Yield performance in heritage spring wheat and barley varieties in organic farming

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Introduction

The grain yield in cereals has increased considerable since the beginning of industrialisation of agriculture, including introduction of modern plant breeding 100-150 years ago. Since beginning of this period, plant breeding has selected and bred varieties suitable to the changing agricultural conditions, and hence to increasing extent focused on conventional high input agriculture as this type of agriculture developed. Most pronounced is probably the plant height, and old high plants are likely to lodge at the nitrogen level normally seen in modern industrial agriculture. Modern varieties are characterised by a high degree of specific resistance genes against selected pathogens on the expense on a broad durable polygenic resistance (Robinson 1995). Organic farming is a low input agricultural system, with some similarities with former agriculture compared with modern industrial agriculture. Therefore, heritage varieties selected for, and adapted to the low input agriculture in former days could have some advantages compared with modern varieties, and/or the advantage of using modern varieties could be less pronounced in the low input organic system. On this background, a project in Denmark has multiplied and studied agronomic and quality traits of mainly Danish heritage varieties compared with modern varieties under organic cropping conditions.

Methods

In spring wheat, 54 varieties no longer in the European Common Catalogue of Varieties of Agricultural Plant Species were compared with 22 high quality varieties on the current Common Catalogue. Trials were carried out over three years at the organically managed farm Mørdrupgård at Zealand, and in one year at Gl.Estrup, Jutland, Denmark. Landraces from Nordic Genebank (NordGen) were extracted by Hans Larsson at Swedish University of Agriculture. Landraces were multiplied, and within the landraces, selection lines were developed. True varieties developed by plant breeders in the period 1882 to 1988 were extracted from Nordic Genebank and multiplied prior to the experiment. This group represent the majority of spring wheat varieties in The Nordic Genebank. As spring wheat has always been a minor crop in Denmark, most of the varieties including the landraces are of Swedish origin, and bred for this area. The modern varieties were delivered by plant breeders in Sweden, Germany, Switzerland and Austria based on their recommendations for good performing varieties with high baking quality under organic conditions in Denmark. The varieties did therefore not necessarily represent the mean of modern varieties.

Protein content was estimated by NIT analysis. Baking test assessing loaf volume was done at Darzau Getreidezüchtung on 20g seed samples in two replicates. Data for loaf volume is only available from the trial at Mørdrupgård 2008.

Two field trial in barley was sown in one year on each of the farms. Varieties included three modern approved malting barley varieties, three 2-rowed landraces, three 6-rowed landraces and one 6-rowed and seven 2-rowed varieties from the period 1868 to 1965. The modern varieties were selected as the recommended malting varieties by the dominating seed companies in Denmark. The older varieties and landraces were selected as the varieties giving the best tasting beer in an experiment among beers brewed on malt from 46 old Danish barley varieties prior to the start of the experiment.

Experiments were sown in 12 m^2 plots in 4 replicates, except spring wheat at Gl.Estrup which had only 3 replicates. Three spring wheat varieties, Øland (landrace), Dacke (released in 1990) and Fiorina (released in 2001) were included in all blocks and experiments in spring wheat, and the mean of these varieties were used to calculate a relative yield and relative protein content within each block. The widely grown modern malting variety Power was used as standard variety for comparison between the two barley experiments.

Statistical p-values were developed by F-test in GLM.

Results and discussion

Spring wheat

As can be seen in Figure 1, there seem to be a tendency of improved yield during the period of modern plant breeding. However, this tendency is weak (R^2=0.17). When looking exclusively within the group of heritage varieties 1882-1988, the tendency of improved yield during the period seem to disappear (R^2=0.02). The protein content seems to be constant over the period (R^2 =0.02).

When the spring wheat varieties were grouped in three groups, landraces, old varieties and modern varieties, a significant effect of group could be seen on grain yield ($p < 0.001$). The modern varieties had a significant higher yield than the old varieties and landraces. The modern varieties had a relative mean grain yield of 107.9 (105.6 – 110.2), the old varieties had a relative mean grain yield of 88.7 (86.8 – 90.9) and the land races had a relative mean grain yield of 88.1 (85.2 – 90.9).

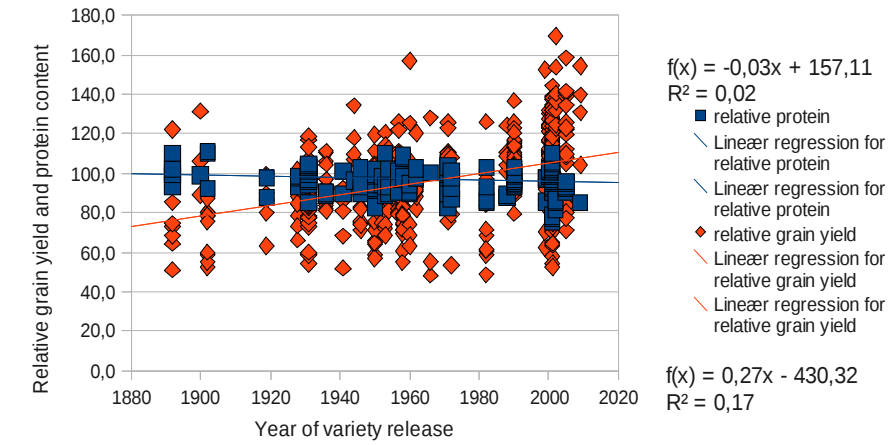
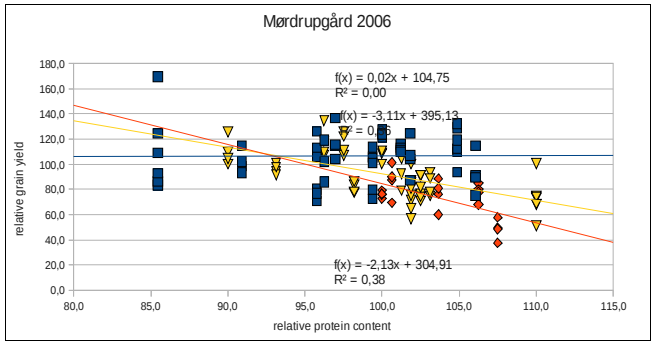


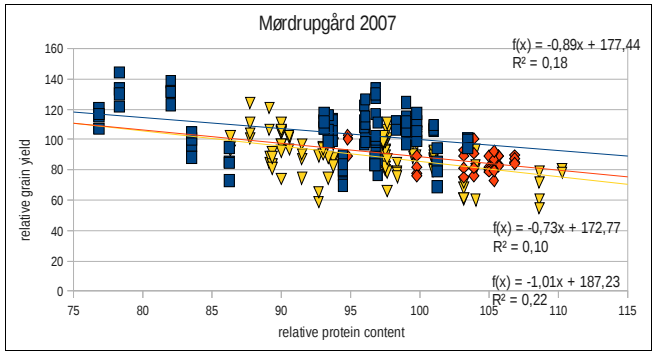
Figure 1: Grain yield and protein content in spring wheat varieties released during the past century. Results for landraces are not presented, as a year of release cannot be determined a landrace

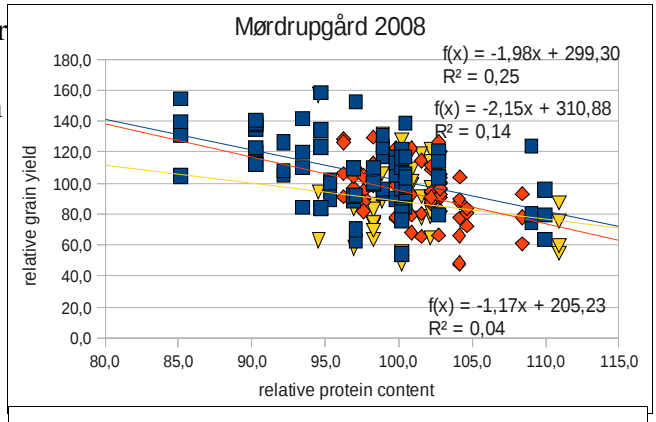
This indicates that the increased yield in the current varieties compared with the heritage varieties may not be an effect of plant breeding, but an effect of the origin of the seed or the selection of varieties to be included in the trial. Plant breeding has developed gradually through the century, and if the increased yield had been an effect of plant breeding, an increased yield would most likely also have been seen also during the period 1882 and 1988. The modern varieties were delivered from seed companies and selected based on their recommendations for organic production, whereas the heritage varieties were multiplied from genebank material and gives a broader diversity of the varieties from this period. This may explain the difference between the varieties on the European Common Catalogue of Varieties of Agricultural Plant Species compared the varieties no longer on this list. Hence, the result does not support the finding of other authors, who concluded a gradual increase in yield though the past and former centuries (Murphy et al 2008, Perry and D'Antuono 1989).

In variety field trials, a negative correlation between grain yield and protein content is often observed (Schlehuber and Tucker 1959). In three out of the four experiments, a week tendency of negative correlation between yield and protein content could be observed for all groups, landraces, heritage varieties and modern varieties (except the group of modern varieties at Mørdrupgård in 2006), but this tendency was not significant (Figure 2 a-c). In the field trial at Gl.Estrup 2007, no correlation between yield and protein content was seen (Figure 2d). The soil at Gl.Estrup is a eutrophic peat soil, whereas the soil type at the tree experiments at Mørdrupgård is a more normal middle loam soil with less nitrogen available in the soil.

There were no correlation between protein or gluten content and loaf volume in these trials. Most likely, the gluten content were in all varieties so high that other factors were limiting for loaf volume. Under these conditions, heritage varieties had 9% higher loaf volume than modern varieties ($p>0.99$). This result is surprising, since modern varieties had a higher gluten index, and a high gluten index is considered as a quality criteria for wheat breeding.







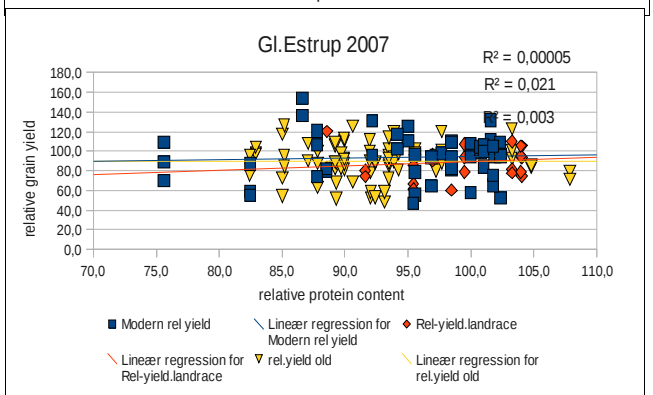


Figure 2a-2d: correlation between yield and protein content in 4 spring wheat field trials grpuped in landraces, old true varieties, and modern varieties.

Spring barley

As can be seen in Figure 3, the modern varieties were the highest yielding with a mean relative yield of 104.2% of Power, and the heritage varieties had an average lower yield of 75.4%. Landraces had the lowest yielding with a mean yield of 46.3% of Power (data not presented in Figure 3). There was a week but still significant difference between the groups in yield ($p=0.09$). However, only few varieties were included in each group and therefore individual varieties had huge impact of mean yield of each group. In the group of heritage varieties, several varieties performed a yield not statistically different from the variety Power, which was the most widely grown modern malting barley in Northern Europe at the time of the experiments. These results indicate that the age of the variety is less important for a high yield than the yield potential of the specific variety. In general modern varieties perform well under organic conditions, but so do some of the heritage varieties.

Mineral content of the spring wheat varieties in this study was included in a study of grain

mineral content published by Hussain et al 2010. The study indicates an improved mineral content in older varieties and landraces compared with modern varieties, which confirms conclusions of Murphy et al 2008. Our study point on improved baking quality in terms of loaf volume in older varieties compared with modern wheat varieties.

The study contradict the general agreement that modern varieties are better than older varieties. This seem not to be the case for the heritage varieties when grown under the organic conditions in this study. Both high yielding and low yielding varieties are found both among heritage and modern varieties.

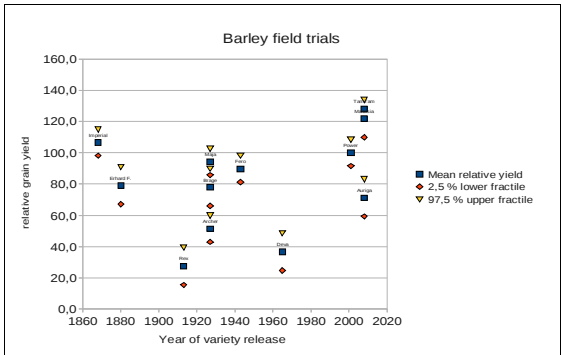


Figure 3: Barley grain yield in two years field trials. grain yield in landraces not presented as landraces has no specific year of release

Modern varieties are bred for high input condition, and under these conditions, the conclusion of improved yield as a consequence of plant breeding may be correct, but our study shows that under Danish organic condition, there may be a slightly higher average grain yield in the modern varieties, but the difference is surprisingly small, if existing at all. It indicates that organic farming in Denmark has achieved little, if at all, from modern conventional plant breeding, as several very old varieties are fully compatible in terms a yield with the normally grown modern varieties.

The results calls for targeted breeding for low input conditions, as breeding for high input condition contribute little to the benefit of organic agriculture and other low input conditions. Research is needed to quantify the effect of the different yield components of breeding on grain and straw yield and quality at low input conditions.

Acknowledgement

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