, there were significant (P < 0.001) differences among the varieties (Table 3) with Expression the highest yielding variety. Mixtures with Expression as one of the components also performed well with two of the mixtures yielding particularly highly; Expression/950-240 and Grafton/Expression yielded 9% and 8% higher than their component varieties, respectively. However, Grafton/95-240 yielded 7% less than its component varieties.

Table 3. Heights and yields of naked varieties and mixtures, with the expected yields of the mixtures and the percentage difference to actual yields.

Variety	Crop Height (cm)	Yield (t ha^{-1} @ 15%mc)	Expected mixture yields (mean of parents)	Percentage difference to means
Expression	100.3	5.43	-	-
Grafton	98.3	4.83	-	-
Racoon	112.7	4.05	-	-
Hendon	51.2	3.84	-	-
Grafton/ Expression	101.8	5.54	5.13	108%
Expression/ Racoon	108.0	5.15	4.74	109%
Hendon/ Expression	89.4	4.51	4.63	97%
Hendon/ Grafton	82.6	4.41	4.33	102%
Grafton/ Racoon	104.9	4.13	4.44	93%
Hendon/ Racoon	96.3	3.93	3.95	99%
SED (57 df)	**3.81**	**0.303**	**-**	

Again the shortest variety, Hendon, gave the poorest yield (3.84 t ha-1). Hendon also had the lowest percentage crop cover earlier in the season (Table 3). However, relative yields were not always related to crop cover. For example, Expression had a very low crop cover early in the season but went on to be the highest yielding pure variety.

Conclusions

The husked varieties generally performed better that the naked varieties throughout the season, from establishment to final yield. The taller varieties of both husked and naked varieties generally out-yielded the dwarfs, which is likely to be the result of increased competition against weeds. New varieties, especially Tardis, also performed promisingly.

Husked varieties Gerald, Tardis and Brochan, and the 3-way mixture, and naked varieties Expression, Grafton and Racoon and their 3-way mixture are being trialled in the harvest year 2006 to verify the last season's results. A mixture of the potential new breeding lines (F2) from IGER lines is also being tested. The replicated plots will be drilled either at a medium (200 kg ha-1) or low (150 kg ha -1) seed rate; low seed rates will be under-sown with clover.

Acknowledgements

The other partners of the project are SW Seed Ltd, BOBMA, HGCA, the Roslin Institute, Bernard Matthews Ltd, British United Turkeys Ltd, the British Poultry Council, ADAS, GB Seeds and Oat Services Further information can be found at www.efrc.com or the OATLINK website, www.iger.bbsrc.ac.uk/OatLink/. This project is sponsored by Defra and SEERAD under the Sustainable Arable LINK programme.

Meta-analysis is a powerful tool to summarize variety mixture effects - exemplified by grain yield and weed suppression of spring barley

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Keywords: meta-analysis, spring barley, statistical analysis, variety mixture, weeds, yield

Abstract

In a new project, we aim to increase the general understanding of the power of meta-analysis to combine existing experimental results on variety mixtures. In this way, explanatory power can be increased compared to separate analyses and overall measures and relationships may be revealed. We will thus pursue to uncover a number of critical issues, including the relative importance of various traits and trait combinations on mixing success. To demonstrate the methods of meta-analysis applicable for variety mixture data, we considered a data set consisting of grain yield and weed ground cover assessments in 16 field trials of six 3-component variety mixtures and their components (part of the Danish BAR-OF field trials). The effects of mixing were analysed separately for each field trial and the results used in a meta-analysis in combination with their standard errors. We also analysed the mixing effects of each mixture by fitting a linear model to the entire data set. Both methods showed an overall positive mixing effect on grain yield and a trend for less weed to be found in variety mixtures. Finally, strengths and shortcomings of the methods are highlighted.

Introduction

In experimental field trials of variety mixtures, the large complexity of interactions between varieties and between varieties and the environment makes it practically impossible to control all factors in single trials, and the results often include a lot of unexplained variation. As a consequence, experimental results from one study may have low explanatory power, information on underlying interactions may be overlooked, and conclusions may ultimately be insufficient and too limited in scope.

Meta-analysis provides a range of statistical procedures to combine and compare research results in a quantitative manner. Current meta-analysis methodology derives primarily from psychology (Glass 1976) and medicine (e.g. Mann 1990), but has lately been increasingly employed within ecological research (e.g. Gurevitch *et al.* 1992; Osenberg *et al.* 1997; Curtis & Wang 1998; Goldberg *et al.* 1999; Leimu & Koricheva 2006). In meta-analysis, comparable effect measures must be calculated from the selected studies. By combining these, explanatory power is increased and overall measures and relationships might be detected. In this respect, meta-analysis may be a useful tool for summarizing the effects of mixing varieties.

In this study we demonstrate some of the meta-analysis techniques, combining individual trial data from field experiments on variety mixtures to obtain summary estimates of mixing effect, and compare the results with those of a linear model fitted to the full data set.

Methodology

We used data from 16 field trials of spring barley, including six 3-component variety mixtures and their component varieties (part of the Danish BAR-OF field trials: Østergård *et al.* 2006). The trials were distributed over 4 localities and 4 years and managed according to one of three different growing systems, roughly characterized as: A) conventional experimental field treated with herbicides and insecticides but no fungicides, industrial fertilizer; B) organic experimental field with mechanical harrowing, animal manure; C) organic experimental field, crop undersown with clover grass, no fertilizer or animal manure. In each trial, varieties and mixtures were arranged in α-design and assessed in 2-3 replicates for grain yield (hkg/ha) and weed ground cover (%; system B only).

For each variety mixture, we estimated the mixing effect with respect to yield and weed cover, respectively, by fitting a mixed linear model to the full set of data consisting of both mixtures and single varieties:

$$Y_{vtrb} = \alpha_v + E_t + F_{tr} + G_{trb} + H_{vtrb},$$

where Y_{vtrb} is the value recorded for variety v in miniblock b within replicate r of trial t. The random terms E_t, F_{tr}, and G_{trb} are assumed independent and normal distributed with zero mean and constant variances. This analysis is referred to as the full model. The mixing effects were then calculated as the contrast in yield or weed cover between a variety mixture and the average of its component varieties.

For the meta-analysis, each trial was considered as a single study, similar to the analyses of Østergård and Willas (2005). An effect of variety mixing was estimated for each mixture in each trial and used as input for the meta-analyses. A version of the described linear model without trial terms was used, and mixing effects were calculated as described above. In each meta-analysis we used a standard fixed effects meta-analysis model (Whitehead 2002), from which a combined meta-estimate of mixing effect ($\hat{\theta}$) was calculated as the weighted mean, weighting trial estimates (i = 1,…,16) by the inversed square of their standard error (w_i):

$$\hat{\theta} = \frac{\sum \hat{\theta}_i w_i}{\sum w_i}.$$

Standard errors of estimates were calculated as the square root of the inversed sum of weights:

$$se\left(\hat{\theta}\right) = \sqrt{\frac{1}{\sum w_i}}.$$

For each combination of mixture and trait, the meta-estimate was tested for equality to 0, using a chi-squared test with one degree of freedom. Further, the overall between-trial heterogeneity in mixing effect on yield and weed suppression was tested using a chi-squared test with 15 and 10 degrees of freedom, respectively (see Whitehead 2000). Also, for yield of each mixture, heterogeneity in meta-estimates among the three management systems was tested, using an ANOVA-analogue of the chi-squared test.

Results and discussion

The single trial estimates, meta-estimates, and full model estimates of mixing effect are shown in Figs. 1 and 2. In general, the estimates were positive for yield and negative for weed suppression. Thisimplies that the mixtures performed overall better than the average of their component varieties.

According to the meta-analyses, four of the six mixtures produced higher yields than the average of their components, three of them significantly (Fig. 1). Likewise, five mixtures suppressed weeds more efficiently than the average of their components, one of them significantly (Fig. 2).

There were generally only small differences between the estimates of the meta-analysis and the full model (Figs.1 and 2). However, the full model always gave less accurate estimates than the meta-analysis, as evident from the wider confidence intervals. This was likely due to dubious model assumptions of homogeneous error variance between trials, which will be reconsidered in forthcoming work.

Tests for between-trial heterogeneity of mixing effect were insignificant for all mixtures and both traits (data not shown). However, this test has low statistical power for rejecting homogeneity when there are relatively few studies or, as in the present study, when they are based on small number of replicates. Hence, in forthcoming work, a meta-analysis model will be fitted that takes into account heterogeneity due to random differences between the studies. For yield, there was a general tendency of heterogeneity in meta-estimates among the three management systems (Fig. 1).

Conclusions

Our results support the general observation that performance of a variety mixture does not simply equal the average of its components. It is also likely that the mixing effect will depend on growing system. Future meta-analyses of variety mixing effects will consider such interactions.

The statistical power of the meta-analyses was sufficiently high to reveal significant effects, despite a relatively small number of trials and considerable variation within and between these trials. The full model, on the other hand, did not fully take into account the variance structure of the data. The analysis of heterogeneity between management systems exemplifies the many useful analytical tools of meta-analysis.

A proper meta-analysis first of all depends on the quality of the data at hand and whether the included studies are representative or biased towards support of specific hypotheses (e.g. Duval & Tweedie 2000). In the effort to produce solid meta-analysis results we have initiated a close collaboration with the researchers in the COST860-SUSVAR network who study variety mixtures.

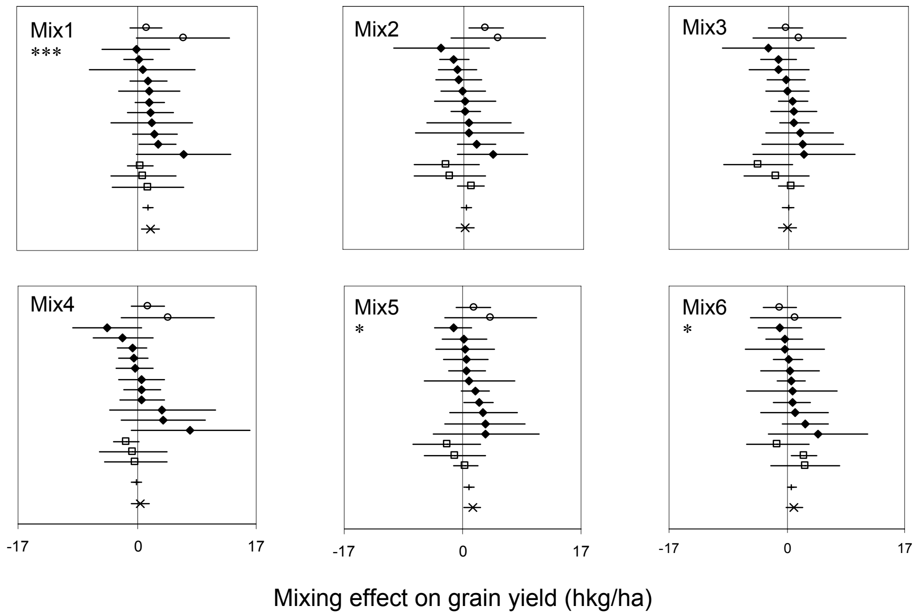

Fig. 1. Estimates of mixing effect on grain yield in variety mixture 1 to 6, including 95% confidence intervals (horizontal lines), for 2 trials of growing system A (circles), 11 trials of growing system B (diamonds), 3 trials of growing system C (squares), meta-estimate (vertical line), and full model (star). Individual trial estimates for each growing system are shown in ascending order. Meta-analysis significance levels: P < 0.05 (*) and P < 0.001 (***).

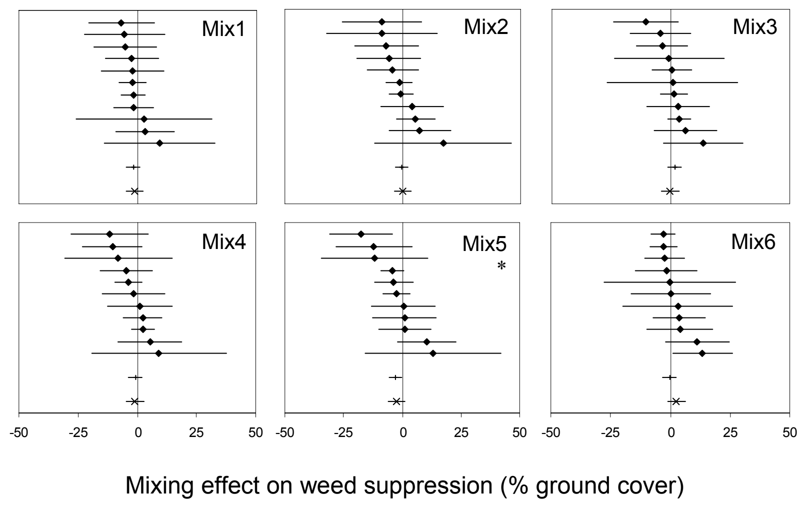

Fig. 2. Estimates of mixing effect on weed cover in variety mixture 1 to 6, including 95% confidence intervals (horizontal lines), for 11 trials of growing system B (diamonds), meta-estimate (vertical line), and full model (star). Individual trial estimates are shown in ascending order. Meta-analysis significance level: P < 0.05 (*).

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Cultivar mixtures in Spanish durum wheat

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Key Words: durum wheat, cultivar mixtures, leaf rust.

Abstract

Foliar diseases are one of the major threats in the cultivation of durum wheat in Spain. Cultivar mixtures may be an effective alternative to foliar diseases. In this experiment three four ways cultivar mixtures are compared with pure standards, being one of the mixtures composed of one resistant cultivar to leaf rust and other to powdery mildew. The reduction in this cultivar mixture was great, suggesting the high potentiality of this method.

Introduction

Andalusia, located in Southern Spain, is a region with an old tradition in cultivating cereals, even previously to the arrival of Romans. Currently, the acreage of wheat in Andalusia consists in more than 600.000 hectars, being more than 80% of them cultivated of durum wheat. The main cause for this large amount of durum wheat is the supplemental subsidy given by the European Union, to reinforce the lack of semolina produced in Europe. One of the major threat to durum wheat are the foliar diseases such as leaf rust (Puccinia triticina), septoria (Septoria tritici), and powdery mildew (Blumeria graminis f. sp. tritici). Those diseases strikes almost all cultivars being resistant varieties scarce. In 2001 a new virulent race of leaf rust showed up in Mexico, USA and Spain that affected seriously to the crop and caused great losses. Catedra (2004) estimated that a susceptible cultivar to leaf rust (and 90% of the durum wheat cultivars were in 2001-2003) could lose a third of its potential yield. The same goes true with septoria and powdery mildew. Farmers are forced to use fungicides (epoxiconazol or/and strobilurin) but in situations of low-input systems such as organic farming this is not allowed.

Cultivar mixture has been proposed as a solution to reduce the disease (Finckh et al. 2000) in low input systems. Cultivar mixture may be of great use in Andalusia to control the airborne disease but also to minimise the effect of drought. Indeed another danger we suffer is the weather. Approximately one in three years there is a more or less severe drought leading to great losses. Since the drought is unpredictable a cultivar mixture with different cultivars differing slightly in earliness may reduce the drought effects.

In this work we proposes the use of cultivar mixtures to diminish the severity of airborne diseases such as leaf rust and powdery mildew.

Methodology

Experiment consisted in field trials. Three four ways mixtures and four pure cultivars were sown in plots of 1×2 meters in three replications. Among the pure cultivars there are one that is resistant to leaf rust (cv. Colosseo) and other that is resistant to powdery mildew (cv. Don Sebastián). One of the mixtures (MD3) contained these two resistant cultivars, while the others contained susceptible cultivars. Powdery mildew infection was natural while leaf rust infection was promoted by placing inoculated plants from the greenhouse in the field. The used isolate was P. triticina “Puerto Serrano”, very virulent on durum wheat. Disease severity was taken once. It must be said that is not easy to assess the severity in a mixture composed by resistant and susceptible cultivars. We tried to calculate an average severity. For powdery mildew the assessment time was about flag leaf emission and for leaf rust was later, when the grain had just left the milky stage.

Results and discussion

When a mixture contains resistant cultivars (like MD3 containing both Colosseo and Don Sebastian) the protection increases greatly. It is just the introduction of only one resistant cultivar in four and the mixture shows a reduced severity, especially with leaf rust where the mixture displayed a severity similar to the resistant cultivar Colosseo. Respect to powdery mildew, the reduction was noticeable but not as great as with leaf rust. Cox et al. (2004) reported that mixtures were significantly more effective at reducing leaf rust than other diseases like tan spot.

Table 1. Severity of leaf rust and powdery mildew in pure cultivars and mixtures.

Characteristics	Cultivar	Leaf rust	Powdery mildew
Check mixture	MD1	21,7 ab	8.3 ab
Product. Mixture	MD2	23,3 ab	7,0 ab
Resistant mixture	MD3 (Col+D.Seb)	11,7 b	4,3 ab
Leaf rust resistant	Colosseo	4,0 b	7,0 ab
Mildew resistant	Don Sebastian	21,7 ab	1,4 b
Susceptible	Don Pedro	38,3 a	15,0 a

Conclusions

We believe than cultivar mixtures can reduce the severity of leaf rust and powdery mildew on durum wheat and, therefore, may help this crop to survive in Andalusia after withdrawal of EU subsidies or in scenarios of low input systems.

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Results of traits with mixture of cereals

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Key Words: mixture culivars, organic and conventional farming, yield, quality

Abstract

According to the COST Action 860 Project in Republic of Macedonia, various trials of cereals mixture cultivars were set up in conventional and organic farming systems. For trials where used Macedonian varieties: four variety of winter soft wheat, one of ray and one of triticale. Conventional trials were fertilized with mineral fertilizers, and herbicides for weed control. Organic farming trials were fertilized with organic fertilizer and no chemicals were used. Others agro-technique measurements where done as a standard production. The yield and some qualitative characteristics where analized by standard methods.

Pure cultivated varieties in conventional and organic production in the region of Skopje showed equal yield (5022 kg/ha). In Strumica average yield of organic farming was 2198 kg/ha or 48 % higher than in Skopje. In the mixture cultivars in conventional trials in both regions higher yield was achieved in Strumica were (5193 kg/ha), furthermore the average yield in Skopje was (4483 kg/ha). The average yield in organic trial was higher in Strumica (5493 kg/ha) than in Skopje (4883 kg/ha). The soil and climatic conditions of the regions had high influence on yielding capacity of cultivars. Under the influence of these conditions the region of Strumica has higher average yield for 644 kg/ha.

Introduction

Mixture cultivars are new way of plant production which is an expansion in the World. In Macedonia many trials with mixture cultivars were done in the past, but most of them are for forage green production, not for kernel. Traditional mixture for kernel production is corn with white been, and many years ago wheat and ray. Usefulness of this production is higher utilization of sun light, weed suspension, more efficiently utilization of nutrition’s and increasing of pest and diseases resistance. Combination of cereals with legume plants in mixture cultivars, the needs of additional nitrogen application isn’t necessary. According the programme - COST Action - SUSVAR Project in Macedonia, mixture cultivars with different cereals and varieties were set up. At the same time the trials were set up in conventional and organic production, in two regions in Macedonia, Skopje and Strumica.

The analyses of the yield and quality were done by corresponding methods.

Methodology

During the production season 2004-2005 in the regions Skopje and Strumica there were set up two trials of mixture culture with different cereals cultivars.

a. Mixture of cereals cultivars by conventional agro-technique measures with application of mineral fertilizers and pesticides “conventional production” and
b. Mixture of cereals cultivars by conventional agro-technique measures and organic fertilizer, without mineral fertilisers and pesticides “organic production”.

Trials where set up at three repetitions with 5 m2 research plots. The sowing was done with 300 kg/ha.

1. The soil preparation was done with conventional agro-technique measures up to good sowing level.
2. The conventional trial was fertilized with 300 kg/ha NPK 10:30:20, as basic fertilization and with 200 kg/ha KAN 27%, as a topdressing. For the weed control was used herbicide Dicocid.
3. The soil preparation was done with conventional agro-technique measures up to good sowing level. The fertilization was done with 20 t/ha good quality organic fertiliser. No topdressing and pesticides where used.

4. The harvest was done with experimental combine. The probes for laboratory analyses where picked up for 1 linear meter.
5. Physicals and chemicals characteristics where laboratory analysed.

At the two trials were included next varieties.

A. Mixture cultivars

1. Wheat-Mila (70 %) and ray-Pelisterka (30%).
2. Wheat-Podobrena Orovchanka (70%) and Triticale-Agrounija (30%)
3. Wheat-Lizinka (50%) and wheat-Olga (50%)

B. Pure cultivars

4. Wheat-SK-135/95
5. Wheat -Lizinka
6. Wheat -Podobrena Orovchanka
7. Wheat-Olga
8. Ray-Pelisterka
9. Triticale-Agrounija

Results and brief discussion

Resultats of the trials are presented in the tables bellow, separately for conventional and organic production.

The average yield of mixtures in both regions for all varieties and mixtures, are 4838 kg/ha at conventional and 5188 kg/ha at organic farming. The difference of 350 kg/ha is 7 % higher yield at organic farming in comparison with conventional production. Pure cultivated varieties in conventional production showed similar yield, besides that separately in the regions there are higher difference. In organic farming system mixtures showed higher difference between mixture and pure cultivars. The average yield of pure cultivated varieties in both regions and methods of production (5335 kg/ha), was higher for 1145 kg/ha in comparison wit the mixtures. The difference between conventional and organic production of mixtures in average value for both regions are 150 kg/ha, or 3 %.

The highest yield at mixture for both regions was achieved with wheat Podobrena Orovchanka and Triticale 5105 kg/ha in conventional and 4915 kg/ha in the organic farming.

The average yield for all mixtures and both regions (5188 kg/ha) was lower for 13% in comparison with pure cultivated cereals (5885 kg/ha). The average yield at organic farming in both regions was higher for 724 kg/ha (15%) in comparison with conventional production.

Table 1: Yield in conventional production system (kg/ha)

Nº	Variants	Average yield for regions		Average yield for varieties	Rang
		Skopje	Strumica		
1	**Wheat-Mila +Ray Pelisterka**	4250	5220	4735	2
2	**Wheat-Mila**	5750	4080	4915	3*
3	**Ray-Pelisterka**	3800	4400	4100	6*
4	**Wheat-P.Orovchanka+Triticale**	4650	5560	5105	1
5	**Wheat-Podobrena Orovchanka**	5450	5140	5295	1*
6	**Triticale-Agrounija**	4380	4920	4650	5*
7	**Wheat-Lizinka+Wheat-Olga**	4550	4800	4675	3
8	**Wheat-Lizinka**	4900	4880	4890	4*
9	**Wheat-Olga**	5850	4000	4925	2*
10	**Average-mixture cultivars**	4483	5193	4838	
11	**Average-pure cultivars**	5022	4550	4786	

Soil and climatic conditions influenced the average yield in both regions. Strumica region had higher yield at mixture in conventional and organic farming in comparison with Skopje. Pure cultivated varieties in region Skopje, showed the same results (5022 kg/ha), but in Strumica at organic farming the yield was 2198 kg/ha higher than conventional production.

* Pure cultivated varieties

Table 2: Yield in organic production system (kg/ha)

Nº	Variants	Average yield for regions		Average yield for varieties	Rang
		Skopje	Strumica		
1	**Wheat-Mila+Ray Pelisterka**	4300	5260	4780	3
2	**Wheat-Mila**	6100	8400	7250	1*
3	**Ray-Pelisterka**	3800	6080	4940	6*
4	**Wheat-P. Orovchanka+Triticale**	5350	4480	4915	2
5	**Wheat-Podobrena Orovchanka**	5400	6640	6020	3*
6	**Triticale-Agrounija**	4180	5950	5065	5*
7	**Wheat-Lizinka+Wheat-Olga**	5000	6740	5870	1
8	**Wheat-Lizinka**	4800	6340	5570	4*
9	**Wheat-Olga**	5850	7080	6465	2*
10	**Average-mixture cultivars**	4883	5493	5188	
11	**Average-pure cultivars**	5022	6748	5885	

The highest yield in mixture culture organic farming was achieved with two wheat varieties (5870 kg/ha), which is higher in comparison with other mixtures. It is 19% higher from the mixture wheat+triticale, respectively it is 23% higher from the mixture wheat+ray.

The average yield for both regions, for mixture (5188 kg/ha) was lower for 13% in comparison with pure cultivated cereals (5885 kg/ha).

Table 3: Average results for regions and system of production (kg/ha)

Nº	Variants	Average yield for regions		Difference	Total average yield for two methods
		Skopje	Strumica		
1	**Average-mixture cultivars**	4683	5343	660	5013
2	**Average-pure cultivars**	5022	5649	627	5335
3	**Average for region**	4852	5496	644	5174

The total average yield for all varieties, regions and methods of production (5174 kg/ha) showed us that chosen Macedonian cereals varieties for trials are with good yielding capacity. The region of Strumica showed higher yield for 644 kg/ha or 13 % in comparison with Skopje. Pure cultivated varieties in Strumica have had higher yield 627 kg/ha or 12 % in comparison with Skopje. Mixture cultivars shoved less average yield than pure cultivated varieties for 322 kg/ha or 6 %.

Differences in the qualitative characteristics at two systems of production and regions are visible.

Table 4: Quality of kernels in conventional production system

Nº	Variants	Skopje				Strumica			
		Moisture	Proteins	Starch	Wet gluten	Moisture	Proteins	Starch	Wet gluten
1	**Wheat-Mila + Ray Pelisterka**	13.6	14.9	52.8	36.5	11.2	15.3	54.8	34.7
2	**Mila**	13.5	13.4	56.3	32.9	10.3	11.2	60.5	24.8
3	**Ray Pelisterka**	13.1	14.8	52.1	36.3	11.6	14.0	55.4	31.9
4	**Wheat-Podobrena Orovchanka+ Triticale**	13.3	14.9	54.6	35.4	10.6	13.8	57.5	32.6
5	**Podobrena Orovchanka**	13.2	14.9	55.4	35.1	10.2	12.4	59.7	29.4
6	**Triticale**	13.4	14.8	54.7	35.2	10.8	14.2	58.0	29.2
7	**Wheat-Lizinka+ Wheat-Olga**	13.5	15.4	54.6	36.8	10.9	14.2	58.6	33.4
8	**Wheat-Lizinka**	13.8	15.9	54.7	38.6	10.5	16.2	56.8	38.3
9	**Wheat-Olga**	14.0	13.7	55.7	32.7	11.0	15.0	56.9	34.9

In conventional production the mixture with two varieties of wheat, accumulated higher quantity of proteins (15.4%), in region of Skopje and wheat+ray (15.3%) in Strumica. Other mixtures had shown the same quantity of proteins (14.9%) in Skopje and 14.2% (wheat+wheat) respectively 13.8% (wheat+ triticale) in Strumica.

Table 5: Quality of kernels in organic production system

Nº	Variants	Skopje				Strumica			
		Moisture	Proteins	Starch	Wet gluten	Moisture	Proteins	Starch	Wet gluten
1	**Wheat-Mila+ Ray Pelisterka**	13.7	14.9	53.8	35.4	10.7	14.2	55.2	30.7
2	**Mila**	13.6	14.4	55.3	34.0	10.3	12.6	59.4	30.3
3	**Ray-Pelisterka**	13,4	15.1	52.5	35,8	11.2	13.0	55.5	28.9
4	**Wheat-P. Orovchanka+ Triticale**	13.8	14.5	54.9	34.5	10.8	12.8	58.3	29.9
5	**Podobrena Orovchanka**	13.3	14.9	55.4	36.4	11.0	15.7	56.0	37.8
6	**Triticale**	13.1	14.8	54.7	32.6	10.9	13.0	55.2	28.2
7	**Wheat-Lizinka+ Wheat-Olga**	13.8	14.7	55.2	35.0	10.9	14.7	58.6	36.1
8	**Wheat-Lizinka**	13.3	16.1	55.2	38.6	10.3	16.1	57.4	39.6
9	**Wheat-Olga**	13.8	13.8	56.0	31.9	10.8	14.9	57.3	36.2

In organic farming system the highest quantity of proteins had mixture wheat+ray (14.9%), respectively wheat+wheat (14.7%) in Skopje and Strumica. Other mixtures showed less quantity of proteins. In the region of Strumica mixture accumulates less quantity of proteins at both systems of production for 5.6% in organic and 4.9% at conventional production.

The average content of proteins for both system of production (14.9%) in Skopje was for 5.7% higher than in Strumica. That means the soil and climatic conditions in region Strumica were better for yield and not as good as for the content of proteins.

Conclusions

- The conventional production of mixture cultivars, in both regions for all varieties and mixtures were higher for 350 kg/ha or 7 % in comparison with organic farming.
- The difference between conventional and organic production of mixtures in average value for both regions are 150 kg/ha, or 3 %.
- The highest yield at mixture for both regions was achieved with wheat Podobrena Orovchanka and Triticale 5105 kg/ha in conventional and 4915 kg/ha in the organic farming.
- Pure cultivated cereals (5885 kg/ha) were with higher yield for 13 % in comparison with mixtures cultivated cereals (5188 kg/ha).
- The chosen Macedonian cereals varieties for trials are with good yielding capacity withaverage yield of 5174 kg/ha.
- The region of Strumica showed higher yield for 644 kg/ha or 13 % in comparison with Skopje.
- The mixture with two varieties of wheat in conventional production accumulated higher quantity of proteins (15.4%), in region of Skopje and mixture of wheat+ray (15.3%) in Strumica.
- The mixture of wheat+ray in organic farming system in Skopje, shown the highest quantity of proteins (14.9%), respectively mixture of wheat+wheat in Strumica (14.7%).
- The content of proteins for both system of production (14.9%) in Skopje was for 5.7% higher than in Strumica.

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Topic II

Evolutionnary processes in diverse crops

Papers or abstracts are based on posters presented at the workshop. They are listed in alphabetical order of first author which is not necessarily the presenting author. At first is presented the introduction by the poster moderator.

Evolutionary processes in diverse crops: Introduction

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The topic of evolutionary processes within diverse crops mostly is concerned with topics at the interface of plant pathology and breeding as already N.E. Stevens (1948), E.C. Stakman (1947) and later H.H. Flor (1956) realised that pathogens react to the human imposed changes in host genetic make-up with respect to resistances. Breeders started in the 1920s to create composite crosses of barley as evolving plant populations (Harlan and Martini, 1929) and it was soon recognised that such populations could be an important tool to deal with evolutionary processes and "evolutionary plant breeding" approaches were thus developed (Suneson, 1956, Jensen, 1952). Recent efforts have been undertaken to produce various composite crosses of winter wheat but also Einkorn in France, UK, and Hungary which have been exposed to natural selection forces for varying periods of time and under various environmental conditions. A challenge is how to study the evolutionary processes in these populations and how to make use of this knowledge on the long run. Research is concentrating on the use of resistance, morphological and molecular markers. At least the molecular markers might make it possible to also assess outcrossing rates in mixtures on the one hand while, on the other hand, they will also be useful to estimate the relative contribution of parents to composite cross populations over time.

Not only the use of genetically diverse single species populations are coming more in focus but also the need to look at inter-specific diversification strategies including living mulches or other ways of achieving low-till or no-till farming systems for environmental protection. Besides the need to understand evolutionary processes within diversified single crops, these processes need to be looked within species mixtures. However, without the recognition of the value of such cropping systems for humans and society at large they will not move out of the experimental stage. Thus, the socio-economic implications and potential costs and benefits have to be analysed and considered.

The six presentations in the session spanned the whole width of topics addressing:

- New breeding approaches especially focussing on:
  - Breeding for organic farming: selection in OF to result in adapted varieties with important features being: Nutrient use efficiency, resistance to seed borne and other diseases, and baking quality.
  - The "modern landrace concept" using composite crosses. Goals can be development of genetic material and to research processes of adaptation
  - Perennial wheat for erosion control
- Evolutionary processes within mixtures over time.
- Evolutionary processes within composite crosses over time
- The ecological, social (appreciation of people) and economic value (productivity) of diversified systems.

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Increasing the diversity of wheat cultivars in Washington State (US)

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Key Words: Organic farming, perennial wheat, cultivar development, selection environment

Abstract

The Inland Pacific Northwest Region (PNW) of the United States is made up of Eastern Washington, Northern Idaho and Northeastern Oregon. Wheat is the most important grain crop in the Inland PNW with approximately 1.8 million hectares grown in 2005. Average annual yields for winter wheat are 4.50 metric tons/hectare, and for spring wheat are 2.96 tons/hectare (Washington Wheat Commission, 2005). Precipitation in the wheat growing areas ranges from 150 mm in Central Washington to 550 mm near the Eastern edge of the state. In the higher rainfall areas, winter wheat yields can reach almost 9 tons per ha. In the drier areas, yields are much lower, around 1.3 metric tons per ha. Other grain crops include barley, triticale and oats; however, none of these is as profitable as wheat. Unless alternate markets develop, most farmers will continue to grow wheat as their major crop. Increasing the diversity within the wheat crop, both by increasing the different types of wheat grown and by increasing genetic diversity within types, is important to the long-term sustainability of dryland farming in this region. Our breeding program has several strategies to increase the genetic diversity of the landscape. This paper explains our organic and perennial programs. The organic program makes use of historic varieties to regain useful genetic variation for traits of importance to farmers interested in organic and sustainable agriculture. Organic wheat production is increasing in the PNW, though our research indicates that organic wheat farmers are not harvesting optimal yields because available cultivars have been selected in high-input systems. The perennial program uses wide crosses between annual wheat and perennial wheat-grasses in an effort to develop a diverse perennial grain crop that has significant environmental benefits.

Breeding Wheat for Organic Systems

The objective of our organic breeding program is to select wheat varieties uniquely adapted to organic agricultural systems in the Inland PNW. The characteristics required of a wheat variety for use in organic production are significantly different from those required for use in conventional production. Many of these characteristics, such as weed competitiveness, insect and disease resistance, nitrogen use efficiency (NUE) and microbial adaptation may be absent from modern wheat varieties because they generally have been bred and selected for uniformity under conditions of intense chemical management.

In 2000, we initiated a breeding program that focuses on selection under certified organic production systems. Our breeding strategy utilizes diverse adapted historical wheat varieties developed before the intensive use of synthetic fertilizers and crop protection chemicals and incorporates traits from these wheat varieties into modern high-yielding breeding lines. We have evaluated 163 historical wheat varieties grown in the Inland PNW from 1842 to 1955 and crossed these to modern wheat varieties to create over 2000 early generation (F_2 to F_5) breeding lines. It is our goal to reintroduce traits of potential value to organic cropping systems from these historic varieties into modern high yielding wheat varieties.

Our research shows that wheat yields in organic farming systems will not be optimized until varieties are grown that have been selected in organic systems. To determine the importance of breeding in organic systems, we compared changes in rank between 35 breeding lines (genotypes) in two systems (certified organic and conventional) over five site/years (locations). Results from analysis of variance showed highly significant ($P < 0.001$) genotype x system interactions for yield. Changes in cultivar ranking and low genetic correlation coefficient estimates suggest that the highest yielding varieties in conventional systems are not the highest yielding varieties in organic systems and that varieties must be selected in organic systems to optimize both yield and quality.

Our specific goals are to breed wheat varieties that 1) optimize yield in organic systems, especially through enhanced NUE and the ability to thrive in soil microbial communities found in organic wheat-based crop rotations; 2) contain durable disease resistance to common bunt (*Tilletia tritici*) and dwarf bunt (*T. controversa*); 3) have competitive characteristics and exude allelopathic chemicals important for weed suppression and; 4) contain quality and nutritional characteristics desired by organic bakers, millers and consumers. If more growers could overcome the agronomic constraints to transitioning to organic agriculture they would have access to value-added marketing opportunities. However, transitioning to organic agriculture is difficult for producers faced with increased weed pressure and varieties that perform poorly under mechanical cultivation, weedy conditions, and organic nitrogen (N) management.

Improving Yield in Organic Systems

One of the biggest challenges to the production of high yielding cereal crops is the provision of sufficient available N. Organic producers often utilize manure or compost to meet N needs, but in many areas the cost of transportation and application make bulky organic fertilizers uneconomical. Improving crop NUE can reduce the total amount of fertilizer N that needs to be applied while maintaining acceptable yields and grain protein content. Enhanced NUE is usually manifested as higher yields and test weight under conditions of low fertilizer input. We have identified genotypes with increased NUE through yield and test weight evaluations in many different low-input environments. Some of these lines are currently being tested in the greenhouse to characterize N uptake and partitioning. The results from this study will help to identify key traits responsible for NUE in these lines and to select parents for future crosses.

In addition to yield trials, we are evaluating lines in the field for genetically controlled traits important to improving NUE. This study is designed to identify genotypes with enhanced NUE in organic conditions and to quantify the range of variation of NUE. Six genotypes each of three different annual wheat types, an advanced bulk population of perennial wheat, and mixtures of each annual line with the perennial bulk are being studied. The annual wheat types include F5 lines from our organic breeding program, F5 lines from our conventional breeding program and historic varieties released prior to 1955. All annual types are soft white winter wheat, except historic varieties, which are cold hardy facultative soft white spring wheat. The perennial bulk population has quality characteristics similar to soft white winter wheat. The N uptake, yield and biomass production of these lines is being evaluated in an organic system to explore the effects of selection environment on NUE, to characterize genetic differences in NUE and to identify important selection criteria. Varieties with high NUE will then be evaluated agronomically and used as parental germplasm in additional crosses.

Developing durable resistance to dwarf bunt and common bunt

Dwarf bunt (*Tilletia controversa*) and common bunt (*Tilletia tritici*) are diseases of winter wheat that occur in areas of the PNW where winters are relatively mild but have persistent snow cover. Infected plants are commonly dwarfed and show an increased number of tillers, and kernels are replaced by a sorus filled with teliospores. Common bunt was the most important disease of wheat from the early to mid 1900s (Line 2002). Fungicidal seed treatments prohibited under organic certification standards now control these diseases. Common bunt has the potential to become an economically devastating disease to organic farmers unless an effective organic seed treatment is developed or genetic resistance is incorporated into organic wheat varieties. We annually screen our advanced breeding lines for resistance to dwarf bunt. Most lines are moderately to highly susceptible to dwarf bunt, however a few lines show high levels of resistance. Our objective is to identify durable resistance to multiple races of these pathogens.

Selecting for Weed Suppression and Allelopathy

Our current program concentrates on identifying and quantifying weed suppression and weed tolerance traits including: height, seed size, canopy coverage, growth habit, leaf area index, emergence, and coleoptile length. There is a large amount of genetic variation for these traits present in the historic varieties and our breeding lines. Another important mechanism for competition with weeds is through the development of varieties with high allelopathic capabilities. According to Wu et al. (1999), “the identification of cultivars with high allelopathic activity and the transfer of such a characteristic into modern cultivars could restore a property that has inadvertently been lost during the process of breeding for higher growth rate and yield." Huel and Huel (1996) found that the highest yielding genotypes under weed-free conditions were not necessarily the highest yielding under weedy conditions. Once we identify useful variation in allelopathy, we will make crosses to assess the heritability of allelopathy and incorporate this trait into numerous lines in our breeding program.

Improving the end-use quality and nutritional quality of wheat varieties

The definition of wheat quality differs depending on market class and on the desired product. Baking and milling tests are performed on all wheat lines from the organic fields. We have conducted end-use quality milling and baking tests for 15 site/years in certified organic systems. These tests have encompassed over 250 advanced breeding lines, 160 historical cultivars and 25 modern varieties. We have also evaluated 63 modern and historical varieties for micronutrient content. We have learned from these evaluations that our major challenges include: 1) the selection of a hard red winter wheat with a high protein content and 2) increasing the current low levels of micronutrients in modern wheat varieties. In 2007, we will begin collaboration with organic bread bakers in the PNW to evaluate hard red wheat varieties in artisan baking conditions. Identifying new niche markets will increase the diversity of varieties and wheat types that are economical to grown in this region.

In 2005, we completed a study to evaluate and compare PNW modern and historical varieties for mineral micronutrients, including copper, zinc, iron, calcium, magnesium, manganese, phosphorus and selenium. Our results show that historical wheat varieties are significantly higher ($p < 0.05$) in most micronutrients than are modern varieties and we were able to identify varieties with high levels of one or more of each of the minerals tested. Currently, we are conducting two additional micronutrient studies. The first compares micronutrient grain content in side-by-side organic and conventional systems for 35 advanced breeding lines. This will help us identify the relative importance between genotype and system when selecting for micronutrient content. Our second study includes modern varieties, historical varieties and their unselected F2 to F6 bulk population progeny grown under organic conditions in two environments. From this study we will be able to determine the heritability of each micronutrient and develop a strategy for optimal selection of varieties with increased micronutrient content.

Perennial Wheat Breeding

Soil erosion is often unavoidable in annual small grain cropping systems and represents a great impediment to the long-term sustainability of agricultural ecosystems. In Washington, steep slopes in the higher rainfall areas increases the risk of water erosion. The drier areas are at risk of wind erosion due to the practice of summer-fallowing every other year with a "dust-mulch" of heavily tilled soil to prevent water loss. These conditions make perennial wheat an attractive solution to erosion problems for many farmers, even though it will be many years before a variety is released. Our program is committed to the long-term effort of breeding economically viable perennial wheat.

Perennial grasses have been recognized for their ability to minimize erosion, outcompete noxious weeds and reclaim drought-ridden or saline soils (Asay and Jensen 1996). Much of the previous work in wide hybridization between wheat and its relatives has been focused on introgressing small amounts of alien chromatin into the wheat genome, while maintaining the basic characteristics of wheat. This project is taking an alternative approach by hybridizing annual wheat with perennial wheatgrasses (*Thinopyrum* spp.) and subsequently breeding for both perennial characteristics and grain production. We are currently working to understand the genetic control of perenniality, the fate of perennial chromosomes in these wide crosses and the nitrogen use efficiency (NUE) of perennial germplasm. This information will allow us to make the best use of the large amount of genetic diversity present in wheatgrass species while efficiently breeding for important agronomic traits.

Field Evaluation and Breeding

Crosses have been made between wheat and several species in the genus *Thinopyrum* (*Th. bessarabicum, Th. elongatum, Th. ponticum and Th. intermedium).* Breeding perennial grain crops has required important changes in strategy relative to typical methods for breeding annual grains. Early generations from wide crosses exhibit dramatic chromosome instabilities that result in significant sterility and the production of highly variable progeny. Our strategy has been to select early generation material strictly based on the ability to regrow vigorously and survive winter following harvest. Seed from plants that have proven to be true-breeding perennials is then used to select progeny in which chromosome balance is achieved (low sterility, high percentage of seed set, balanced karyotype). In the fall of 2001, 1700 perennial lines that had achieved some degree of chromosome stability were planted. These lines were harvested in summer 2003 and are now being used in bulk selection strategies. Bulk selection should have several advantages over pedigree strategies for breeding perennial grain crops. Higher yielding, chromosomally balanced genotypes should rapidly come to dominate the population, while seed from stabilizing lines will be maintained. In the autumn of 2003, portions of the bulked populations were established at five field sites in three different agronomic zones in Eastern Washington (low, intermediate and high rainfall zones). In 2005, perennial nurseries consisting of 35 F_4 to F_5 populations were planted in three locations. These nurseries represent our first fully replicated yield, quality and regrowth trials of perennial wheat.

Genetic Control of Regrowth after Reproduction

A series of addition lines consisting of an annual background (Chinese Spring) with one added chromosome from perennial Th. elongatum was created in order to better study the effects of individual wheatgrass chromosomes. Our lab has demonstrated that chromosome 4E, from the perennial wheatgrass Thinopyrum elongatum, can confer perennial regrowth when added to annual wheat cultivars. We have completed an integrated physical and genetic map of chromosome 4E and have isolated molecular markers that should occupy the region containing the critical Post-Sexual Cycle Regrowth (PSCR) gene(s). These efforts demonstrated that almost the entire short arm of 4E can be translocated and the plant will still not regrow. Conversely, three quarters of the short arm can be deleted and the plant will still regrow. This confirms our suspicion that the PSCR gene is located in the centromeric portion of the chromosome. The PSCR gene(s) induces meristem survival and subsequent rounds of growth in wheats that normally behave as annuals; this trait is thus essential for induction of the perennial growth habit.

Perennial Contributions to NUE

Previous research shows that extensive root systems and longer duration of photosynthesis may contribute to efficient nitrogen use. Larger root mass and rooting depth and longer leaf duration are key traits of perennial grasses that are under significant genetic control. Because of potentially favorable characteristics, perennial grains offer the possibility of dramatically improving NUE to reduce nitrate leaching and to reduce the need for nitrogenous fertilizers when used in a polyculture with annual grains. Our research is assessing the agronomic feasibility and NUE of perennial/annual mixtures and a diverse perennial bulk population. Perennial genotypes will be tested as both one and two year old plants. The series of addition lines and individual perennial lines are being evaluated in the greenhouse for nitrogen uptake and partitioning.

Conclusions

The combination of genetic studies and field breeding will help us successfully capture the diversity of wheat wild relatives while also developing an economically viable perennial grain. In time, we hope to release several broadly adapted perennial wheat varieties. These will at first be targeted to marginal environments and highly erodible slopes. Many farmers have expressed interest in growing perennial wheat, particularly if it reduces input costs while protecting the soil. We are working with several farmers on this project as well as in collaboration with scientists at the Land Institute in Salina, Kansas.

In the next few years, we also plan to release annual wheat varieties bred under organic management practices specifically for organic systems. This will allow organic farmers to optimize crop performance on their farms, and help conventional farmers transition to using organic practices. Although most farmers in Eastern Washington are not currently considering organic certification, all are looking for ways to reduce input costs, especially for nitrogen fertilizers. We feel that breeding for organic systems will benefit all farmers by producing varieties that perform well under limited-input conditions.

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The possible use of "founder effect" to produce locally adapted cereal "varieties"

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Key Words: Organic breeding, einkorn, bread wheat, composite cross

Abstract

The basic axiom of organic farming is, as clearly indicated in the name, the ban of synthetic chemical products in agriculture to decrease their negative impact on the environment, and to improve food safety. Even if the sustainability of organic farming and its impact on human health and food safety are already accepted, the independence of the organic sector is still questionable. Unfortunately organic agriculture still depends strongly on seed industry, especially on conventional plant breeding.

Increasingly conventional plant breeding programs are focused on bio- and gene technology, thereby forcing the organic sectors reliance on conventional breeding. Moreover, conventional breeding efforts in the past have largely developed in response to the demands of intensive agriculture production. Alternatively, organic farming supportive of a philosophy promoting the self-regulating principles of the soil, the plants, and the animals, requires a distinct breeding program. On the other hand, organic farming wants to increase on farm biodiversity, and in many cases prefers to grow local landraces or traditionally used neglected crop species as a source of special heritage of functional foods. Unfortunately the reintroduction of traditional landraces to organic farming is not the best practice, as most of them are not competitive on the production, mostly because of their relatively low resistance.

To solve this problem a new technique to produce “modern landraces” seems to be necessary. The establishment of new composite crosses in combination of the “founder effect” probably can results in a fast way of modern landrace production with comparable resistance and quality. The aim of our recent study is to evaluate the possibility of such system using einkorn and bread wheat composite crosses.

Aknowledgement

The recent study was financed by the GAK alakor-5 project grant from the Hungarian Agency for Research Fund Management and Research Exploitation.

Changes in variety composition in spring barley mixtures over years

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Key Words: spring barley, variety mixture, molecular markers, selection

Abstract

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. 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. The six mixtures and derivatives of these were included in the large Danish BAR-OF variety trials in the years 2002-2005 (Østergård et al. 2005). Here, a subset of this material is considered: only trials from 2003 and 2004 at the sites Flakkebjerg, Foulum and Jyndevad with organic growing conditions. In 2003, the mixtures were composed of seeds from conventional multiplication of the component varieties in equal weight proportions taking into account differences in seed germination. Seeds harvested from the mixtures were in 2004 sown at the same location, 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.

Four of the six mixtures could be successfully described by the markers chosen. In all cases, changes from the 1:1:1 proportions were found after two years of natural selection and competition between the components of each mixture. For one mixture, changes between locations were revealed whereas for the remaining three mixtures, changes in similar direction were found for all locations. The latter may to some extend be a consequence of the removal of small seeds before sowing; this would give a disadvantage to components with the low TGW which also was indicated by the results. In conclusion, among the four mixtures considered, only in one mixture an interaction with the environment was observed indicating local adaptation of this mixture. In this mixture one of the varieties had very high weed suppression ability and at the same time being very susceptible to netblotch. The environment where the decrease in that component was pronounced had much netbloch and the component increased slightly in frequency in the two other environments. Further analyses of the relation between changes in frequencies of components and characteristics of the components and the environments are in progress.

Acknowledgements

The BAR-OF project has been funded by Danish Research Centre for Organic Farming (DARCOF II) and the participating institutes.

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Diversity and evolutionary changes in a wheat composite cross as assessed by resistance frequencies and morphological parameters

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Key Words: Composite cross, genetic diversity, winter wheat, natural selection, brown rust, Puccinia recondite

Abstract

In 2004-2005, seed of the F3 of a winter wheat population resulting from a composite cross of 20 parents was grown under organic conditions at the University of Kassel and morphological traits assessed. Changes from the F3 to the F4 for resistance frequencies towards selected brown rust (*Puccinia recondita*) isolates were studied with the aim to get an insight into the genetic diversity of the CC and to identify possible useful markers to follow the population evolution.

Morphological variability of the CC in the field was high and overall disease occurrence very low. Tiller heights varied between 30 and 137 cm with a mean of 88 cm. Both, the F3 and the F4 were highly diverse for resistance to brown rust. Resistance frequency to one out of five brown rust isolates increased significantly from F3 to F4 while it decreased for one other isolate. There were no changes for the other three isolates.

There is a need to study the evolution of the wheat population under varying environmental conditions to determine possible selective effects of pathogens and other factors.

Introduction

Conservation of genetic resources requires very high attention at present and in the future, since rapid genetic erosion is occurring within all crops (Hammer, 2004). The need to maintain genetic diversity within modern breeding programmes as a whole has been widely accepted and, for example, the conscious widening of the genetic base in wheat by CIMMYT since the 1970s (Rajaram and van Ginkel, 2001; Dreisigacker et al., 2004) has indeed led to an increase of diversity within modern wheat varieties (Reif et al., 2005). However, overall, the genetic diversity among wheat lines targeted for different environments is still low (Dreisigacker et al., 2004).

There is a need for innovative approaches to genetic conservation because the capacity for seed storage is limited and maintenance of diverse populations through periodic cultivation and storage of small seed samples inevitably leads to genetic erosion (Dreisigacker et al., 2005). Also, the “static” conservation of germplasm in storage does not allow for continuous adaptation to environmental challenges such as changing disease pressure or global climatic changes (David et al., 1997; Murphy et al., 2004).

In modern high-input conditions pesticides and chemical fertilizers are being used to reduce environmental variation and modern cereal varieties have been developed with the aim of combining high productivity and uniform product quality in such conditions. Under low-input conditions, however, especially in organic farming, there is little possibility to reduce biotic stresses such as disease, insect and weed infestations and abiotic stresses such as variable soil conditions with the help of chemical inputs. Rather, this variation has to be dealt with by growing appropriate varieties and by adapted crop and farm management practices. Within-crop diversification is one approach that could help meet these demands (Murphy et al., 2004; Finckh and Wolfe, 2006). Because of the absence of landraces in many areas of the northern hemisphere and also their low attractiveness in terms of yield and quality in comparison to modern varieties Murphy et al. (2004) called for new approaches to the development and selection of what they termed “modern landraces”, i.e. bulk populations developed from superior germplasm and further subjected to local farmer participatory improvement using simple selection schemes. This approach may be particularly suited to low-input and organic conditions as then the farmers may be able to “breed crop varieties and landraces that will help improve the sustainability and profitability of their farm” (Murphy et al., 2004).

Composite cross (CC) populations are produced through intercrossing a number (e.g. 20) of different parent varieties with desired traits in all possible combinations and bulking the harvested seeds of the following generations without conscious selection in the field (Suneson, 1956). CCs can be used for production purpose, selection of new varieties and dynamic conservation of genetic resources. CCs incorporate a wide range of genetic variation and they can therefore be adapted through simple mass selection to a range of different environments.

While traditional breeding methods have mainly focussed on homogeneous wheat lines, the CC breeding approach could give new insights into how heterogeneous populations evolve over time in the field whilst achieving high yield and quality standards at the same time. This so called “evolutionary plant breeding” could contribute to the development of organic varieties that possess the flexibility to meet the different needs of organic agriculture under highly variable conditions (Phillips and Wolfe, 2005).

Table 1: Wheat composite cross populations produced by John Innes Centre

Wheat population	Number of var. crossed	Male steriles
Quality (Q)[a]	12	+
Quality (Q)	12	-
Yield (Y)[b]	9	+
Yield (Y)	9	-
All (A)	20	+
All (A)	20	-

+/- male steriles included/ excluded

[a] High quality parents were: Bezostaya, Cadenza, Hereward, Maris Widgeon, Mercia, Monnopol, Pastiche, Renan, Renesana, Soisson, Spark, Thatcher

[b] high yield parents were Bezostaya, Buchan, Claire, Deben, High Tiller Line, Norman, Option, Tanker, Wembley

In 2001, a new European composite cross project for winter wheat named “Generating and evaluating a novel genetic resource in wheat in diverse environments” was initiated by Elm Farm Research Centre (ERC) and the John Innes Centre (JIC) (http://www.efrc.com), with the aim to create winter wheat populations of high adaptability from either high yielding parents or parents with high baking quality or both (Table 1). The different populations are currently subjected to a multitude of European environments to study adaptive processes with respect to soil and climatic conditions and disease pressure. Genotypical (DNA), phenotypical (morphological and resistance), yield and quality traits will be used to study the evolution of these populations.

Table 2: Known resistance genes in the parent varieties of the composite cross

LR resistance	Cadenza	Hereward	Mercia	Monopol	Pastiche	Renan	Spark	Buchan	Tanker	Bezostaya 1	Normann	Soisson	Wembley
3a				**none detected**						**x**		**none detected**	
10		**x**	**x**										
13[5]	**x**	**x**	**x**		**x**		**x**				**x**		**x**
14a						**x**							
17b											**x**		
26								**x**	**x**				
34										**x**			
37						**x**		**x**					
	1	2	1	3	1	2	1	1	1	4	1	1	1

1=Singh et al., 2001, 2=Winzeler et al., 2000, 3=Lind, BAZ Aschersleben, personal communication, 4=McIntosh et al., 1995, 5 LR13 is adult plant resistance.

Resistances against brown rust are known in several of the parents in the composite cross, namely for LR3a, 10, 13, 14, 17b, 26, and 34 (Table 2).

In 2004, seed of the F3 of the population resulting from a composite cross of 20 parents was transferred to the University of Kassel to assess morphological traits and resistance frequency changes over time. With the aim to get an insight into the genetic diversity of the CC and to identify possible useful markers to follow the population evolution, changes from the F3 to the F4 for resistance frequencies towards selected brown rust (*Puccinia recondita*) races were studied.

Methodology

Table 3. Virulences (v) and avirulences (A) against relevant leaf rust resistance genes in five leaf rust isolates used for inoculation of the F3 and F4 of a wheat composite cross originating from 20 parents

	Lr-gene					
Isolate[1]	3a	10	17	26	34	37
1	v	v	A	v	A	v
4	v	A	v	v	A	A
5	v	A	A	v	A	A
11	A	v	v	A	v	v
17	v	A	A	v	A	A

[1] Isolates were obtained from and characterised for virulences by Dr. Kerstin Flath, BBA Kleinmachnnow.

Seed of the F3 was sown in the field in autumn 2004 and grown under local organic conditions without applying conscious selection. Growth stages and tiller height were measured on about 200 tillers three times during the season. Leaf and foot diseases were also assessed during the season.

Resistance to a total of 11 brown rust isolates of *P. recondita* was analyzed in the F3 and for five selected races in the F4. The isolates had been collected, characterised for virulences, and maintained by two different German laboratories (Univ. of Bonn and Fed. Agr. Research Station, Kleinmachnow). The virulences to the relevant resistance genes in the five selected isolates are given in Table 3. Each isolate was inoculated on 106 to 145 seedlings at 3rd leaf stage of the F3 and the F4, respectively. Around 100 seedlings of the fully susceptible variety Monopol were inoculated as control. Infection types were assessed after 12 days, using classes of 0 to 4. To determine frequency changes over time, type 0 to 2 were grouped as resistant, type 3 and 4 as susceptible.

Results and discussion

The F3 population in the field was highly diverse. The tiller heights were normally distributed, with a mean of 88 cm, the maximum height was 126 cm and the minimum height 30 cm, which is a maximum variation of almost 1 m between the tallest and smallest tiller (Fig.1). The flag leaf angles varied from erect (32%) to about 45^o (57%) to nearly flat (10%) while the distance between the flag leaf and the head ranged from 0-25cm at maturity (mean 11.1 +/-6.1cm).

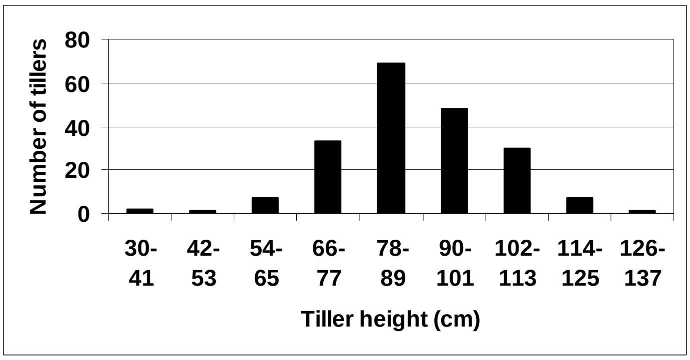

Fig. 1. Tiller height distribution at heading stage in the F3 of the CC population originating from all parents grown in 2004/2005 at University of Kassel (n=197)

The two major diseases observed were Blumeria *graminis* (powdery mildew) and *Drechslera tritici-repentis* (DTR), however, overall disease incidence and severity was low in 2004. For example, on June 21, 1% or less diseased leaf area (DLA) was observed on 130 out of 198 assessed tillers and more than 5% DLA on 24 tillers. Nine days later, DLA was above 5% on 94 tillers (Fig. 2).

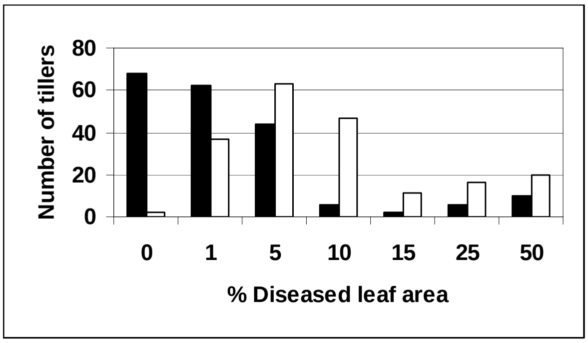

Fig. 2. Distribution of diseased leaf area on June 21 (filled bars) and on June 30 2005 (open bars) in the F3 of the CC population originating from all parents grown in 2004/2005 at University of Kassel (n=198) under organic conditions.

There was considerable variation in the F3 in resistance against the 11 different brown rust isolates that were used. The frequencies of low infection types (LIT, reactions of 0, 1, and 2) ranged from 0.20 to 0.52 while the frequencies of high infection types (HIT, reactions of 3 and 4) ranged from 0.32 to 0.79. A high resistance level was detected when wheat plants were inoculated with isolates 1 (LIT=0.65) and 3 (LIT=0.58) while when plants were inoculated with isolate 9, 11, 15 and 17 they showed a low resistance level (HIT 0.70, 0.70, 0.75, 0.80, respectively). Isolate 1 is avirulent on Lr10, Lr26 and Lr37, while it is virulent to Lr 13 (adult plant resistance, therefore irrelevant in seedling tests). In contrast, isolate 3 is avirulent on Lr 10 and Lr 37 and virulent on Lr13 and Lr26. As the mentioned resistance genes should be common in the F3 population tested, because they were present in two parent varieties (Tab. 2) the high resistance level could be due to Lr 10, 26 and 37. Isolate 9, 15 and 17 were avirulent on Lr 26, but virulent on Lr 10. As the three isolates showed HIT, it could be possible that Lr 26 plays a minor role in the F3 population, even though it was present in two of the parent varieties.

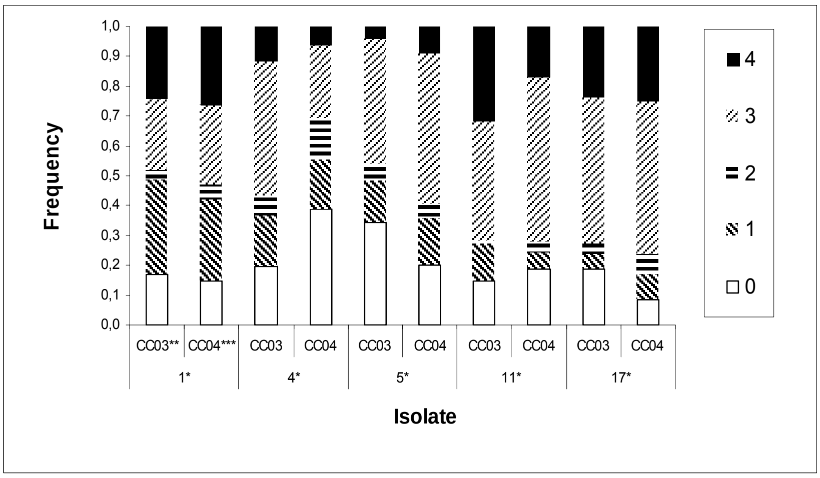

Fig. 3 Frequencies of reaction types of the F3 (CC03) and F4 (CC04) to 5 isolates . Between 106 and 145 plants were tested with each isolate

Reactions against the five isolates with varying virulences (Table 3) changed somewhat from the F3 to the F4 (Fig. 3). When considering the low and high infection types as above as resistant and susceptible, resistance frequencies to isolate 1, 11, and 17 changed only slightly from the F3 to the F4. However, resistance frequency to isolate 4 increased significantly from 44 to 69% ($P<0.001$, χ^2 Test) while resistance to isolate 5 decreased from 0.54 to 0.41 ($P=0.029$, χ^2 Test). Isolates 4 and 5 are avirulenct on Lr 26 but virulent on Lr 10 and 37 but they differ in virulence on Lr17 (Table 3), a resistance that was carried by one parent only (Table 2). However, brown rust disease pressure on the F3 population grown in the field was very low and it is not possible to attribute the shifts to selection forces coming from disease or linkage of brown rust R- genes to other traits. To understand such shifts a more detailed analysis of neutral and selected markers will be necessary. The variation, robustness and large allelic variation make SSR markers ideal for the study of evolutionary genetic studies (Röder et al., 1998) and they have been used to study wheat CC populations and landraces (Dreisigacker et al., 2005; Zhang et al., 2006; Rhoné et al., 2006). By now, in addition to neutral markers, also microsatellites linked to selected traits such as resistances (e.g. Suenaga et al., 2003; Dreisigacker et al., 2004; Rhoné et al., 2006) or vernalisation requirements and earliness (Goldringer et al, 2006) are available.

Conclusions

To determine the processes of adaptation to different growing conditions such as organic or conventional management or pathogen pressure, CCs grown in various environments with and without disease over time should be compared. This would allow for the selection of new material specifically adapted to local conditions.

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Biodiversity development in cereal based semi-natural agro-ecosystems

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Key Words: Biodiversity, genetic variation, cereal, crop mixture

Introduction

Open space is becoming increasingly scarce in the Netherlands as much of it is needed for residence, business and infrastructure. The remaining space is used for agriculture, recreation and nature. People require more space per person, commercial land use is expected to increase and societal demands of land use for recreation and nature conservation are also growing. Farmers can only obtain a license to produce when they use the agricultural land with respect, taking into account environmental care and leaving room for natural elements in their production systems. The aim of this study is to design sustainable agricultural production systems, which are appreciated and valued by society (People, Planet, Profit). Choices are made to build an all-round production system, which might bring about they are not maximal for each perspective individually. A three-year field experiment is carried out under low input conditions in which species diversity is large and in which the genetic diversity within crops is also high. Genetic diversity enhances stability of biodiverse production systems (Booth and Grime 2003) and are better able to withstand a variety of pests and diseases (Finckh, Gacek et al. 2000). compared to genetically poor populations. Species diversity or 'mixed cropping' can contribute to stability in agro-ecosystems, prevent erosion, yield higher, attract useful insects and improve the radiance of fields. (Baumann, Bastiaans et al. 2002); (Hauggaard-Nielsen and Jensen 2004); (Butts, Floate et al. 2003); (Hooks and Johnson 2003). Especially in legume-cereal mixtures, it was found that under low-input conditions intercropping systems can give higher yields than in the monocropping situation, because of an increase in nutrient use efficiency and – in case of the legumes being a component – nitrogen transfer (McLaughlin and Mineau 1995); (Ruijven and Berendse 2003).

Material and methods

In this experiment cereals (rye and barley) are intercropped with pea in association with re-introduced wild herbs. The resulting four combinations for each cereal, e.g. cereal monocrop, cereals intercropped with pea, cereals with introduced herbs and cereals intercropped with pea and introduced herbs. Each treatment is replicated four times, both on a sandy soil and on a clay soil. The genetic diversity within the barley crop is created by growing a mixture of 11 varieties; genetic diversity in rye is inherent to its cross-pollinating nature. The cereal seeds harvested in one year are used as sowing material for the next season. The introduced herb species include *Papaver rhoeas, Centaurea cyanus, Chrysanthemum segetum, Misopathes orontium, Matricaria recutita (sand soil)/Matricaria inodora (clay soil).* Several parameters were assessed to analyse the ecological value (Planet), the productivity of the system (Profit) and the appreciation of people (People). Development of genetic diversity in the cereals is measured after three years. On the species level the composition and size of the herb, nematode and carbide beetle population were recorded. In addition several chemical parameters of the soil and the harvested products were assessed. People were interviewed.

Preliminary results

Preliminary results indicate yield was higher in mixtures with pea, especially in 2005. Only pea yield decreased in the presence of introduced herbs. Weed and introduced herb composition altered significantly between systems already after one growing season. People appreciate fields with introduced herbs more then conventional fields. A conclusion about applicability of these systems in society will be written in which the different parameters are combined.

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Evolutionary Breeding of Wheat

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Key Words: Organic Farming, wheat breeding, composite cross populations, variety mixtures, pedigree line breeding, environmental buffering

Abstract

The task of reducing or eliminating synthetic inputs in wheat production is set against the challenge of environmental variation, which is increasing as a result of accelerating change in the global climate. One approach is to provide a large amount of segregating genetic variation so that the crop population can respond, continuously, to natural selection. This has been started by generating a number of Composite Cross Populations (evolutionary breeding) in wheat, based on high yielding parents or high quality parents or a combination of all. The three types of population are subdivided into those with or without genetic male steriles in the population.

Early results from field exposure under organic and conventional farming systems indicate that the populations are performing at least as well as the means of the parents and the means of physical mixtures of the parents. There are some hints of improvement, but these are small or not significant, at least after two generations of exposure to natural selection in the field.

Introduction/Problem

For the past century, wheat breeding has been based successfully on the pedigree line approach. However, the consistent high yields obtained in the UK and other parts of Europe with pedigree line varieties have depended to a considerable extent on the application of a wide range of synthetic inputs including fertilisers, pesticides and growth regulators to minimise the impact of environmental variation. Such inputs are becoming increasingly expensive in cash terms and in their own impacts on the environment, so there is increasing pressure to find ways of minimising their use, or indeed, eliminating them, as in organic farming. Furthermore, the useful effects of synthetic inputs on environmental variation are likely to become increasingly difficult to maintain as global climate change accelerates and increases environmental variation. To try to answer this problem through breeding would require the provision of considerable, extra genetic variation.

Pedigree line breeding is highly conservative in genetic and evolutionary terms. Varieties are sought that, individually, can occupy very large areas across different countries. They have some flexibility in terms of response to environmental variation, but it is limited. At the other end of the spectrum, segregating populations of wheat derived from many parents should be able to adapt to different environments both within and between seasons, depending on the range of parental genotypes involved. However, breeders currently have little interest in this kind of approach partly because it is perceived that there is no market for such material and partly because there is no current legal framework for registration, multiplication or distribution of populations. Furthermore, using the population approach for wheat production with no synthetic inputs, would require selection for a different spectrum and prioritisation of plant characters. These include, for example, weed competition and crop nutrition, which are both complex characters.

Experience with variety mixtures (Finckh & Wolfe, 2006), species mixtures (Tilman, et al. 2001) and populations (Phillips & Wolfe, 2005) shows that genetical complexity can be valuable in both natural and agricultural systems. Including a range of different genotypes in the plant community increases the overall capacity of the community for change and response. It also means that there is a potential for *complementation* among plants and characters and also for compensation if some components fail in a particular environment. Against these positive aspects of variation lies the possibility of competition which may lead to the demise of agriculturally desirable genotypes and characters. However, the generality of observations suggests that, more often than not, genetic diversity can be helpful both in the productivity and stability of the plant community.

Variety mixtures, for example, have often been shown to be successful in terms of restricting the spread of air-borne pathogens in conventional agriculture, leading to enhanced productivity and yield stability. However, such improvements are less obvious with mixtures grown under organic conditions, partly because air-borne pathogens are less important and partly because the component varieties of the mixtures (bred for conventional agriculture) are inadequate in dealing with the variability commonly experienced in organic farming systems.

The literature is unclear about the potential value of variety mixtures compared with segregating populations. There are arguments that wheat evolved as line mixtures and that selection of components for mixtures should ensure that they all have agricultural value. Segregating populations, on the other hand, should have the potential for a dynamic response to changing environmental values or, in other words, they are still open to natural selection. Moreover, fitness means the ability to leave more offspring which should correlate well with greater seed production or higher yield in agronomic terms. For these reasons, we decided to develop a series of wheat populations and to follow their performance under natural selection in organic and conventional farming systems.

Methodology

Elm Farm Research Centre, with the John Innes Centre, developed six composite cross populations (CCPs) based on 22 historically successful wheat varieties. They were derived from all possible combinations of 10 high yielding parents (45 crosses: YCCP), or 12 high quality parents (66 crosses: QCCP), or intercrosses from all 22 parents (231 crosses: YQCCP). Each of these bulk populations was subdivided into those that did, or did not, contain a range of male sterile crosses (33: CCP(ms)) developed from naturally occurring male sterile parents crossed with the other parent varieties.

The F1 and F2 generations were completed in the glasshouse in 2001 to 2003. The first field exposure of the populations was in 2003/04 in the F3 generation. The populations, their parents and mixtures of the high yielding, high quality and all parents were sown at 2 organic (Sheepdrove Organic Farm, Berkshire and Wakelyns Agroforestry, Suffolk) and 2 conventional sites (Metfield Hall Farm, Suffolk and Morley Research Centre, Norfolk). In 2004/05, replicated experiments, in a randomised block design, were established at the same four sites, again containing all populations, parents and mixtures.

Measurements of crop growth and development were taken throughout the season as well as post-harvest yield and quality assessments. Further replicated trials will be harvested at the same sites in 2006 and 2007.

Results and brief discussion

Yield

The overall average yields from four sites (organic and conventional) and two years were 7.9 t/ha for the parents, 8.1 t/ha for the mixtures and 8.2 t/ha for the composites. The same average yield was obtained for the composites with or without the genetic male steriles. The direction of the trend was encouraging but not significant.

More detail of the yields for harvest year 2005 are shown in Table 1. As expected, the yield levels of the CCPs followed those of the parents, with the Y CCPs producing the highest yields and the Q CCPs the lowest. Interestingly, in all four site comparisons of the Y set, the CCP outyielded the parental mean, with three of the four YQ comparisons showing a similar advantage for the CCPs. In the Q set, the CCPs outyielded the parental means in only half of the four comparisons.

Overall (bottom section of Table 1), the yields under organic conditions were about 60% of those under conventional conditions. This represented a considerable improvement over the previous year when yields were lower. Data for 2004 harvest were less complete than for 2005 and are not shown. As an indication, however, average yields under organic conditions were 2.58 t/ha compared with 8.42 t/ha for the conventional sites. In other words, under the more favourable climatic conditions of 2004-5 compared with 2003-4, conventional yields increased by about 38% compared with 258% for the organic plots. The low organic yield in 2004 may have been due partly to some site-specific problem, but the data nevertheless indicate the degree to which large-scale use of synthetic inputs may ameliorate poor environmental conditions although, of course, the cost is high.

Although the yield advantage for the CCPs appears small at this stage (F4), experience from the literature (see Phillips & Wolfe, 2005) indicates that this may be related to the earliness of the observation: in the Californian barley composites it was found that a large improvement in yield did not occur until later, perhaps up to F15.

Table 1. Mean grain yields (t Ha^{-1} @ 15% moisture content) of Yield (Y), Quality (Q) and Yield and Quality (YQ) composite cross populations with or without male sterility (CCP(ms)) and their parental means (harvest year 2005).

Site/ system	Y	Q	YQ	l.s.d.
Metfield (conv)				
CCP(ms)	11.4	10.5	11.1	0.49
Parental mean	11.2	10.0	10.6	
Morley (conv)				
CCP(ms)	10.5	9.1	9.2	0.90
Parental mean	9.6	8.8	9.3	
Sheepdrove (org)				
CCP(ms)	6.0	5.0	6.1	0.54
Parental mean	5.4	5.4	5.4	
Wakelyns (org)				
CCP(ms)	6.6	5.9	6.7	0.83
Parental mean	6.5	6.3	6.4	
Conventional				
CCP(ms)	10.9	9.8	10.1	0.83
Parental mean	10.4	9.5	9.3	
Organic				
CCP(ms)	6.3	5.5	6.4	0.54
Parental mean	6.0	6.0	5.9	

There was a tendency for straw length to be higher in the CCPs than in the parents; this follows experience with other CCPs where it seems that competition within the population often leads to increased height. Nevertheless, the Y CCPs tended to be shorter than the YQ and Q CCPs (tallest), following the pattern of the parents. Shorter straw and higher yield in the Y CCPs led to a higher Harvest Index, again following the pattern of the parents.

Overall, plant height measurements appeared similar at both organic and conventional sites, despite the use of growth regulators at the conventional sites.

Grain quality

As is evident from Table 2, the pattern of protein content (and indeed, of Hagberg Falling Number values) followed expectation with the Q parents and CCPs showing higher values than the YQ and Y material. However, there was no significant improvement from the CCPs relative to the parents.

Although grain quality improved overall from 2004 to 2005, along with yield, the quality levels, even in 2005, were not high.

Among other characteristics measured, the CCPs have shown considerable progress in plant establishment from the first year of field exposure (2003-4) through to the current year (2005-6). Disease generally, both air-borne and seed-borne, was at low levels in both years of exposure under organic conditions. This characteristic was difficult to judge under conventional conditions because of fungicide applications.

Table 2. Mean protein concentrations (%) of Yield (Y), Quality (Q) and Yield and Quality (YQ) composite cross populations

Site/ system	**Y**		**(YQ**	**l.s.d.**
Metfield	12.5	13.5	12.9	0.84
Morley	11.6	12.7	12.4	0.59
Sheepdrove	13.2	13.8	13.1	1.32
Wakelyns	9.6	10.4	10.7	1.22
Conventional	12.1	13.1	12.7	0.57
Organic	11.1	12.1	11.9	1.50

Conclusions

The composite cross populations have performed as expected according to their categories; the Yield composites had higher yields and HIs, and the Quality composites had higher protein concentrations and HFNs. Although the populations performed within the range of the parents, they often yielded higher than the mean of the parents.

At this stage, in the second generation of exposure in the field, the parental means, mixtures and CCPs are similar, with only a hint of better performance from the CCPs. This suggests that so far, there is little interaction among the different genotypes available. An investigation of relative stability among parents, mixtures and populations also showed a slight, but non-significant, improvement in the populations.

If there were any positive effects of hybrid vigour in the early generations of the CCPs, it seems that they may have been overshadowed by selection against some of the weaker genotypes occurring in the populations. As indicated in the literature, it may be that patience is required before more obvious and positive signs of population adaptation occur.

Harvest year 2006 will provide more extensive data because some of the populations are being grown at six sites in England and at other sites in France, Germany and Hungary. However, if progress remains slow at this stage, a short-term form of exploitation of the populations might be to mix them with currently successful varieties. For example, the Y CCP could be mixed with some proportion of, say, Claire and Deben for use in the UK. In other countries, Claire and Deben would be substituted by local high yielders. This approach might ensure stable high yields, although, of course, preliminary trials would be needed to gauge the appropriate composition and proportions for each region.

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<u>Topic III</u>

Genetic diversity

Papers or abstracts are based on posters presented at the workshop. They are listed in alphabetical order of first author which is not necessarily the presenting author. At first is presented the introduction by the poster moderator.

Genetic diversity: Introduction

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Genetic diversity is the basics for all sustainable selection and breeding work. A breeding program must posses some basic elements in order to produce varieties:

1. It must collect or create genetic variability
2. It must be able to distinguish genetic effects from environmental ones
3. It must fix the variety genetic constitution or control the changes over time

Both in more or less unconscious selection in a species done by our ancestors during growth and harvest over hundreds and even thousands of years – and in a modern breeding program the genetic diversity in the species has been the source to development of new varieties/ products.

The 14 presentations in this session focus on the source of variation in old and new collections of landraces and populations in order to create (find) new varieties. But one can also focus on the genetic diversity within a certain crop to be grown: i.e. a genetic variation mixed in a crop in order to achieve a better stability to different causal effects on yield or quality.

This workshop concerns cereal species which with one exception (rye) are self pollinators, and this has of course a big impact on the term genetic diversity. In open pollinating species like for instance grasses the genetic variation due to the breeding system itself is the cause of a better stability to environmental changes. The similar situation is also in an unselected population of wild cereal collections and to some extent also in ancient landraces. The selection has been carried out as mass selection on phenotypic important characters and the genetic variation is to some degree intact. With the Mendelian laws in mind and with new genetic knowledge the pedigree breeding and pure line development for sure produced efficient varieties!

The big question, however, has been in what environment selection should take place and for many breeders the answer has been quite simple: the best performing for high yielding. But of course this is correct only if the varieties will get the best conditions all the time and everywhere. And all know that this is not the case. With the official trial system we can say that the variation in environment are taken care of to some extent, but with only two years of trials in the best areas of production this may be misleading.

And the results are supposed to be wrong or misleading when converted to other growing systems like low input production or organic production. This has often led to discussions in separate levels depending on standpoint of reality. Talking about high yielding pure lines (HY) they often show “low stability” presented as a steep slope in an environmental/variety yield diagram. A low yielding, high stable variety might be better in low yielding environments. A mixture of high and low yielding varieties will give an intermediate yield and a better stability than HY. So is also the case for breeding populations and landraces. Often the HY is as good also in low yielding environments, and the ranking of varieties is the same in different environments, but there are lots of examples of the opposite.

Breeding specific for organic production require organic breeding environments. In order to manage to utilize the genetic diversity for organic purposes this would probably be necessary. **It is not enough to grow tall plants or old varieties!**

The economical situation however is a big challenge for organic breeding. Therefore a compromise is often necessary, and testing conventional varieties in organic environments may show up good alternatives.

Observations on long-termed wheat variety trials under organic and conventional conditions in Germany

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Key Words: Organic Farming, variety trials, breeding

Abstract

In this contribution, some ideas and possible ways to evaluate non orthogonal variety trials under organic and conventional conditions over many years are illustrated. It is intended as a basis for discussion, not as a definite presentation of results. The main questions, on which the evaluations were basing, are: (1) May varieties with aptitude to ecological and conventional systems (or HI- and LI-conditions in general) be identified? (2) Is special variety testing for ecological conditions necessary or is the information obtained with conventional variety testing sufficient? (3) Is a differentiation of environments within organic farming necessary? The high number of available data permits approaches, which are not possible evaluating single experiments. It could be shown that varieties respond differently to environmental factors and that differentiation of environments within organic farming is necessary.

Introduction

One of the most important breeding aims in Germany has been yield stability over a wide range of environments. Adaptation to special environments has, as far as now, hardly been considered in practical breeding or variety testing. These aspects are discussed only recently, mainly for the special case of organic farming, where special varieties and appropriate variety testing might be needed.

Organic farming is done in very different environments and farm systems. Unlike in conventional agriculture, there are fewer possibilities to compensate these differences by fertilisation or use of pesticides or herbicides. Consequently, the yield levels of wheat in Germany are varying over a range of 300%, from approx. 2.5 to 7.5 t/ha. We can suppose, that genotypes with „special“ aptitude to the whole range of environments occurring in organic farms, will difficultly be found and a further differentiation of environments will be necessary. However, criteria for a suitable differentiation are still lacking. On the one hand, it is not possible to breed special varieties for all possible environmental conditions - on the other hand, the differentiation should be fine enough to allow specific adaptation.

To find an answer on these questions, an analysis of experimental data obtained in many different environments on a large number of genotypes is necessary. A possible data source is given by variety trials which are yearly conducted both under organic and conventional conditions, and the results of the VCU testing.

Variety trials under conventional conditions are conducted yearly in various locations in each of the larger federal states of Germany. Aim of these trials is to give a basis for variety recommendation. Thus, evaluation is done at the level of the single federal states and limited to comparison of means; a joint analysis over many years has rarely been done.

Organic variety trials were firstly conducted in the mid-eighties; actually, in each of the major federal states variety trials are regularly conducted in organic farms in 2 to 4 locations, but generally fewer varieties are tested than in the conventional variety trials.

Another source of data are the results of the VCU testing, which are done both in HI- and (relatively) LI-environments, i. e. without use of pesticides and with reduced N-fertilisation. The latter are of particular interest, because they might give better indications for organic farming than the trials conducted under HI-conditions.

The following questions are of particular interest for data evaluation:

- Can varieties with special aptitude for organic and conventional systems (or High-input or low-input systems in general) be identified?
- Is special variety testing for ecological conditions necessary or is the information obtained with conventional variety testing sufficient for recommendation?

- Is differentiation of environments within organic farming necessary? This differentiation may concern environments with high or low yield potential, but also regional differences or farming systems.

Aim of this contribution was to present first observations on those data, and to propose possible ways for evaluation. The analysis is difficult because of the irregularity of the datasets; many problems have still to be resolved. This contribution was therefore intended more as a basis for further discussion, then as a ready presentation of results.

Data material

The examined data included the results of the VCU testing and variety trials conducted in the federal states of Germany from 1991 to 2005 both under organic and conventional conditions. Table 1 gives an overview over the structure of the data material. This data material was integrated by results of own variety trials conducted in 2002 and 2003 in southern Bavaria under organic and conventional conditions (261 datasets). Only the average value for grain yield, in part also of quality traits like RMT volume and Zeleny sedimentation value were available, not the raw data, which would include the plot replications. In this contribution, only yield data are considered. Since the variety trials are organized independently in the single federal states and the varieties of major interest changed during the years, the dataset is not orthogonal; thus we treated the „environment“ (given by year and location) as random factor and limit our considerations to varieties tested in a high number of environments.

Table 1 Main characteristics of the data material

	Datasets
VCU testing	3660
Variety testing, conventional	28058
Variety testing, organic	3051
Datasets, total	**35399**
Locations	293
Years	15 (1991-2005)
Varieties	456
Varieties (N >30)	120

Results and discussion

The environments, where the trials were conducted, covered a wide span of Yield levels; both in the organic and in the conventional trials (fig. 1). Yield levels in the trials were considerably higher then those achieved normally under practical conditions. (The average wheat yield levels in Germany are of approx. 3,8 t/ha in organic farming and 7,4 t/ha in conventional agriculture). Subsequently, it will be shown, that these differences might be big enough to cause different rankings of varieties and thus, may be a source of errors in variety recommendation.

Using intravarietal linear regression (Finlay and Wilkinson, 1963), a part of the varieties showed to be adapted, relatively to the overall mean of varieties, better to environments with high or low yield potential respectively, even if these aptitudes seem to be not very pronounced in most cases (see fig. 2 for examples). However, it has to be considered, that almost all of the examined varieties have been bred for adaptation to high-input-systems in a relatively wide range of natural environmental conditions – the opposite of what we were looking for. If even under these conditions differently adapted varieties may be found, it can be concluded, that genotypes with a much more specific adaptation might be selected in appropriate breeding projects.

It became evident, that the results of the conventional variety testing and of the VCU trials (both under HI and LI conditions) did correlate only very poorly with the results of the organic variety testing (Fig. 3). According to these data, testing under organic conditions will be probably necessary. As is shown by the VCU data obtained under reduced input („conv. LI“), reduced fertilization and absence of pesticides seem not to be sufficient to simulate the conditions of organic farming.

In fig. 4, an example is shown, that the slopes of the regression lines may vary considerably according to the yield level of the test environments, leading to different valuations of its aptitude according to the regression approach. This has consequently to be used carefully, and any extrapolation should be avoided.

In our considerations, environments were differentiated according to their yield levels. However, there are many different factors limiting yield, like water availability, soil characteristics, management practises, climate etc. An important subject of further investigations will be to differentiate the environments according to these factors and to define appropriate target environments for variety development.

As far as now, following conclusions are possible:

- Varieties with aptitude for environments with high or low productivity may be identified. These properties are not very pronounced, but may cause different rankings. Appropriate breeding projects might produce varieties with a more specific adaptation.
- Variety testing performed under HI-conditions is only of limited significance for organic farming. or other LI-conditions.
- The conditions in organic Farms of Germany may be very different; consequently differentiation of environments would be necessary both for breeding and for variety testing.
- Determination of suitable criteria for differentiation (beyond yield level) will be necessary.

Figure 1 Yield levels in the test environments (density of distribution)

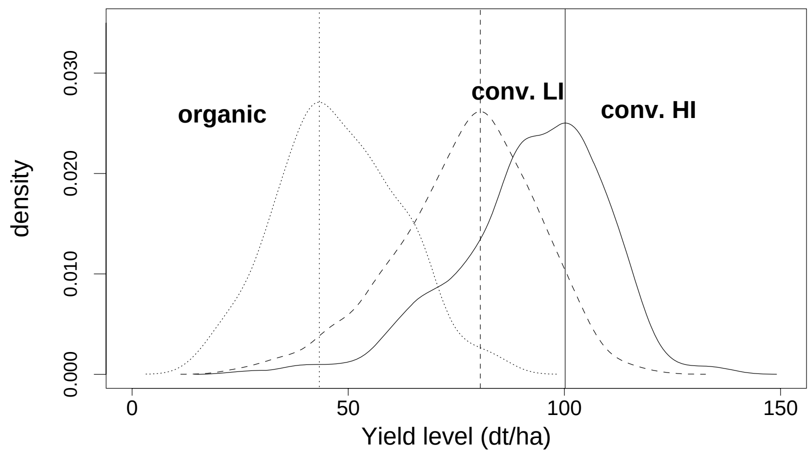

Figure 2 Intravarietal linear regression of yield on environmental mean: examples for varieties where the slope of the regression line was lower (cv. Batis) and higher (cv. Ritmo) than 1 (“high-input-“ and “low-input-“ Varieties, respectively) The full line is the regression line, the broken line represents the diagonal line (slope=1).
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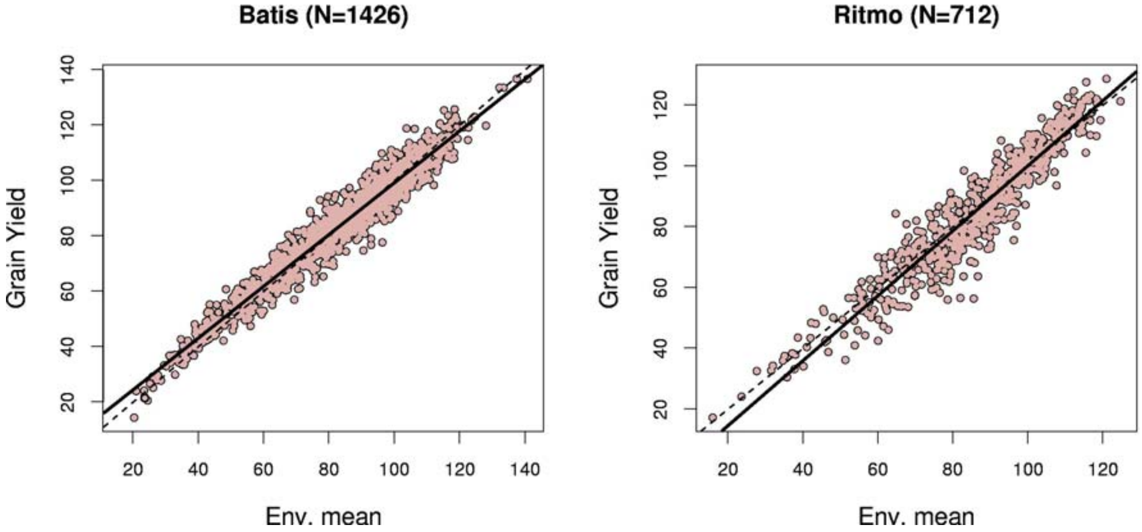


Figure 3: Relations between results of trials conducted under different environmental conditions. Each point corresponds to a variety; filled circles represent those tested in more than 50 environments in the conventional and in more than 12 environments in the organic trials.

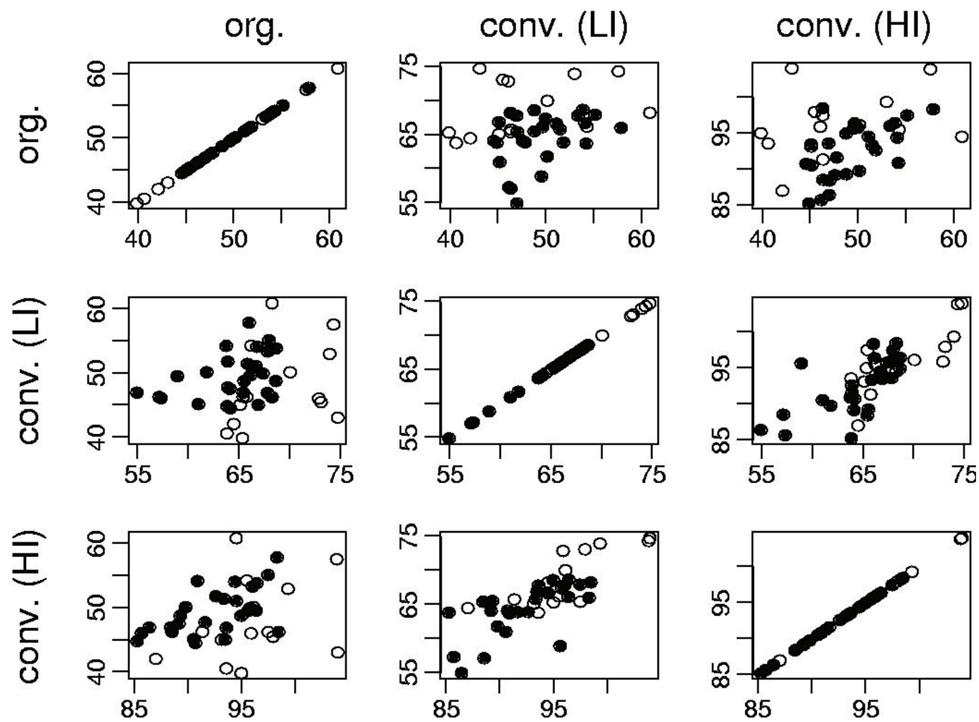
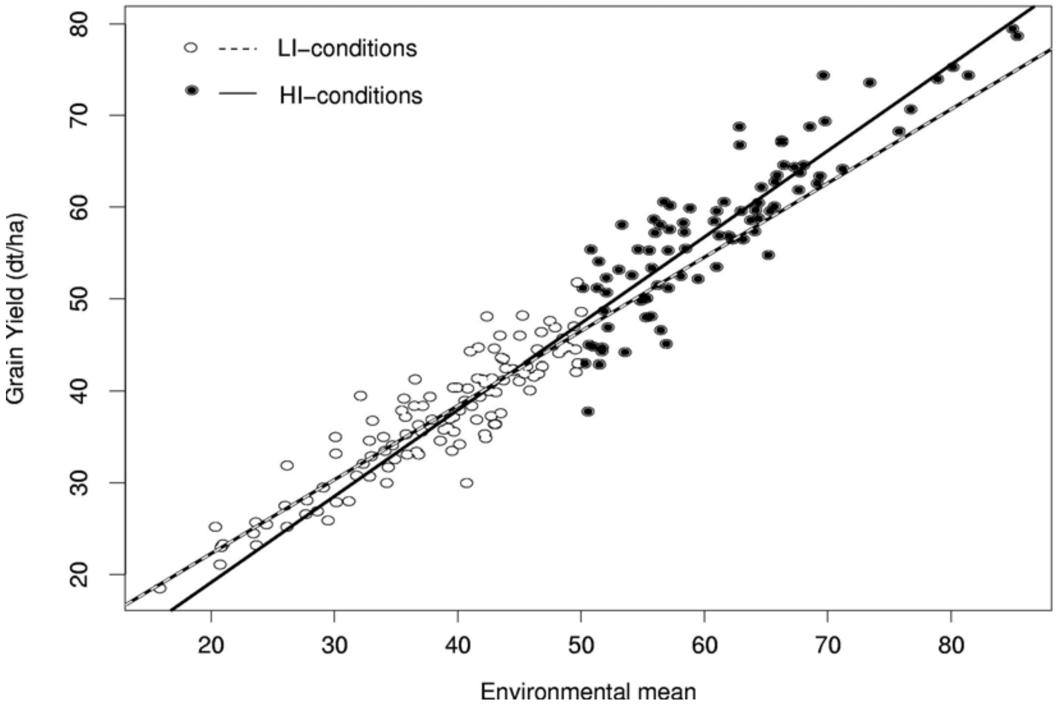


Figure 4: Intravarietal linear regression: regression lines calculated for high-yielding and low-yielding environments, cv. Bussard (the lines are extrapolated to visualize the difference in slope).



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Barley Landraces as Source of Resistance for Powdery Mildew and Leaf Rust for Breeding for Organic Farming

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Introduction

Organic farming is gaining social, political and scientific importance and recognition. The proportion of the organic area in total agricultural land in EU countries is about 3.0% and is steadily growing. Because of this it is growing need for breeding varieties for organic farming with effective resistance to abiotic and biotic stresses (16).

Powdery mildew (Blumeria graminis f.sp. hordei) and leaf rust (Puccinia hordei) are major pathogens of barley in many regions of Europe. Barley landraces constitutes a rich genetic resource, and many examples of their successful use have been reported. However only for less than 2 percent of barley landraces the attempts were made to identify powdery mildew and leaf rust resistance genes using differential lines and isolates (1, 3, 4, 8, 12, 15).

The objective of this study was to determine the powdery mildew and leaf rust resistance in barley landraces collected from Asia and to select resistant lines for breeding for organic farming.

Methodology

Seed samples of 484 barley landraces were used for screening for resistance to powdery mildew. These landraces were collected in Nepal (226), India (43) and Pakistan (215) and originated from Centre for Genetic Resources in the Netherlands (CGN). The infection types were scored according to a 0 - 4 scale. Cultivar Manchuria (CI 2330) was used as a susceptible control.

Twenty one differential isolates of powdery mildew were used (Tab. 1). These isolates were kindly provided by Dr. H. J. Schaerer (ETH, Zurich, Switzerland) and originated from collections of the Risø National Laboratory, Roskilde, Denmark; Danish Institute for Plant and Soil Science, Lyngby, Denmark and ETH, Zurich, Switzerland. The isolates were chosen according to their virulence spectra on the Pallas isolines differential set and 7 additional cultivars.

In preliminary study, about 30 plants per landrace were evaluated in greenhouse with isolate 33. Isolate 33 represented the most avirulent isolate available allowing the expression of maximum number of resistance genes. From resistant landraces 120 single plant lines were selected (Tab. 2, 3, 4). These lines were tested in seedling stage with 21 differential isolates of powdery mildew. In addition, seed samples of these barley landraces were used in preliminary study for screening for resistance to leaf rust using the most virulent isolate available.

Results and brief discussion

Geneticists, plant pathologists and breeders working with barley are constantly looking for gene pools from which new genes can be introduced into existing cultivars in order to improve their resistance to major diseases including powdery mildew (2, 5, 6, 11, 14,15). Such gene pool are barley landraces, especially those originated from differentiation centres of barley such as Mediterranean region, and many powdery mildew resistance genes used commercially are derived from these landraces (3, 4, 5, 15). This was confirmed in this study.

Nine tested lines were resistant to all isolates used. Based on the fact that isolates used in this experiment had collectively virulences to all major resistance genes used in the past and currently in Europe, it may be concluded that these lines showed high level of resistance to the powdery mildew virulence genes occurring in Europe. Therefore, this germplasm should be very useful in barley breeding programs as new sources of resistance to powdery mildew.

In most selected lines the presence of unknown genes were postulated. Presence of a high number of unknown genes in barley landraces is in agreement with findings from other studies (3, 4, 5, 15). Many lines were characterised by resistance reaction type 2. Infection type 2 is different from infection types conferred by most of powdery mildew resistance genes used in Europe. These genes confer mostly infection type 0 and 1 (3, 8, 15). Barley accessions expressing intermediate resistance to a wide-array of isolates provide a more stable resistance in barley cultivars to powdery mildew (15).

The use fungicides and resistant cultivars are available for the effective control of powdery mildew. During last thirty years fungicide control of B. graminis f. sp. hordei has been used to reduce the severity of powdery mildew in the field. However, many pathotypes of B. graminis f. sp. hordei that are resistant to commonly used fungicides have been identified. In addition, fungicide cost and environmental concerns regarding pesticide use have led to a gradual reduction in their use for control of powdery mildew (9, 10, 11, 13).

Breeding for resistance, as an alternative approach to control of powdery mildew, has been very successful, inexpensive and environmentally safe (9, 10, 11). Molecular markers should be developed used to speed up introduction of these newly identified genes into advanced breeding material by marker assisted selection (MAS) (4, 5, 6, 7). Many strategies for effective use of resistance genes in order to increase their durability were developed. Such strategies are: use of multiline cultivars, combining ('pyramiding') different resistance genes into one cultivar and deploying cultivars with different resistance genes over space (e.g. cultivar mixtures) and time (winter versus spring barley) (9, 10, 11, 17).

There are resistance genes which have not been exploited, and new sources of resistance are still being found in barley landraces and wild relatives (3, 8, 15). Such new sources of resistance to powdery mildew have been described in this study. Determination of powdery mildew resistance genes based on tests performed on seedlings using isolates with different virulence spectra is effective and sufficient for breeders and pathologist needs (3, 8). However, it may not always predict adult plant resistance. Confirmation of putative resistance genes or alleles can only be established through evaluation of progeny from crosses and backcrosses among appropriate genotypes (3, 8, 15).

This investigation identified new sources of resistance to barley powdery mildew and leaf rust in lines selected from barley landraces collected in Asia. These new sources confer resistance to all or a large number of powdery mildew virulence genes prevalent in Europe and may contribute significantly to the diversity of the powdery mildew resistance gene pool available for barley breeders.

Conclusions

The results presented here come from the tests performed on seedlings, which may not always predict adult plant resistance. However, determination of powdery mildew and leaf rust resistance genes based on tests performed on seedlings using isolates with different virulence spectra is effective and sufficient for breeders and pathologist needs. Confirmation of putative resistance genes or alleles can only be established through evaluation of progeny from crosses and backcrosses among appropriate genotypes.

In general, results of this study confirmed that barley landraces possess leaf rust and mildew resistance genes different from genes present in cultivated varieties. As isolates of powdery mildew used in this experiment had virulences corresponding to all major resistance genes used in Europe to date, it may be concluded that these lines had resistance to all powdery mildew virulence genes prevalent in Europe. These highly resistant lines should be used as new sources of effective resistance to powdery mildew of barley in breeding programmes for organic farming.

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Breeding in different environments to suit the needs of each farmer

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Key Words: durum wheat, genetic diversity, drought

Abstract

In two regions of southern France, yields of durum wheat varieties recently registered in France are compared with yields of old varieties bred in Mediterranean regions. In good soils, new varieties have higher yields than older ones. However, they do not improve yields in poor dry soils. The reintroduction of Mediterranean genetic material has been suggested to suit the needs of those areas.

Introduction/Problem

Durum wheat varieties officially registered in France are bred and tested in high-yield and high-input environments. Are these varieties able to improve yield in less productive regions of southern France?

Methodology

Six varieties are compared in two regions of southern France. Three of them have been recently registered on the French official list (Biensur, 2001; Joyau, 2002; Karur, 2002). They are rather late and produce high yields in the environments in which they have been tested and registered. Three of them are older and earlier varieties: Argeles, 1996; Claudio (1998 – Italy) and Grazia (90's - Italy): out of them, Argeles is the only one registered on the French official list. Claudio and Grazia are registered on the European list and are the result of Italian or Mediterranean breeding programmes.

Two environments are compared: the region of Arles, characterized by deep soils, a maritime climate and early cycle; the plateau de Valensole, characterized by a continental climate, late cycle and drought. Yield potential reaches 7.5 t/ha aroundArles but only 4.5t/ha on the plateau de Valensole. Trials were carried out over a period of 5 years.

Results and brief discussion

In a high yield potential environment, the three recently registered varieties produced better yields than the older ones in four of the five years of trials. By contrast, in a dry environment, these recent varieties frequently (4 years out of 5) produced lower yields than the old ones. On average, there is a difference of 6% between the two groups.

Conclusions

Testing and breeding varieties only in good soils and high-input environments may lead to a progressive reduction in genetic resources and to a lower adaptation of the varieties to regions and crop management systems with less potential.

Genetic diversity in crop allelopathy

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Keywords: crops allelopathy, allelochemicals, genotypic differences, breeding, weed management

Abstract

Allelopathy in part of existing in nature ”chemical war between plants” has potential to be utilized in practice as an alternative, complementary to mechanical and cultural methods of weed management in sustainable and organic farming. Although several examples of successful employment of allelopathy are known and much more show the potential for allelopathy use, it is still in the infant stage and ready to use technology(ies) for weed management is/are not available yet. Among others, one of the ways of allelopathy exploitation is cultivation crops of high allelopathic potential. For this however, wide scale selection and breeding together with reliable and reproducible screening methods are needed. Quite a few methods for allelopathy evaluation are employed but for wide scale screening the biotests based on germination and root length are most commonly used. Many major crop species are known as possessing high allelopathic activity and most intensively it was studied in rice with thousands of genotypes being tested that demonstrated great genotypic differences in this species. Similarly in wheat, among over 500 genotypes great differences in allelopathic activity were also found. Studies in other crops like barley, oat, rye, sunflower with much lower number of accessions showed great genotypic variation too. These provide clear evidence that potential exists for breeding crops toward enhanced allelopathic potential but it must be strongly underlined that intensive studies and close collaboration between scientists is needed before allelopathy would be offered to use in practice.

Introduction/Problem

Allelopathy holds promise for exploitation, as complementary to other practices, for weed managements and in recent years is receiving an increasing attention. Possibility of allelopathy employment is of importance for sustainable and especially for organic agriculture where weeds became most serious treats. Among several possibilities (intercropping, pre-crop mulching, application as pellets or natural herbicides and so on) crop breeding for high allelopathic potential seems to be the most attractive though the most challenging ones. Putman & Duke (1974) stated that ancestors of present crops have possessed high allelopathic activity, which has been lowered along with breeding toward other valuable traits. Wide scale screening, and classical breeding together with achievements in modern molecular technologies, once genes involved in allelopathy are identified, shall provide potential for crop allelopathy enhancement.

The goal of this presentation is to summaries available literature results on genotypic variation in selected crop allelopathy.

Methodology in studies on crop allelopathy

Several approaches and quite a few methods for evaluation of plant allelopathic potential are employed. Assessments are performed both in field, growth chambers, greenhouse and in laboratory. In the field, growth chambers and greenhouse crop plants in rotation, inter-cropping, cover crop, pre-crop mulching, pellets, crop residues and extracts as donors of allelocompounds are evaluated based on weeds germination, plants number, fresh and dry weights along with crop performance, yield and yield parameters. In the laboratory, using biotest as source of allelochemicals the extracts and leachates of plants various organs, exudates and volatiles are most common but biologically active compounds of allelopathic mode of action known as being synthesized by plants are also used. The allelopathic effects in biotests using various methods (Petri dish, rolled filter paper, sandwich method, equal-compartment-agar-method) are estimated based on germination, seedling growth (length, fresh and dry weights), seedling malformation but for wide scale screening germination and root length are the most often measured parameters. Under controlled conditions, physiological, biochemical and molecular mode of action of allelochemicals are also studied using more sophisticated methodology and equipments including micro-array technology. The effects are also estimated based on identifications and quantifications of biological active compounds and studies on their biosynthetic pathways using GC, HPLC and mass spectrometry.

Results

Crop allelopathy has been most intensively studied in rice with thousands varieties screened in many laboratories (Duke *et al*. 2005 and references therein) and international effort for allelopathic rice cvs. is undertaken with variety PI 312 777 effectively suppressing barnyardgrass in the field. Ahn *et al*. (2005) evaluating 78 cvs. of local Korean rice, based on 6 parameters of inhibitory effects on barnyardgrass growth, have found that average inhibition ranged from zero to 56.1 %. Even greater differences in inhibitory effects against barnyardgrass growth were found when residues of 114 cvs. of rice were the sources of allelocompounds (from 0.0 to 77.2 % in average for 7 parameters) (Jung *et al.* 2004). In evaluation of hulls activity of 91 cvs. rice inhibition of barnyardgrass from 6 to 59 % was recorded (Ahn & Chung 2000). Great differences in allelopathic activity between 28 rice cvs are also reported against arrowhead root growth (Seal *et al*. 2004). Earlier studies also showed great genotypic differences in rice as reviewed by Olofsdoter (2001).

Although, studies on allelopathy of other crops are much less advanced great genotypic variation are also reported. Wu *et al* (2000) evaluating 453 genotypes of wheat, collected from all over the world, demonstrated that their inhibitory effect on ryegrass root length differed by ~11 fold. In the same laboratory it was showed that that the amount of DIMBOA (major wheat allelocompound) in shoots or roots of 58 wheat genotypes ranged from non-detected level to over 730 mg/kg DM (Wu *et al*. 2001). In review by Ma (2005) genotypic differences in wheat allelopathy toward weeds and other crops are also reported. The inhibitory effect on mustard and ryegrass germination of 11, proposed for organic farming in Poland, winter wheat cvs. ranged from 57 to 83 % and from 69 to 92 % respectively.

Bertholdsson (2004) evaluating allelopathic activity of 127 cvs of barley showed that they inhibited root growth of ryegrass between 42 and 70 % and pointed out that decreasing trend in allelopathic activity is observed due to introduction new cultivars.

Studies with 24 oat cultivars showed significant differences in allelopathic potential (Grimmer & Masiunas 2005) similarly as Fay & Duke (1977) in evaluation of 3000 oat accessions for exudation of scopoletin (known from inhibitory activity and being exuded by oat plants).

Among cereals winter rye is also known from allelopathic activity. Burgos *et al*. (1999) conducting studies with 8 winter rye cultivars showed significant differences in concentrations of DIBOA and BOA (major allelochemicals in rye), and that cv. of highest and lowest concentrations coincides with high and low inhibitory effect on goosegrass in biotest using aqueous extracts. Reberg-Horton *et al*. (2005) observed that all 10 cvs. of rye inhibited both redroot pigweed and goosegrass with stronger and significant effect and differences between rye cvs. in case of redroot pigweed. They also reported that the phytotoxicity effect of aqueous extracts correlated with the level of DIBOA concentration in respective cultivars.

Sunflower is also listed as a crop of high allelopathic potential and significant differences (from inhibitory to stimulatory) between 26 cvs. were found by Macias *et al.* (1999). In studies of 37 of sunflower cvs. and breeding lines significant differences in inhibitory effects against mustard and 33, common to Europe, weed species were observed (Gawronska *et al.* submitted) while in case of winter wheat germination was hardly affected (Ciarka *et al.* submitted).

This is a short summary of available literature and there are many more data related to the above crops as well as to many other crop species of allelopathic activity.

Conclusions

1. Although exploitation of the existing in nature "chemical war between plants" is still in the infant stage the presented above summary of selected studies showed that **potential exist for crop breeding toward high allelopathic activity.** 2. Wide scale **screening**, **selections, and classical breeding** together with achievements in **modern molecular technologies**, once genes involved in allelopathy are identified, **shall provide basis for crop allelopathy enhancement**.

3. It must be strongly emphasized that intensive studies and **close collaboration between scientists of various disciplines** are needed before allelopathy, as complementary to other agricultural practices for weed managements would be offered to use in practice.

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Performances of winter wheat and triticale cultivars under low input technology

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Key Words: Organic Farming, low input, winter wheat, triticale

Introduction

Practical breeding for Organic Agriculture needs to realize small grains cultivars with high yield potential, bread-making quality and resistance to diseases. The main objectives in the breeding programs are to improve the nutrient efficiency, weed suppression ability (new ideotype of plant), as well as the resistance to leaf, spike and soil born diseases, using efficiently the screening methodologies under artificial and natural tests.

In Romania, where under the umbrella of ARDI- Fundulea, functions a Research Centre for Organic Farming, new research directions have been initiated, based mainly on breeding strategies for low-input and organic farming systems utilized in various environmental conditions like: simultaneously routine screening of advanced breeding genotypes in conventional and low-input field conditions, including also organic farming system for wheat, triticale and barley; the breeding for resistance to diseases, with emphasize on breeding for resistance to Fusarium and associated mycotoxins and Tilletia; the initiation of molecular approach of selection for such traits etc.

The first step of our research was devoted to know the yield performances in organic farming system of the registered and perspective cultivars of winter wheat and triticale, in order to select those with better perspective, either to be directly cultivated in such conditions and/or to be used in the breeding programs.

Methodology

During two years, 15 winter wheat and 11 triticale cultivars have been tested in a complete block design with 6 replications , in conventional, low-input and organic farming systems: winter wheat in five locations in southern-eastern part of the Danubium plain and triticale in 11 locations, respectively.

Results

The correlations between yield registered in all three conditions shown for both crops, more or less, the same reaction. Only, the coefficients of correlation between yield in conventional and low-input system were quite high and significant (0.88 and 0.85 in winter wheat and triticale, respectively). The correlations between yield realized in conventional/organic farming and low-input/organic farming, were low and not significant in both crops. However, there were some cultivars, that registered high yield performances in all three types of testing conditions in the both small grains crops, wheat and triticale respectively. In triticale, it is interesting to notice, that among these cultivars are either tall and short straw types.

According to the first results, it is suggested that for a successful selection of more adapted cultivars to organic farming, it is necessary that larger number of wheat and triticale genotypes to be tested.

Conclusions

From the registered and perspective cultivars tested simultaneously in two years, under conventional low-input and organic farming systems, just a few performed well enough in organic farming conditions. Broadening the genetic base for better-adapted varieties in such conditions is needed.

Diversity of Spring Barley Grown in Latvian Organic Farms and Possibilities for its Improvement

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Key Words: organic farming, spring barley varieties, genetic diversity

Abstract

The objective of the study was to analyse the situation in Latvian organic farms regarding to the choice of spring barley varieties. The results of variety testing and testing of diverse barley genotypes were used with the purpose to evaluate farmers' choice and to recommend strategies for improvement of barley genetic diversity on Latvian organic farms. The data from around one third of the organic farms was analysed. Only 39 % of surveyed farms were growing barley. A significant part of barley area (38.7%) was sown with unknown varieties. The most widely spread varieties were 'Abava', 'Rasa' and 'Annabell'. According to the previously made organic variety trials, the most suitable varieties to the organic growing conditions in Latvia are 'Idumeja', 'Rasa', 'Abava' and 'Malva'. New breeding lines from conventional breeding program were comparatively better yielding than older varieties. Therefore, direct use of old material is not recommended, but it can be included in breeding due to traits like plant height and disease tolerance. In order to improve the diversity of spring barley in Latvian organic farms, it would be useful to include in breeding these genotypes or to introduce them for growing. Especially the genotypes with such currently deficient useful traits like rapid early growth speed, taller plants, plantophyle growth habit, larger leaf size and different resistance types to loose smut.

Introduction/Problem

Organic farming is a comparatively new and developing agricultural branch in Latvia. The area and number of farms increases every year. In the two last years the certified agricultural land area has been increased 2.3 times and has reached 104 235 ha and the number of organic farms has increased 2.7 times and was 2 653 in 2005. Processing enterprises for organic products are developing gradually.

Although there are a lot of educational events for organic farmers organised, many of them do not have sufficient information about the importance of the variety choice. A lot of farmers do not even know the name and peculiarity of crop variety they grow. Sometimes organic farmers choose not appropriate intensive type varieties.

The objective of this study was to analyse the situation in Latvian organic farms regarding to the choice of spring barley varieties. The results of variety testing and testing of diverse barley genotypes were used with the purpose to evaluate farmers' choice and to recommend strategies for improvement of barley genetic diversity on Latvian organic farms.

Methodology

The total number of certified organic farms in Latvia was 2 653 in the end of 2005. In our study we have analysed 839 organic farms from different regions in Latvia, which is close to one third of the total number of farms. The data about barley varieties and growing area were collected from 147 barley-growing farms. The average area of spring barley was 5 ha on those farms. The information was based on the data farmers provided to the official certification organisation.

Testing of 11 barley breeding lines and 11 diverse barley genotypes was performed in organic growing conditions in 2005. Breeding lines with the appropriate traits for organic farming were selected from the conventional breeding program and 11 barley genotypes bread in different time periods, and different countries with possible advantages for organic farming were included in the trial (Table 1). Varieties 'Abava', 'Idumeja' and 'Ruja' are currently included in the Latvian Plant Variety Catalogue. Some old varieties and landrace 'Latvijas vietejie' were chosen because of possibly better adaptation to the growing conditions similar to organic farming. The trial was arranged in 4 replications, plot size 12 m2, a random layout. Untreated seed was used; seed rate 400 germinating seeds per m2. Growing conditions: sod-podzolic loamy sand, pH KCl 5.4, organic matter 2.1 %, P2O5 208 mg kg-1, K2O 173 mg kg-1, previous crop potato. Only green manure was used in crop rotation. N content in soil before sowing was 28 kg ha-1.

Results and brief discussion

Only 39 % of the surveyed farms were growing barley. Farmers used the greatest part of the produced grain on organic farms themselves as forage and as seed material. A part of farmers sold barley as feed to other organic farmers. The number of barley varieties was not very large. About 39% of farmers did not indicate variety they were growing. That means farmers do not pay sufficient attention to suitability of variety to organic conditions and specific variety traits. A large part of farmers was growing the same varieties before changing from conventional to organic farming and did not think about choosing a more appropriate variety.

The most widely spread variety was ‘Abava’ (25.8%, Fig.1), which is a quite old, medium tall, extensive type variety. The second largest area was sown by variety ‘Rasa’ (10.5%), which is the only variety currently recommended for organic farming in Latvian Plant Variety Catalogue. Intensive type variety ‘Annabell’ was grown in 9.5% of the organic barley fields mainly by farmers in transition period from conventional to organic farming. The next largest area was occupied by varieties ‘Balga’ (marked erectophyle plant type) and ‘Idumeja’, which is recommended to organic farmers by the breeders due to its earliness and low infection with loose smut. From the further varieties with smaller growing areas only ‘Malva’ could be appropriate for organic growing conditions.

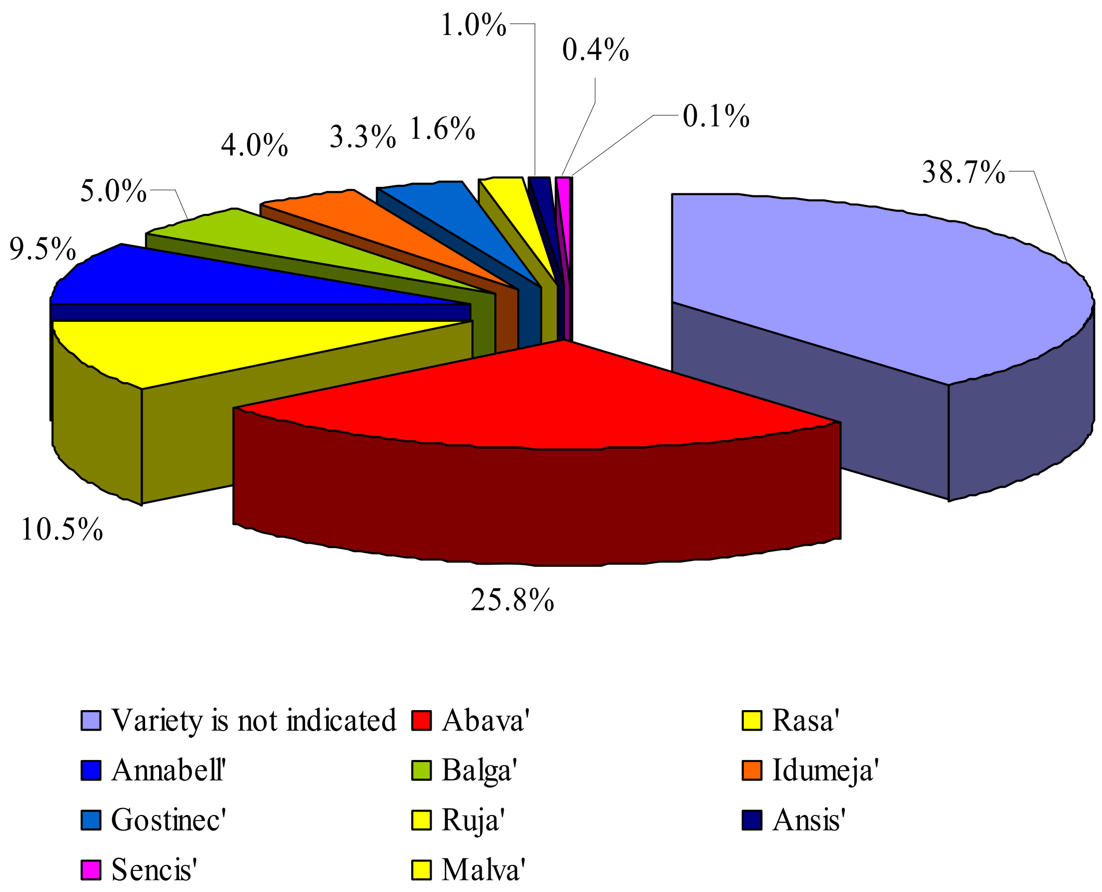

Figure 1. Structure of spring barley varieties in analysed organic farms

Testing results of the six most suitable registered varieties in organic conditions in four locations in Latvia showed, that the positive traits of variety ‘Idumeja’ were earliness, low infection with loose smut and high TGW, but the yield level was medium and the volume weight low. ‘Malva’ was comparatively resistant to loose smut and good yielding, but infection with leaf stripe was registered. The best yielding variety was ‘Ruja’, but the seed treatment against loose smut in seed production is required. ‘Rasa’ was good yielding, but infection with loose smut was possible. ‘Abava’ had the highest plants from the tested varieties, but the yield was comparatively low (Legzdina et al., 2005). 'Annabell' and 'Ansis' are short straw intensive type varieties, which are used mostly by organic farmers in transition period, which continue to grow the same variety. 'Annabell' and 'Gostinec' are very susceptible to loose smut; it can be a serious problem for organic seed growers.

The highest yields were obtained from the new barley breeding lines (Table 1); 5 of them had significantly higher yield if compared to the check variety 'Idumeja'. It was confirmed by a significant positive correlation between grain yield and the year of registration, breeding or growing (fig. 2). Breeding lines and new varieties had comparatively shorter plants than the old varieties. There was a significantly negative correlation between the plant height and the yield. That is in contradiction to findings in other studies. The lower yield level and taller plants of the old material can explain it. There was no correlation found, if the older varieties were excluded from correlation analysis. Plant height was recognised as one of the most important barley traits for organic farming, which correlates positively with the yield. In large-scale comparison of barley varieties and variety mixtures in organic and conventional conditions plant height was found to be one of the traits, which correlates with grain yield differently in organic and conventional conditions. (Ostergaard, Jensen, 2004). Inclusion of perspective breeding lines and older varieties with tall plants in pedigrees of organic breeding program might be useful for creation of genetic diversity for selection. Direct use of the old varieties cannot be recommended.

Table 1. Testing results of breeding lines and diverse barley genotypes in organic growing conditions, 2005, Priekuli, Latvia

Variety, line	Origin	Approximate year of registration / breeding / growing	Grain yield, t ha^{-1}	Growth habit, 1-9*	Length of vegetation, days	Plant height, cm	TGW, g	Volume weight, g l^{-1}	Diseases	
									Loose smut, plants per plot	Net blotch, 0-4**
Breeding lines (n=11, min-max values)	Priekuli PBI, Latvia	2000-2005	**2.44 - 3.33**	1 - 5	95 - 107	64 - 92	45.0 - 54.8	661 - 703	0.2 - 23	0.5 - 2.75
Miranda	The Netherlands	1974	**3.17**	6	103	74	47.2	685	4.5	3
Abava	Latvia	1978	**3.13**	3	106	87	49.0	684	8.7	2.75
LIA 6107	Lithuania	2003	**3.13**	3	103	68	46.1	691	24.5	1.75
Aura	Lithuania	1996	**3.09**	3	103	69	45.5	662	16	2
Dziugiai	Lithuania	1947	**2.97**	2	103	107	47.4	710	17.5	1.25
Austrian Early	Austria	1919	**2.89**	2	103	104	45.7	698	1.2	1
Idumeja	Latvia	2002	**2.87**	2	99	73	50.0	671	0	3
Ruja	Latvia	1999	**2.85**	3	108	76	49.3	638	8.7	2.75
Primus	Sweden	1901	**2.72**	5	109	107	50.0	694	0	2
Latvijas vietejie	Latvia (landrace)	1850	**2.07**	5	109	101	50.2	635	1	2.25
Lawina	Germany (hulless barley)	2002	**1.87**	2	103	90	46.1	804	146	2

* - in tillering stage; 1- erectophyle; 9- plantophyle; ** - 0-no infection; 4 - very strong infection

Significant negative correlations between the yield and the duration of vegetation and days until flowering time were stated. It shows, that early ripening varieties might be more suitable for organic farming than the late ones. Earliness can be associated with fast early development and competitiveness with weeds. Negative correlations between the yield and the length of vegetation period were found in some years for breeding lines in conventional conditions as well (Legzdina, Gaike, 2004). Grain yield correlated significantly positive with lodging resistance (old varieties showed a tendency to lodging), starch content in grain and volume weight. The negative correlation with the disease infection level was not significant. Varieties 'Primus' and 'Latvijas vietejie' could be included in breeding also because of the low infection level with loose smut. Hulless barley variety 'Lawina' had low yield, high starch content and a very high infection with loose smut.

Competitiveness against weeds is one of the most important distinguishing traits for organic varieties if compared to the conventional ones. For winter wheat following traits were recognised as determinative for weed suppression: plantophyle growth habit in contradistinction to erectophyle type, tall plants, large leaf size, high tillering capacity, and rapid early growth (Hoad et al., 2005). To improve the diversity of spring barley on Latvian organic farms, it would be useful to include in breeding or to introduce for growing genotypes with such useful traits like rapid early growth speed, taller plants, plantophyle growth habit, larger leaf size and different resistance types to loose smut.

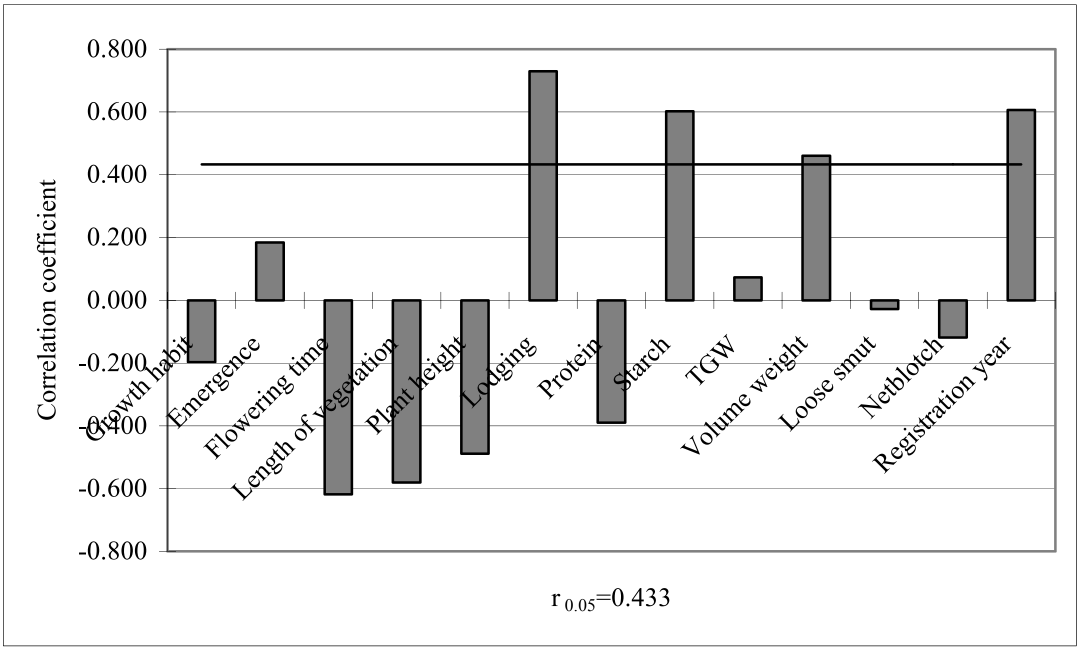

Figure 2. Correlation coefficients between barley yield and other traits

Conclusions

A large part of organic farmers in Latvia does not pay sufficient attention to the choice of barley varieties they grow. Some farmers continue growing the same mostly intensive type varieties they have had as conventional farmers.

Broadening of genetic diversity of barley varieties for organic growing conditions in Latvia is required to optimise crop ideotype. It can be done by including genotypes with currently not available traits useful for organic farming in organic barley breeding program.

New breeding lines from the conventional breeding program were comparatively better yielding than older varieties. Therefore, direct use of old material is not recommended, but it can be included in breeding due to traits like plant height and disease tolerance.

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Effect of cultivated wheat varieties on the wheat powdery mildew population in Hungary between 1970-2004

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Abstract

The composition of the pathogen population depends highly on the resistance of the commercially grown varieties. Over the last more than three decades there has been a considerable change in the wheat variety composition in Hungary. The number of registered and multiplied varieties grew during the period of 1970-2004 from around 10 to around 100. The majority of the leading cultivated varieties in the 1970's carried none, or the *Pm8* resistance gene. From 1981 until the late 90's the gene combinations *Pm5+8* and *Pm2+6* were predominant in the wheat production areas of Hungary. Since then varieties with *Pm8* and one or more additional powdery mildew resistance genes have been widely employed (Limpert et al, 1994; Svec et al, 2002). Investigations on the physiological specialization and virulence of wheat powdery mildew have been underway in Martonvásár since 1970. Important microevolutionary processes have taken place in the wheat powdery mildew population over the last thirty-five years (Szunics et al, 2001). The average virulence complexity has increased from 2.03 (1973) to 5.71 (2003). In order to prove the effect of the man-guided evolution of the wheat powdery mildew population we have examined the data with the most advanced methods for diversity analysis of pathogen populations. The annual pathogen collections and variety sets were compared using the Kosman (Kosman 1996) and the normalized average Manhattan distances, respectively. Calculations were done using the KOIND package (Schachtel and Kosman, 2002) and NTSYSpc package, version 2.1 (Exeter Software, Setauket, NY). The correspondence between the distance matrices was significant according to the Mantel test with a correlation of 0.775. Thus, the changes in the variety composition of wheat explain 60% of the changes in the wheat powdery mildew population.

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Assessment of the suitability of cereal varieties for organic farming

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Key Words: organic farming, cereal crop, conventional varieties

Abstract

Organic agriculture is a growing sector and needs variety improvements for further optimisation of its farming system. The first step is to identify the best existing, conventionally bred varieties for organic practices and for organic propagation. During the 2004-2005 period cereal crop varieties were evaluated for organic agriculture at the Lithuanian Institute of Agriculture. Having assessed 18 varieties of winter and 18 varieties of spring cereals under organic farming conditions, some varieties were discriminated as possessing important and valuable traits for practical use in organic farming: rye – 'Rūkai' – high yielding capacity, winterhardiness, high grain quality; 'Joniai' – resistance to powdery mildew; wheat – 'Alma' – early maturity, high grain quality; 'Bill' – high yield, resistance to lodging, powdery mildew and bunt; barley – 'Tilia' – high yield, early maturity; triticale - 'Tornado' and 'Fidelio' – high yield, winterhardiness, resistance to lodging and diseases. Spring barley – 'Aura'- resistance to lodging and high protein content, 'Pasadena' and 'Annabell'- high yield, resistance to lodging, 'Ūla' – large kernels, 'Barke'- high malting grain quality. Spring wheat – 'Hena' – high yield and grain quality, 'Baldus' – resistance to lodging and diseases. Oats – 'Jaugila' – high grain quality, 'Cwal', 'Belinda' – high yield, 'Nelson' - resistance to lodging.'

Introduction

Organic agriculture is a growing sector**.** Organic farming is affected by many factors, such as management, climate and soils, all of which interact over time and space (Olesen 1999). The average of the proportion of the organic area in total agricultural land use among the EU countries was 2.8%. For Lithuania, it was 69430 ha in January of 2006. As most European governments strive for a growth in organic agriculture of up to 10% by 2010, there is a need for improvement of varieties, not only by improving organic seed production but also through the development of organic plant breeding programmes for better adapted varieties (Lammerts van Bueren 2003).

Organic farmers profit from the improvements of conventional breeding, but this does not imply that those are the best varieties for use in organic farming systems. Varieties supplied by conventional breeding are developed for farming systems in which high levels of artificial fertilisers and agro-chemicals are applied. The organic farming system differs fundamentally from conventional agriculture in the management of soil fertility, weeds, diseases and pests. Organic farmers depend greatly on conventionally bred and produced varieties, but require varieties better adapted to organic farming systems for further optimisation of organic agriculture. This includes a greater need for varieties contributing to higher yield stability.

Consequently, the first step in plant breeding for organic farming systems is organic propagation of the most suitable, existing varieties. First of all, there is a significant lack of information in Lithuania on the relative performance of modern crop species and varieties under organic conditions. Institutions such as the Lithuania University of Agriculture (LUA) and the Lithuanian Institute of Agriculture (LIA) have carried out some variety trials before. (Rekomendacijos žemdirbystei 2000).

Important varietal characteristics for organic agriculture are as follows: nutrient acquisition ability (root morphology, nutrient uptake and use efficiencies, low-nutrient tolerance, symbioses); competitive ability (morphology, weed tolerance, growth rate, allelopathy); ecological combining ability (good performance in variety and species mixtures); disease resistance (morphology, specific and non-specific resistance properties, disease tolerance); other characteristics, including tolerance to attacks by pests and tolerance to climate- induced stress (water, temperature). Many selection criteria, e.g. resistance to many pests and diseases and abiotic stress factors have similar importance in both organic and conventional breeding systems (Vogt-Kaute 2001).

There is no doubt that varieties or lines with appropriate characteristics exist among current and older collections of varieties, in breeding programmes and in gene banks in different countries. There is a pronounced need to develop a research network to identify such lines either for direct use or as potential parental lines in breeding programmes (COST Action 860 2004).

The objective of this study was to evaluate conventional varieties of cereal crops for organic agriculture, to determine their yielding potential and impact of plant species and variety on yield and quality, and to identify the most appropriate varieties for organic farmers.

Methodology

During the year 2004-2005 36 Lithuania-registered varieties of winter (18) and spring (18) cereals were evaluated for organic agriculture at the Lithuanian Institute of Agriculture. The varieties were sown in 5x1.7 m2 plots in 3 replications. Field studies were conducted on a loamy Endocalcari-Epihypogleyic Cambisol (CMg-p-w-can) light loam in Dotnuva (55o24'N, 23o50'E), soil pH was neutral (7.3), humus content 2.1%, available P 50-80 mg kg-1 and K 100-150 mg kg-1. The preceding crop was fallow. The field was certified for organic agriculture. No agrochemicals and fertilizers were used. In the trails we assessed the period of maturity (days), plant height (cm), grain yield (t ha-1), main yield components, 1000 kernel weight (TKW) (g), hectolitre weight (HLW) (g l-1). Statistics on yield and competitive factors was made.

Results and discussion

Winter cereal crops

In 2003-2004 conditions for wintering were favourable for the crops. The winterhardines of most varieties tested was scored by 8-9 points. In 2004-2005 the conditions were not so favourable and the mean score was 7.2. The worst wintering was exhibited by wheat 'Tauras', barley 'Tillia' and triticale 'Tornado' (Table 1).

The mean of winterhardines for all crops was 7.9 points. The summer of 2004 was variable in terms of temperature and rainfall distribution: at the beginning cool and rainy, afterwards quite wet but sufficiently warm. The plant growing period extended by about two weeks, and some varieties lodged. Lodging resistance ranged from 4.3 to 9 points (within scale 1-9, where 9- very resistant). In 2005 summer all varieties was standing. Wheat 'Bill' and triticale 'Tornado', 'Fidelio' had the best lodging resistance (9 points). Plant height ranged from 84.5 (wheat 'Bill') to 190 cm (rye 'Lietuvos 3'). The maturity time ranged between 200 and 219 days. Varieties of winter barley matured very early (200-202 days) (Table 1). All rye varieties matured later than the other crops (218-219 days).

Varieties produced high yields under organic conditions in 2004. The trial mean was 6.80 t ha^{-1}. However, in 2005 the yield was lower (trial mean 4.05 t ha^{-1}). The winter wheat produced a wide range of yields, some reaching 6.94 t ha^{-1} while others barely 4.21 t ha-^{1}. 'Bill' was the best performing wheat variety, while 'Tauras', 'Alma' and 'Seda' performed worse. The yield statistically significantly differed from the trial mean only for those four varieties (Figure 1).

The winter rye produced yields from 5.10 to 6.16 t ha-^{1}. The tetraploid variety 'Rūkai' was the best performing rye variety, while others performed worse. The differences between the rye varieties and the trial mean were not statistically significant. The two registered winter barley varieties produced a yield ranging from 4.63 to 4.93 t ha-^{1}. The yield of triticale varieties ranged between 5.95 – 6.05 t ha-^{1}. For all varieties of winter cereals the yields were considerably higher in 2004.

Spring cereal crops

Due to the weather conditions in 2004, the spring cereal crops growing period extend by about two weeks, and some varieties lodged. Lodging resistance ranged from 4.6 to 9 points (within scale 1-9, where 9- very resistant). In 2005 year lodging resistance ranged from 5 to 8 points. More resistant to lodging were barley and wheat varieties. Barley 'Aura', 'Alsa', 'Annabell' and wheat 'Baldus' had the best lodging resistance (8.5 points). Plant height ranged from 62.5cm (barley 'Annabell') to 114.4 cm (oats 'Migla'). The maturity time ranged between 90.5 and 103.5 days. Varieties of barley matured earlier (90.5-93.5 days) (Table 2). Varieties of wheat and triticale matured later than the other crops (98.5-103.5 days).

Varieties produced rather good yields under organic conditions in 2004. The trial mean was 3.80 t ha-1. However, in 2005 the yield was higher (trial mean 4.40 t ha-1). Only oats varieties produced higher yields in 2004. The yields produced by barley ranged from 3.76 t ha-1 to 4.42 t ha-1. 'Pasadena'and 'Annabell' were the best performing barley varieties (Figure 2). The yields produced by oats ranged from 3.83 to 4.51 t ha-1. 'Jaugila' was the worst performing oat variety, while others performed better. The differences between the barley and oat varieties and the trial mean were not statistically significant. The registered spring wheat varieties produced a yield from 3.80 to 4.82 t ha-1. 'Hena' was the best performing wheat variety, while 'Munk' and 'Baldus' performed worse. The yield statistically significantly differed from the trial mean only for wheat variety 'Hena'.

Table 1. Agronomic traits of winter cereal crop varieties, LIA, 2004-2005

Variety	Crop	Winter-hardiness*	Lodging resistance*	Plant height, cm	Maturity, days	HLW, g l^{-1}	TKW, g
Širvinta	wheat	9	6.7	129.0	214.0	786	49.9
Ada	wheat	7.5	8.9	105.0	215.0	806	41.8
Seda	wheat	7.5	7.7	110.0	215.5	734	48.2
Tauras	wheat	6.5	7.5	102.5	215.5	752	42.8
Alma	wheat	8.5	7.3	105.0	212.0	788	44.8
Milda	wheat	8	8	106.5	215.0	803	42.8
Lina	wheat	8	7	102.0	215.5	794	43.4
Bill	wheat	7.4	9	84.5	215.5	765	45.6
Lars	wheat	7.4	8.5	98.0	215.0	800	43.4
Zentos	wheat	7.2	7.9	110.5	216.5	793	45.2
Rūkai (tetr.)	rye	9	7.7	142.0	218.0	693	45.7
Duoniai	rye	8.2	8.9	141.5	218.5	709	41.8
Joniai	rye	8.5	8.2	138.5	218.0	719	38.3
Lietuvos 3	rye	9	7.2	190.0	218.5	720	39.8
Carola	barley	7.4	8.4	95.0	200.5	572	41.9
Tilia	barley	6.9	8.9	98.5	202.0	521	46.3
Tornado	triticale	6.7	9	107.5	215.5	727	44.6
Fidelio	triticale	9	9	152.0	218.0	726	42.4
Trial mean		7.85	8.07	117.7	214.4	734	43.8
LSD_{05}		2.45	2.21	39.72	5.21	35.38	7.30

*** -** scale 1-9, where 9- very resistant

Many foliar fungal diseases (powdery mildew in cereals, many soil borne diseases) are of minor importance in organic farming systems, because disease preventive agronomic measures (use of resistant cultivars, suitable rotations and nutrition balance management) prevent disease development. However, some foliar and post-harvest diseases can cause significant economic losses in organic farming systems. The consequences of losses due to pests and diseases in organic farming systems differ considerably, depending on region, crop, farm structure or market demands. In general, yields in organic agriculture are 20% lower due to a lower nitrogen- input (up to 50% less nitrogen) and in some cases due to pests and diseases (Mäder et al. 2002).

The powdery mildew in 2004 infested winter wheat, rye and barley. More resistant to mildew were wheat 'Bill', rye 'Joniai', 'Lietuvos 3' and barley 'Tilia'. The variety 'Lars' was distinguished for better resistance to tan spot, caused by Pyrenophora tritici-repentis. Of the two triticale varieties 'Fidelio' was found to be more resistant to leaf diseases (tan spot and septoria). The rye variety 'Lietuvos 3' was more severely infested by rhynchosporium and brown rust. The tested barley varieties were highly susceptible to leaf diseases, and 'Carola' also to powdery mildew. Of all the wheat varieties tested only 'Seda' and 'Bill' were resistant to common bunt (Tilletia tritici).

Powdery mildew in 2004 infested spring barley, wheat and triticale. More resistant to mildew were barley 'Barke' and 'Annabell', wheat 'Hena' and triticale 'Gabo'. The variety 'Hena' was distinguished for better resistance to other leaf diseases too. The oats were also infested with crown rust and tan spot. The oat variety 'Belinda' was more severely infested with crown rust. Less susceptible to diseases were 'Cwal', 'Jaugila' and 'Migla'.

Table 2. Agronomic traits of spring cereal crop varieties, LIA, 2004-2005

Variety	Crop	Lodging resistance*	Plant height, cm	Maturity, days	HLW, g l^{-1}	TKW, g	Crude protein, %
Auksiniai 3	barley	8.2	84.4	91.0	696	48.4	12.9
Aidas	barley	7.3	77.7	93.5	656	47.3	13.2
Luokė	barley	8.3	82.4	91.0	647	50.8	12.2
Ūla	barley	7.8	84.2	91.0	646	54.3	14.0
Aura	barley	8.5	81.7	92.0	655	48.5	14.8
Alsa	barley	8.5	86.0	92.0	660	45.9	13.9
Pasadena	barley	7.5	65.7	90.5	636	48.0	11.6
Annabell	barley	8.5	65.2	91.5	647	47.2	12.0
Barke	barley	7.8	72.2	92.0	658	52.3	11.9
Jaugila	oats	5.3	106.9	97.5	514	34.9	13.7
Migla	oats	6.3	114.4	98.5	515	35.7	12.3
Cwal	oats	7.0	106.5	98.5	499	32.9	12.2
Belinda	oats	7.0	97.4	98.5	489	36.7	12.4
Nelson	oats	7.5	95.2	98.5	496	44.1	11.8
Munk	wheat	8.0	85.5	98.0	759	38.1	12.0
Hena	wheat	8.0	98.9	101.5	793	40.7	12.4
Baldus	wheat	8.5	82.4	99.0	757	33.7	12.0
Gabo	triticale	8.0	116.2	103.5	693	45.8	11.6
Trial mean		7,7	89.0	95.4	634.1	43.6	12.6
LSD_{05}		1.95	10.54	3.29	24.11	4.17	1.68

*** -** scale 1-9, where 9- very resistant

In 2005 in winter wheat and barley the prevalent disease was powdery mildew, in later stages leaf diseases occurred, but not in abundance. Rust infested winter rye at milky stage. Strong infection of common bunt was found in winter wheat from 2.1 to 88.9 % of infected spikes. More resistant to common bunt were 'Bill', 'Lars' and 'Zentos'. The varieties 'Seda' and 'Tauras' were highly susceptible to common bunt.

Powdery mildew in 2005 was a predominant disease in spring barley and wheat. The oat and triticale varieties were found to be more resistant to leaf diseases.

Conclusions

Having assessed 36 varieties of cereal crops under organic farming conditions some varieties were discriminated as possessing important and valuable traits for practical use in organic farming: rye – 'Rūkai' – high yieldinging capacity, winterhardiness, high grain quality; 'Joniai' – resistance to powdery mildew; wheat – 'Alma' – early maturity, high grain quality; 'Bill' – high yield, resistance to lodging, powdery mildew and bunt; barley – 'Tilia' – high yield, early maturity; triticale - 'Tornado' ir 'Fidelio' – high yield, winterhardiness, resistance to lodging and diseases. Spring barley – 'Aura' - resistantce to lodging and high protein content, 'Pasadena'and 'Annabell'- high yield, resistance to lodging, 'Ūla' – large kernels, 'Barke'- high malting grain quality. Spring wheat – 'Hena' – high yield and grain quality, resistance to diseases, 'Baldus' – resistance to lodging and diseases. Oats – 'Jaugila' – high grain quality, 'Cwal', 'Belinda' – high yield, 'Nelson' - resistant to lodging

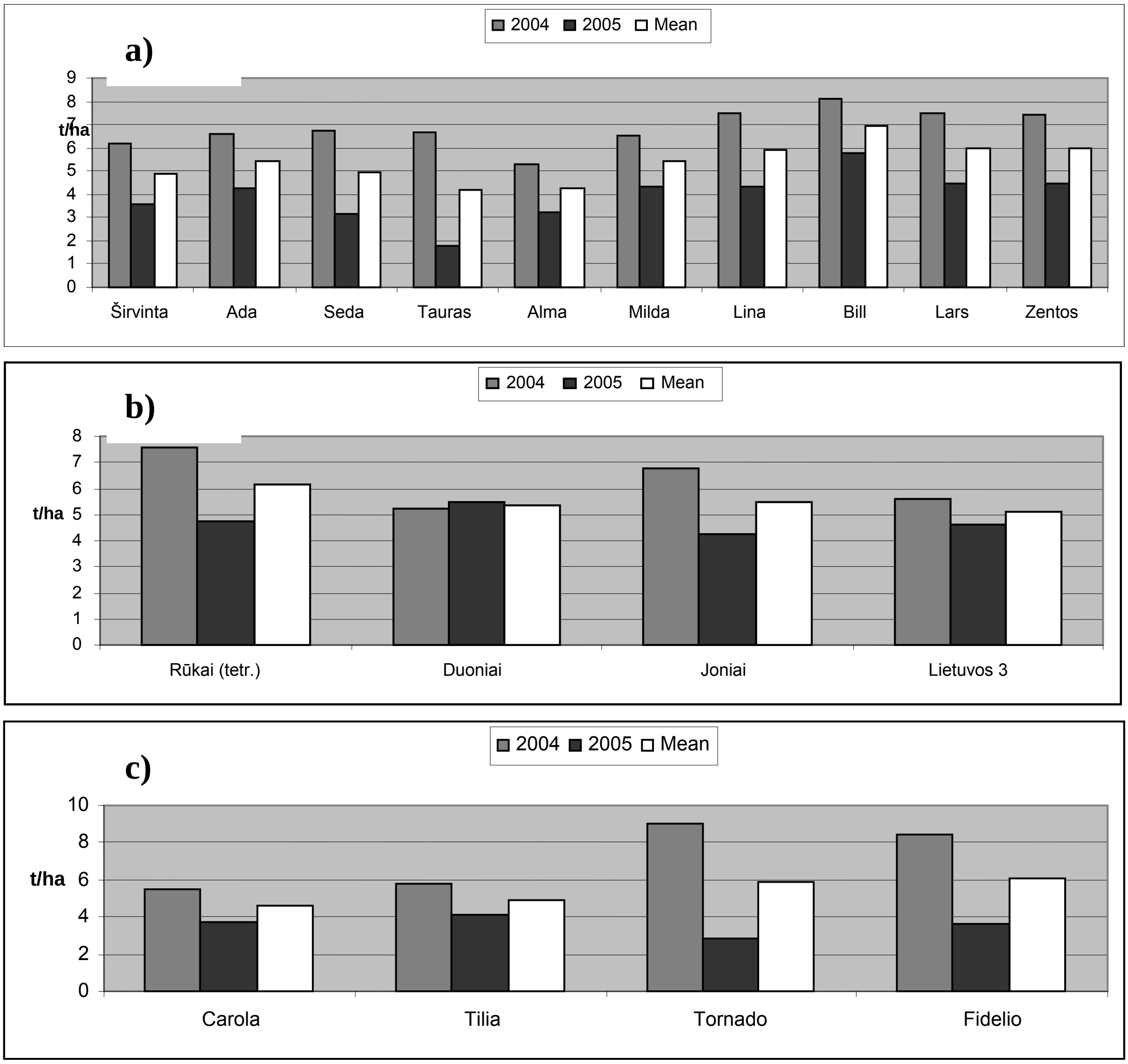

Figure 1. The yield (t ha^{-1}) of winter cereal crops varieties, LIA, 2004-2005, (a – wheat, b – rye, c - barley and triticale (*Tornado, Fidelio*))

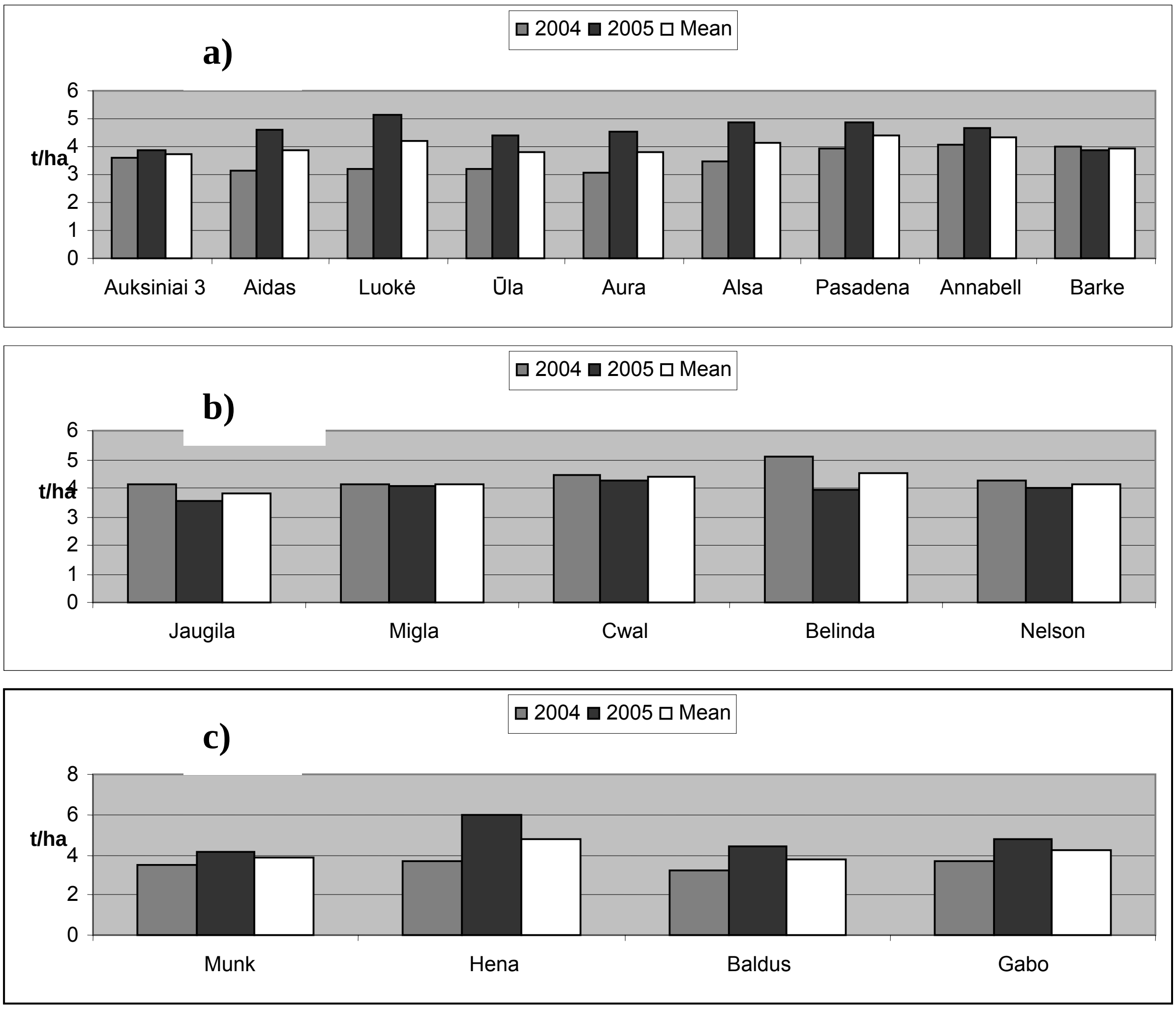

Figure 2. The yield (t ha^{-1}) of spring cereal crops varieties, LIA, 2004-2005, (a – barley, b – oats, c - wheat and triticale (*Gabo*))

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Diversity evaluation of wheat germplasm resources of Madeira Island based on some agronomic and technologic proprieties

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***Key words**: wheat, quality, productivity, technological proprieties.*

Abstract

Knowledge of the magnitude from cultivar and environment effects on the variation of technological quality traits is important to bread wheat breeding programs. This study analyse the data of protein content, hardness, sedimentation volume, wet gluten, falling number, alveograph parameters and water absorption from six traditional wheat varieties cultivated under integrated agriculture systems in order to evaluate if is possible established a correlation among the productivity, bread making quality parameters and the allelic variation of HMWG. The results obtained in different quality and agronomic tests shows high correlations among different parameters.

Introduction

The food quality of wheat is affected by many factors, such as variety and growing conditions (Miezan et al., 1977). Wheat technological quality for the milling and baking proposes is determined by the protein quantity and quality and the degree of starch damage and amylase content. The quality of wheat flour for bread making depends on the viscoelastic properties of the dough, which are influenced by the quantity and quality of the storage proteins of the endosperm, particularly of the HMW glutenins. Payne et al.(1987) discovered a correlation between the presence of certain HMW-GS and gluten strength, measured by the SDS-sedimentation volume test.

Wheat marketing systems established a primary classification of hexaploid wheat based on endosperm texture, for example the hardness or softness of the grain, because this trait determines many of its potential end-uses (Brites et al., 2003a). Hard textured grains require more grinding energy than soft textured grains to reduce endosperm into flour, and during this milling process a larger number of starch granules become physically damaged. Since damaged starch granules absorb more water than undamaged granules, flours from hard wheats are preferred for yeast-leavened bread baking, while flours from soft wheats are preferred for manufacturing cookies and cakes (B. Varga et al. 2003).

The main goal: To evaluate the bread making quality of 6 wheat cultivars and to correlate with the allelic variation of HMWG and the several agronomic traits.

Materials and Methods

In this study were utilised 6 traditional cultivars from Isoplexis-Germobanco collection. The experimental design for each cultivar consisted of 3 replications arranged in a randomized complete block.

The extraction and electrophoretical separation of glutenin (SDS-PAGE) was done according to ISTA Method (Cooke, 1992). To study the technological proprieties the following parameters were determined: protein content (PC); Zeleny sedimentation test (ZI); "W" value (baking strength index or deformation energy of dough); "P" value (tenacity, or maximum pressure, expressing the dough resistance to deformation); "L" (dough stability to disruption), P/L, wet gluten (WG), falling number (FN), grain hardness (H) and water absorption (WA). Each parameter analysis was carried out at least twice. The following agronomic traits are measure: hectrolitre weight (HW), 1000-grain weight (TS), plant height (PH), fresh biomass yield per m2 (RBF), total dry matter content (PMST), total biomass yield (TRBF), number of ears per plant (NEP) and grain average weight per plant (PGE).

Results and Discussion

The Spearman's correlations showed a statistically significant correlation among high molecular glutenin subunits, protein content, Zeleny sedimentation test, baking strength index, tenacity, dough stability, P/L, wet gluten, falling number, water absorption, fresh biomass yield per m2 , total dry matter content, total biomass yield, number of ears per plant and grain average weight per plant. This results clearly shown the genetic influence on some wheat technological and agronomic traits.

Hectolitre weight wascorrelated with the protein content, plant heigh and average grain weight per plant, this demonstrated that the hectolitre weight depend not only of the 1000-grain weight, but also on grain weight per spike and on the spike number, as was demonstrated by Pushman and Bingham (1976).

The thousand grains weight was high correlated with protein content, grain hardness, dough stability, baking strength index, tenacity, P/L , water absorption, total dry matter content and grain average weight per plant.

There was also high correlation among the baking strength index, the falling number, tenacity and the dough stability.

Wheat kernel hardness is highly heritable, and is affected to only a small degree by growing and harvesting conditions. However was not found a significant correlation with the high molecular glutenin subunits, but there was a significant and strong correlation with the falling number, Zeleny test, baking strengh index, wet gluten, dough stability, water absorption and number of ears per plant.

The plant height was negatively correlated with fresh biomass yield per m2, total dry matter content, total biomass yield and positively correlated with grain average weight per plant (PGE).

Conclusions

This study was a first attempt to evaluate the Madeira wheat conservation varieties according to bread making qualities and agronomic features.

The results show a significant correlation among HMWGS, technological and agronomic traits.

The most important correlations are detected between protein content and grain hardiness; baking strength index and falling number, number of ears per plant, baking strength index, yield biomass or dough stability and HMWGS; yield fresh biomass and dough stability and tenacity and hectolitre weight.

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Diversity evalutation of wheat germplasm resources in Madeira Island based on seed storage protein and technological properties

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Key words: wheat, seed storage proteins, genetic identification, technological proprieties.

Abstract

The bread making quality is an important feature in wheat genetic improvement. Therefore the screening of germplasm for varieties identification with the most adequate technological traits must be achieved before breeding. The electrophoretical analysis of storages protein was performed on 30 traditional wheat cultivars collected in Madeira Island. High molecular weight glutenin (HMWG) subunits show high polymorphism with allelic combinations corresponding to the *loci GluA1*, *GluB1* and *GluD1*. Obtained protein patterns are reproducible. The gliadin patterns were also analysed. These patterns allowed establish a genotype formula for Madeira wheat cultivars. These formulas are used to identify the cultivars. A correlation between the alleles related to bread making quality and some technological proprieties was detected for several Madeira wheat cultivars.

Introduction

The identification of wheat cultivars only is possible if their morphologic traits are well defined and quite different, but there are some limitations on those cases where the cultivars are closed related (Hinrichsen et al. 2002). Molecular techniques allow the identification of different genotypes of one cultivar, especially in the case when there is not evident phenotypical difference inside the cultivar (Payne et al. 1987; Plaschke, 1995). Storage proteins are simple and shipped molecular markers, which allow the fast evaluation of different cultivars or genotypes of one cultivar. The HMW glutenin subunits are encoded by Glu-A1, Glu-B1 y Glu-D1 loci where numerous alleles were identified (Payne y Lawrence, 1983; McIntosh et al. 1994). The correlation between HMWG alleles and the bread making quality was show (Payne, 1987; Branlard et al. 1992b).

Six major Gli loci are localized at the homoeologous chromosomes of group 1 (Gli-1) and 6 (Gli-2), which control the most gliadins (Payne et al. 1982). Several additional loci encoding a few minor gliadin bands have been identified (Pogna et al. 1993; Ruiz and Carrillo 1993; Metakovsky et al. 1997). The gliadins polymorphism has been used to analyse genetic diversity within several germplasm collections (Metakovsky et al. 1990 and 1991; Metakovsky and Branlard 1998).

The propose of our work was to characterize the wheat germoplasm of Madeira Island with storage protein and see if there was a correlation among the detected alleles, bread making quality scores and technological proprieties.

Materials and Methods

Thirty wheat cultivars collected in Madeira Island were used to analyse the allelic diversity of storage protein. Proteins were extracted from individual grains. The extraction and electrophoretical separation of glutenin (SDS-PAGE) and of gliadins (ACID-PAGE) followed the ISTA Method (Cooke, 1992). To study the technological proprieties the following parameters were determined: gluten content; Zeleny test; "W" value (baking strength index or deformation energy of dough); "P" value (tenacity, or maximum pressure, expressing the dough resistance to deformation); "L" (dough stability to disruption) and water absorption. Each parameter analysis was carried out at least twice.

Results and discussion

Obtained results are shown on the table 1 and 2. They show that is possible to identify and to distinguish the Madeira wheat cultivars through storage protein patterns. The gliadin analyse allow the elaboration of a genotype formula (Table 1) of each cultivar (Konarev, 1979). We can establish a relation between the HMW glutenin and the bread making quality of wheat genotypes (Table 2).

Table 1. gliadin genotype formulas of local wheat cultivars.

Wheat cultivars	Genotype formula
Branco	ω24201713107 γ151211751 β1411109763 α221510
Russo	ω2321201816131083 γ86542 β1514121086531 α21201918171513128
Branco	ω242221171414131294 γ12111087641 β151413119742 α19181412
Vermelho	ω2421191615103 γ1097532 β14111086 α21191817161512
Vermelho	ω25232017151412107641 γ1412108541 β151413118642 α2018161210
Branquinho	ω22201286421 γ1311976531 β14118541 α19181613
Vermelho	ω2623201711752 γ1412986431 β14131185 α21191715116
Galhoto	ω23201816131842 γ7531 β149853 α211916151412976
Raposo	ω242120191812105З γ15121098753 β1210984 α21191817161512
Serra	ω23222018863 γ13118642 β151412109652 α201917151412107
Cabeiro	ω242219181076 γ1311861 β141311108642 α222120181б151310
Preto	ω2624211810743 γ151311107421 β1312962 α222018171411
Barbela	ω2524221916121110986521 γ12118765421 β14131087532 α222119161513
Leacock	ω242118104 γ12107541 β15131211972 α212018161513
Leacock	ω2723211916111075 γ119741 β1511982 α21201918161513
Canalha	ω272624211816864 γ10987542 β15141097654 α22201918161412
Doiradinho	ω211097 γ1512964 β141211108621 α211813
T. S/pragana	ω282421201813964 γ141198642 β13129852 α211918151311
Branco	ω22201181 γ141194 β1413111063 α211816
Branco	ω24222011108 γ13119743 β151110874 α20181691
Temporão	ω242113129 γ1311983 β14111073 α17161281
Doiradinho	ω20121064 γ1413841 β15127531 α21
Rapadinho	ω24212017129 γ141298432 β141297631 α181412963
Rapadinho	ω242220171412119 γ151311108752 β141311106421 α20181514104
Raposinho	ω252320141291 γ1412873 β1512107642 α2119171411
Cedo	ω97 γ15141191 β14131195 α2213
Rapado	ω24212017131074 γ1211975 β15121097641 α2218171614125
Novo	ω2523212018121052 γ121110653 β151412109876431 α1816145
Cana roxa	ω22201286421 γ1311976531 β14118541 α19181613
Mentana	ω2523201412111861 γ12852 β141096532 α22191712
Galhoto	ω13121042 γ151387541 β133

Table 2. Correlation between HMWG subunits and the data of technological tests of local wheat cultivars

	locus			Quality	Zeleny	Hectrolitre	Dry	W	P/L	Water
	Glu-A1	Glu-B1	Glu-D1	Score	test	weight	gluten			absorption
Branco	n	20	n.d.	2	17	77,33	15,8	0	0,000	65,9
Russo	2*	20	n.d.	32	13	81,476	12	104	3,773	60,2
Branco	2*	20	n.d.	17	19	82,671	11,6	109	0,631	64
Vermelho	n	6+8	n.d.	2	13	80,598	16,7	161	2,530	75,5
Vermelho	n	13+16	n.d.	32	26,75	83,3125	12,8	157	2,575	63,7
Branquinho	n	7+8	n.d.	18	14,5	77,905	14,4	204	4,473	69
Vermelho	n	21, 7+8	n.d.	23	16,25	82,639	10,65	0	0,000	68,3
Galhoto	2*	13+16,8	2+12	69	23,75	81,886	11,1	119	2,649	66,4
Raposo	2*	13+16	2+12	69	13,75	74,402	13,7	136	0,950	71
Serra	n	13+16, 8	2+12	39	20,5	81,472	10,3	20,2	0,826	66
Cabeiro	2*	7+8	2+12	55	12	79,26	10,6	102	1,209	65,7
Preto	1	7+8	5+10	52	12,5	81,219	11,2	116	2,123	65,9
Barbela	2*	13+16, 9	2+12	69	28	82,8795	15,1	121	0,722	66,5
Leacock	n	13+16	2+12	39	25	77,779	9,4	123	1,378	60,8
Leacock	2*	17+18	5+10	78	31,75	80,911	15,2	133	0,754	69
Canalha	n	7	2+12	15	23,75	77,675	12,1	84,6	0,386	62
Doiradinho	n	7	2+10	15	12,75	82,213	9,8	74,8	0,852	61
T. S/pragana	1	6+8	2+12	24	24	82,469	10,7	98,4	0,543	62,5
Branco	n	7+8	2+12	25	12	78,153	10,5	65,5	0,419	59
Branco	n	13+16	2+12	39	12	79,017	10,8	68,9	2,397	66,5
Temporão	2*	7+8	2+12	55	13	83,297	11,6	278	1,392	67,5
Doiradinho	n	13+19	2+12	39	18	78,042	11,4	88,6	1,066	62,6
Rapadinho	2*	7+9	5+10	80	18	84,106	12,61	155	0,912	64,4
Rapadinho	2*	7	2+12	45	26,5	83,954	10,6	115	0,625	61,3
Raposinho	2*	13+19	2+12	37	19,5	80,91	13	46,3	1,103	61
Cedo	n	13+16	2+12	39	13	76,596	13,7	110	1,205	67,8
Rapado	2*	13+16	2+12	69	11	82,154	9,9	121	2,587	62
Novo	2*	13+16, 9	2+12	69	23,5	78,454	12,9	253	3,100	65
Cana roxa	2*	13+16	2+12	39	25	82,004	12,9	112	1,264	69,5
Mentana	n	7+9	5+10	50	12,75	81,613	12,9	133	2,856	65,2
Galhoto	2+	13+16	2+12	69	13,5	77,829	11,1	110	3,114	71

The subunits of the locus Glu-D1 (2+12 and 5+10) are considered bread making quality markers. The subunit 2+12 and subunit 5+10 are related with poor and good bread making quality, respectively (Payne, P. 1987). However the subunits 13+16 of the locus Glu-B1 and the 1 and 2* subunits of the locus Glu-A1 are also related with the good quality (Branlard et al., 1992b).

The bread making quality of the evaluated cultivars is poor, as was demonstrated by the results of the technologic tests, verifying a correlation with the presence of the subunit 2+12 (Serra, Leacock, Canalha, Doiradinho, S/pragana, Raposinho, Cedo, Cana roxa, etc.). The cultivars Leacock (quality score- 78; Zeleny test-31,75; hectolitre weight-80,9; gluten- 15,2; W- 133; P/L- 0.754; water absorption- 69 and Rapadinho (quality score-80; hectolitre weight- 84; gluten- 12,61; W- 155; P/L- 0,912; water absorption- 64,4) show the subunit 5+10, confirmed the correlation between this subunit and the bread making quality. The utilization of the HMWG on the evaluation of bread making quality of cultivars has a great advantage over to the technological test, since only half seed is need for the electrophoresis.

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Breeding for varieties adapted to low-input conditions: Should we use old varieties?

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Key Words: low input, organic, cereal production, stability of grain yield, stability of baking quality, genotype-environment interaction, fertilisation levels, selection criteria

Abstract

A field trial was conducted in order to compare old and modern Swiss winter wheat varieties under low input conditions. Modern varieties yielded in general better. Regarding baking quality the old variety Probus performed relatively well, too. Further breeding for varieties that are especially adapted to low input conditions could therefore also take advantage of old varieties as genitors.

Introduction/Problem

The steadily increasing demand for environmentally sound produced food by the consumers encourages farmers to switch production towards low input and in particular organic production systems in Europe. Besides its good social and political acceptance, low input farming allows also to reduce production costs. However, cereal production under low-input conditions can be biased by large fluctuations of grain yield and baking quality between years and between fields. Adapted varieties can help to stabilise yield and quality performances of cereals. The aims of our project are (1) to characterize wheat genotypes adapted and not adapted to low-input agriculture and (2) to elaborate selection criteria that facilitate breeding of wheat varieties for low-input agriculture. In the trial presented here, we compared the performance of old and new varieties grown at low input conditions.

Methodology

The performance of ancient and modern Swiss winter wheat varieties, representing the past 80 years of selection, were compared in a field trial. The following Swiss winter wheat varieties were used; the year of inscription into the national catalogue of varieties is given in parenthesis: Mont-Calme 245 (1926), Mont-Calme 268 (1926), Probus (1948), Zenith (1969), Arina (1981), Piotta (2003) and Zinal (2003). The French variety Caphorn (2001) was added for comparison as a high yielding variety from a different gene pool. The field trial was set up with two nitrogen fertilization levels (70 and 120 kg N/ha) without fungicide application, thus respecting the prescriptions of the Extenso programme of the Swiss government. Yields, protein content and protein quality of the grain were determined. The protein content of the grain was estimated by NIRS (near infrared spectrometry) and protein quality was determined by using the method of Zeleny. The first field trial was executed in 2005. It is currently repeated under conventional low-input and organic growing condition.

Results and brief discussion

The yields of the modern varieties were in general better than those of the older ones in both fertilizer treatments (Fig. 1). Brancourt-Hulmel et al. (2003) reported the same for varieties from the French genepol. There was yet no statistically significant difference in terms of yield between the two N-fertilizer treatments. Also the protein content and Zeleny-indices were not different between the two treatments. It is conceivable that the differences between fertilizer treatments were not sufficiently big to permit a differential reaction of the varieties. Protein contents were in the old varieties higher than in the modern varieties. This is a well known phenomenon and described as dilution effect (reviewed by Feil (1992)). Zeleny indices were rather low in all varieties, but in particular in the two oldest varieties Mont-Calme 245 and Mont-Calme 268. In contrast the old variety Probus performed relatively well (Fig. 2).

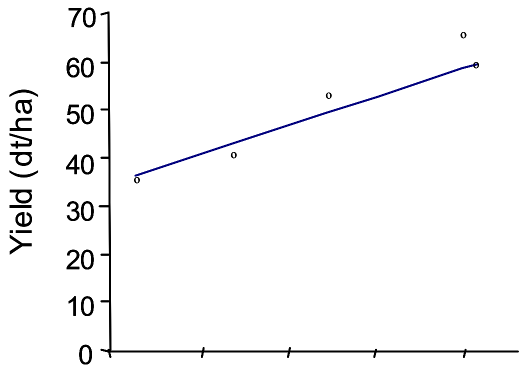

Fig. 1. Linear regression of the yield obtained in our field trial on the year of creation of the varieties. The genetic progress the yield corresponds to a gain of 0.3 dt per year.

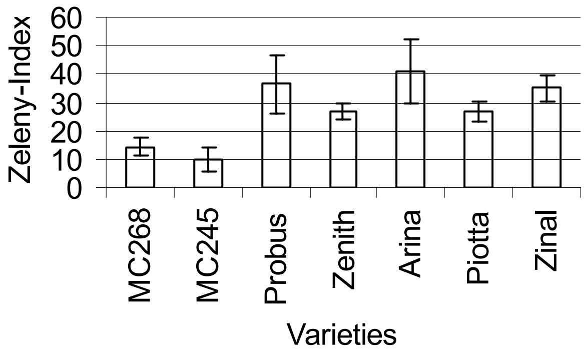

Fig. 2. Zeleny indices obtained from our field trial. The old variety Probus performs as well as the modern Variety Zinal.

Conclusions

This results show that the modern varieties yield better than the old ones under low-input conditions. In terms of backing quality also old varieties like Probus are still of interest for further breeding.

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Comparison of two test networks for winter wheat in organic or extensive conditions

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Key Words: Test network, value for cultivation and use, organic farming, low input production, winter wheat

Abstract

A comparison of two test networks for winter wheat showed that varieties behave very similar in both organic and conventional cropping systems. Varieties bred under organic conditions passed the VCU requirements for the inscription in the Swiss National Variety Catalogue in both extensive and in organic test conditions.

Introduction/Problem

Between 2002 and 2004, the Swiss government has financed the comparison of two networks for variety trials, the one under extensive production conditions (conventional in Switzerland) and the other under organic production conditions. During this period the Value for Cultivation and Use (VCU) could be obtained in one or in the other network, for the inscription in the Swiss National Variety Catalogue. This comparison intended to evidence possible interactions between crop management systems and wheat varieties. These results have been described elsewhere by Schwärzel et al. (2006) and the technological behaviour of the varieties was specified by Kleijer and Schwärzel (2006).

Methodology

During 3 years, two experimental networks were carried out, one in extensive conditions, the other in organic farms. On the contrary of the extensive, seeds for the organic experiment were not treated. In both cropping systems, neither growth regulators nor fungicides were applied. The extensive network consisted of 10 locations, the organic of 8 to 9 locations depending on the year, both distributed all over Switzerland (Fig. 1).

Fig. 1. Map of Switzerland with all the locations of the organic and extensive network.

In the extensive network, each year 36 varieties were cultivated in a lattice design with three replications. In the organic network, 20 varieties were grown with three replicates in a randomised bloc design. From 2002 to 2004 a total of 68 winter wheat varieties have been tested for the inscription in the Swiss National Variety Catalogue or for the Recommended Variety List. 13 to 15 varieties were cultivated in both test networks every year, 7 of them were present during the whole experiment period.
The results presented here, base on the observations of the 7 varieties tested during the total duration of the study. Data sets have been compared using the Analysis of Variance module of the software WIDAS (MSI Dr.Wälti AG, Buch, Switzerland). The coefficients of correlation (r) have been calculated on the average of the 3 replications of each variety in each year.

Results and brief discussion

The concordance of the data in the two networks was very high. Effects of variety, year and cropping system were highly significant for the majority of the studied parameters (Tab.1). Except for earliness, the analysis of variance did not show any interaction between variety x cropping system for the other parameters.

Tab. 1. F-Values of the analysis of variance and its factors for the diverse parameters.

Factors of the analysis of variance	Yield	Lodging	Plant high	Earliness	Hectolitre weight	Thousand kernel weight
Variety (6)	8,30 ***	7,24 ***	99,87 ***	418,16 ***	25,26 ***	47,09 ***
Year (2)	23,61 ***	42,06 ***	83,44 ***	3,00	26,36 ***	26,24 ***
Cropping system (1)	294,58 ***	27,24 ***	89,02 ***	32,30 ***	2,73	4,20 *
Variety x year	0,71	2,15 *	0,33	4,54 ***	1,68	1,09
Variety x Cropping system	0,77	0,11	0,67	3,94 ***	0,43	0,84
Cropping system x year	6,33 **	6,98 **	0,70	5,20 **	4,25 *	19,97 ***

( ) = degrees of liberty *** significant by 0.1 % ** significant by 1 % * significant by 5 %

The average yield in the organic network corresponded to 71% of the yield obtained under extensive condition, the coefficients of correlation (r) between the two cropping systems varied between 0,76 and 0,88 (Tab. 2). The stems are on average 7% shorter and lodging occurred 22% less frequently in organic conditions than in extensive conditions. The varieties are on average half a day earlier in ear emergence in organic farming conditions (r from approximately 0,97). The hectolitre weight and the thousand-kernel weight are almost identical in the two cultivation schemes (r from 0,90 to 0,99). Correlations obtained with the 7 common varieties (Tab. 2A) were very similar to the ones calculated with the 13 to 15 varieties present simultaneously in both trial networks at least one year (Tab. 2B). Similar results have been obtained in Austria and in France (Oberforster 2005; Rolland et al. 2004).

Tab. 2. The coefficients of correlation (r) between the results of the 7 common varieties of the organic and extensive trial network, present during the three years of experience (table A). Coefficient r of the varieties in test, present at least one year simultaneously in both trial networks (table B).

Table	Year		Yield	Lodging	Plant high	Earliness	Hectolitre weight	Thousand kernel weight
A	2002	(6)	0,88 **	0,98 ***	0,99 ***	0,98 ***	0,99 ***	0,97 ***
	2003	(6)	0,82 *	1,00 ***	0,99 ***	0,98 ***	0,90 **	0,91 **
	2004	(6)	0,76 *	0,86 **	0,99 ***	0,96 ***	0,91 **	0,92 **
B	2002	(13)	0,90 ***	0,95 ***	0,99 ***	0,96 ***	0,97 ***	0,95 ***
	2003	(12)	0,88 ***	1,00 ***	0,96 ***	0,98 ***	0,92 ***	0,90 ***
	2004	(14)	0,75 **	0,84 ***	0,99 ***	0,96 ***	0,92 ***	0,93 ***

( ) = degrees of liberty *** significant by 0.1 % ** significant by 1 % * significant by 5 %

A simulation shows that the test of value for cultivation and use (VCU) is more selective in organic farming conditions than in extensive ones, for all the types of varieties, i.e. organic or extensive varieties.

The objective of this study was to evidence possible interactions between cropping system and variety. It may permit to verify a differential reaction of varieties upon different crop management methods. A similar study, conducted during 3 years on forage culture under organic and integrated crop management conditions concluded that official tests under integrated crop management are also valuable for organic farming (Suter et al. 2003).

In Austria, VCU tests are conducted in a mix network of 9 conventional and 4 to 5 organic locations. A mix network could be an interesting option for Switzerland as well. Overall, other varietal traits, such as the resistance to seed- and soilborne diseases, the ability to concurrence with weeds, or the nitrogen use efficiency, arguably give more important information to organic producers than the comparison of the performance of the variety in different cropping systems.

Conclusions

The data here presented suggest that the varieties of winter wheat behave in a very similar way in organic farming and in extensive conditions.

Acknowledgements

We gratefully acknowledge Dr Fabio Mascher for helpful discussions and the corrections of this abstract.

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Estimating diversity of durum wheat landraces using morphological traits

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Abstract

The demand for high quality food and protection of the environment has resulted in an increase of organic and low-input agricultural systems. Modern varieties and hybrids are not always suitable for that kind of agriculture since crops may have lost traits of importance for organic farming through conventional plant breeding selection. Screening landraces might be a useful approach to identify such traits. Landraces are populations with high yield stability especially in low input agricultural systems due to their heterogeneity. The structure of these populations, therefore, can be used as a model for the development of variety mixtures suitable for organic and low-input farming. The objective of this project was to study genetic structure of durum wheat landraces by describing intra-population diversity.

To assess the genetic diversity twenty Greek wheat landraces from the Hellenic Germplasm Bank were used along with three commercial cultivars. Observations were taken from 90 plants in each landrace and genetic diversity was estimated within the landraces on twenty-one morphological traits. The estimation was based on the genetic diversity index for ordinal and the coefficient of variation for continuous traits.

The analysis of the results showed a significant heterogeneity for the majority of the under study traits. Traits with low value of intra-population variation were the time of ear emergence, the plant height without awn, spikelets per spike, glume shape, awn existence and awn colour. A significant range concerning the phenotypic diversity and the coefficient of variance was observed for each trait among populations. Interestingly, values for the glume beak length ranged from 0.12 to 0.8, for glaucocity of culm neck from 0.04 to 0.61 and glaucocity of the flag leaf blade from 0.02 to 0.63.

However, all populations showed similar values regarding mean phenotypic diversity and mean coefficient of variation with values in the range of 0.3-0.4 and from 20-30%, respectively. The results showed a stable mean level of heterogeneity for all populations and the source of such heterogeneity varied among the populations.

The Breeder's Eye – Theoretical Aspects of the Breeder's Decision-Making

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Key Words: organic plant breeding, sociology of knowledge, epistemology

Abstract

The report describes an empirical research project which investigated the peculiarity and role of knowledge gained through experience in plant breeding from the breeder's perspective. In this paper, a theory respecting the breeder's decision-making process will be presented. The categories of knowledge that are important for the decision-making process will be sketched and three levels of consciousness elaborated. The integration of all levels of knowledge and consciousness is what in the end determines whether the breeder's decision-making activities are competent or not. This complexity is defined as intuition in the sense of an invariant present. The empirical findings will be briefly discussed with respect to their importance to organic agricultural science and organic plant breeding.

Introduction

The history of professional plant breeding is a story of success because the increases in harvests in the 20th century have to be regarded within the context of the development of new varieties through plant breeding. In the scientific literature on the subject, this success story is traced back to developments in the natural sciences, especially in the fields of botany, genetics and statistics.

This interpretation, however, oversees the fact that the scientifically codified knowledge has a broad basis in the experience of the plant breeders. Although the plant breeders and experts are aware of importance of knowledge gained thorough experience and it has even been granted its own category, the "breeder's eye", no scientific studies have been carried out on this topic to date

The significance of knowledge gained through experience has to a large extent been ignored in the relevant literature on the subject or only mentioned in the form of a metaphor, the "breeder's eye". Paraphrased as a "prophetic gift" (Rümker 1889; Broili 1910) or "trained eye" (Kraus 1917; Molz 1917), it does indeed insinuate that significant relevance is granted to experience, but at the same time its qualities, however, do not seem to be more closely definable. With the increasing trend towards more scientific approaches in the textbooks on plant breeding, other synonyms for the "breeder's eye" appeared in the relative literature on the subject such as "eye-jugdement" and "visual selection" (Jensen 1988: 348). The characterizations of the breeder's actions remain, however, rather meagre (Duvick 2002; Lammerts van Bueren 2002). "Patient", "persistent and "interpersonal skills" were specified as the decisive personal qualities of a breeder. In some texts, the success of the breeder's activities was traced back to his insight, intuition and perceptivity (Jensen 1988: 366ff; Duvick 1999; 2002).

As manifold and enlightening the findings from such studies are, the breeder's concrete praxis is not taken into consideration in them. The breeder's daily life is characterized by innumerable decisions which could hardly take place without a reserve of experience he can fall back upon. The breeder's decision-making behaviour is, therefore, the key category if one wants to understand plant breeding and its success. The following study deals with the subject. Based on the example of the crossbreeding of self-fertilizing cereals, the breeder's decision-making activities will be reproduced and analysed in each specific temporal-space, situational context. While taking the complex knowledge of the breeder into account, a theory of the breeder's decision-making behaviour – the breeder's eye – will be developed.

Methodology

The investigation of this very personal field of knowledge took place in the form of a qualitative-empirical sociological study. The research describing the breeder's own experience gained at the beginning of his career as a plant breeder endeavours to document the special quality of knowledge gained through experience. The decision-making process is the focus of interest. This participatory observation approach (Spradley 1980) was complemented by five interviews with cereal breeders. The collection and analyses of the data as well as the design of the research process was based on the "grounded theory" principles (Glaser et al. 1967).

Findings

In the following, three levels of consciousness will be differentiated on the basis of three different praxis elements which are closely interlaced in workday breeding routine (organization activities, selection and cross-breeding planning). The last two elements are concerned with the decision-making process in breeding in a narrow sense. It is always about decision-making in a concrete situation. Before that aspect is dealt with, a brief description of important categories of knowledge will be presented. The diverse dimensions of decision-making in the field of breeding will be made transparent against this background.

The Breeder as a Farmer – Vegetational Consciousness

In general, the most important tasks are similar each year and are comparable to those that take place on a farm. The various breeding tasks are oriented towards the development of the vegetation. Taking the wetter and soil conditions into account, sowing, cultivation measures and finally the harvest have to be planned and carried out. From this perspective, many of the tasks are similar to those of a farmer.

The planning and utilization of the available resources takes place in accordance with the specific breeding goals. The tasks are planned and executed if possible in such a way so that the interesting phenomena appear to be "well differentiated". Only in this manner can appropriate decisions be made. In order to differentiate well, numerous efforts have to be made: special successions of crops are decided upon, or artificial infections are introduced in order to aggravate the appearance of specific diseases, or sowing is carried out at an especially early or particularly late date in order to test the appropriateness under extreme conditions and to make the selection in accordance. These are often the measures that a farmer would frequently not carry out.

For the breeder, the organizational activities and the resource planning are linked to their way of perceiving the vegetation cycle. The employment of temporary workers and assistants has to be planned and steered in accordance with the available resources. Evaluations, harvest tasks, processing tasks or analyses have to be planned so that the necessary data are available in the "decisive" situations. The decision-making situations, especially with respect to selecting, take in the case of winter corn place in the period between the harvest and the next sowing as well as the vegetation period in the following spring. Along with the vegetation, the breeder also experiences the growth of the breeding line under the conditions of a specific year and place.

The temporal order of the growing process along with the aspects of the organizational activities and resource planning comprise the level of the vegetational consciousness. Although important aspects of the breeder's activities are touched upon and the temporal order can be grasped by a non-breeder, the breeder's decision-making process cannot be understood that way. It only becomes transparent when the diverse generations of the varieties are taken into account. Before that is explained, a brief overview of categories of knowledge will be presented.

Categories of Knowledge and Decision Matrixes

The breeder's decision-making activities are based on knowledge that is present at various levels during the decision-making process. The fundamental categories of knowledge will be briefly characterized in a first step and brought together in a second step in order to develop a decision matrix.

Sensorial Presence

Sensorial presence purely signifies sensory perception. Although the visual sense dominates, other senses are also involved: tasting and smelling while checking the taste of backing trials, evaluating the firmness of the loaf. The sensorial presence *is* presence. The contents of the sensorial presence can be very different in accordance with where the breeder is at the moment: investigating the plants in the field or data in his office.

Mental Presence

The term “mental presence” signifies the notion of the configuration that is present in the imagination of the breeder when considering a breeding line. As a significant part of experience, it can hardly be explicitly perceived (Polanyi 1985/1966). Mental presence does not mean a static momentary impression but rather a configuration won in time-space contexts. The course of the vegetation conveys the time configuration, and cropping in various locations the space configuration. Mental compactness is defined as the experience gained over many years and in many places. Mental presence is generated in the past and can be called up in the presence and serve as guidelines for future actions.

Knowledge Derived from Data

Knowledge derived from data is data material that is collected in very different measuring acts: evaluation data, analysis data, yield data. As characters (numbers) they are physically present and have to be interpreted before they become data knowledge. This interpretation act is also an act which gives them a frame that embeds the data in a specific space-time, generation context while taking into account knowledge of the methodological ability to make a statement. The interpretation does not lead to the fact that the data material is all encompassing, but the interesting data “entangled in chronicles” (Schapp 1976). Through the act of interpretation, the data *becomes* history.

Chronicle Knowledge

Chronicle knowledge is also present in decision-making activities. The existing chronicles, e.g., the chronicle of varieties and their descent comprise various aspects: graspable characterization categories capable of being designated that are capable of making a statement without personal experience and the data knowledge entangled in these chronicles. Both aspects signalize that with the exception of fundamental basic experience in terminology *no* personal experience with a particular, concrete breeding line is necessary. The mental presence, on the other hand, can *only* be established by means of personal experience; it is associatively implied in the chronicles. The chronicles as such are dynamic: some aspects are forgotten, new aspects are added. The older the chronicle, the more it gains the character of an anecdote. Chronicle knowledge is knowledge generated in the past.

Breeding Goal

Breeding pursues a goal. The “targeted” goal can, as a rule, only be achieved after 10 to 15 years. The expectations with respect to the efficiency and the appearance of a variety are established and fixed with the goal itself. The above-mentioned mental presence and data knowledge categories are, however, formulated here as expectations. The breeding goal accompanies the selection activities in the subsequent generations. Generally clearly articulated during the cross-breeding planning, it can alter and lose importance in advanced generations. The breeding goal is part of the chronicle of the variety. In a concrete decision-making situation, it anticipates the future.

Decision-making Matrix

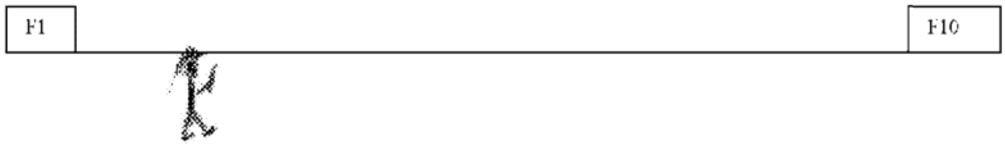
These separately sketched categories of knowledge help to illustrate the many-dimensional decision-making process in a concrete situation. The decision is preceded by a process of weighing the factors that can, according to the specific decision-making situation, comprise several categories of knowledge. In the concrete decision-making situation, the breeder has either plants, grains or numbers in front of him in accordance with the place where the decision is made (sensorial presence). The breeder has a more or less well-constructed notion of a breeding line or from the parents (mental presence). He knows the chronology (chronological knowledge). He already has data in front of him that have been interpreted with respect to their space-time context (data knowledge). That is confronted by the breeding goal that points towards the future and formulates specific properties as expectations and these, once again, as form and data expectations. The balancing out of these three levels – presence and existence, experience and knowledge, breeding goal and expectations – lead to the decision. This decision-making matrix, however, does not take the weighing of the individual elements of knowledge in the diverse decision-making situations into consideration. This will be briefly sketched in the following.

The Selection Activities – the Generational Consciousness

After crossbreeding, the next generation grows on the ear of corn, the first filial generation or “F1”for short. A new variety can grow out of each F1-corn. This is decided by the breeder’s selection activities in the subsequent years. From “F2” on, the combination of the parenthood properties “split” significantly and only after approximately 6 years can one calculate with a constant hereditary transmission. By means of continual selection activities during this time, the desired properties are selected over the years until all of the properties are “genetically homozygous.”

A Generation Cycle – Early and Delayed Selection in Contrast

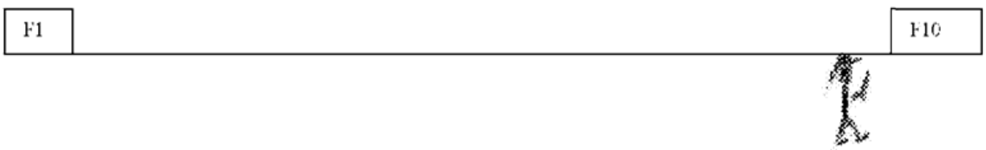
Early Selection:



In the first few years, the basis of judgment is considerably limited to the plants growing in the field. It takes years before enough data are collected. Too little of a breeding line can be harvested to test the yields. Despite the restricted data basis, approximately 90% of the selection decisions must be made during the first three generations (Becker 1993).

The sensorial presence plays an important role in the selection activities during this phase. Disease, reactions to deficiencies and the height of the plants are examples of factors that can be easily judged during this phase. The evaluation is made on the basis of the available knowledge about the parent plants that are physically not present (mental presence). The properties and descent of the parent plants (chronicle knowledge) are passed on in the chronicles of one of the parent plants. If the breeder has had personal experience with the parent plants, they are mentally present when the breeder envisions the new variety (mental presence). Mentally present knowledge plays a significant role during this phase; however, it centres on the parents and not the breeding line itself. The young breeding lines are first appraised, then analysed and finally their peculiarities and productive capacity are studied on the basis of the yields. In this phase of a breeding programme, the selection decisions are made during the vegetation period, the harvest of the elite ear and the appraisals of the corn during the preparation for sowing.

Delayed Selection:



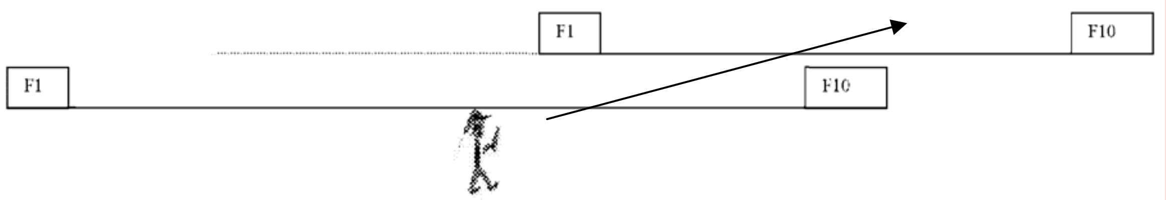
More and more data are collected over the generations. The data basis for judging a breeding line grows continually and becomes broader. The appraisals of many different properties by checking the yields and analysing the quality make the productive capacity of the diverse breeding lines in different habitats more and more clear. The breeders make efforts to visit all of the locations at least once. The breeding line itself writes its own chronicle. The chronicle is filled with the experiences gained in the past years that, in accordance with the age of a breeding line, gradually represent the breeding line. The growth phases have been experienced over the years (temporal configuration). Limited to one location in the beginning, the test cropping expands to various locations which gives the breeder the opportunity to experience its characteristics in various locations (spatial configuration). The temporal and spatial configurations make it possible for the breeder to evaluate the potential of the breeding line. They indicate a characteristic of the breeding line that is mentally present and of major importance for further decisions. The singular sensorial confrontation loses importance. It becomes part of the overall impression. The tremendous amount and density of data in subsequent filial generations is framed by the mental presence of the breeding line. Mental presence and data knowledge determine the breeder’s decision making during this breeding phase.

If the selection decision is based during the early generations on the sensorial presence of the still young breeding line, the chronicle knowledge about the parents plants and the mental presence of the parent plants, the fundamental knowledge sifts in the course of the generations to become data knowledge and the mental presence of the breeding line itself. The breeding line now writes its own chronicle. The breeding goal loses its importance over the course of the generations. The breeding line has to be convincing on the basis of its efficiency and the selection activities can no longer influence it. The place the decisions are now made is in general an office.

Generational Consciousness

In contrast to the breeder in his role as a farmer (vegetational consciousness), during the selection activities, the consciousness expands to include the entire generational cycle (generational consciousness). The breeder, male or female, has to keep all of the generations in mind. He or she has to know what can be meaningfully evaluated in which generation and when important decisions have to be made. Methodological security is linked with generational consciousness.

Planning Crossbreeding – Consciousness in Hereditary Flow



Planning crossbreeding is another key decision-making situation in modern cereal breeding. As a rule with respect to winter grain, it generally takes place in winter in an office. When the planning is being carried out, the parents whose properties complement each other with regard to the breeding goal are combined. Frequently the basis for the crossbreeding planning are approved varieties, or – upon a mutual agreement between the breeders – nucleous breeding stock from the current variety which is being evaluated. The combination takes place in this context on the basis of the available data and the known properties. The crossbreeding planning, however, also includes firm internal breeding lines. From the phase F5 on, more and more questions arise: What can the breeding line offer? Will it become a new variety, should it be discarded, or does it offer valuable properties that, although they do not suffice for an own variety, should be preserved and further developed thorough further crossbreeding?

The crossbreeding planning is with respect to the involved categories of knowledge the most sweeping. The chronicles of the own breeding lines are known. The comprehensive data are embedded in the mental presence. Data knowledge and mental presence determine the choice of the new crossbreeding partner that complement the properties of the breeding line and can develop it further. The sensorial presence has a correctional influence at most. The significance of the properties that are to be further developed are the focal point of interest; the real breeding line is “only” the carrier of the properties. The awareness of the properties rises above the sensorial presence of a breeding line and becomes a flow of properties, to an awareness within the hereditary flow of the properties. When planning the further crossbreeding of one’s own breeding line, there is, hence, another level that is based on a profound knowledge of the breeding material.

Conclusions

In order to understand the decision-making activities of a breeder, it is necessary to take the situational context into consideration. That determines at which point in time it is possible to make a meaningful decision. The breeder’s knowledge is based on hybrid knowledge composed of knowledge gained through experience and scientific knowledge. The complexity determines the intuitive character of the breeder’s decision-making activities. Intuition in this context does not mean an intuitionally-based arbitrary decision but rather a well-founded decision that is, however, due to the complexity of the individual determinants difficult to describe. The intuitive character is reinforced by the necessity to make many thousands of decisions within an extremely short period of time. The presence and skillful integration of all time, space and knowledge levels in a decision-making situation is what determines in the end competent breeding decision-making activities and endows the experienced breeder with the breeder’s eye.

In contrast to discursive cognizance that is based on sense perception and conclusions based on one another, intuitive cognizance – in this context as a basis for a decision – can be conceived as a ‘mental conception.’ Thus one of the basic concepts of Edmund Husserl’s phenomenology is the so-called “Wesensschau” (taking a look at the essence or substance itself) that makes it possible to find access to the intrinsic structure of an object and abstract it from the individual particularity or chance variations. The invariant is present in intuition, in direct contemplation (Lübcke 1998: 81ff.). The significance of intuition as the recognition of the invariant is also clear in the breeder's decision making.

The findings prove that intuition – which is called here 'the breeder's eye' – must be understood as the integration of many levels of knowledge. It also plays a role in modern plant breeding which is scientifically based. Scientific knowledge and knowledge gained through experience are not opposites but rather complementary fields of knowledge. Analogously, it can be presumed that intuition is also present in other disciplines within the field of agricultural science. Intuitive knowledge should be taken seriously and made accessible to research methodology. The goetheanists (goetheanism) and the phenomenology of nature (Timmermann 2005) have dedicated themselves to this task.

The impulse leading to the organic movement and, in particular, organic farming was the subjective consternation of the individual faced by the destructive treatment of nature which led to a quest for alternatives. Taking subject-oriented knowledge seriously has, hence, to be a natural part of the organic discipline in agricultural science. Subject-oriented forms of generating knowledge must imperatively, thus, belong to the research methodology used in an organic agricultural science and organic plant breeding.

It is extremely important for the organic plant breeder to learn to understand the significance of the multiple sensorial phenomena and, in so far as meaningful, to incorporate and materialize them in the new varieties. That, on the other hand, means that the breeder must intensively study the material that can only be achieved by proceeding professionally in a communicative context with organic farming.

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Topic IV

Variety and species mixtures - Diseases and soil

Papers or abstracts are based on posters presented at the workshop. They are listed in alphabetical order of first author which is not necessarily the presenting author. At first is presented the introduction by the poster moderator.

Variety and species mixtures - Diseases and soil: Introduction

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In many parts of the world where intensive agriculture is practiced the idea of growing cereal variety and species mixtures is not enthusiastically received. Comments such as "we tried that 30 years ago and it didn't work then" are sometimes made. In fact they did "work then", but this perception comes from a disconnected industry where the needs of the end-user are paramount and the consequences of their demands are not connected with the needs of the growers never mind the greater network of socio-economic and environmental consequences. Much emphasis has therefore been placed on challenging end users and meeting their needs which are reflected in some of the previous poster sessions. However, it is refreshing in this session to focus on the disease-limiting attributes of mixtures and how they might be optimized. In the context of current environmental concerns and the drive towards low input and organic agriculture, disease control in integrated systems assumes ever greater importance as chemical intervention options are by definition restricted.

The posters in this session are not all about mixtures but they are about environmental heterogeneity and its consequences. They are about operating disease control options in the real world, in a systems biology approach. Nevertheless, there are several themes which occur several times through these presentations, namely component complexity; rotation and intercropping, tillage and weeds. The following list highlights these themes in particular presentations:

- A. Newton 'The effects of spatial scaling in host heterogeneity on epidemics of a plant pathogen': ***Sown using farm drills – component complexity***
- A. Tratwal et al. 'Variety and species mixtures - their influence on the main disease and pest occurrence': ***Reduction in winter diseases, component complexity and pests***
- B. Henriksen et al 'Effect of a barley variety mixture on Fusarium grain infection': ***Variety/mixture choice, rotation & tillage effects on FHB***
- I. Björnsson et al. 'Spring barley cultivar mixtures with different levels of *Rynchosporium secalis* resistance': ***Less lodging and disease but no yield gain in 2-component mixtures***
- M. Fernández-Aparicio et al. 'Disease reduction in intercropping': ***Intercropping oats with legumes and cereals – strategies to maintain yield but reduce disease***
- M. Jalli et al. 'Effect of crop rotation on wheat diseases': ***Rotation and tillage effects on Septoria and Net blotch***
- J. Baddeley et al. 'Nitrogen transfer between intercropped clover and winter wheat': ***Intercropping: N transfer important over SHORT distances***
- MC. M. Bennett et al. 'Fungal pathogen development in conventional and weedy winter wheat': ***Crop micro-environment effects caused by weeds***
- M. Lutz et al. 'Swiss wheat varieties differentially attract naturally occurring Pseudomonas spp. in a soil dependent manner': ***Soil-micro-organism-variety effects are important***

Some of these points were discussed in the following questions:

- ✓ **Component complexity:** Do we need more than 3 components for stability, efficacy and durability? How should they be deployed?
- ✓ **Soils, rotation & intercropping:** how can we exploit soil benefitials – by utilizing particular genotypes? Using genotypes in inter-species mixtures? Using genotypes in intra-species mixtures? What traits should we measure?
- ✓ **Weeds:** microclimate and effect on soils – how important are they? What is the importance of density effects in this context?

The important factors are understanding heterogeneity in particular growing systems and how we might best ensure sustainable production with particular emphasis on stabilizing disease.

Nitrogen Transfer From Red and White Clover to Spring Barley

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Key Words: Red Clover, White Clover, Intercrops, Nutrient Transfer, Organic Farming

Abstract

We measured the uptake of nitrogen by spring barley at different distances from a boundary with either red or white clover in a field experiment. Clover plants at the boundary with the barley were labelled with a foliar ^{15}N application. Total uptake of N by the barley was not significantly affected by its distance from the clover boundary. However, measurements of the isotopic label showed that 1% of the N from the white clover and 2.5% of the N from the red clover were transferred to the barley. We conclude that the transfer of N between clover and cereals takes place over an appropriate spatial scale but, at least within the first year, it is unlikely to provide agronomically significant supplies of N.

Introduction

In many low input and organic farming systems nitrogen-fixing legumes, grown in combination with grasses, are a vital part of the fertility-building phase of a rotation, providing an input of N to the soil that is used by the subsequent cash crops (Watson *et al.* 1999). This pattern of rotation management has however an inherent inefficiency, since substantial amounts of the N released following cultivation of a grass/clover ley are susceptible to loss to the atmosphere and in drainage water (Vinten *et al.* 2002a; Vinten *et al.* 2002b). An alternative route to satisfy the N requirements of a cereal may therefore be to grow it synchronously with a leguminous crop, with the aim of using the transfer of N between the legume and cereal within a growing season to provide at least some of the nutrient requirement of the cereal. This approach may also reduce nutrient loss from the system, as crop mixtures can be more efficient than monocultures in capturing resources.

Previous studies have demonstrated the potential for limited nutrient transfer in crop mixtures (Jorgensen *et al.* 1999), although the extent to which this can be manipulated through management remains largely unknown. In this study we have measured the uptake of N by barley grown together with red and white clover in order to improve our understanding of N uptake and exchange in crop mixtures.

Methodology

We established spring barley and clover in a field experiment on the Craibstone Estate, Aberdeen (N057°11’, W002°12’). The soil was a sandy loam of the Boyndie soil series, pH 5.7 and 3.4% organic C (0-20 cm). In spring 2003, ten 6 x 20 m blocks were drilled with spring barley (*Hordeum vulgare* 'Static', 400 seeds m^{-2}, 11cm row spacing) with 6 m gaps between adjacent blocks. These intervening gaps were drilled with alternating red clover (*Trifolium pratense* 'Merviot' at 12 kg ha^{-1}) or white clover (*T. repens* 'S184' at 7 kg ha^{-1}) such that each of the blocks of barley had a boundary with both red and white clover. In early June, a ^{15}N label ($(^{15}NH_4)_2SO_4$ at 40 atom %, 4 g N m^{-2}) was applied to a 15 cm wide strip of clover adjacent to the barley using a fine spray (similar to McNeill *et al.* 1997). Samples of plants and soil were collected to determine the distribution of the ^{15}N immediately after labelling. Before harvest in September, barley plants were sampled from rows 11, 22, 33 and 44 cm from the clover boundary. These were analysed for total N and their isotopic enrichment using a mass spectrometer. The fraction of N transferred was calculated as the amount of excess ^{15}N in the barley/amount of N initially applied to clover. Yield and total N uptake of barley was measured in samples (0.15 x 3.5 m) taken at distances of 0.1, 1 and 3 m from the clover boundaries.

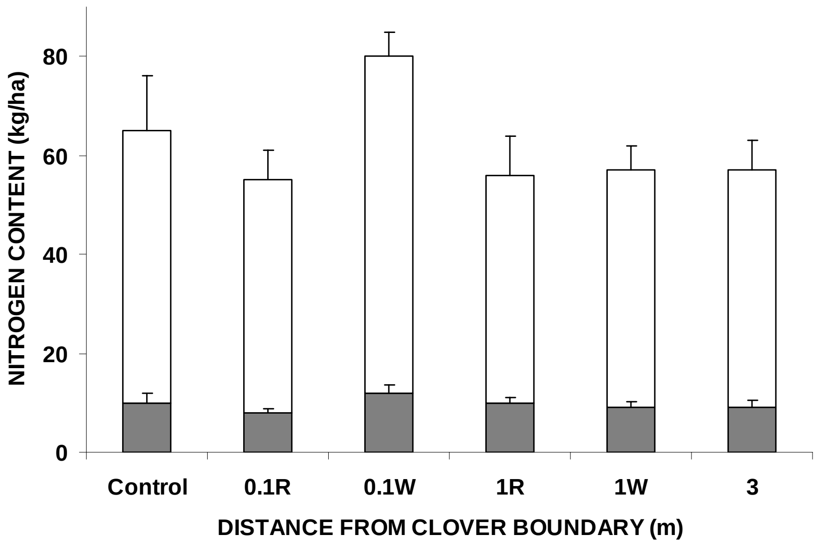

Fig 1. The nitrogen content in fractions of spring barley grown between blocks of red (R) or white (W) clover. Dark bars represent grain-N and white bars represent straw-N. The control treatment was grown adjacent to ryegrass.

Results and discussion

Distance from the clover boundary did not significantly affect the grain N or total plant N content of barley (Fig. 1). There was some evidence of N transfer to the barley adjacent to the labelled clover although this occurred only over short distances (Fig. 2). Our calculations suggest that at most about 2.5% of the label applied to the red clover and around 1% of the label applied to the white clover was transferred to adjacent barley plants.

The measurement of N transfer between adjacent crops in the field is technically challenging and any approach has inherent limitations. We found that despite careful application of the label, up to 10% could be detected on the soil surface. Foliar-applied label may behave differently to N naturally present in the plant. In addition, our plots had a high weed biomass meaning that N transfer could have occurred via weeds rather than clover. Notwithstanding these potential problems, our study demonstrates that any transfer of N from clover to cereals is likely to be confined to a narrow boundary between adjacent plants.

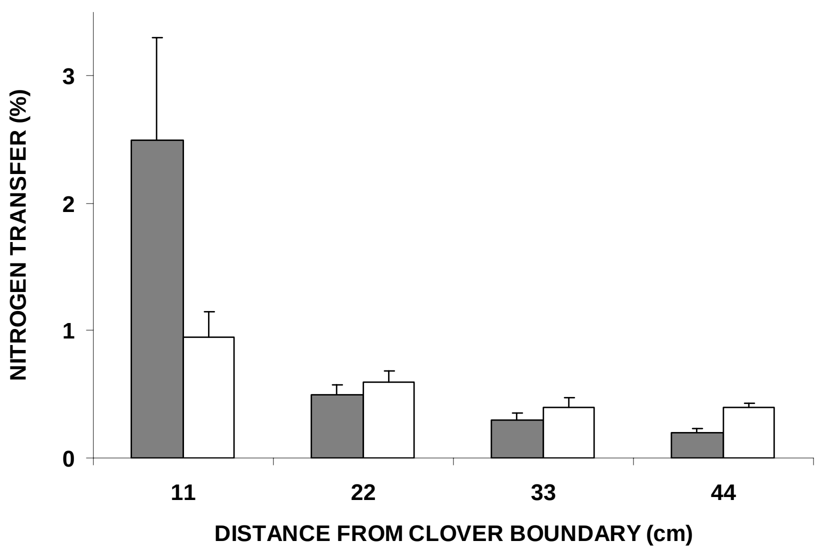

Fig 2. The percentage of ^{15}N in spring barley at different distances from ^{15}N-labelled red (dark bars) or white (light bars) clover.

Conclusions

Although this study has indicated that in newly established clover the amounts of N transferred to a cereal are not likely to be agronomically significant, this may not be the case for older clover swards. We have also demonstrated that the transfer of N between clover and an adjacent cereal crop takes place over the short distances that would typical be found when intimate mixtures of the two crops are grown in the field. In addition to these nutrient transfer issues, crop/legume mixtures offer other potential benefits that warrant further investigation.

Acknowledgements

We thank D. Simpson, M. Shepherd and O. Pauline for technical support. Funding was provided by the Scottish Executive Environment and Rural Affairs Department.

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Fungal Pathogen Development in Conventional and Weedy Winter Wheat

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Key words: weed understorey, disease, crop microclimate, crop architecture

Introduction

Basic changes to crop husbandry, such as crop density or changes in weed management, can affect the epidemiology of disease in various ways. Many studies have documented the effects that weeds have on wheat crop growth in terms of competition and yield loss. Few have looked at how a weed understorey may affect disease development. In low-input cereal systems the crop microclimate may be radically different compared to conventional high-input homogeneous systems and this is likely to influence the growth and development of both plant and pathogen. The effectiveness of weed growth in promoting or reducing stem-base diseases (caused by *Pseudocercosporella herpotrichoides* and *Microdochium nivale*) and the foliar disease, septoria tritici blotch (STB) (caused by *Septoria tritici*) in different cultivation systems (conventional and low-herbicide wheat) was investigated.

Materials and Methods

The experimental design was factorial (2 x 6) with weeds (2 treatments) and disease (3 pathogens and 3 controls) as main factors; winter wheat cv. Riband was used. Five common broad-leaved arable weeds were sown in designated weedy plots, while weed-free plots were maintained by the use of herbicides. Plots were inoculated with one of the pathogens, *P. herpotrichoides, M. nivale* or *S. tritici;* control plots were sprayed with water.

Architecture measurements, including height of ligule/tip above ground and leaf lengths (Lovell *et al.,* 1997) were recorded on wheat from weedy and weed-free plots. Crop microclimate was monitored by using temperature and relative humidity (RH) loggers that were placed alternatively in weedy and weed-free plots. Disease incidence and severity of eyespot and brown foot rot (BFR) was scored on a 0-3 scale; STB was recorded as the percentage diseased leaf area. Yield measurements (based on 40 ears plot^{-1}) included 1000 grain weight (g), number of grains ear^{-1} and total yield plot^{-1} (Kg m^{-1}). Statistical analysis was conducted using Statview® (SAS Institute Inc.). Factorial analysis of variance (ANOVA) and Fisher's Protected LSD multiple comparison test were used to separate treatment means.

Results

The measured components of wheat architecture were significantly influenced by the presence of weeds. In all samples, the height above ground of leaf ligules and leaf tips was significantly greater in weedy plots compared to weed-free plots ($P<0.05$). Similarly, leaf lengths were longer on tillers taken from weedy plots ($P<0.05$).

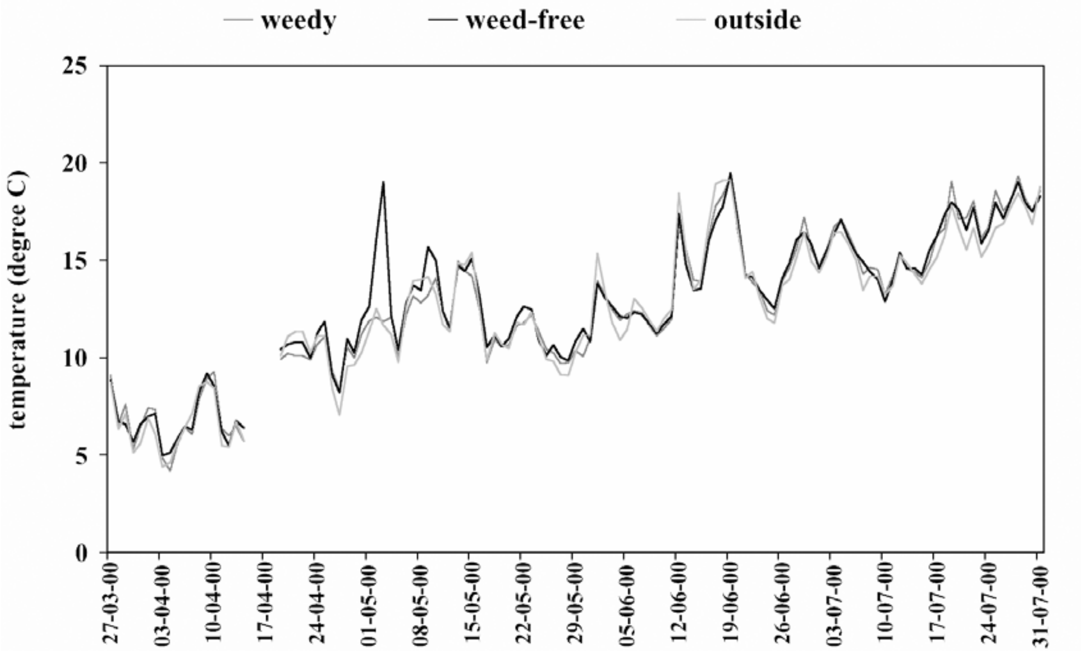


Figure 1. Mean daily temperature values in weedy and weed-free plots and from an outside sensor from March to July.
Missing values from 15th to 18th April inclusive.

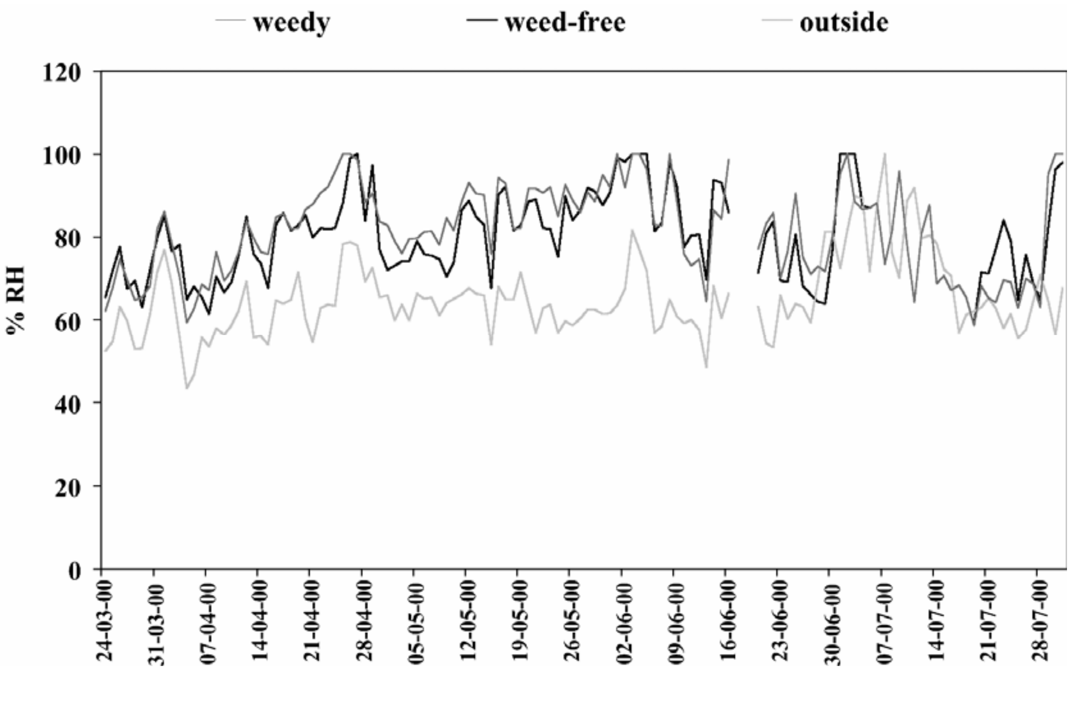


Figure 2. Mean daily RH (%) values in weedy and weed-free plots and from an outside sensor from March to July.
Missing values from 17th to 19th June inclusive.

Profiles from in situ temperature and RH sensors in weedy and weed-free plots showed that the greatest difference in mean daily temperatures between treatment plots occurred during the months of April and May, when weedy plots had lower temperatures (Figure 1) and higher RH than weed-free plots (Figure 2).

Repeated measures ANOVA revealed that the disease x weed interaction was significant for eyespot (P<0.05), with disease severity being greatest in weedy plots inoculated with P. herpotrichoides (Figure 3). The severity of BFR caused by M. nivale was significantly greater on nodes (P<0.001) and internodes (P<0.001) in inoculated plots compared to control plots (Figures 4, 5), but the main treatment effect of weeds was not significant. Nonetheless the highest severity of nodal BFR was recorded at the end of the season (GS 83) in weedy plots inoculated with M. nivale (Figure 4). Analysis of severity data for STB showed that inoculated plots had significantly greater disease than control plots early in the season (Figure 6) but by GS 83 this effect was no longer significant due to similar disease levels in both control and inoculated plots (Figure 7). The main treatment effect of weeds on severity of STB was not significant on any of the sample dates (Figures 6, 7).

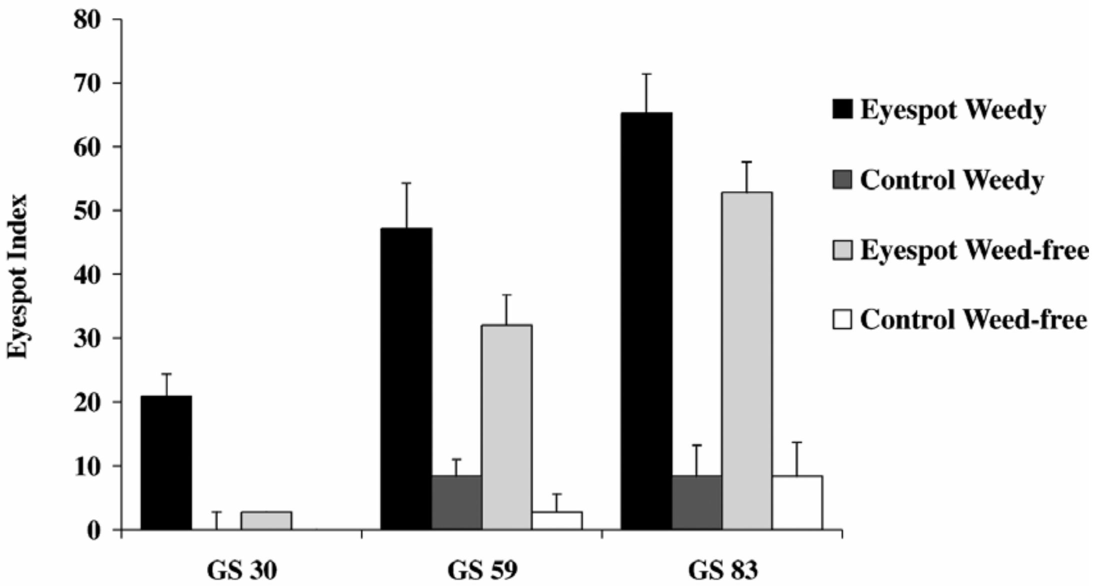
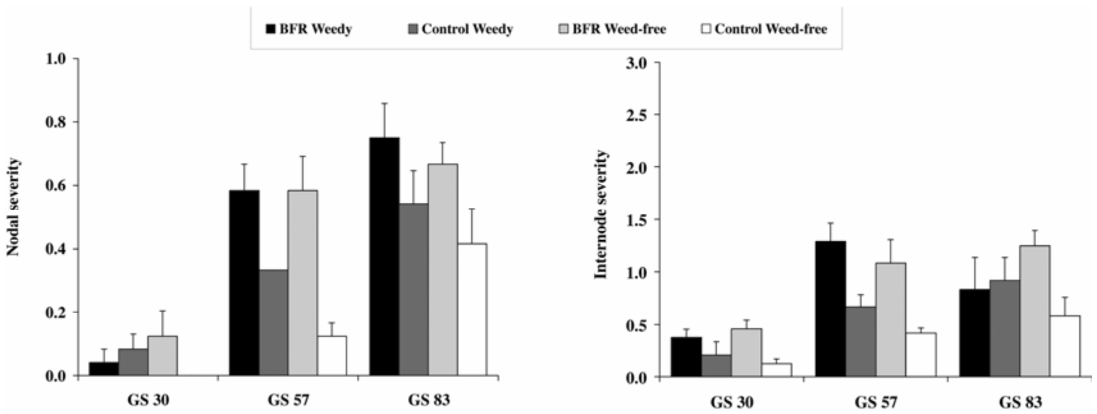
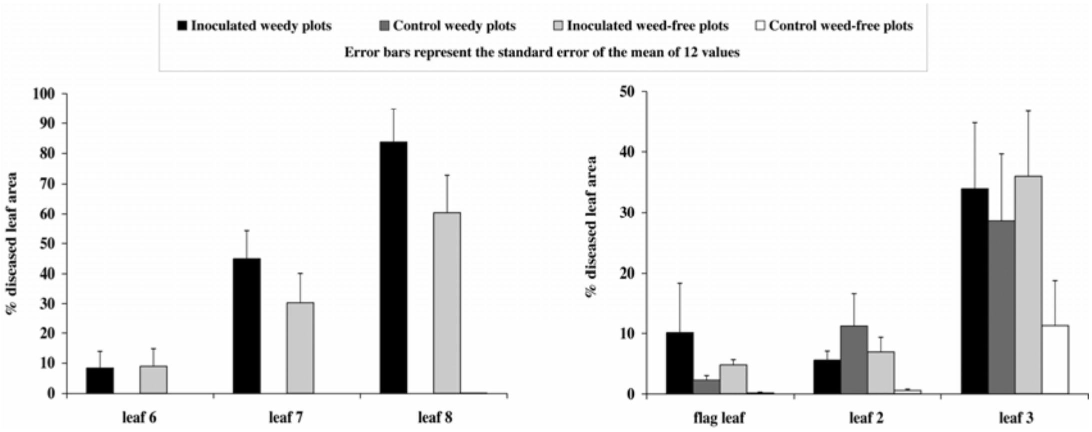


Figure 3. Severity of eyespot in weedy and weed-free plots. Error bars represent the standard error of the mean of 4 values.

The determined effects on yield by the different pathogens proved to be insignificant but the influence of weeds as a factor affected various components of yield. When analysed it was found that yield plot–1 and number of ear-bearing tillers plot–1 were significantly lower in weedy plots infected with P. herpotrichoides compared to weed-free plots (P<0.05). There were no significant differences in yields from plots infected with M. nivale or S. tritici regardless of the presence of weeds.



Figures 4 & 5. Severity of BFR on nodes and internodes in weedy and weed-free plots. Error bars represent the standard error of the mean of 4 values.



Figures 6 & 7. Percentage septoria tritici blotch at GS 30 (left) and 83 (right).

Discussion

Results demonstrated that competition affected the growth strategy of wheat in weedy plots leading to etiolated wheat plants with increased separation of leaves in the upper canopy. This may have influenced disease development, especially with regard to STB as inoculum transfer from lower infected leaves might have been less effective on these etiolated plants. This would have been aided by the presence of the weed understorey that may have physically impeded spore movement in weedy plots.

The time from stem elongation (GS 30, April) onwards is crucial in relation to disease development of eyespot, when weather determines whether or not lesions become severe (Higgins & Fitt, 1985). Data from our field trial showed that disease differences between weedy and weed-free plots were most evident from mid-April to the beginning of May (Figures 1, 2), coinciding with the time of maximum weed density. During this period relatively low temperatures (~10ºC) and high RH (>85%) accompanied by high rainfall during April and May would have favoured infection by eyespot. It is likely that the weeds provided a more conducive environment for spore production and infection for a longer period of time compared to weed-free plots.

While the presence of an understorey of weeds would have been expected to provide a conducive environment for the development of BFR, there was little evidence from the results of the field trial to suggest that weeds contributed to significantly greater levels of disease on nodes or internodes. It is possible that the residual level of fungi causing foot rot symptoms may have influenced these results. The high levels of infection in both control and inoculated plots may have been caused by residual levels of Fusarium species in the soil and is consistent with the fact that the treatment effect of weeds was not significant (Figures 4, 5).

Conclusions

It is apparent that a low-herbicide cereal cropping system may have markedly different effects on disease development compared to a conventional cropping system, largely as a result of the modified environmental and physical parameters of the cereal crop. Environmental factors such as air movement (Scott *et al.,* 1985), penetration of solar radiation and surface temperatures (Legg & Bainbridge, 1978) may prove significant in their influence on disease development, particularly of stem-base pathogens. Manipulations of the physical architecture of the crop may severely affect splash-dispersed pathogens, such as *S. tritici* by influencing raindrop penetration. Further detailed investigations are required in the light of these findings but it is evident that weed threshold levels could be critical in determining disease development by certain cereal pathogens.

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Barley mixtures in Iceland, two component mixtures with *Rhynchosporium secalis* resistance

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Key Words: Spring Barley, Mixtures, Rhynchosporium secalis

Abstract

The performance of the scald (Rhynchosporium secalis) susceptible cultivar Rolffi in two component mixtures with different Rh-resistant Norwegian lines/cultivars was tested in Korpa research station in Iceland. The mixtures did not out yield the component varieties in pure stands. The mixtures showed somewhat lower disease progress and less lodging and straw breakage. This indicates a possible lower disease build-up in continuous cultivation.

Introduction

Icelandic barley cultivation is in general a low input cultivation with moderate fertilizer inputs and low levels of chemical use. Most of the crop is for on-farm animal feed. The main production disease is Scald caused by the fungus Rhynchosporium secalis. Scald is usually not a problem on first year fields but can cause severe yield losses in the second year and onwards. A common practice is to grow barley for 2-4 years in rotation with grass. Many of the early maturing cultivars adapted to Northern conditions do not have Scald resistance and the possibility of growing them in a mixtures with Rhynchosporium resistant cultivars (Rh-resistant) is therefore of interest. In the spring of 2005 two field trials were sown in Iceland and identical trials were sown in two locations in Norway. This paper reports the results of the Icelandic trials.

Materials and methods

The Icelandic trials were sown in two locations, at Miðgerdi farm in Eyjafjörður in Northern Iceland and at Korpa research station in Reykjavik in South-west Iceland. The Midgerdi trial was severely damaged in spring frosts and therefore not harvested. The Korpa trial was sown on the 6th of May and harvested on the 19th of September. The trial was on peat soils in a ten-year-old barley field. The Finnish cultivar Rolffi, known to be very sensitive to scald, was grown in two component mixtures (50:50) with eight Norwegian Rh-resistant lines/cultivars. The eight Norwegian lines consisted of three pairs of lines with different sources of Rh-resistance and one pair with double resistance.

The trial was a random complete block design with three reps. The plots were scored for scald four times during the season and for lodging and straw breakage before harvest. The plots were harvested and the grain yield, 1000 kernel weight, and hectoliter weight measured.

Results and discussion

The results for the mixture performance are presented in Table 1. The mixtures did not out yield the component cultivars/lines grown in pure stands. 1000 kernel weight, hectoliter weight and dry matter were similar but the mixtures showed somewhat lower disease levels and less lodging/straw breakage. Only one mixture performed better than the component varieties in pure stands (Table 2).

Table 2. Mixture performance of two component mixtures of Rh-resistant lines and the Finnish cultivar Rolffi at Korpa.

	Rolfi+	*Comp. mean*	*Mixture performance*	
Grain yield, tons DM/ha	3,3	3,5	-0,14	*-4%*
1000 kernel weight, g	26	27	-0,7	*-3%*
Hectl. Weight, g/100 ml	54	54	-0,1	*0%*
DM %	57	58	-0,9	*-2%*
Disease score (17. Aug.), 0-9	3,8	4,0	-0,20	*-6%*
Comb. lodging/straw brk. Score (0-9)	4,1	4,4	-0,22	*-5%*

Table 3. Mixture performance of two component mixtures of Rh-resistant lines and the Finnish cultivar Rolffi , grain yield (tons DM/ha) at Korpa.

Cultivar/line	*Rolffi +*	*Comp.mean*	*Mixture performance*	
Tiril	2,7	3,1	-0,37	*-12%*
Lavrans	3,4	3,7	-0,36	*-10%*
GN02094	3,4	3,6	-0,24	*-7%*
GN02187	3,3	3,5	-0,20	*-6%*
GN02098	3,5	3,6	-0,17	*-5%*
NK96748	3,0	3,1	-0,15	*-5%*
GN02134	3,4	3,4	0,03	*1%*
GN02124	3,9	3,6	0,33	*9%*

The correlation between disease scores and the lodging/breakage was 0,71, which is in accordance with earlier findings in Iceland. The correlation between disease scores and grain yield was –0,52.

Conclusions

Two component mixtures of the Finnish cultivar Rolffi and Rh-resistant Norwegian lines did not out yield the component varieties in pure stands. This was despite the fact that mixtures showed lower disease progress and therefore less lodging and straw breakage. The lower disease scores for mixtures could indicate a possible lower build up of disease in continuous barley cultivation.

Effect of barley variety mixtures on *Fusarium* grain infection

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Keywords: spring barley, variety mixtures, Fusarium head blight, F. avenaceum

Introduction

Fusarium head blight (FHB) is a widespread and destructive disease in cereals. Several species within the fungal genus *Fusarium* are able to attack the head of the plants and infect the grains. The greatest concern arising from *Fusarium* attack is the reduced grain quality due to the production of a range of toxic metabolites with adverse effect on human and animal health, such as feed refusal, vomiting, and immunosuppressive or carcinogenic effects (D'mello et al. 1999; Placinta et al. 1999). In Norwegian cereals, the prevailing species have been *F. avenaceum*, *F. poae, F. tricinctum* and *F. culmorum* (Kosiak et al 2003). The toxin commonly detected in wheat is the trichothecene deoxynivalenol (DON). The more toxic HT-2 and T-2, also belonging to the trichothecene group, are often found in Norwegian barley and oats (Langseth & Rundberget 1999). Three different cultural practises are today considered to be of prime importance for combating FHB and the production of mycotoxins in wheat; deep tillage, the choice of the preceding crop in the rotation and the choice of appropriate cultivars, as varietal effects does exist (Dill-Macky and Jones 2000; Champeil et al. 2004). Differences in resistance against *Fusarium* head blight in Norwegian cereal varieties are mainly investigated in wheat. Differences in FHB resistance between barley varieties have been observed within years, although not consistent over years (Elen et. al. 2003). Little information is available on the level of FHB or Fusarium infection levels in variety mixtures. Variety mixtures are able to restrict the development of air borne pathogens like powdery mildew (*Blumeria graminis*), yellow rust (*Puccinia striiformis*) and leaf rust (*P. recondita, P. hordei*) and the evidence of this is considerable (Harjit & Rao, 1988; Malik *et al*., 1988; Kolster *et al*., 1989; Wolfe, 1990). However, also splash-dispersed diseases like *Septoria* infections may be restricted in mixtures (Gieffers & Hesselbach, 1988). The *Fusarium* species dominating in Norwegian cereal grains are considered to be mainly rain splash spread. In the present study we wanted to investigate how three barley varieties would affect the level of *Fusarium* grain infection when grown in mixtures compared to pure stands.

Methodology

Harvested grain from 2005 from two field trials with mixtures of three barley varieties were investigated for natural *Fusarium* grain infection. The field trials were located in mid-Norway (Verdal and Kvithamar). Each variety was grown separately, and in 50:50, as well as 30:70 and 10:90 mixtures with one of the other genotypes. Only two varieties were mixed in each treatment. In total, 15 treatments (mixture or pure stands) were compared. Within these 15 treatments, also mixtures with barley varieties and a winter wheat variety, as a catch crop, were included. Harvested grains were analysed for the incidence of different *Fusarium* species and *Fusarium* infection in total, using selective agar method, Czapek-Dox Iprodion Dichloran agar (CZID) (Abildgren et al. 1987). The seeds were plated on CZID directly (without surface sterilisation). The *Fusarium* infection was recorded as percentage infested kernels after 8 days of incubation under alternating 12 hours NUV-light/12 hours darkness at 25°C.

Results and discussion

The *Fusarium* infection level in harvested grains from the Verdal field varied between 34-59% (Fig 1). The Kvithamar field was too heavily infected to differentiate between treatments, with 98-100% *Fusarium* infection in the grains (mainly *F. avenaceum,* data not shown). The dominating *Fusarium* species in the Verdal field were *F. avenaceum* and *F. tricintum*, while *F. culmorum* and *F. poae* were present at a very low rate. Differences in *Fusarium* grain infection levels appeared between the different varieties in pure stands and between mixtures and pure stands. Grain from the variety

'Lavrans' had the highest *Fusarium* contamination (59%) while pure stands of 'Gaute' and 'Tiril' had 34% and 43% respectively (Fig. 1). A mixture with 'Lavrans' and 'Tiril' (90:10) had 51% infected grains, while higher proportions of 'Tiril' in the mixture appeared to lower the infection rate to the same level as for 'Tiril' in pure stand. Also mixtures with 'Tiril' and 'Gaute' had infection levels at the same rate as the two varieties in pure stands. The *Fusarium* resistance level in Norwegian barley varieties is not well documented, but a previous investigation of natural *Fusarium* infection levels in different varieties does not indicate any consistent differences in resistance over years (Elen et. al., 2003). In general, somewhat higher *Fusarium* frequencies have been recorded on seeds of 6-rowed than on 2-rowed barley varieties in Norway (Brodal and Skinnes, 2006) Morphological characters and plant architecture may be one of several mechanisms with influence on *Fusarium* grain infection levels between varieties, and thus may also affect disease development in variety mixtures. The *Fusarium* species present in the fields in this study are considered to be mainly rain splash spread. Differences in morphology and growth pattern at early stages between the varieties may influence the microclimate and the splash dispersal of *Fusarium* conidia. Investigation of a white clover understorey in a wheat clover intercrop demonstrated that the understorey was able to cause a decrease in splash dispersal of *Septoria tritici* spore movement to the crop level compared to monocrop (Bannon & Cooke, 1998). Crop architecture, early growth and ground cover of winter wheat that may influence the level of splash dispersal of *Fusarium* spores to the heads, are also suggested to explain lower levels of mycotoxins and *Fusarium* infections in harvested winter wheat grains in Norway compared to spring cereals (Elen, unpublished). However, substantial amounts of data on *Fusarium* grain infection levels in variety mixtures are needed before any conclusions can be drawn. The present results from the barley variety mixture trials are based on two replicates mixed to one sample only, and have to be considered as strictly preliminary. Harvested grains from similar field trials will be investigated in 2006.

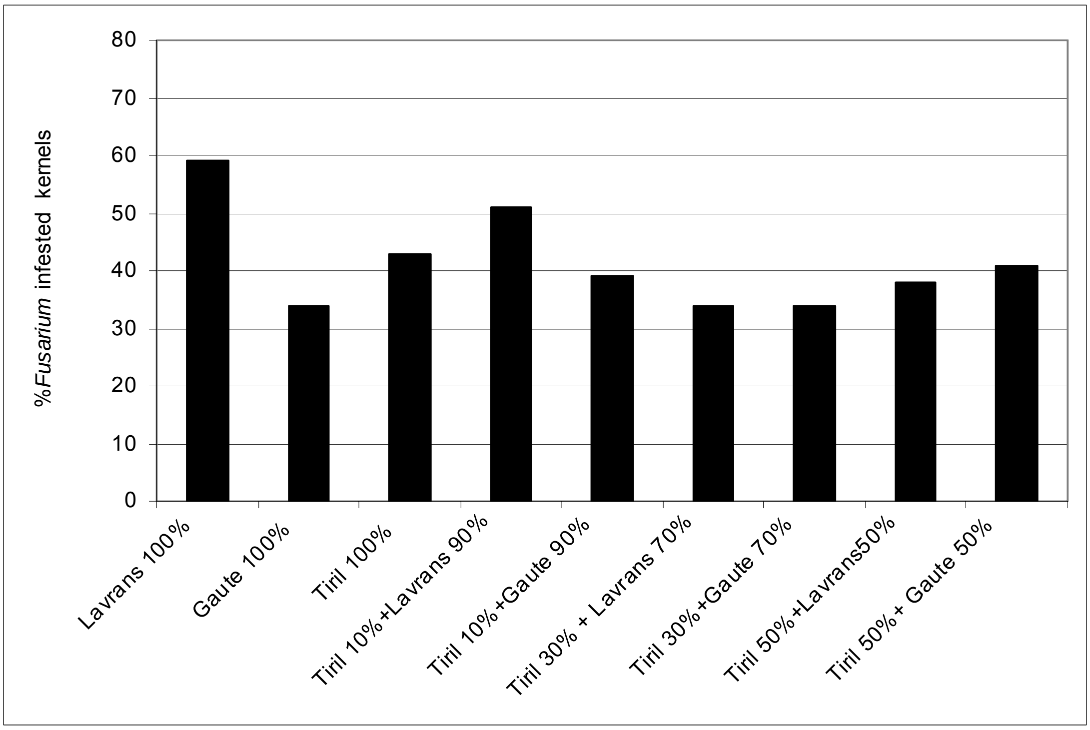

Fig. 1 Percentage *Fusarium* infection in harvested grains of the three barley varieties Lavrans, Gaute and Tiril, each grown in pure stands and in 50:50, as well as 30:70 and 10:90 mixtures with one of the other varieties.

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Preliminary results on the effect of crop rotation on wheat diseases in no-tillage and tillage systems in Finnish low input farming

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Key Words: crop rotation, direct drilling, plant protection, Stagonospora nodorum, Pyrenophora tritici-repentis,leaf spot diseases, root diseases

Introduction

Plant protection in no-tillage systems brings new challenges for research. The aim of our project is to study the role of plant diseases, pests and weeds in direct drilling cultivation which is becoming more widespread in Finland (8 % of the total area of cereal and oilseed crops in 2006). The objectives of tillage are to develop a good seedbed, control weeds, and destroy insect pests and diseases in the debris. New solutions are needed to replace the positive effect of tillage when changing from tillage to direct drilling system. Crop rotation is essential for the effective control of soil- and residue-borne diseases of wheat. The purposes of this research are to focus on how wheat diseases might be affected by reduced tillage practices and crop diversification, and to find sustainable methods to Finnish low input cereal growing.

Methodology

Research is conducted in Jokioinen in Finland. In 2003, two years before research began, the field was direct-drilled with spring wheat. In 2004, the crops were spring wheat, barley and turnip rape. In the autumn 2004, the field area was divided in two research sites, in tillage and in no-tillage systems. The research started in 2005 with spring wheat, barley, turnip rape and pea as studied crops. The trial consists of eight different rotation systems both in tillage and no-tillage systems (Table 1).

Table 1. Crop rotation trial plan.

	2003	2004	2005	2006	2007	2008	2009
1	wheat	wheat	wheat	wheat	wheat	wheat	wheat
2	wheat	turnip rape	wheat	barley	wheat	turnip rape	wheat
3	wheat	wheat	turnip rape	wheat	barley	wheat	turnip rape
4	wheat	barley	wheat	turnip rape	wheat	barley	wheat
5	wheat	wheat	barley	wheat	turnip rape	wheat	barley
6	wheat	wheat	turnip rape	barley	pea	wheat	turnip rape
7	wheat	turnip rape	barley	pea	wheat	turnip rape	barley
8	wheat	barley	pea	wheat	turnip rape	barley	pea

The pathogens studied were *Stagonospora nodorum, Pyrenophora tritici-repentis* and stem and root diseases caused by different *Fusarium* species. In 2005, disease assessments were done on 200 plants per treatment at three different growth stages. The causal agents of stem diseases were isolated and identified on selective agar media. Soil samples were taken in the beginning of the research and after harvest to study the interactions of soil microbes, plant diseases and cultivation methods in aim to determine how different crops influence the microbial community structure and activity in soil rhizosphere. Soil samples were taken from three depths: 0-5 cm, 5-10 cm and 10–20 cm. These results are not analysed yet.

Preliminary results

Results from the year 2005 indicate that wheat monoculture increases the risk for leaf spot diseases, both in normal tillage and in no-tillage systems. However, the risk is higher in no-tillage plots. In 2005, there was no significant difference between barley and turnip rape as a pre-crop to wheat leaf spot diseases (Fig. 1). The results are explained by the earlier infection of plants in monoculture plots which had visible symptoms (0.5 % infection) at seedling stage whereas the plants grown after barley or turnip rape were clean.

In no-tillage plots, the effect of rotation was significant to *Fusarium* diseases on stems: no-tillage and monoculture increased substantially the amount of *Fusarium avenaceum* but not *Fusarium culmorum*. Similar phenomenon was found on the pathogens studied from wheat heads. Probably because of a low root and stem disease level in 2005, there was not a significant effect of pre-crop on the total amount of root diseases on wheat (Fig 2). The yield data correlates with the disease data. Spring wheat grown in monoculture had significantly lower yield both in tillage and no-tillage systems compared to wheat grown after barley or turnip rape. There was not a significant difference in the effect on yield between barley and turnip rape as a pre-crop (Fig 3).

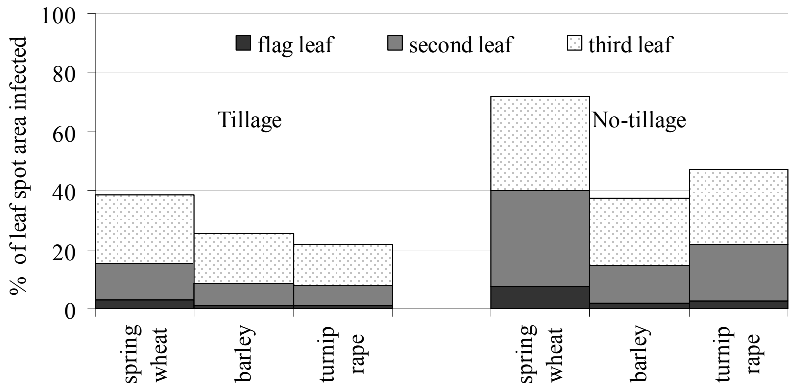

Fig. 1. Percentage of *Stagonospora nodorum* and *Pyrenophora tritici repentis* infected area on spring wheat with spring wheat, barley or turnip rape as a pre-crop in tillage and no-tillage systems. Observations were done on three upper leaves at early milk ripening stage

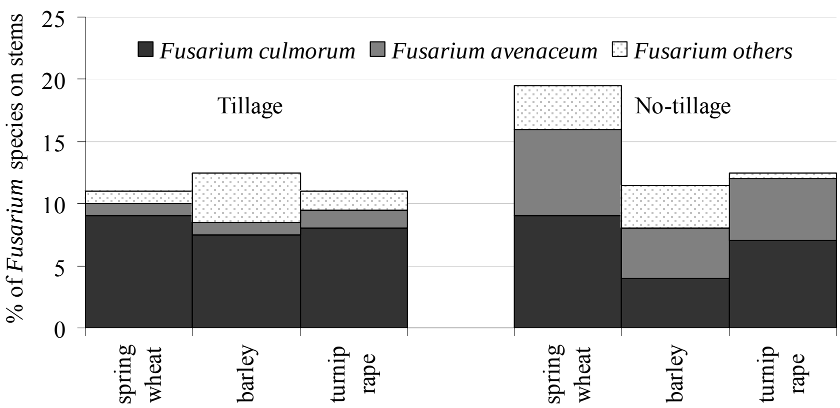

Fig 2. Percentage of different *Fusarium* species on spring wheat stems with spring wheat, barley or turnip rape as a pre-crop in tillage and no-tillage systems. Observations were done at early milk ripening stage.

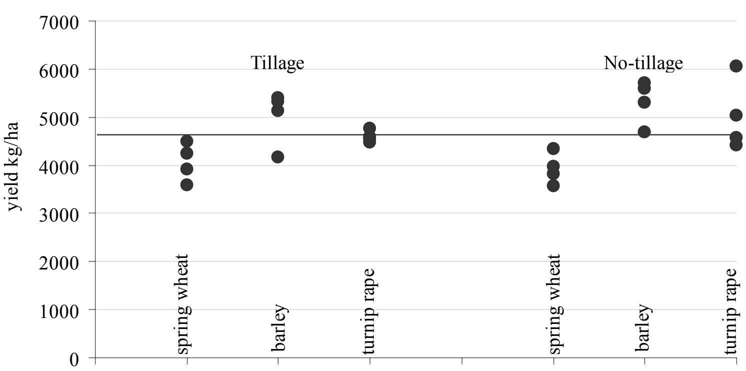

Fig 3. Yield of spring wheat plots with spring wheat, barley or turnip rape as a pre-crop in 2005. Average yield marked with a line.

Conclusions

No-tillage system has several advantages compared to conventional tillage system: it reduces soil erosion, improves soil structure and reduces energy inputs. However, movement to new cultural management practices might lead to new disease problems (Paulitz 2006). Our preliminary results indicate that in Finnish no-tillage system, leaf spot disease might cause more severe problems than root and stem diseases compared to conventional tillage system. However, the severity of root and stem diseases is highly correlated with water content in soil which might differ significantly between growing seasons (Wiese 1998).

On the contrary to Krupinsky research (2004), in our trial the yield level of wheat grown in monoculture was significantly lower than wheat grown after barley or turnip rape. Similar phenomenon was observed with barley: barley grown after wheat yielded in average 960 kg less than barley grown after turnip rape. These differences in the yield cannot only be explained by the amount of diseases in different treatments. In the coming three years, our research will continue in the aim to find more explanations for the positive effect of crop rotation by studying the activity of different soil microbes in several crop rotation systems.

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Swiss wheat varieties differentially attract naturally occurring *Pseudomonas* spp. in a soil dependent manner

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Key words: wheat varieties, Pseudomonas spp., 2,4-diacetylphloroglucinol. phlD, low-input soils

Abstract

Improvement of plant fitness and yield by natural occurring root colonizing microorganisms is of special value in low-input or organic wheat production. Beneficial soil bacteria such as certain *Pseudomonas* strains are known to promote plant growth by several mechanisms. Thus, these microorganisms are able to circumvent potential negative consequences of low-input cropping systems such as the limited supply of nutrients and higher disease pressures often observed. A significant potential exists to further improve beneficial effects by breeding wheat genotypes with a greater capacity to sustain the interactions with these bacteria. However, the interaction of crop plants (e.g. at the variety level) and bacteria as well as the conditions which favor the accumulation of beneficial microorganisms are largely unknown. Therefore, a main goal of this study was to obtain essential information about the impact of wheat genotypes on the frequency and genetic diversity of beneficial *Pseudomonas* ssp. in low input soils.

Three Swiss wheat varieties with a different genetic background were examined for the traits mentioned above in two distinct soils and bacteria were isolated from three different ecological niches, soil, root surface and the inside of the roots. We could show that the wheat varieties differed in the accumulation of pseudomonads carrying the *phlD* gene (which is essential for the production of the antimicrobial compound 2,4-diacetylphloroglucinol and therefore disease suppression). Furthermore, a significant interaction between soil origin and wheat variety on root colonization by *Pseudomonas* spp. was found.

The effects of spatial scaling in host heterogeneity on epidemics of a plant pathogen

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Key Words: Barley Mixtures, epidemics, spatial, scale, trade-offs

Abstract

Cultivar mixtures control disease in many host-pathogen systems. The exposure of pathogens to host heterogeneity associated with deployment of mixtures can be manipulated through the scale on which component cultivars are deployed. As the host-genotype unit area decreases a trade-off is predicted between the suppressive mixture effects and the selection for pathotypes with complex virulence that are able to overcome this. To test this prediction barley plots were sown in regular grid patterns and infection with *Rhynchosporium secalis* (Rhynchosporium) was recorded to determine the effect of spatial scaling of host heterogeneity on disease progress. Two groups of four cultivars, one from cultivars grown in the UK and the other from cultivars grown in Poland, along with all their respective three-component mixtures, were also grown in a field trial in equal size blocks of different spatial arrangements. These were 'monoculture' blocks, a 'homogeneous' mixture of all eight cultivars, and a 'structured' arrangement comprising a random mixture of all eight monoculture plots and all the three-component mixtures within each of the two cultivar groups. This was to create different selection pressures on the pathogen populations in each block. Infection with both *R. secalis* and *Blumeria graminis* f.sp. *hordei* (powdery mildew) was recorded.

Linear mixed-effects and variogram models were used we examine the trade-off between scale and disease reduction. The results confirmed that the optimum balance between mixture efficacy and guarding against selection for adverse pathotypes is at neither extreme of monoculture or homogeneous mixture of different genotypes. For *R. secalis*, a splash-dispersed pathogen, the optimum patch size is much larger than that reported for other pathogens and spore dispersal characteristics and environmental factors are identified as major scaling parameters. In the structured block experiment the random mixture did not significantly reduce infection compared with the monoculture for powdery mildew, but the structured arrangement achieved a 38% reduction. Rhynchosporium was equally reduced by 64% in the homogeneous and structured blocks compared with the monoculture. This demonstrated the potential of spatial deployment patterns to reduce pathogen spread but also the scale dependency on pathogen dispersal characteristics.

Such plot-scale geometrical deployment is clearly impractical on a farm scale, but the principles can be used to devise patchy mixtures strategies which can be achieved using normal farm drills. A preliminary experiment achieved better reductions in Rhynchosporium in a crude, patchy *in situ* mix in a farm drill hopper than with thoroughly pre-mixed seed of winter barley.

Disease reduction in oats when intercropped with other cereals

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Key Words: Crown rust, intercropping, powdery mildew

Abstract

Intercropping oats with legumes has a beneficial effect on plant growth and yield, but this in turns results in increased rust and powdery mildew infection. On the contrary, intercrops with other cereals maintain forage and grain yield and tend to reduce rust and mildew infection.

Introduction/Problem

Intercropping is a method for simultaneous crop production and soil fertility building (Willey 1985). Intercropping is regarded as an ecological method to manage pests, diseases and weeds via natural competitive principles that allow for more efficient resource utilization (Liebman and Dyck 1993). Intercropping was a common practice before the 1950ties, before mechanisation, plant breeding and use of synthetic fertilizers and pesticides were implemented in a more intensified agriculture. Intercrops of legumes and grasses in pastures are still widely used, but arable intercropping (cereals, grain legumes, oil seeds) for feed and human consumption declined in past decades in industrialized countries, although is still a common practice in many areas with less intensified agriculture. There is however, a renewing interest in intercropping linked to the need for reducing nitrogen cost and soil erosion and the potential for increasing land use intensity (Francis 1986). There is also interest in intercropping in organic farming to produce animal feed sources of organic origin, with a need to increase organic cereal and grain legume (protein) crop production, to balance the European organic deficits.

Crown rust, caused by Puccinia coronata f.sp. avenae is the most widespread and damaging disease of oat. There have been severe epidemics in virtually every oat-growing region of the world. Moderate to severe epidemics can reduce grain yield by 10 to 40%. Individual oat fields may suffer total crop failures. Weather conditions most favourable for oat growth also favours crown rust, so greatest yield losses commonly occur in years when oat yields should be highest. Powdery mildew, caused by Erysiphe graminis f.sp. avenae is another widespread foliar disease of oat although less damaging than crown rust. It can be important in humid regions such as maritime northwest Europe and along the Atlantic seaboard.

The objectives of the present studies were to study the effect of various intercrops in oat yield and disease reduction.

Methodology

Field experiments were performed during seasons 2003-2004, 2004-2005 and 2005-2006 at Córdoba, Spain, in which oat (cv. Aspen) was grown both as sole crop and mix intercropped with either triticale (cv. Peñarroya), barley (cv. Aspen), faba bean (cv. Prothabon), vetch (cv. Mezquita) and pea (cv. Athos) at the ratio 1:1 (50% oat : 50% other crop). Experimental units were 1.5x4 m plots, in randomised blocks with 3 replications. Rust and powdery mildew severity (% leaf area affected) were scored in 10 individual plants per plot. Total plant biomass and grain yield was measured in 1 m2 per plot.

Results and brief discussion

Intercropping oat with legumes maintained or increased forage and grain yield compared with growing oat as sole crop. A similar increase was already reported by Carr et al. (1998) in intercrops with pea. No significant increase or reduction in forage or grain yield were observed in oat intercrops with other cereals.

Rust severity increased markedly in oat when intercropped with faba bean and vetches. The reason for the increase when intercropped with faba bean might be double: 1) nutritional: the faba bean/Rhizobium provide nitrogen to the oat that are bigger in the intercrop than in the solecrop; 2) microclimatic: faba bean provides a cover to oats. Intercrops with peas had no effect on rust, whereas intercrops with cereals tended to reduce rust infection.

There was little powdery mildew in the seasons studied, what precluded to discern clearly the potential effect of the intercrops. However, it was clear that powdery mildew infection increased in itercrops with faba bean. No significant effect was detected in intercrops with other legumes or with cereals, except intercrops with barley that significantly reduced powedery mildew infection in 2004-2005 season.

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Variety and species mixtures – their influence on the main disease and pest occurrence

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Key Words: sustainable production, variety mixtures, ecological farming

Abstract

In Poland, every year, about 17% of all cereal growing area are mixtures – variety and species mixtures. Usually species mixtures are more popular because they are used for feeding animals. In Poland low-input and ecological farms are more and more popular and that's why one can observe that mixtures will be grown on the larger scale than now. For last five years at the Plant Protection Institute, Poland, field experiments with variety and species mixtures and their influence on disease and pest reductions were provided.

The results of four years (disease incidence) and one year (pest occurrence) field experiments designed to evaluate epidemiological effects of variety (winter barley) and species (spring wheat, spring barley, oat) mixtures are presented. The studies were carried out in two places (south and west part of Poland).

In the four year experiment impact of different barley varieties and their different two- and three-component mixtures were tested with reduced dosages of fungicides on disease reduction in the mixtures compared with pure stands were evaluated.

In two, one year experiments impact of species and variety mixtures on pest reduction compared with pure stands were evaluated (without chemical control).

Introduction

Monoculture of modern cereal crops are popular mainly due to the technical and organizational reasons. The main advantage for farmers - they are easier in crop husbandry, quality and product use. On the other hand genetically uniform monocultures are suffering from biotic and abiotic stresses. In monocultures one can observe more frequent and severe of plant diseases - in monoculture chemical protection of crops is a norm.. In order to keep high and stable grain yields and quality in monoculture one has to use high inputs (Wolfe et al. 1997, Finckh et al. 1997, 1999). Experimentally and practically it has been proved that cultivar and species mixtures can constitute an alternative to cultivar growing in pure stands. It has been found that in mixtures operate different epidemiological and ecological factors, which lead to considerable disease reduction, pest and weed control, which finally result in higher and more stable grain yields than in barley varieties grown in pure stands (Finckh et al. 2000, Gacek et al. 1999, Wolfe et al. 1997).

The use of variety mixtures (mainly in barley cultivation) has been introduced widely into practice during the nineties. The main concentration has been on species mixtures and spring barley mixtures.

The mixtures are design particularly for control of powdery mildew, but more general recommendations for their use are:

- broad genetic variation, more resistant plant can be a „barrier" for pathogens
- yield of the mixtures are usually greater and more stable
- reduced need for fungicides (low costs and environment protection)
- variety mixtures can be cultivated in the same way as pure stands. (Gacek et al. 1996).

Methodology

During the four growing seasons (2001-2005), experiments with winter barley variety mixtures combined with different fungicides treatments were done in two sites, namely in Experimental Station for Variety Testing Słupia Wielka (Wielkopolska District – west part of Poland) and Plant Breeding Station Bąków (Opole District – south part of Poland).

In the experiments, four different winter barley cultivars (Bombay, Gil, Gregor, Bażant) and composed of them two- and three-way mixtures (Bombay/Gil, Bombay/Gregor, Gil/Gregor/Bażant) were used. On the experimental plots different treatments with fungicides were used, namely:

- untreated plots (control)
- one treatment with 0,25, 0,5 and full dosage of fungicides
- two treatments with 0,25, 0,5 and full dosage of fungicides

During the vegetation season powdery mildew observations were done 3-5 times using 1-9 scale (where 9 – fully resistant, 1 – fully susceptible). In order to compare the disease levels on different cultivars in pure stands and on their mixtures combined with different fungicide treatments the Area Under Disease Progress Curve (AUDPC) (Finckh et al.1997) was evaluated.

The grain yield from all the experimental plots was measured and for mixtures presented as the comparison to expected height of the yield. Expected yield of the mixture – average of the pure stands yield.

The studies concentrated on the pests occurrence in winter barley variety mixtures were carried out in the vegetation season 2004/05 at two places – Słupia Wielka and Bąków. Second experiment was carried out in 2005 at the Plant Protection Institute Experimental Station Winna Góra (west part of Poland). In this experiment three different spring cereals (wheat, barley, oat) and their two-way mixtures were used. During the vegetation season the main pests occurring on cereals were observed, namely: leaf miners (*Agromyzidae*), leaf beetles (*Oulema*) and thrips (*Thripidae*).

Results and brief discussion

The development of powdery mildew in different treatments was analyzed on the basis of the Area Under Disease Progress Curve (AUDPC). On the base of the AUDPC value the reduction of powdery mildew in the mixtures occurring due to epidemiological and ecological factors functioning in mixed stands (Wolfe et al. 1975) were also evaluated. In general, cultivar mixtures were less affected by the disease, than pure stands both on plots without and with fungicide control.

The biggest and most frequently occurring disease reduction was observed in the most genetically diverse - three-component mixture (Gil/Gregor/Bażant) (Tab. 1-3). In the growing season 2001/02 (Tab. 1) about 50% powdery mildew reduction was observed at three-component mixture with 1 treatment with full dose of fungicide (two treatments with full dose – 21,5% of disease reduction). In the growing season 2002/03 because of late frost in the spring (March) plots at Bąków were completely destroyed. In the experiment at Słupia Wlk. 25% of plots were destroyed. In the same growing season due to adverse weather conditions, generally very low incidence of powdery mildew was observed.

Table 1. Powdery mildew reduction according to the area under disease progress curve – 2001/02

Place	Chemical treatment	Powdery mildew reduction (%)		
		Bombay/Gil	Bombay/Gregor	Gil/Gregor/ Bażant
Bąków	Control	18,7	7,2	11,5
	1 treatment ¼ dose	no reduction	no reduction	10,1
	1 treatment ½ dose	4,9	16,4	no reduction
	1 treatment full dose	no reduction	no reduction	no reduction
	2 treatments ¼ dose	30,8	no reduction	17,8
	2 treatments ½ dose	no reduction	18,1	10,2
	2 treatments full dose	9,3	0,0	33,3
Słupia Wlk.	Control	33,8	4,1	35,0
	1 treatment ¼ dose	36,1	20,4	27,2
	1 treatment ½ dose	47,9	no reduction	28,6
	1 treatment full dose	10,8	20,2	50,4
	2 treatments ¼ dose	5,2	26,8	13,9
	2 treatments ½ dose	24,5	25,2	15,9
	2 treatments full dose	38,1	24,3	21,5

In the 2003/04 vegetation season (Tab. 2), again, bigger reduction were observed in the three component mixture (at both places in combination with two treatments and ¼ dose of fungicide). About 40% of powdery mildew reduction (comparing to pure stands) were observed at the mixture Bombay/Gil

Table 2. Powdery mildew reduction according to the area under disease progress curve – 2003/04

Place	Chemical treatment	Powdery mildew reduction (%)		
		Bombay/Gil	Bombay/Gregor	Gil/Gregor/Bażant
Bąków	Control	no reduction	34,8	30,7
	1 treatment ¼ dose	6,4	no reduction	no reduction
	1 treatment ½ dose	48,0	32,8	12,5
	1 treatment full dose	23,6	no reduction	12,2
	2 treatments ¼ dose	36,9	14,0	55,6
	2 treatments ½ dose	15,7	24,6	13,3
	2 treatments full dose	38,5	20,0	6,1
Słupia Wlk.	Control	33,5	14,1	19,8
	1 treatment ¼ dose	33,3	38,8	17,0
	1 treatment ½ dose	16,5	32,9	29,1
	1 treatment full dose	39,3	6,7	8,1
	2 treatments ¼ dose	24,7	7,1	48,3
	2 treatments ½ dose	44,8	24,7	6,3
	2 treatments full dose	43,6	43,9	20,6

Table 3. Powdery mildew reduction according to the area under disease progress curve – 2004/05

Place	Chemical treatment	Powdery mildew reduction (%)		
		Bombay/Gil	Bombay/Gregor	Gil/Gregor/Bażant
Bąków	Control	30,2	26,6	no reduction
	1 treatment ¼ dose	no reduction	26,9	no reduction
	1 treatment ½ dose	21,5	no reduction	42,3
	1 treatment full dose	2,5	no reduction	no reduction
	2 treatments ¼ dose	no reduction	11,3	22,3
	2 treatments ½ dose	no reduction	no reduction	no reduction
	2 treatments full dose	17,8	29,5	no reduction
Słupia Wlk.	Control	31,1	no reduction	24,9
	1 treatment ¼ dose	31,1	31,7	18,8
	1 treatment ½ dose	29,6	23,7	36,2
	1 treatment full dose	14,8	21,1	20,7
	2 treatments ¼ dose	32,6	20,6	9,9
	2 treatments ½ dose	26,6	30,4	40,9
	2 treatments full dose	6,5	no reduction	18,2

In the fourth year of the experiment (Tab. 3) mixtures with bigger and most frequently occurring reductions were Bombay/Gil and Gil/Gregor/Bażant.

As far as the grain yield is concerned, generally yield advantage was observed in the mixtures compared with pure stands (mixing effect). Furthermore yield increase was also observed between treated and untreated plots (chemical control effects) (Tab. 4).

In the mixture Bombay/Gil at all different chemical treatments yield increase were observed.

Table 4. Yield (dt/ha) and expected yield of mixtures in different combinations of chemical control – average from two sites and four years.

Mixture	Chemical treatment	Yield	Expected yield	Increase
Bombay/Gil	Control	75,5	74,3	1,1
	1 treatment, ¼ dose	82,3	80,7	1,5
	1 treatment, ½ dose	79,2	78,9	0,2
	1 treatment, full dose	82,5	82,5	0,0
	2 treatments, ¼ dose	84,5	83,8	0,7
	2 treatments, ½ dose	84,3	82,8	1,4
	2 treatments, full dose	88,8	87,9	0,9
Bombay/Gregor	Control	74,2	73,3	0,9
	1 treatment, ¼ dose	80,9	80,2	0,7
	1 treatment, ½ dose	80,4	80,1	0,3
	1 treatment, full dose	82,1	82,3	-0,2
	2 treatments, ¼ dose	81,1	83,0	-1,9
	2 treatments, ½ dose	84,0	83,3	0,8
	2 treatments, full dose	85,8	89,2	-3,4
Gil/Gregor/Bażant	Control	75,8	75,3	0,5
	1 treatment, ¼ dose	82,0	81,6	0,4
	1 treatment, ½ dose	82,4	81,0	1,4
	1 treatment, full dose	82,6	84,0	-1,4
	2 treatments, ¼ dose	84,3	84,5	-0,3
	2 treatments, ½ dose	85,6	85,4	0,3
	2 treatments, full dose	88,5	90,8	-2,4

In the experiment with winter barley variety mixtures in case of leaf miners (*Agromyzidae*) – the reductions were observed in all mixtures at Bąków (10-17%) and no reductions at Słupia Wlk. Reductions of the *Oulema* spp. occurrence were observed at Słupia Wlk. (Bombay/Gregor – 27,5%) and at Bąków (Bombay/Gil – 26,9%, Gil/Gregor/Bażant – 7,1%) (Tab. 5-6).

Table 5. The number of the pests (per 25 plants) occurring on the winter barley plants (Bąków)

Pure stands/ mixtures	Leaf beetles (*Oulema* spp.)		Leaf miners (*Agromyzidae*)	
	Numb	Reduc	Numb	Reduc
Bombay	4,75		2,00	
Gil	6,00		4,00	
Gregor	5,00		4,00	
Bażant	6,00		5,00	
Bombay/Gil	3,75	26,88	2,75	14,52
Bombay/Gregor	6,50	no	2,25	17,38
Gil/Gregor/Bażant	5,00	7,14	3,5	10,40

Table 6. The number of the pests (per 25 plants) occurring on the winter barley plants (Słupia Wlk.)

Pure stands/ mixtures	Leaf beetles (*Oulema* spp.)		Leaf miners (*Agromyzidae*)	
	Numb	Reduc	Numb	Reduc
Bombay	3,00		6,25	
Gil	4,25		7,5	
Gregor	3,50		7,25	
Bażant	2,25		10,25	
Bombay/Gil	4,00	no	7,5	no
Bombay/Gregor	2,25	27,5	9,00	no
Gil/Gregor/Bażant	5,00	no	8,25	no

The reductions of pests occurrence in spring cereals were observed only in case of leaf beetles - in mixtures spring wheat/spring barley (SW/SB) and spring wheat/oat (SW/O) – Tab. 7.

Table 7. The number of the pests (per 25 plants/ears) occurring on the spring cereals and their mixtures (Winna Góra)

Pure stands/ mixtures	Leaf beetles (*Oulema*		Thrips (*Thysanoptera*)	
	Numb	Reduc	Numb	Reduc
spring wheat (SW)	5,75		299,25	
spring barley (SB)	7,00		125,00	
oat (O)	14,75		220,25	
SW/SB	6,25	6,89	227,00	no
SW/O	6,75	36,77	220,25	no
SB/O	9,50	no	206,75	no

Conclusions

1. In general, winter barley variety mixtures were less infected by powdery mildew (*Blumeria graminis* f. sp. *hordei*) than varieties grown in pure stands.
2. The highest and most frequently occurring reductions of powdery mildew were observed in more genetically diverse three-component mixture (Gil/Gregor/Bażant).
3. High reductions of powdery mildew were observed in two-component mixtures Bombay/Gil.
4. Winter barley variety mixtures can constitute an alternative to varieties growing in pure stands, especially for ecological farms – reductions were observed in combination without chemical control.
5. Varieties mixtures combined with reduced fungicide treatments had a positive effect on winter barley grain yield.
6. The influence of the winter barley variety mixtures on pests occurrence is difficult to interpret and the next studies are necessary.
7. In spring species mixtures with wheat only reductions of leaf beetles occurrence were observed.

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This proceeding comprises papers based on oral and poster presentations at the COST860 - SUSVAR workshop on cereal crop diversity held in La Besse, France, 13-14 June 2006. The support by COST is acknowledged.

SUSVAR stands for 'Sustainable low-input cereal production: required varietal characteristics and crop diversity' and COST is an intergovernmental framework for European co-operation in the field of scientific and technical research. The SUSVAR network, initiated spring 2004, now includes researchers from more than 100 institutions in 28 European countries.

The main aims of the SUSVAR network are to ensure stable and acceptable yields of good quality for low-input, especially organic, cereal production in Europe. This will be achieved by developing ways to increase and make use of crop diversity, by establishing methods for selecting varieties, lines and populations taking into account genotype-environment interactions and by establishing common methodology for variety testing where appropriate. The present workshop focused on ways to increase and make use of crop diversity from the production to the product.

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