CHARACTERISTICS OF SPRING BARLEY VARIETIES AND CROP DIVERSITY FOR ORGANIC FARMING AND VARIETY TESTING

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Abstract

Results from Danish spring barley variety trials including about 50-120 varieties and variety mixtures on three locations over three years under organic as well as conventional farming systems demonstrate the importance of genotype-environment interactions. This has implications for potential future organic VCU-testing; here results are shown for grain yield.

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Further, grain yield results from of six variety mixtures and their 14 component varieties indicate that variety mixtures may be less influenced by genotype-environment interactions compared to pure line varieties.

Introduction

Modern varieties have been developed with the aim of combining high productivity and standardised product quality under high-input conditions. The organic growing system is a system where pesticides and inorganic fertilizers are generally not allowed. Hence, biotic and abiotic stresses have to be overcome by growing appropriate varieties and by practicing good farm management. An important question is whether modern varieties possess the right combinations of characteristics to ensure a stable and acceptable yield of good quality when grown under different organic growing conditions. It is well known that varieties often perform and yield differently in different environments due to genotype-environment interactions, so it may be important to evaluate characteristics of varieties in organic as well as in conventional farming systems. However, it remains unclear to date whether the differences between conventional and the organic growing systems are large enough to justify breeding and testing of varieties in both environments.

Despite quite intensive testing of varieties, predictions of future performance of varieties, when grown on specific locations, are known to be very difficult; this especially within organic growing systems, where no pesticides and fertilizers can help stabilize performance. Therefore, using mixtures of appropriate varieties might be a way to obtain more stable and acceptable yields. Variety mixtures have so far been studied especially in relation to effect of reducing disease severity under conventional farming conditions. Varietal characteristics and crop diversity in organic cereal production are considered in a Danish project on organic spring barley (BAR-OF, 2002) as well in a European COST Network on sustainable low-input cereal production (SUSVAR, 2004).

Cereal production is important for Danish agriculture constituting an area of about 1.5 million ha. The latest figures for the Danish organic cereal production areas (from 2003) is that 2.8% of the total cereal production area is organic, e.g., 2.6% of the total Danish spring barley of 580000 ha and 58.6% of the total Danish spring wheat area of 13000 ha. The varieties grown are of conventional origin and officially tested under conventional VCU-testing (Value of Cultivation and Use). Results from large variety trials in the BAR-OF project with 50 to 120 varieties and variety mixtures grown in different growing systems at three locations in three years will be considered here.

Danish spring barley field trials (BAR-OF trials)

Field trials were conducted on experimental research areas at three Danish locations: Jyndevad, Foulum and Flakkebjerg. Three different growing conditions were studied either resembling organic systems (i.e. no pesticides, weed harrowing or grass-clover undersown, and low input of organic fertiliser (e.g. slurry)) or conventional systems (use of herbicides and synthetic fertiliser according to local standards, however, without use of fungicides). All together, data were collected in five to six different environments (system x location) in each year 2002 to 2004. The conventional conditions were only applied on two locations in each of the years 2002 and 2003 constituting all together 4 of the 17 environments and the organic conditions with grass-clover undersown only on 2 locations in the year 2004. Many different disease- and growth characteristics were assessed (Table 1). Here we will focus on grain yield.

Table 1

Characteristics measured in BAR-OF variety trials

Agronomical traits	Disease, weed and grass-clover assessment	Yield and quality traits
▪ Plant emergence ▪ Plant density spring ▪ Date of heading ▪ Culm length ▪ Lodging ▪ Breaking of culm ▪ Breaking of ear ▪ Date of ripening ▪ Reflectance ▪ Leaf Area Index	▪ Powdery mildew ▪ Barley leaf rust ▪ Net blotch ▪ Scald ▪ Ramularia ▪ Species specific weed assessments ▪ Grass-clover assessments during/after harvest of cover crop	▪ Grain yield ▪ Protein content ▪ Starch content ▪ Specific weight ▪ Kernel weight ▪ Grading

More than 150 varieties and variety mixtures were included in the trials (not all varieties were studied each year) representing actual and coming new varieties with different expectations for performance in organic systems as well as varieties from other sources being potential 'organic' candidates. Among the variety mixtures six 3-component mixtures were specifically constructed based on information from official variety testing at the beginning of the project. These mixtures consisted mostly of high yielding varieties. They were made according to official certification requirements with respect to relative yield, disease resistance, and date of ripening. However, larger differences between component varieties than accepted according to the rules for culm length were introduced as this parameter is related to weed competitiveness and this trait have specific focus for organic farming.

Results and discussion

Sixty-six varieties from the BAR-OF variety trials were also tested in the Danish VCU testing in the years 2002-2003 (Anonymous, 2002, 2003). Relative grain yield data from the VCU testing was compared to the results obtained in the BAR-OF trials averaged over the three locations (Fig. 1). From this comparison it is seen that the relative yield of these varieties in the two types of system are related, i.e., high yielding varieties in the VCU testing are to a large extend also high yielding under organic conditions, e.g., the variety 'Simba' yielded the very best in both systems. However, large significant differences were found between the ranking of some of the varieties in the two systems. As an example the variety 'Danuta' is very well adapted to the organic conditions in the BAR-OF trials, e.g., it has high weed competitiveness, whereas it yielded very poorly in the VCU-testing.

The opposite is the case for the variety 'Lux' with very low culm length and high disease susceptibility. Further, for varieties with relative grain yield around 110 in the VCU-testing there is a significant difference between their grain yield under organic conditions. Therefore, information about performance under organic conditions is insufficient when using only conventional VCU-testing.

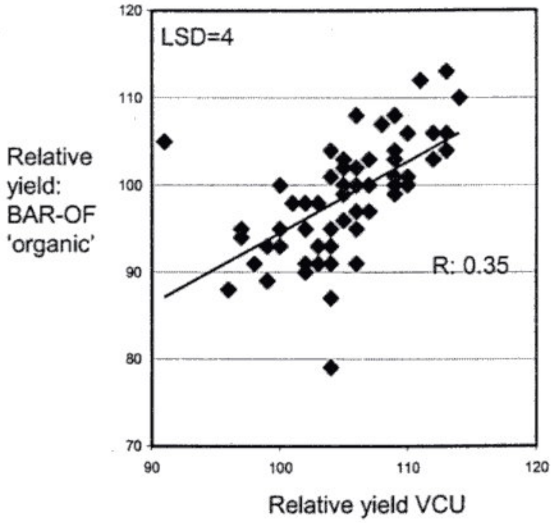

Fig. 1. Relative yield in 2002-2003 of 66 varieties from the VCU testing (100= 72.5 hkg/ha) compared to yields obtained in the BAR-OF trials (100=49.7 hkg/ha)

This conclusion is supported by an extensive statistical analysis of the predictability of conventional VCU-testing information on disease and growth characteristics for the grain yield of 50 varieties in either conventional systems or organic systems within the BAR-OF project (Østergård et al 2005). The varietal characteristics from VCU-testing consisted of 1) disease severity assessment for each variety to each of four prevalent diseases (barley powdery mildew, barley leaf rust, scald and net blotch) observed in official trials without fungicide treatment; and 2) other growth characteristics assessed in official trials with fungicide treatment: culm length, tendency to lodging, tendency to breakage of straw and ear, and date of ripening (Anonymous 2001,2002). In addition, a combined measure for the years 2002-2004 for competitive ability of each variety against weeds (Hansen, 2002) calculated from information on canopy height and Leaf Area Index from herbicide treated trials was included as a competition index. This index has been part of the VCU-testing since 2002. Using factorial regression analysis, the best model for predicting the observed grain yield each year from these characteristics the previous year was found. With this model, the residual variance component for varieties was lower for observations from the conventional growing system than from the organic growing system implying that the VCU-characteristics better predicted the observed grain yields from the conventional growing system.

Genotype-environment interactions between varieties and different growing conditions can be visualised graphically by bi-plots based on an AMMI (Additive Main effects Multiplicative Interaction effects)-analysis (Gabriel, 1971; Kristensen & Hill, 2002). Such an analysis of observed grain yield data for 82 varieties and variety mixtures from two locations, two systems and two years (2002-2003) are shown in Fig. 2. The lines represent the two growing systems ('organic' conditions and 'conventional' conditions) and point's different varieties and variety mixtures values corrected for year and location means. The length of a line indicates how much the varieties in total deviate from the variety means in this system. Varieties close to the origin are relative stable in yield between systems, whereas varieties that are far away from the origin show large deviations from the means in one or both of the two systems. According to the results (Fig. 2), some varieties yielded very different in the two systems, e.g. variety 'Troon' (19757) performing much better in the organic system than in the conventional system and the opposite for 'Alexandra' (19740) and a breeders line (20086). 'Danuta'(19459) being an outlier in Fig. 1 also in this analysis turned out to be badly adapted to the 'conventional' conditions in the BAR-OF trials and 'Lux' (17242) was about average in the conventional system but far below average for the organic conditions. The variety mixtures (e.g. 20187) tended to be located between the two lines indicating that their yield is not so much influenced by the differences between the growing systems. A detailed analysis of common characteristics of varieties in the same part of the graph as well as detailed characterisations of the different environments including abiotic and biotic stress factors as well as climatic data are waiting.

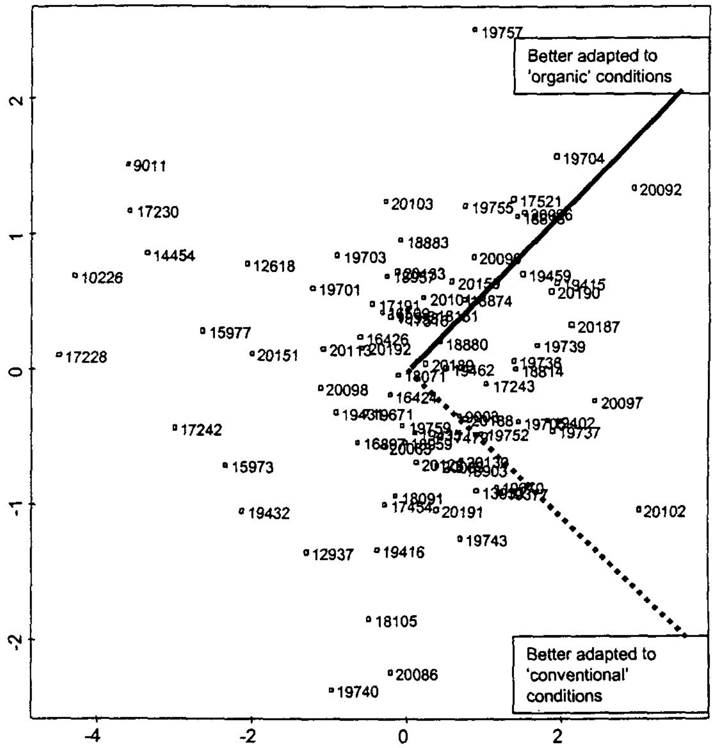

Fig. 2. Bi-plot showing for each variety and variety mixture the grain yield in a certain growing system, as deviation from overall grain yield average. The project-ion onto each line multiplied by the length of the line indicates the value of the deviation in the respective system in hkg/ha (bold line is 'organic' conditions, and broken line is 'conventional' conditions).

Yield stability is desirable and may be difficult to obtain in organic farming systems. As variety mixtures are known to reduce disease development and expected to be more efficient in using available nutrients and compete with weeds, we investigated the yield stability of six variety mixtures compared to their 14 component varieties over all 17 different environments. For three of the six mixtures, the grain yield was significantly higher than the average yield of its components; in none of the mixtures it was significantly lower. The variation in grain yield over environments of all variety mixtures was compared to the variation of all component varieties. The six mixtures had on average a better yield stability, i.e., were less variable over environments, than the 14 component varieties grown in pure stands with respect to actual yield as well as to rank values of yield (Østergaard et al 2005). Such results are important for the ongoing discussion in EU about marketing of conservation varieties (Council Directive 98/95/EC).

Conclusion

It has been unclear whether the differences between conventional and organic growing systems are large enough to justify breeding and testing of varieties in both environments. To investigate this we conducted large variety trials. Conclusions from such trials depend on the range of varieties tested as well as on the range of organic and conventional environments studied. Here, we have included a broad spectrum of varieties, however, most of the varieties were conventional varieties bred for high-input growing conditions. Further, the systems we have chosen to compare may be more similar than what is found between conventional high-input farms and certified organic farms. Therefore, even bigger genotype-environment interactions may be found in other studies. However, the final decision concerning implementation of organic VCU-testing is also based on economic possibilities and the establishment of organic plant breeding involves many other aspects relating to the organic principles, e.g., breeding techniques, specific traits, participatory aspects. By the end of this year a Danish protocol for spring barley variety testing for organic farming systems will be available. This protocol is developed on the basis of the trials in the BAR-OF project.

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