Introductory considerations on crop diversity

Anders Borgen

Agrologica, Houvej 55, DK-9550 Mariager, e-mail: borgen(AT)agrologica.dk

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.

References

Anonymous 1994: EU-regulation no. 2100/94, 27th July 1994
Anonymous 2006: Statistics Denmark 2006: Online version: http://www.dst.dk/HomeUK.aspx

Hole, D.G., A.J.Perkins, J.D.Wilson, I.H.Alexander, P.V.Grice and A.D.Evans 2005: Does organic farming benefit to biodiversity? Biological Conservation **122**:113-130

Hauggaard-Nielsen,H., Ambus, P. and Jensen, E.S. 2001: Interspecific competition, N use and interference in pea-barley intercropping. Field Crops Research **70:**101-109.

IFOAM 2005: The IFOAM norms for organic production and processing version 2005. ISBN 3-934055-58-3;132 p.

Kinane, J. and Lyngkjær, M.F. 2003: Effect of barley-legume intercrop on disease frequency in an organic farming system. Plant Prot. Sci. **38**:227-231

Wolfe, M.S., K.E.Hinchliffe, S.M.Clarke, H.Jones, Z.Haigh, J.Snape and L.Fish 2006: Evolutionary breeding og wheat for low input systems. Proceedings from the European joint Organic Congress – Organic Farming and European Rural Development Odense 30-31th May 2006. ISBN 87-991343-3-0; page 374-375

Plantedirektoratet 2006: Statistik over økologiske jordbrugsbedrifter 2005. 20 pages.

Østergard, H, K. Kristensen and M.Hovmøller 2006: Genetic potential for grain yield in spring barley varieties and variety mixtures in variable organic environments. Proceedings from the European joint Organic Congress – Organic Farming and European Rural Development Odense 30-31th May 2006. ISBN 87-991343-3-0; page 372-373