Diversifying cereal production

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Abstract

Modern cereal production has reached a stage of homogeneity, where both environment, nutrition and culinary quality suffers. In order to increase cereal diversity, projects have started investigating heritage varieties, and varieties and species with exotic traits. Well performing varieties and landraces will be used as they are, or will be used as genetic donors in a participatory breeding programme developing composite cross population focussing on disease resistance or special quality traits.

Introduction/Problem

Micro breweries and farm milling are being popular in many European countries. The concept is often based on quality product and traditional production methods. Modern varieties are in general not fit to facilitate this niche, as the niche production has its relevance in being different from the conventional industrial production. Conventional breeding and approvement of new varieties are expensive, and it is not profitable to approve varieties adapted for a small region or a small niche marked. The niche therefore has an unsatisfied demand for raw material with special traits and story telling, which is missing in modern varieties.

Heritage varieties offers a unique storytelling, and research investigating heritage varieties in other countries has demonstrated that high quality varieties with acceptable cropping parameters can be found in many regions. However, the heritage varieties in Denmark and their agronomic performance and quality aspects are unknown.

For niche production, special quality traits is a permanent demand, and the colour of cereals is a trait very visual for the consumer. Purple wheat has been introduced in Austria and Germany with some success, but the range of grown varieties is narrow, and the available varieties has a reputation of poor backing quality and suboptimal agronomic performance.

Climate is changing, and new crops like millet and sorghum not previous able to grow in Northern Europe, may be able to grow here now.

Compared with grassland and forest production, cereal production has a high risk of nutrient leashing and soil erosion. In organic farming, mechanical weed control is increasing the risk of soil degradation, and there is a demand for a changed cropping methods, or for cereal varieties with a changed growth habit.

Participatory breeding is another way to tell stories along with the cereal commodity, and with participatory breeding, cropping parameters and quality aspects can be developed for special purposes at each individual farm or marked segment. Composite cross population offers a good tool in the hands of participatory breeders, and can at the same time introduce genetic diversity into self pollinating cereals with positive effects on stability in yield and quality. CCPs cannot be, and does not need to be approved according to the seed regulation, as it will be used for home saved seed.

CCPs are likely to be able to control most plant epidemic leaf diseases, if the parental line have multiple resistance genes against the diseases, which is likely for diseases like powdery mildew and rust diseases in cereals. Some disease is likely to be there, but an epidemic will be delayed in a diverse population. However, using home saved seed for consecutive years without seed treatment does carry the risk of development of seed borne diseases. Only few varieties have effective resistance genes against common bunt (*Tilletia tritici*), and it is not acceptable if this disease is present in the crop even in a small frequency of infected plants. I therefore believe that growing organic CCP winter wheat will lead to problems with common bunt if precautions are not taken.

Methodology

The project on heritage varieties started in 2006, and in 2007 the search for purple cereals and other exotic trait started. Development of CCPs is planed to start in 2007.

Heritage varieties

The history of cereal cropping in Denmark is being studied, and relevant varieties are requested from genebanks. The seed is grown under organic conditions for both demonstration and multiplication. Cropping parameters (yield, lodging, disease resistance, weed competitions etc.) and quality traits (backing and malting quality) is being assessed, and the varieties is evaluated for potential use in organic farming.

In the first year, the genebank accession of heritage varieties are grown in small rows at SLU, Alnarp, Sweden and Agrologica, Mariager, Denmark. Seed from this initial multiplication are grown in plots in loamy soil at Mørdrupgård, Lynge in Eastern Denmark and in sandy soil at the National Agricultural Museum, Auning, Western Denmark. A total of 2.5 hectar of plot trials are grown in 2007, including 200 varieties. Results presented in Table 1 is from spring wheat trial at Mørdrupgård 2006 as a mean of 4 replicates under rainfed conditions with no manure application on a pre-crop of green manure. Quality parameters are made by NIT analysis except for wet gluten analysis made by hand washing and subjective evaluation.

Alternative cereals

Crops with special quality traits or growth behaviour is studied at Agrologica. These crops include:

Cereal crops with the ability of regrowth after harvest can contribute to prevention of erosion and will reduce energy consumption for soil tillage. Four accessions of perennial wheat are planted in the season 2006-7, and 4 accessions of perennial rye will be planted in autumn 2007. The varieties will be assessed for cropping traits, including tendency of regrowth after harvest. All varieties are of Russian or American origin. The varieties of perennial wheat will be crossed, and a CCP will be developed and selected for regrowth behaviour.

Midsummer rye (*Secale cereale* var. *multicaule*) has the ability of huge vegetative production before vernalisation. In organic farming this is an advantage after spring fallow, where it is too late for a spring crop and too early for a common winter cereal. Ten accessions of midsummer rye of Nordic origin are planted in the season 2006-7. The varieties will be assessed for taste, seed size and yield.

Purple wheat has a high content of anthocyanins, nutritional flavanoid antioxidants. Many varieties are available, but none of them have been grown in Denmark. 36 accessions of purple wheat and 3 accessions of blue wheat (*Triticum aestivum* var. *tschermakianum*) are planted in the season 2007 and will be assessed for backing quality and seed colour. The purple wheat *Indigo* has an anthocyanin content of about 200mg/kg, which is close to the content in red wine. A visual inspection of the de requested genebank accessions show a huge difference in surface colour, and *Indigo* is far from being the most colourful. The varieties will be crossed with well known backing quality wheat and will either be used as parental lines in traditional breeding for single line selection, or a CCP will be developed from the offspring.

New cold tolerant varieties of sorghum have been developed in resent years. Due to the already and expected climate change, this crop may have a future also in the northern climate of Denmark. Three accessions of sugar sorghum are planted in this season and will be assessed for yield, taste and days for maturity.

One of the practical and economical disadvantages of the production of faro cereals like einkorn are the presence of husk. Some accessions of einkorn are naked seeded (*Tritici sinskajae* and mutations from *T. monococcum*), and will be tested for agronomic performance. Seven accessions of naked einkorn are planted this season.

Development of Composite Cross Populations

Previous CCPs are developed by inter crossing a number of parental lines. If 6 parental lines are used, the optimal genetic diversity will be made if all 6 varieties are crossed with all the 5 other varieties. In this case, 6*5=30 crossings is needed. However, I believe that the limiting factor for obtaining genetic diversity is not the number of possible parental lines, but the budget of the project, and this means the number of crossings the breeder can make in a season. If for example 30 crossings is the possible amount of work for the project, a higher degree of genetic diversity could be made by parring crosses between 15 different varieties.

The normal way to cross cereals are to emasculate the mother plant, and to isolate this plant with one pollen donor. In this way 20-40 seed will develop with the two known parental varieties. In development of a CCP, the breeder does not need to know the pedigree of each individual cross. The important information is which genes are included within the entire population.

At present, 100 varieties have been identified having a low susceptibility for common bunt, but in general, their backing quality and yield potential is unknown. About 30 of these varieties will be selected as parental lines. 30 plots will be sown with all varieties included in each plot. In each plot, one variety will be emasculated, and left for natural pollination among the other 29 varieties. In this way, all varieties will act as mother plants in equal proportion (3.3%), and each of these will be crossed with several, but not necessarily with all other varieties. It will be unknown who will be crossed with who, but the entire gene pool will be included in the population. It is believed that with a limited budget of the project, this will be the way for optimal genetic diversity.

Table 1: Quality and yield of spring wheat varieties at Mørdrupgård 2006

Heritage spring wheat varieties 2006

Variety	Year of breeding	kg/ha	rel.	Test Z	Starch	Protein	Gluten	Wet gluten	Wet gluten per ha	Gluten quality
Fiorina	<10 years	3002	100	64,9	65	16,0	32,2	35	10.506	Short and stiff
Peko	1944	2833	94	61,6	67,2	15,4	29,8	39,6	11.218	Soft and smooth
Ring	1957	2814	94	65,2	68,2	15,6	30,3			
Sappo	1971	2654	88	58	69	14,4	26,7	37,5	9.951	Strong and stiff
Amy	1971	2570	86	66,1	66,4	16,0	31,7	41	10.539	Strong and elastic
Algot	1960	2538	85	61,5	68,6	15,4	28,9	37,5	10.539	Strong, resilient and elastic
Walter	1957	2325	77	68,7	66,2	16,2	32,5	40	9.299	Strong, smooth and elastic
William	1982	2322	77	60,7	68,1	14,9	27,9	30	6.965	Short and gritty
Prins	1962	2213	74	68,4	66,5	16,4	32,5	27	5.975	Strong, resilient and elastic
Atson	1954	2132	71	69,8	66,7	16,3	33,4	42	8.954	Strong, resilient and elastic
Hallands hvede	Landrace	2096	70	65,1	66,7	16,1	31,8	41,5	8.698	Strong, resilient and elastic
Fylgia	1933	2022	67	66,2	66,1	16,5	31,6	36	7.281	Strong, smooth and elastic
Svenno	1953	1933	64	74,9	65,6	17,6	34,8	42,5	8.214	Strong, smooth and elastic
Ølands st. kærner	Landrace	1878	63	63,9	64,9	17,0	33,3	40	7.510	Strong, resilient and elastic
Øland	Landrace	1846	61	63,7	66,1	16,0	31,5	50,5	9.320	Soft and elastic
Kärn	1946	1837	61	69,4	67,2	16,4	32,6	37,5	6.888	Strong, resilient and elastic
Pondus	1950	1618	54	69	66,5	16,3	32,7	34	5.503	Strong and stiff
Kolben	1892	1606	54	74,9	65,6	17,6	34,8	45	7.229	Strong, smooth and elastic
Ölands börst	Landrace	1164	39	69,3	64,1	17,2	33,9	54	6.286	Strong and elastic

Modern spring wheat varieties, 2006

Variety	Year of breeding	kg/ha	rel.	Test Z	Starch	Protein	Gluten	Wet gluten	Wet gluten per ha	Gluten quality
Dacke	1990	2970	110	70,0	65,0	16,0	33,0	45,0	13.367	Resilient and elastic
Monsum	<10 years	2942	109	55,6	68,2	14,1	26,6	18,5	5.442	Very stiff
Casana	<10 years	2922	109	69,9	64,3	17,3	34,5	41,5	12.128	Strong and elastic
Scalin	<10 years	2894	108	68,7	64,0	17,3	34,3	38,5	11.143	Strong and elastic
Michael	<10 years	2850	106	65,9	63,8	16,7	33,5	39,0	11.117	Soft, and not resilient
Nadro	<10 years	2718	101	73,1	63,3	>18	35,6	42,5	11.553	Short, stiff and gritty
Fiorina	<10 years	2690	100	66,6	66,2	16,8	33,8	35,0	9.414	Short and little resilience
Safrania	<10 years	2581	96	63,4	68,2	15,0	28,8	30,0	7.742	Very short and stiff
Toronit	<10 years	2564	95	61,9	66,1	15,8	30,1	20,5	5.256	Short and stiff
Quarna	<10 years	2338	87	70,6	63,3	17,5	35,3	29,0	6.781	Strong and little resilience
AC Vista	<10 years	2134	79	56,6	68,7	14,1	27,6	30,6	6.531	Strong and stiff
Kärntner Früher	1959	2064	77	65,6	65,2	16,2	31,9	43,5	8.978	Strong and resilient
Ølandshvede	Landrace	1953	73	65,4	64,4	17,1	32,4	50,0	9.764	Soft and elastic
Carasso	<10 years	1872	70	62,3	66,2	15,8	28,5	41,5	7.769	

The traditional way to develop wheat with high backing quality is to cross varieties with good backing quality and to select lines among the offspring. The aim of this project is to maintain the genetic diversity within the offspring. Therefore, a tool for mass selection of backing quality is needed. The seed lot of the CCP will therefore be sorted for seed size, seed density and for protein content using a TriQ-sorter based on NIR analysis on a single seed basis. In this way, it is expected that the population will increase from generation to generation in seed size and genetic potential for increased protein content.

Results and brief discussion

As the project with heritage varieties started in late spring 2006 and the other projects started this year 2007, only few results are ready for publication at the present stage.

The result of the initial trail with modern and Swedish heritage varieties made in spring 2006 is shown in Table 1. Both groups contain both high yielding and low yielding varieties, and in average, small differences are seen in gluten content measured with a standard NIR analysis. However, when looking at the quantity and quality in wet gluten, the gluten in the modern varieties seems to take up less water resulting in a lower content of wet gluten (mean: 34,3) of a short gluten structure with good stability, compared with the heritage varieties with a higher content of wet gluten (mean: 40,0) with a generally smooth, resilient and elastic quality. However, the mean covers over a huge difference in both groups.

Future project plans

In 2007 and 2008, the variety trial with heritage wheat varieties will be analysed in the same way as in 2006 shown in Table 1. The barley varieties will be tested for malting quality, including taste. The trial in 2007 include 168 varieties, of which 70% are wheat and spelt and the rest are barley and oat mainly of Swedish origin. Parallel to this, multiplication of the sample of Danish heritage varieties will go on and will gradually be included in the variety trial when the amount of seed allows it. In 2008 the variety trial will include mainly the Danish varieties and only a minor selection of Swedish heritage varieties and modern European varieties.

The project with alternative cereal traits will continue with selection for varieties with good agronomic performance and quality, and breeding will focus on transfer of relevant traits into well adapted varieties. The focus will be varieties with high content of anthocyanins, perennial cereals and large seeded midsummer rye varieties with improved yield through maintenance breeding.

Composite crosses will be developed in winter wheat focusing on resistance to common bunt in high quality backing, and in spring wheat the development will focus only on gluten quality. A CCP will also be developed in perennial wheat, and one in purple wheat.