Report

Hybrid Varieties for Organic Cereals? Prospects and acceptance of hybrid breeding for organic production



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1 Summary

This report provides information and arguments for the discussion on whether or not hybrid varieties are in keeping with the tenets of organic farming. The report focuses on rye. While maize and vegetable hybrid varieties have already become established in organic farming without any fundamental decision having been taken in the matter it is still possible to form opinions and take strategic decisions where it comes to cereals in Switzerland. This applies particularly to rye.

Hybrid varieties result from a targeted cross of two different pure breeding lines with the progeny surpassing the parental lines in terms of yield. As the next generation would genetically segregate, seed will have to be bought in every year. The production of hybrid varieties in rye and other self-sterile plants requires three steps: (1) Development of inbred lines in the different original populations; (2) test cross matings between the inbred lines; (3) production of the hybrid variety for the market by way of targeted pollination. To this end self-pollination must be prevented in the maternal line. In rye and many other plant species breeders work with maternal lines which are pollen sterile due to cytoplasmatic inheritance. In the self-fertile wheat pollen production is prevented by means of chemical gametocides. As the latter is not in keeping with the standards for organic seed production, hybrid wheat is not yet an option in organic farming.

Hybrid breeding was first introduced in the US in the early 20th century for maize. The combined impact of new varieties, mechanization and intensification have multiplied maize yields in the US six-fold during the 20th century.

At present hybrid rye varieties give 10-20% higher yields than open-pollinated varieties. In our strip trials, carried out in 2003/04, we also observed improved lodging resistance and improved sprouting resistance (falling number) compared to open-pollinated varieties. An example calculation using conservative figures shows that at present an organic farmer in Switzerland using hybrid rye could achieve an extra return of approximately 260 to 400 sFr./ha (provided the rye can indeed be sold).

The general advantages of hybrid varieties over open-pollinated varieties in self-sterile crops such as rye and maize are as follows: Higher yields, uniformity, swift progress in breeding, and – an advantage to the breeder – the farmers' inability to save seed and replant.

Four aspects of hybrid breeding are currently criticized: (1) Adverse effects on the more subtle intrinsic qualities through continued inbreeding and pollen sterile maternal lines in the breeding process; (2) farmers' dependence on the seed industry; (3) ethical problems regarding interventions into plants' flowering biology and the change in meaning of seeds from cultural asset to farm input; (4) genetic depletion resulting from the loss of recessive genes and from using uniform male-sterile cytoplasm. All these arguments have future repercussions. They concern the tenets of organic farming. There is a great need for further research concerning the quality issue in particular. The problem of genetic depletion is more relevant to self-sterile crops (rye) than to hybrids of self-fertile crops (rapeseed, barley and in the distant future perhaps also wheat).

Abstaining from the use of hybrid varieties in organic bread cereal production in Switzerland would give a clear signal to upstream and downstream sectors (breeders/trade and consumers respectively) that organic farming strives to consider long-term and future aspects of independence, quality, and diversity and that it would be ready to forego current agronomic advantages to this end.

2 Introduction

Organic agriculture is based on four principles: The principle of health (human health is inseparable from ecosystem health), the principle of ecology (agriculture should be based on living ecological systems and cycles in its specific production environment and it should maintain the ecological balance and protect and sustain the common environment), the principle of fairness (both among people and between people and other living beings) and the principle of care (agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment). These four principles are currently under review in an open discussion process within the International Federation of Organic Agriculture Movements and will shortly be adopted. They are composed as ethical principles and spell out the ethical foundation of organic agriculture (IFOAM 2005). Organic farmers produce organically because they want to shape the world in a different manner than is currently the norm. The organic agricultural movement defines its standards in accordance with these principles and it is constantly confronted with the need to decide whether new or newly discussed farming inputs, techniques or processing steps will be permitted or rejected by the standards. With regard to genetic engineering the movement has clearly and unequivocally defined its position (IFOAM 1997). However, hybrid breeding has also repeatedly been called into question.

In practically all crop plant species hybrid varieties are gaining ground and intensive research into hybrid breeding is taking place.

When it comes to maize in Europe there are no longer any alternatives to the hybrid varieties, apart from a few landraces which only hold interest as specialties. The situation will soon be similar with regard to many vegetable varieties, sugar beet and sunflowers. In rapeseed the share of hybrid varieties has increased rapidly: in Germany it still stood at 18-20% in 2001 but for the 2004 sowing they already comprised approximately 50% of the area under rapeseed (winter 2003). In the German Descriptive Variety List open-pollinated and hybrid varieties of rye are currently evenly represented, while the share of hybrid varieties under cultivation stood at approximately 60% in 2003. The first hybrid varieties of wheat have been placed on the market and the first hybrid variety of barley was approved in 2003 in Great Britain. Internationally, work is focussing on the development of hybrid varieties of rice, cotton, millet and sorghum in addition to maize.

Prior to the introduction of genetic engineering, the organic farming movement only gave occasional consideration to plant breeding methods. The main exception were small pioneer-type plant breeding initiatives which developed breeding methods and varieties specifically for biodynamic agriculture (Kunz & Karutz 1991, Müller 1998, Bauer 2004) and which were critical of hybrid breeding from the outset.

With the introduction of genetic engineering in the 1990s the wider organic movement began to consider that even the “classic” plant breeding practices are not always in keeping with the basic tenets of organic agriculture. Conferences were held, discussion papers published, and draft standards drawn up which are to regulate the type of breeding methods to be approved for organically produced crops (Karutz 1998, Lammerts van Bueren et al. 1999, Wiethaler et al. 2000, FiBL 2001, Arncken 2002a, 2002b).

In the context of these discussions hybrid breeding has also been caught in the cross-fire of criticism or some of the older criticisms voiced in the organic farming movement were picked up again.

With regard to maize and vegetables this discussion is more or less pointless at present as hybrid varieties have become established in organic farming to such an extent that their exclusion is not feasible at the current time – not least due to a lack of alternatives in many cases in terms of the varieties on offer.

However, in the case of rye the situation is much less decided. With rye the hybrid varieties are now also pushing their way into the bread grain sector. This has prompted DEMETER International to exclude the use of hybrid cereals in their standards. Bio Suisse, the Swiss organic umbrella organization, is also debating this issue at present.

The same problem will soon arise with regard to rapeseed.

For wheat the question is not yet relevant as the few hybrid wheat varieties currently on the market can only be produced with the help of gametocides (see Section 3.4) the use of which is not in keeping with the standards for the production of seed for organic agriculture.

The in part somewhat complex steps and mechanisms used in breeding and the assessment of these steps in terms of their compliance with the principles of organic agriculture complicate the decision-making process. The purpose of this report is to provide information to aid this process.

3 Basic information

3.1 Glossary

Hybrid	Progeny of a cross between two different varieties (first generation). The genotype is heterozygous as it contains a maternal and a paternal share.
F1	Filial generation 1, first generation originating from the cross.
Double-cross hybrid	Hybrid resulting from the cross of two hybrids.
Three-way hybrid	Hybrid generated by pollinating a hybrid maternal line with an inbred line or with a synthetic population of two or more inbred lines (example: rye varieties currently on the market).
Hybridizing mechanism	Prevention of self-pollination achieved by mechanical, chemical, or biological means, required for the large-scale production of cross-bred seed.
Pureline variety	Common in self-fertile crops (*e.g.* wheat): all plants of the variety have one common ancestor and are uniform, stable, and have the same homozygous genotype.
Open-pollinated variety; OP variety	Used to be the norm for self-sterile crops (*e.g.* rye): all plants of the same variety form a large population where individual plants differ slightly from each other and pollinate each other in each generation. The genotype is heterogeneous and heterozygous. The variety description and characterization pertains to the statistical mean of the population.
Synthetic variety	The maintenance of varieties and the production of seed are carried out on a regular basis using defined, identically reproducible components (clones, inbred lines, or populations) which flower at the same time. Due to its heterozygosity the variety is not yet genotypically stable. Each generation is different. Each category of seed (pre-basic seed, basic seed, certified seed) is a defined generation.

Heterozygous	The genetic characteristics inherited from the maternal side differ from those inherited from the paternal side.
Homozygous	The genetic characteristics contained in each cell as inherited from the maternal and paternal sides respectively are similar.
Homogenous	Uniform.
Heterogeneous	Diverse, different.
Recessive	Masked; a recessive genetic trait is only expressed if the same trait was inherited from ovule and pollen.
Dominant	Masking; a dominant trait inherited from one of the parents dominates the plant's phenotype and masks a possibly present recessive trait inherited from the other parent for the same characteristic.
Gametocide	Chemical causing pollen sterility when applied to the plant.
Pollen sterile	A plant develops fertile ovules but no pollen. If the flower is pollenized with other pollen it can develop seeds.
Cytoplasm	Basic substance of the living cell, containing the organelles (plastids, mitochondria, nucleus).
Heterosis	Increased productivity in the F1 compared to the mean of the two homozygous parents resulting after crossing two lines.
Inbreeding depression	Reduced productivity of self-sterile plants resulting from forced self-pollination.
Self-incompatibility	The phenomenon that a plant does not produce seed when fertilized with its own pollen or with pollen of genotypically similar individuals. However, rye is not fully self-incompatible so that forced self-pollination leads to 1-7% of the ovule producing seed.
Selfing	Self-pollination (often forced).
Mitochondria	Organelles within the cells where aerobic respiration occurs. Similar to the nucleus, mitochondria contain DNA.
DNA	DNA (deoxyribonucleic acid) carries the genetic information of a cell. It encodes the information for the production of proteins and is able to self-replicate.
CMS	Cytoplasmic Male Sterility is based on the modification of mitochondrial DNA which, in conjunction with certain nucleic genes, leads to pollen sterility.
Maintainer	Nucleic genes which maintain pollen sterility in CMS lines.
Restorer	Nucleic genes which restore pollen fertility. These are dominant.
Pollen fertile	Equipped with sufficient quantities of normal, fertile pollen.
Self-fertile plants	Plants the ovules of which are predominantly fertilized by pollen of the same flower (*e.g.* because the pollen is ripe already and the stigma is receptive prior to the flower opening). Examples: wheat, oats, barley, rice, rapeseed (with 10-50% self-sterility).
Self-sterile plants	Plants the ovules of which are predominantly fertilized by pollen of other plants of the same species. Examples: Rye, maize.

3.2 What are open-pollinated varieties?

Open-pollinated varieties are only available for self-sterile plants (*e.g.* rye, maize). In self-fertile crop species (wheat, barley, rapeseed to approximately 80%) pureline varieties are the alternative to hybrid varieties. However, as this report focuses primarily on rye, we will give special attention at this point to the difference between open-pollinated varieties and hybrid varieties. Open-pollinated varieties form a large population where individual plants differ slightly from each other and pollinate each other in each generation. The genotype is heterogeneous and heterozygous. The variety description and characterization pertains to the statistical mean of the population. Many different breeding methods are used in population breeding, often with smooth transitions between them.

The simplest and oldest method in population breeding is **mass selection** whereby plants with the desired traits are selected from within a genetically variable starting population. The seed harvested from the selected plants is mixed and grown out again as an improved population. It can be sufficient to take this step once or it may be necessary to repeat it many times to arrive at a “variety” (Becker 1993).

In the **modified ear to row method** the plants to be selected are assessed on the basis of their progeny. The seed harvested from the plants selected in the first step is not mixed but grown in progeny rows and a proportion of the seed is reserved for later use. The best rows are then selected. Normally they can only be reliably assessed after flowering at which point they will already have been pollinated by an uncontrolled pollen cloud. Therefore the seed harvested from these rows will not be sown but instead the reserved seed of their mother plants is sown again in progeny rows. Now the pollen cloud only contains pollen from the selected plants. The best thus pollinated lines are then harvested and used for further breeding (Becker 1993).

Nowadays population breeding is often used to obtain improved source material for the production of hybrid or synthetic varieties.

The key idea in breeding **synthetic varieties** is to develop a variety from a number of defined components (clones, inbred lines, or populations) by open pollination over a number of generations. These components are assessed individually and can be maintained genetically unaltered so that the variety can continuously be synthesized anew from these components. Such a variety has not yet reached a genetic equilibrium. The individual generations (pre-basic seed, basic seed, certified seed) are not morphologically and phenotypically identical and are not interchangeable (MLUV 2005). Synthetic varieties are particularly common in feed plants. The German Variety List currently contains three synthetic varieties of rye (Bundessortenamt 2004). Of the criticisms regarding hybrid breeding given in Chapter 4, the farmers' inability to save seed and replant also applies to synthetic varieties. It is recommended that farmers change varieties annually, as the performance of saved and replanted varieties may decline in subsequent generations (Bayerische Landesanstalt für Landwirtschaft 2004). While the genetic diversity of synthetic varieties depends on the number of parental components used, it is definitely greater than in hybrid varieties. The development of synthetic varieties does not require a hybridizing mechanism.

3.3 What are hybrid varieties?

Simply put, hybrid varieties are the result of crossing two different breeding lines. They represent the first generation originating from the cross (F1). They differ from pureline varieties and open-pollinated varieties in that the seed they produce will not be saved and replanted but the parental lines have to be crossed each time to produce new seed (Fig. 1).

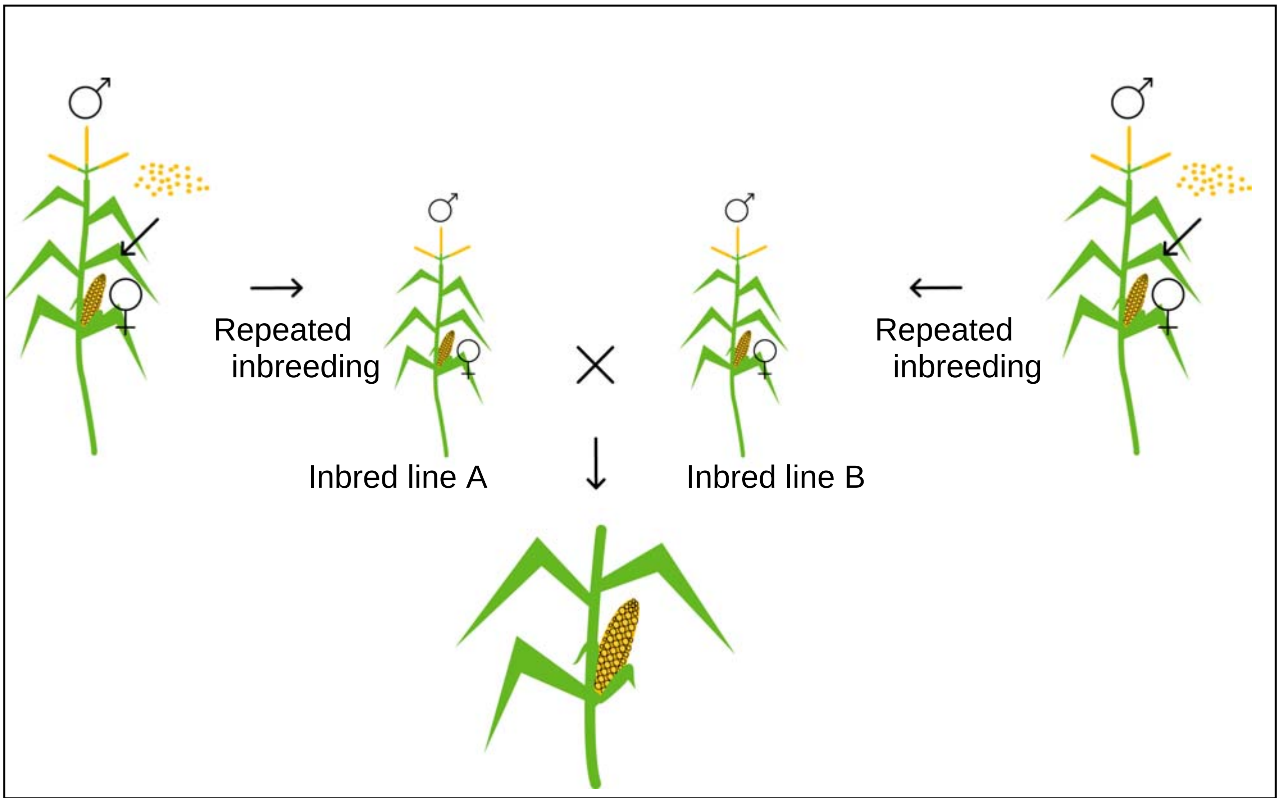

Fig. 1: Development of a hybrid variety (Source: FiBL 2001, 9)

The above illustration does however simplify reality in that hybrid varieties are often double-cross hybrids (hybrids resulting from the cross of two hybrid varieties) or three-way hybrids (generated by pollinating a hybrid maternal line with an inbred line).

The development of hybrid varieties in self-sterile plants (*e.g.* rye) requires three steps (in self-fertile plants such as wheat the first step is not needed):

1.) Development of inbred lines in the various original populations. In German rye breeding, the two original populations are the "Petkus" and "Carsten" gene pools which are genetically very distant from each other. For inbreeding purposes the plants are forced to self-pollinate (the ears are protected from foreign pollen by means of a greaseproof paper bag), the small amount of seeds that form are propagated and "selfing" is repeated over a number of years. This phase is very costly if a new hybrid breeding programme is started for a self-sterile plant, since inbreeding depression (see below) lets many lines expire.
Once a certain number of fairly vigorous inbred lines have been developed, they are continuously improved by means of crossing, selfing, and selection.

2.) Test cross matings between the different inbred lines in order to find the best hybrids.

3.) Production of hybrid seed for the market by way of targeted pollination. In order to steer pollination at a large scale self-pollination must now be prevented in the maternal line. This will be explained in the section on “hybridizing mechanisms”.

3.4 Why and when did hybrid breeding arise? – Heterosis and uniformity

3.4.1 Heterosis

The progeny of a cross between genetically different plants are generally bigger, more vigorous, and higher-yielding than their parents. This phenomenon drew the attention of many scientists from as early as the 18th century, amongst them the American geneticist G.H. SHULL (1914) who suggested the term “**heterosis**” to describe it. He understood heterosis as the increased productivity in the heterozygous F1 compared to the mean of the two homozygous parents (Becker 1984) (see glossary). If in the following generations the progeny is self-pollinated, performance gradually drops, *i.e.* inbreeding depression becomes evident until the plants are once again more or less homozygous. At that point the mean performance level of all homozygous lines is similar to that of the original parents (Fig. 2).

In self-sterile plants (*e.g.* rye) heterosis is significantly more pronounced than in self-fertile plants (*e.g.* wheat). The practical importance of hybrid breeding is also more important with regard to self-sterile plants. And heterosis is much more pronounced for the trait of yield than for qualitative traits, such as plant height or protein content.

As early as 1909 SHULL proposed to commercially utilize this effect for the purposes of crossing inbred lines of maize, but the first inbred strains did not provide sufficient yields for economic seed production. It was only when JONES (1918) put forward the idea of producing double-cross hybrids that the breakthrough for the method of inbreeding and crossing in American maize breeding was made (HEPTING and OLTMANN 1985). The first double-cross hybrid entered the market in 1921 and by 1944 already more than 80% of the maize growing areas in the US were sown in hybrid maize (KLOPPENBURG 1988). In the course of the 20th century dramatic yield increases were achieved in maize crops: While during the first decade US farmers harvested an average of 14-15 dt/ha (Schweizerisches Landwirtschaftsdepartement 1910, p. 156), yields had increased roughly sixfold to 85 dt/ha by 2002/2003 (USDA Production Projections, quoted in HGCA 2003).

3.4.2 Uniformity

A second aspect of hybrid breeding concerns the high uniformity of the plants which occurs after crossing the two inbred lines. This aspect is often an even more important argument for hybrid breeding than heterosis itself; however, it only applies to self-sterile plants. It was also an important reason for the success of hybrid breeding in maize, as it accommodated the process of mechanization in agriculture which occurred around the same time; one could say that in many cases it was the very factor that made mechanization possible.

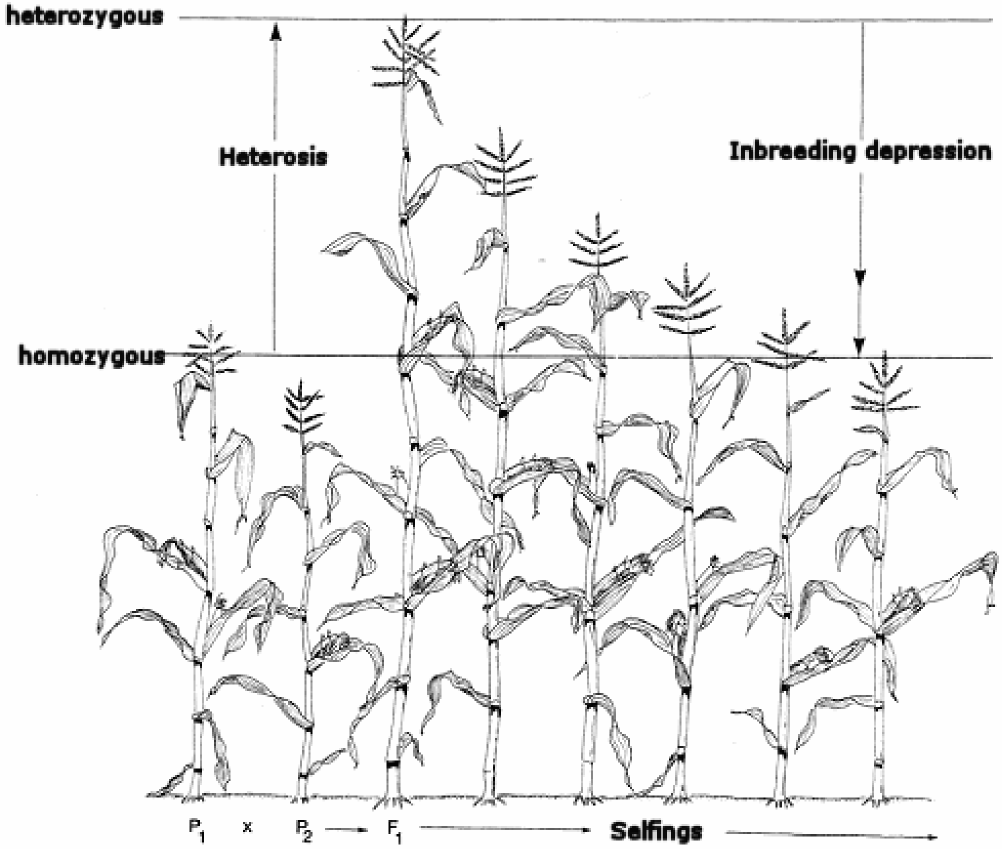

Fig. 2: Heterosis and inbreeding depression in maize (Source: after Becker 1993, p. 146).

In self-sterile plants nature uses a number of biological ways to prevent the pollen of a plant from fertilizing its own inflorescence. In most such species, and also in rye, this is achieved through genetic self-incompatibility. Successful fertilization requires the pollinating plant to be genetically different from the seed parent plant. This is the reason why such species always exhibit a degree of difference and diversity in their population – their reproductive community. The variety description and characterization pertains to the statistical mean of the population. Such varieties are termed **open-pollinated varieties**. However, such populations always contain plants which deviate from the mean and selection can be used to increase the proportion of plants within the population that display such deviating characteristics. The same happens continuously by way of natural selection. Therefore open-pollinated varieties are subject to constant change and evolution, which has two effects: Firstly maintenance breeding is required to maintain the desired characteristics and secondly every open-pollinated varieties always contains a certain undeveloped future potential. In the language of genetics these are recessive genes which are masked by their dominant alleles and thus are not expressed. It is only when inbreeding brings two such recessive genes together in the one plant that they find expression and can, if they represent desirable traits, be bred for – or if they are not desirable, they can be eliminated. Both actions are taken in hybrid breeding as the parental lines of a hybrid varieties are bred from various original populations by means of inbreeding (forced self-pollination).

If open-pollinated varieties are grown agriculturally, they represent – in addition to their current use – a large-scale genetic reservoir for the future, grown out under field conditions. In other words, their production combines **current use** and **future potential**. If hybrid varieties replace open-pollinated varieties, higher yields and greater uniformity often entail greater current benefits (at least at a superficial level). However, the aspect of future development is much diminished and the reservoir of genetic diversity is limited to breeding gardens and the gene banks' freezers.

3.5 Hybridizing mechanism

This section addresses a central precondition for the production of hybrid seed, *i.e.* pollen sterility. The somewhat complicated details are explained here in order to demonstrate how much research and selection work is expended in this field associated with hybrid breeding. The presentation largely follows that of Becker (1993).

The large-scale production of hybrid seed requires a "hybridizing mechanism" which prevents self-pollination in the maternal line. This can be achieved by **mechanical**, **chemical**, or **genetic** means.

The example of maize: the mechanical route

Mechanical means are the easiest option in maize on account of its monoecious flower morphology where male and female inflorescences are on the same plant but physically separate. The male inflorescences (panicles) at the terminal end of the plant can be pulled out or cut off, either manually or by machines. Seed parent and pollenizer are grown in strips adjacent to one another. For all plants from which the panicles were removed one can be certain that the seeds they form result from the desired cross.

The example of wheat: the chemical route

The chemical route of treating the seed parents with gametocides is predominantly used in self-fertile plants such as wheat. Despite intensive research in this field there are as yet no fully satisfactory gametocides for any plant species, i.e. none which generate complete pollen sterility, which are as independent as possible from weather conditions and the developmental stage of the plants, and which at the same time do not have side effects on plants, the environment, or human health. In Germany no gametocide has as yet been approved for wheat; therefore all hybrid wheat for use in Germany is grown in France.

For organic farming this route, and thus hybrid wheat, is not an option as it is not in keeping with the standards for the production of seed for organic agriculture.

The example of rye: the genetic route

The genetic route is based on the fact that in all plant species there are occasional pollen sterile individuals. Pollen sterility can be caused by a number of factors. Most important for hybrid breeding is a genetic system which is based on the combined action of nucleic and cytoplasmic genes: **cytoplasmic male sterility** (**CMS).** CMS is based on the modification of mitochondrial DNA which, in conjunction with certain nucleic genes, leads to pollen sterility but which in conjunction with other nucleic genes results in fully fertile plants. The nucleic genes which maintain pollen sterility are called **maintainers**. Those nucleic genes which restore pollen fertility are called **restorers**. The latter are dominant.

With the aid of CMS, hybrid seed can thus be produced economically and at a large scale. At first the maternal line is developed through breeding and then CMS is crossed in. In order to maintain and propagate the maternal line it is pollinated with a paternal maintainer line. All the progeny is pollen sterile. However, for all crop species where the seed is the actual crop the hybrid variety itself must not be pollen sterile. Therefore the hybrid variety's paternal line must be a restorer in order to allow for normal seed development.

In order to produce a hybrid variety, three lines must therefore be propagated to pre-basic seed level: the seed parent inbred line, the maintainer line, and the pollen parent inbred line. Two lines must be propagated to basic seed level: Seed parent and pollen parent. These two can then be used to produce certified seed which is placed on the market for commercial production. In a three-way hybrid, such as is customary for rye, the seed parent is a hybrid itself, allowing for high yields and germination rates (Tomerius 2001). Moreover, in rye the pollenizer used is routinely not one single inbred line but a synthetic population of two or more inbred lines (Wilde 2004) (cf. Fig. 3). (Sometimes restorers are not used in vegetative crop varieties (*e.g.* some vegetable varieties) and hence these varieties can not produce any seed).

Functioning and established CMS systems are available for a large number of plant species, *e.g.* for rye, sugar beet, sunflowers, oilseed rape, sorghum, millet, and many vegetable crops. CMS mostly arises when cytoplasm and nucleic genes do not "match", *i.e.* if they have come together through the crossing of genetically extremely distant lines. Primitive forms or wild species of crops are often used as CMS sources and the nucleic genes of the highly bred material are crossed into such CMS mother plants by means of repeated backcrossing. If no restorers can be found in the highly bred material, these will also have to be transferred from the primitive or wild species through backcrossing (Becker 1993). Such a process takes many years to complete.

Hybrid breeding developed particularly fast in oilseed rape, following the selection in 1982 in the breeding garden of *Norddeutsche Pflanzenzucht Lembke* of a spontaneous male sterile mutant for which all known oilseed rape varieties and lines can act as restorers (*i.e.* fertility will be fully restored) (Frauen 1999). Apart from an additional transgenic hybrid system owned by Plant Genetic Systems, there is another hybrid system for oilseed rape established in France: the INRA-Ogura hybrid system. Here selection assisted by molecular markers succeeded in breaking the close link between fertility restoration and (undesirable) high glucosinolate content in rapeseed ("Extra" variety, Monsanto) (Brunner 2001).

A number of different CMS sources have been described for rye. However, for practical applications it is mainly the "Pampa" cytoplasm found in 1970 in Argentinean wild rye (*Secale multicaule*) that has gained acceptance. Immediately after its discovery, the University of Hohenheim in Germany, followed later by a number of other European breeding stations, embarked on a rye hybrid breeding programme (Geiger 1990).

In barley, the hybridizing mechanism of the first variety, licensed in Britain in 2003, is also based on male sterility (Syngenta, no year).

CMS sources have also been discovered for wheat but the performance of the experimental hybrids based on these sources was only marginally better than that of the corresponding best pureline varieties (Geiger 1990). Therefore hybrid breeding in wheat has focussed on the chemical route. The advantage for the breeder is that all lines and varieties can directly be used as hybrid parents without the need to cross CMS cytoplasm and the restorer gene into the breeding material.

Three years prior to production of bread grains

Production of pre-basic seed. The maternal line A is cytoplasmic male sterile (CMS). In order to propagate it a fertile maintainer form of the maternal line with normal cytoplasm is grown in adjacent strips. The progeny of the maternal line are pollen sterile. Separately from the above the fertile pollinating line B and the fertile father C (restorer) are propagated. The restorer line contains genes which more or less completely restore maternal fertility.

Two years prior to production of bread grains

Production of basic seed. Cultivation of lines A and B in adjacent strips, so that line B pollinates line A and cross-bred seed can be harvested from line A. The restorer line is propagated separately.

One year prior to production of bread grains

Production of certified seed. The pollen sterile single hybrid AxB is grown out with a 5% admixture of the fertile restorer C the pollen of which pollinates the hybrid.

Production of bread grains

Cultivation of the three-way hybrid (AxB)xC with restored pollen fertility. Admixture of 5% open-pollinated rye to ensure sufficient quantity of pollen.

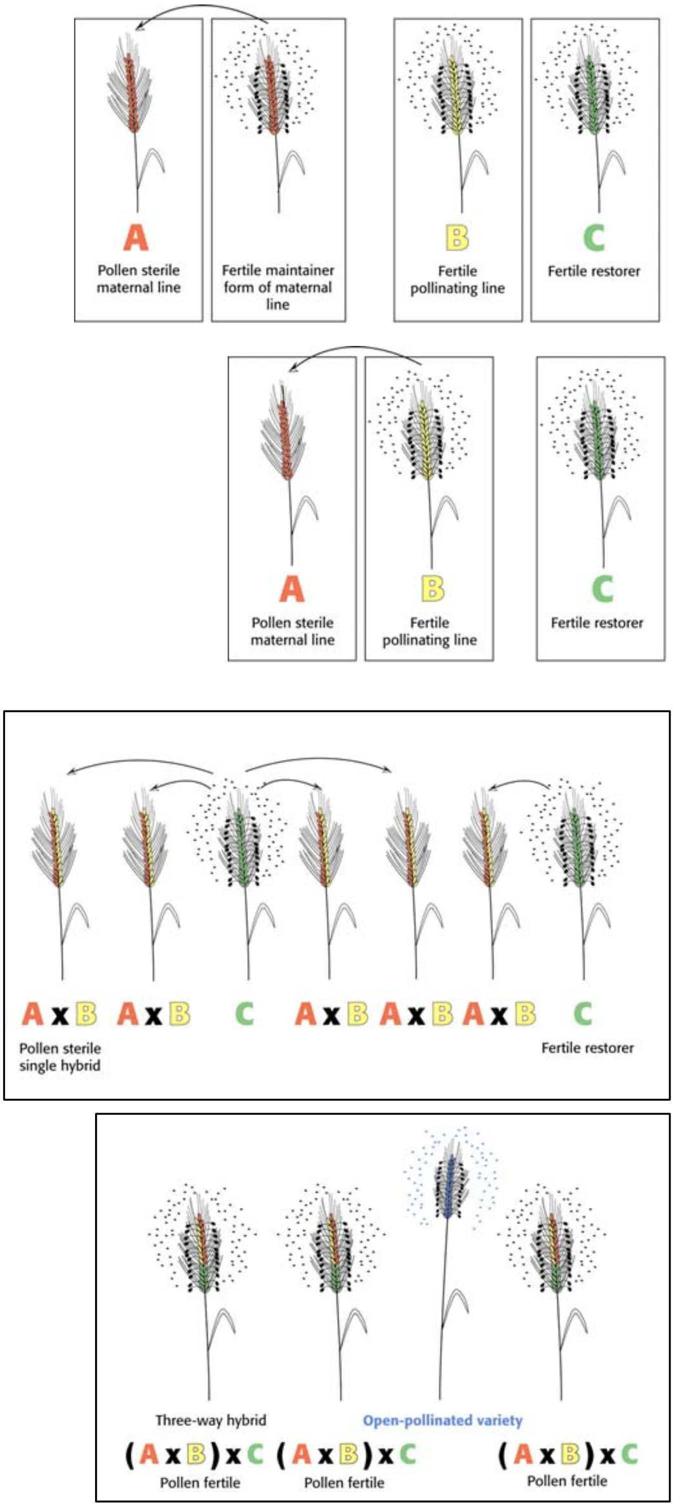

Fig. 3: Seed production in hybrid rye.

4 Current state of debate on hybrid rye in Switzerland and neighbouring countries

Swiss consumers eat little rye bread. Rye is often mixed in with wheat, giving the bread a characteristic taste. In contrast to the Nordic countries, Switzerland, with the exception of Valais, has practically no rye bread specialities. Therefore there is not a great deal of demand for or interest in organic rye on the part of processors. Rye constitutes only 5% of the overall amount of bread grains used and 75% of this rye is imported. Pre-cleaned rye weighing 73-74 kg per hectolitre makes about 100 sFr/dt. However, rye suits all crop rotations focussed on cereals, it is not very demanding in terms of nutrient supply, it thrives well on marginal sites and can be grown at altitudes to approximately 2000 m above sea level. The only thing it does not tolerate is water-logged soil or prolonged snow cover.

In Switzerland, 18.4 ha of organic rye for certified seed was inspected in the field in 2004. Of this, 3.8 ha was under hybrid rye. Therefore, one can assume that currently approximately 20% of organic rye is hybrid rye (Klaus Steiner, Bio Suisse advisory commission on tillage crops, pers. comm.). Since the autumn of 2004 the Bio Suisse advisory commission on tillage crops (*Fachkommission Ackerkulturen*) has been discussing the issue of hybrid rye and the Bio Suisse Label Commission “Production” (*Markenkommission Anbau*) has now been asked to take a decision on the matter. Bio Suisse is thus the first organic farming organization to be dealing with this issue apart from the Demeter Association which in 2001 had included a prohibition on hybrid grains (with the exception of maize) in its production standards (prior to this the standards only gave recommendations in this regard).

In German organic farming rye is the crop with the biggest share in the area under cereals (39,500 ha, equivalent to 25.3% of organic cereal crops (ZMP 2005)). In 2003 and 2004 the German Demeter Association was trying to convince the other member associations of the German Federation of the Organic Food Sector (*Bund Ökologische Lebensmittelwirtschaft*, BÖLW) to ban the use of hybrids. However, the Naturland and Bioland organic farming associations are not as critical of the move towards hybrid breeding.

In the 2004 nationwide evaluation of German variety trials for organic winter rye and winter triticale carried out in the German regional states (*Länder*) the four most-tested open-pollinated varieties (Hacada, Matador, Nikita, Recrut) showed a relative yield of around 100% (benchmark varieties Hacada and Nikita), whereas the three most-tested hybrids (Avanti, Askari, Treviso) showed on average a 20% higher yield (Meyercordt et al. 2004). In a two-year comparative trial (six environments), Haas (2002) compared three open-pollinated varieties (Danko, Hacada, Born) and two hybrid varieties (Avanti, Fernando) of rye with regard to their nitrogen efficiency. In the mean of all six trials the hybrid varieties’ grain yield was 24% higher. The mean grain nitrogen yield of the hybrid varieties was 14.5% higher than that of the open-pollinated varieties. The hybrid varieties have thus been shown to be higher-yielding and more nitrogen efficient.

According to Thomas Kerschbaummayr, a staff member at the *Ernte* association (Bio Austria) with responsibility for the development of production standards and their implementation, the issue is not being discussed in Austria. In the context of the Austrian evaluation study on organic seed breeding *(“Saatgut für den Biologischen Landbau – Österreichische Biosortenzüchtung”*) hybrid varieties are only considered negative if they have been produced using gametocides. Currently that technique is only applied in wheat but not in barley or rye (ARGE Bio-Landbau, 2003).

5 Report on strip trials of rye varieties

5.1 Strip trials in 2002/03

In the production years 2002/2003 and 2004/2004 non-replicated strip trials were carried out on commercial organic farms in order to test and compare hybrid and open-pollinated varieties of rye in the field.

Hybrids such as the new Picasso variety have a number of advantages over open-pollinated varieties such as Matador or Oktavian: Picasso is more resistant to lodging and sprouting and showed a 10% higher yield in our strip trials. A new open-pollinated variety from Germany called Nikita did almost as well as the hybrids (Fig. 4). In terms of weight per hectolitre Picasso ranked second at the Kölliken site but gave the worst result at the Frick site (Fig. 5).

5.2 Strip trials in 2003/04

The hybrids' advantages in terms of production techniques (better lodging resistance, higher yields) were confirmed in this production year. The best open-pollinated varieties, Nikita and Matador, gave a mean yield of 55 dt/ha. The best hybrid variety, Avanti, yielded on average 70 dt/ha between the two holdings. This German variety gave a 5 dt/ha higher yield than the Picasso variety widely cultivated in Switzerland. At the Kölliken site Avanti did extremely well, yielding 80 dt/ha (Fig. 6).

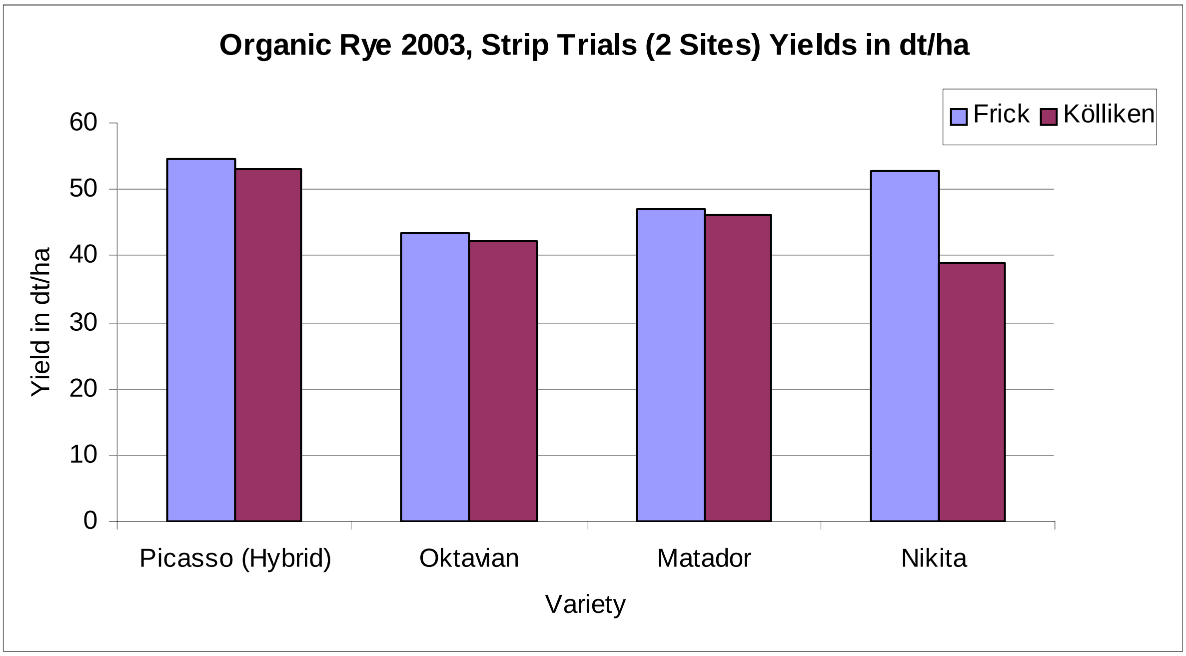

Fig. 4: Yields in the 2003 rye strip trials.

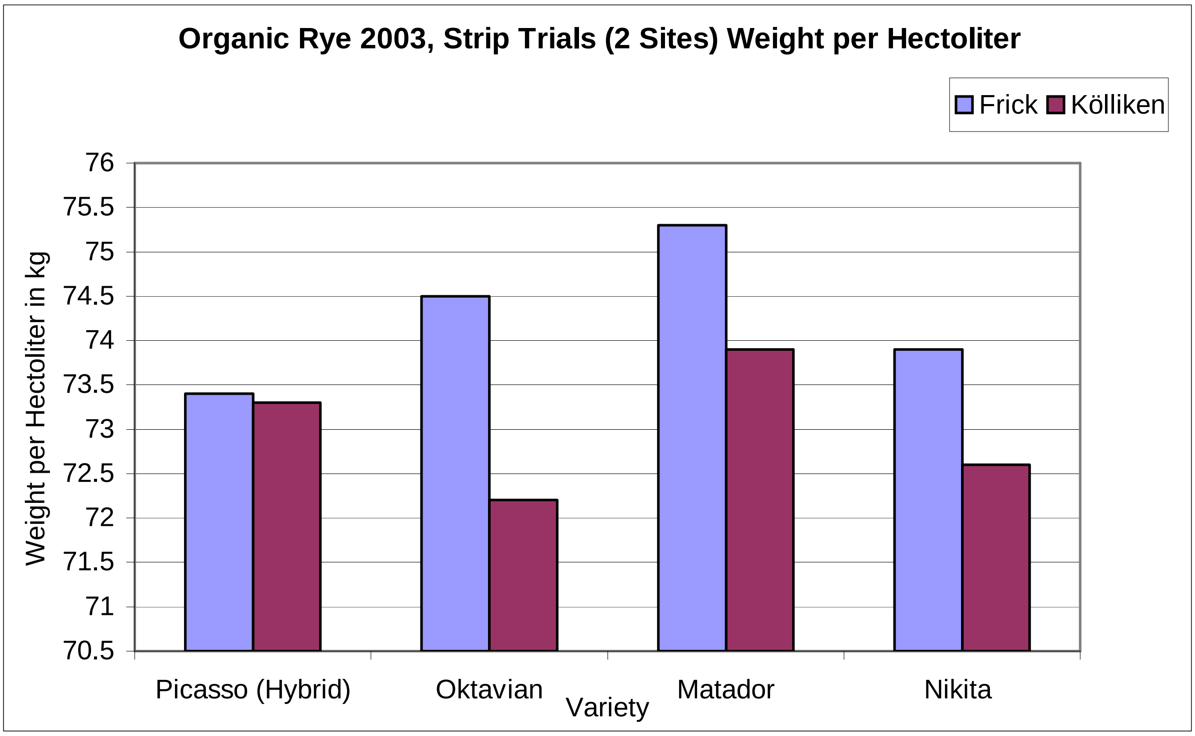

Fig. 5: Weights per hectolitre in the 2003 rye strip trials.

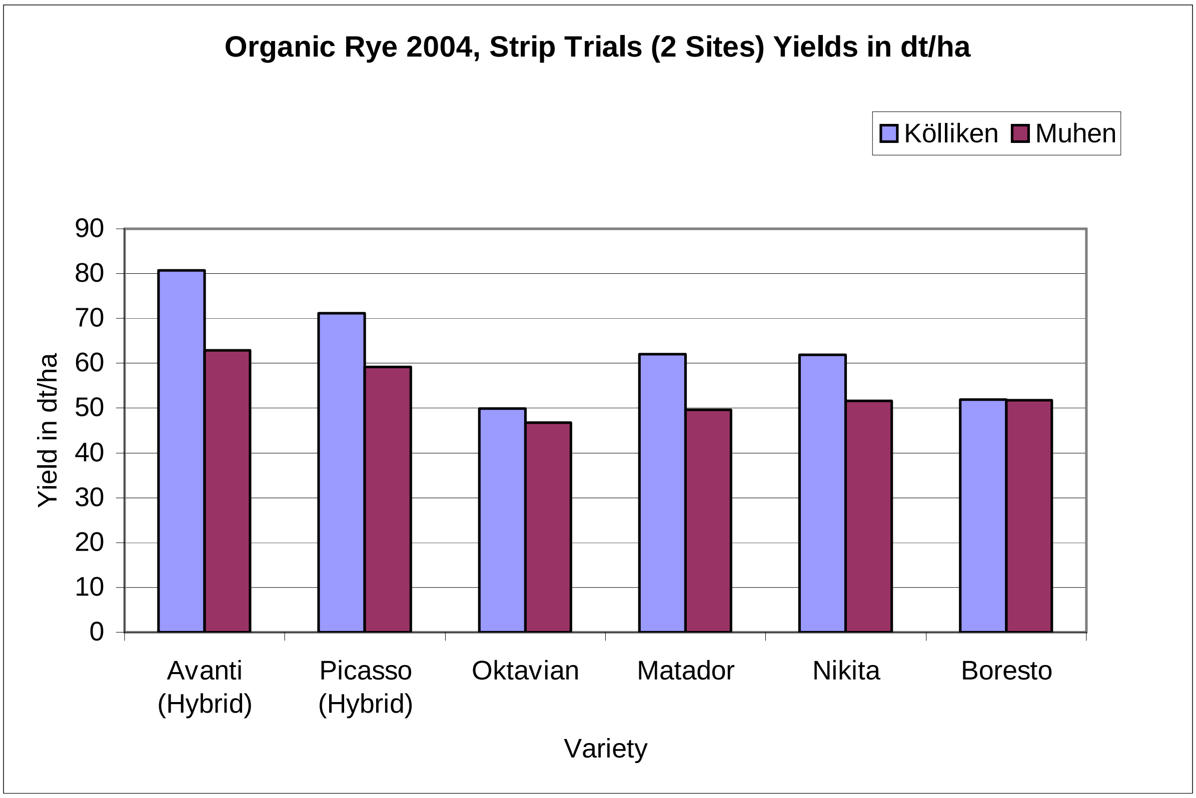

Fig. 6: Yields in the 2004 rye strip trials.

At Kölliken the good relative performance was due to the fact that all open-pollinated varieties were slightly to strongly lodging, which impeded harvesting. Particularly strongly lodging varieties were Boresto (see Fig. 7) and Oktavian.

Fig. 7: The hybrids are more resistant to lodging. In the photo, the Picasso hybrid variety is shown on the left and the Boresto open-pollinated variety on the right.

Growing to a height of 110-120 cm the hybrid varieties showed good lodging resistance on all sites. The open-pollinated varieties grew to 130-160 cm. The least lodging resistant variety was Boresto.

The hybrids had nice, long, well-formed ears but there was some incidence of ergot.

The falling number was determined at the Kölliken site (see Fig. 8). The open-pollinated varieties had a falling number of around 200, with the exception of Boresto, and the hybrids around 250. A falling number of less than 160 attracts penalties. In this year sprouting at this site was not a problem.

The protein content was determined at the Muhen site. The average protein content was 10.5% with little variation between varieties. Oktavian had the highest protein content (11%) and Avanti the lowest at less than 10% (Fig. 9).

The differences between the two sites, Muhen and Kölliken, in terms of soil conditions and climate are insignificant. While the Lehmann holding in Muhen does not have any livestock and imports all manure in the form of slurry, the Maurer holding in Kölliken produces sufficient amounts of farmyard manure. The more intensive fertilization at the latter farm resulted in a 10dt/ha higher yield on average for all varieties.

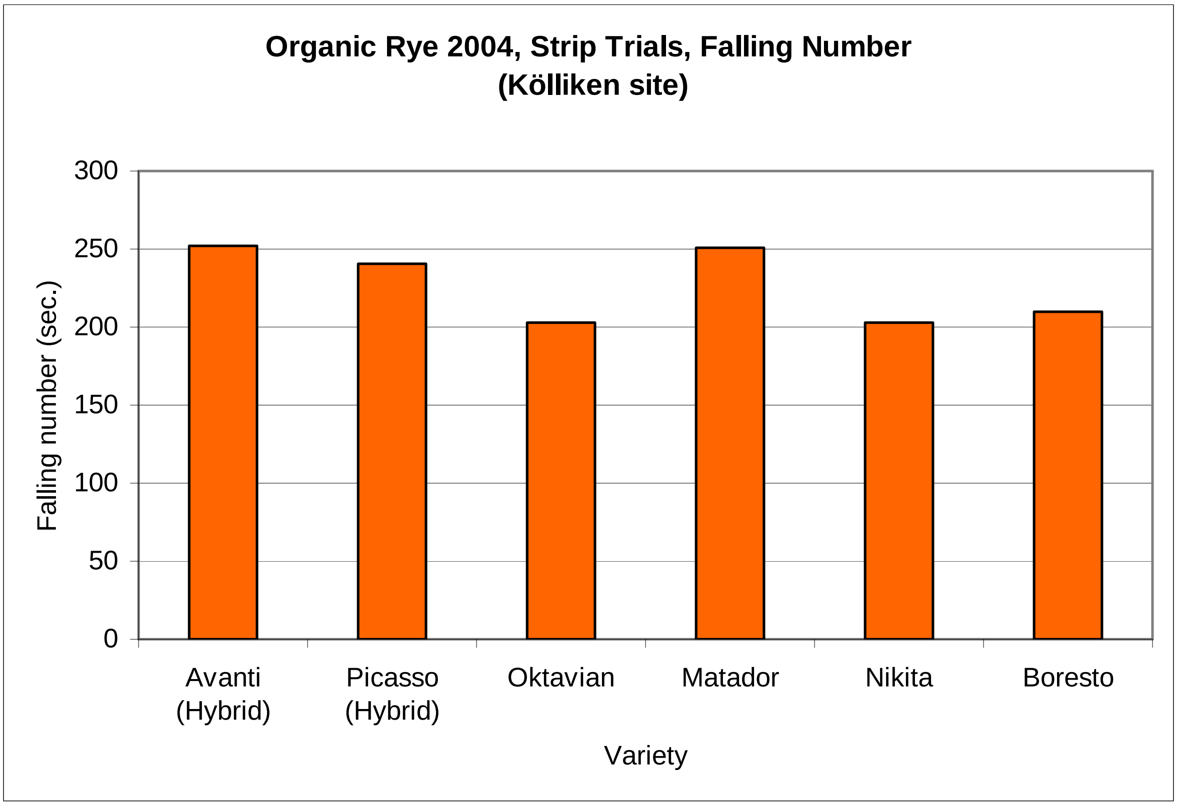

Fig. 8: Falling numbers at the Kölliken site; rye strip trial 2004.

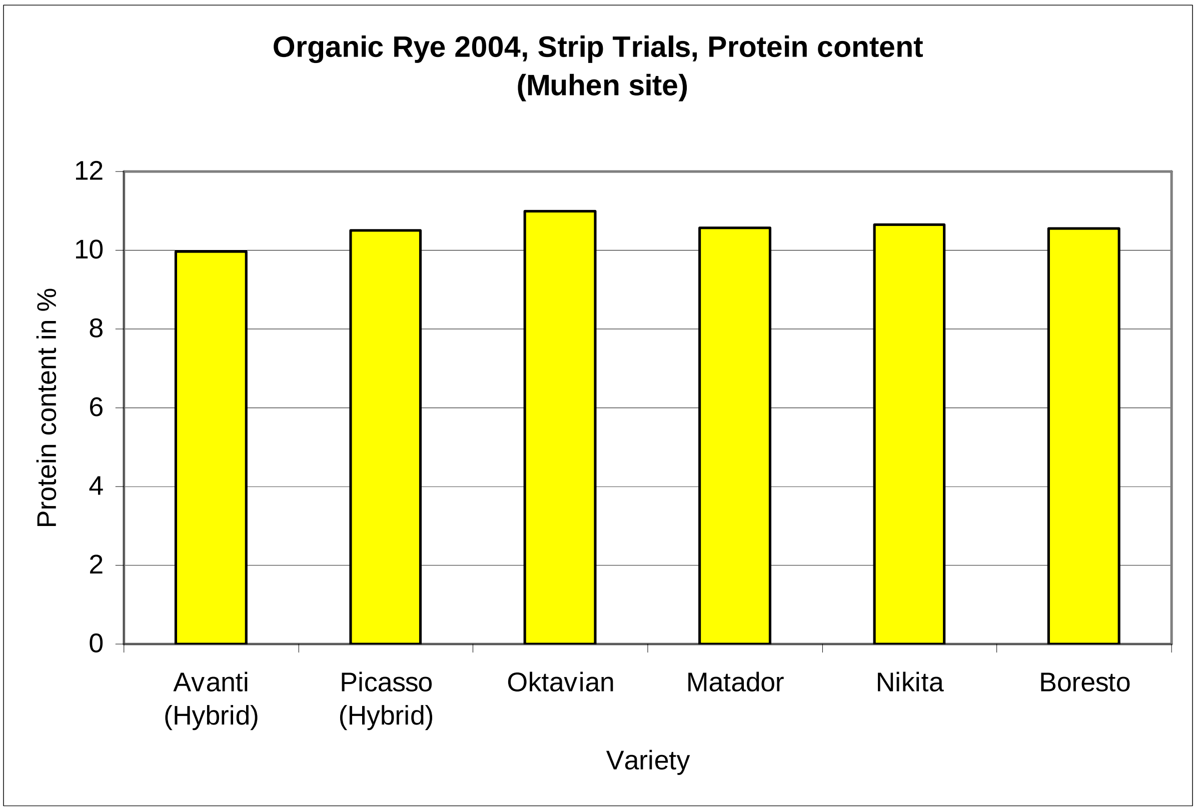

Fig. 9: Protein content at the Muhen site, rye strip trial 2004.

5.3 Example calculation

At present the extra revenue from using hybrid rye is tempting for farmers as the following example calculation demonstrates:

100 kg organic rye seed, Matador variety (open-pollinated): sFr. 168.57

100 kg organic rye seed, Picasso variety (hybrid): sFr. 292.40

Sowing 150kg/ha of the open-pollinated rye will cost the farmer 252.86 sFr/ha. According to the variety recommendations the hybrid rye has a better germination rate and 30% less seed is required per unit area, resulting in costs of 307.02 sFr/ha.

At a yield of 45 dt/ha for the open-pollinated rye and a selling price of 100 sFr/dt the farmer makes 4247.14 sFr/ha after deduction of the seed cost. If the hybrid rye yields an additional 10% the farmer makes 4642.98 sFr/ha after deduction of the seed cost, *i.e.* he earns an additional 395.84/ha. Even if he does not sow at a lower density he can still make 4511.40 sFr/ha, *i.e.* an additional 264.26 sFr/ha. In view of the 2004 trial results this calculation is quite conservative. The additional earnings from using hybrid rye can be significantly higher – provided the rye can be sold at all.

If all the farmers were growing hybrid rye a decline in prices would be unavoidable on account of marketing problems.

6 Hybrid varieties – the pros and cons

6.1 Advantages of hybrid varieties

6.1.1 General advantages of self-sterile plants, independent of crop species

- **Heterosis**: The progeny of a cross between genetically different plants are higher-yielding than their parents. Heterosis is much more pronounced for the trait of yield than for qualitative traits, such as plant height or protein content.

  At the start of a hybrid breeding programme the inbred lines are often rather puny and heterosis following crossing is strong. With continued inbreeding and selection the individual line performance of the inbred lines increases while the **relative** importance of heterosis slowly declines.

  Currently, better yields can be achieved in most crops with hybrid varieties rather than with open-pollinated or pureline varieties.

- **Uniformity:** Hybrid varieties are more uniform than open-pollinated varieties. Such uniformity can not be achieved by population breeding. With regard to many of the vegetable varieties this aspect is an even more important argument than the higher yields.

- **Swift progress in breeding**: Self-sterile plants allow for quicker establishment of many characteristics such as disease resistance or quality aspects in hybrid varieties. In the inbred lines selection is carried out for these traits. For disease resistance, which is often inherited in a dominant fashion, it is sufficient if one of the two inbred lines carries the resistance in order for the hybrid varieties to be resistant. The diversity of populations, in contrast, means that it takes much longer to achieve a certain level of resistance.

- **Inability to save seed and replant:** If seed from a hybrid variety is saved and replanted a non-uniform crop results which does not give the same yield and quality as the bought-in F1 seed. The plants segregate genetically. Therefore it is recommended to purchase new hybrid seed on an annual basis. Hybrid varieties can be said to have “built-in” product protection for the breeder.

The second and third points are of no relevance to **self-fertile plants**, as pureline varieties are uniform in themselves and resistances can be as easily established within them. In self-fertile plants the heterosis effect is generally weaker than in self-sterile plants.

6.1.2 Current advantages of hybrid rye, judging from strip trials in Switzerland

- Higher earnings.
- Greater resistance to lodging.
- Greater resistance to sprouting (better falling numbers).

However, greater resistance to sprouting and yield increases are not inevitably coupled with the hybrid nature of the plants. In contrast to uniformity, these benefits can also be achieved in open-pollinated varieties by means of further progress in breeding.

6.2 Criticism of hybrid breeding

The criticism of hybrid breeding is largely independent of the crop plant species.

6.2.1 Loss of intrinsic quality

Biodynamic circles in particular fear that the increasing substitution of open-pollinated varieties with hybrid varieties entails an erosion of intrinsic crop quality, *i.e.* their ability to provide nourishment.

Biodynamic farming is based on the teachings of Rudolf Steiner (1862-1925) who strove to make metaphysical realities, which came naturally to him, accessible and comprehensible to Western thinking and render them fruitful for society. In his lecture series on agriculture he emphasized that with regard to foods for humans the life-forces the foods contain are the primary concern and are much more important than size, brilliant appearance, financial returns or immediate successes (Steiner 1924, 102 f). The use of mineral fertilizers is rejected as these are not able to bring life-forces into the soil and ultimately give rise to a loss in nutritional quality (Steiner 1924, 176).

Representatives of the biodynamic farming movement have dealt with plant breeding from the early days and have tried to follow Steiner's advice. One of Steiner's recommendations is that one should "preferably leave the path of breeding through crossing and backcrossing" and best develop crop plants from wild varieties "through outcrossing and sharp selection" (Riese 1998, 5). It is not explained what exactly this means. This advice, which incidentally can not be found as a direct quote in Steiner's work, in conjunction with a scepticism towards large size and immediate success in plant breeding have brought about a rejection of hybrid breeding amongst researchers with a biodynamic orientation. While most of the modern biodynamic breeding projects do engage in cross-breeding, a certain scepticism remains attached to "crossing and backcrossing".

The rejection of hybrid breeding has entailed a ban on the cultivation of hybrid varieties of cereals (except for maize) in the Demeter Standards. However, even biodynamic farming has embraced hybrid vegetable varieties to such an extent that a prohibition on their cultivation is not feasible at the current time.

An argument put forward time and again in relation to the intrinsic quality of hybrids is that hybrid breeding influences plants basically in the same manner as the use of mineral fertilizers (Hagel 2001c, 868; Müller 2000, 4).

A meaningful comparative growing trial involving hybrid and open-pollinated varieties of rye was conducted by the biodynamic breeder Karl-Josef Müller in Northern Germany. Nine open-pollinated varieties and seven hybrid varieties of rye were tested on a para-brown earth with a soil quality index (*Bodenpunkte*) of 30 points. At 31 dt/ha the hybrid varieties showed a 33% higher yield on average than the open-pollinated varieties (average of approx. 23 dt/ha). As the hybrid varieties grew to a much lesser height (this was not a heterosis effect but resulted from selection in the parental lines) they had to have a much higher metabolism than the open-pollinated varieties in order to achieve the comparatively very high grain yields (for this site). This increased metabolism was visible in a clearly darker green foliage of the hybrids in the field which could also be measured by means of determining chlorophyll density. These results point in the same direction as Müller's theoretical considerations: In hybrids "growing and unfolding as the otherwise typical starting point of stem growth must predominate. The processes which, through differentiation until the cessation of stem growth, lead towards ripening are held back" (Müller 1996, 213, translated). Müller (2000, 3) also regards this as the reason for the increased susceptibility of hybrid varieties to leaf rust (*cf.* Bayerische Landesanstalt für Landwirtschaft 2004, 13), which is being addressed today by means of new efforts in resistance breeding (Wilde 2004).

Another important fact regarding the biodynamic understanding of quality is that the hybrid varieties in rye and self-sterile vegetables originate from pollen sterile parental lines and in some instances also show a lower pollen fertility than the open-pollinated varieties (see Fig. 3). According to biodynamic understanding, the polarity between "growing and unfolding" as more soil- and water-related growing qualities predominating in the plants' juvenile phase and "differentiating and ripening" as more light- and heat-related growing qualities predominating in the plants' ripening phase, are mirrored in the polarity of ovule and pollen (*cf.* Rispens 1991). According to Müller (2000, translated) "pollen transfers the heat qualities, which lead to seed ripening, into the fruit otherwise dominated by growth processes" and "if the ovule does not receive pollen it remains "hypothermic" in its life processes and lingers at the level of mere vegetative "reproduction" which usually and naturally predominates during stem growth in the form of the "reproduction" of leaves from node to node."

In the biodynamic understanding of quality, heat qualities are seen as helpful and necessary for the vigorous development of the so-called "Ego-organization" (Ich-Organisation) of human beings. The "Ego-organization" allows for the realization of one's own impulses and ideals in life and, at the physiological level, also for a healthy immune system.

The lack of pollen can also result in a higher incidence of ergot as the flowers with unfertilized stigmas remain open for longer and thus provide a gateway for the infection. Normally the large ergot sclerotia can be satisfactorily removed with modern seed cleaning methods. However, Lauber et al. (2005) found ergot alkaloids in each of 51 samples of rye flower and grains they assessed (both from non-organic and organic farming). In the dry year of 2003 when the sclerotia were comparatively small and difficult to clean from the crop the ergot content exceeded the maximum permitted values in 23% of samples. Apart from one sample, all such transgressions concerned non-organic products. "One possible cause of the generally lower [ergot] contents in the organically produced products could be the ban on hybrid varieties (more susceptible to ergot infection) by some of the organic inspection and certification bodies." (Lauber et al., 2005).

Another aspect concerns the future potential contained in the cereal grain. The consumer of hybrid grains is given the harvest which, were it sown, would result in the F2. Many of these grains would grow into unsatisfactory, weak, or imbalanced plant types. If one grain grows into a healthy, vigorous plant and another into a weakling it would not appear to be far fetched to assume that some part of this future quality might influence the food quality of the respective cereal grain.

The assertion that hybrid breeding leads to a loss of intrinsic quality can not as yet be proven using purely analytical methods (Elers 2004, Arncken 2003). In a comparative trial on carrots

Fleck et al. (2002) found higher mineral contents and lower ratios of mono- to disaccharides in open-pollinated samples compared to F1-hybrids. However, this variety trial involved different types of carrots (Nantaise types / Berlikumer) with differences in optimal lengths of growing periods. In a comparative trial of maincrop carrots involving four OP-varieties (for one of these varieties seeds from two years were used in the course of which the population had improved) and two hybrid varieties, Henatsch (2002) found a lower dry matter content, a higher nitrate content, and a lower ratio of mono- to disaccharides in the hybrids, which she interpreted as resulting from an incomplete ripening process. Arncken et al. (2006) carried out a two-year comparative trial of three hybrid varieties and three open-pollinated varieties of carrots and found no significant differences between the variety types spanning both years.

If the storage qualities of seed are considered a quality trait, then this is rather in favour of the hybrid varieties. Stahl & Steiner (1998) assessed the loss of seed viability of five open-pollinated varieties, three hybrid varieties, four CMS inbred varieties and three CMS single hybrids at 14% moisture content in the seed and stress storage at 30°C over 80 days. Seed viability decreased in the following order: hybrids > open-pollinated varieties > CMS single hybrids > CMS inbred varieties.

The assumption that hybrid breeding entails a loss of holistic quality is first of all based on theoretical considerations and internal conceptions on the part of the scientists concerned. One has to consider what adequate research methods might be available which could help assess the asserted loss of non-material qualities. A number of different methods, mostly termed holistic, come into question which have already been used for comparative studies on organic and non-organic foods (Weibel et al., 2001; Woese 1995; Alföldi et al. 1998). So far such research has primarily used “picture-forming” methods after Balzer-Graf & Balzer (1991), and the Sensitive Crystallization Method after Pfeiffer in particular, mainly for vegetables: White cabbage for storage (Elers 2004) and carrots (BLE 2003, Fleck et al. 2002, 2001, Henatsch 2002). Elers (2004) was able to clearly assign the variety types in a blind test using the picture-forming methods of capillary dynamolysis and copper chloride crystallization. However, the variety types were not characterized as part of the study.

In BLE (2003) two hybrid varieties and two open-pollinated varieties of carrots from the trial by Arncken et al. (2003) were examined using the copper chloride crystallization method and digital image evaluation. In the first year it was not possible to assign the variety types to groups. In the second year the two open-pollinated varieties formed one group but the two hybrid varieties formed a group each. In this project the variety types could not be distinguished by means of electrochemical measurements. The assessment of the physiological amino acid status showed that the hybrid varieties had lower values for total free amino acids, total nitrogen in free amino acids, nitrogen in total protein, ratio of total nitrogen in free amino acids to nitrogen in total protein, and degree of amidation of asparic acid. These results indicate a physiological amino acid status similar to carrots which had received less nitrogen fertilizer as part of the project. The interpretation of the results is as follows: “It is possible that the strong growth inherent in the hybrid varieties leads to a higher metabolization of available nitrogen.” (BLE 2003, 201).

Fleck et al. (2002, 2001) characterized hybrid carrots as mainly “showing little differentiation” and “vegetative” with “ageing tendencies”, while the open-pollinated varieties were predominantly attested higher degrees of “form intensity”. For the hybrids to achieve a similar “radiatory image quality” as the open-pollinated varieties the sap of the hybrids had to be more concentrated than those of the OP-varieties. Especially in defined stress conditions there was less evidence of “disintegration” in the open-pollinated varieties. When considering these results however, one must take into account the reservations expressed above regarding the variety types. Henatsch (2002) assigned the hybrid varieties distinctly lower expression indices for the vital quality traits “typical of carrot”, “differentiation”, “vitality”, “stability”, “fruity”, “root-like” and clearly higher expression indices for the vital quality traits “vegetative” and “ageing”.

With regard to rye, Balzer-Graf (1996) compared the nine open-pollinated varieties and seven hybrid varieties used in the growing trial by Müller (1996) (*cf.* p. 23). The author classified the open-pollinated varieties as “more typical of rye (fruit/seed-like), differentiated, well ripened, well vitalized” and the hybrid varieties as “less typical of rye (seed/fruit-like), vegetative-undifferentiated, more devitalized”. A negative correlation between yield and vital qualities was thus established. Within the two variety groups the newest varieties in either group displayed a trend towards less favourable vital qualities. Another study working with the same material compared the bioluminescence of hybrid and open-pollinated varieties in rye (Strube 1996). Here the decay curve for light persistence in the hybrid varieties showed a higher degree of hyperbolism. As this was the case for both germinating and dry grains, the interpretation is that the hybrid varieties are less ripe and thus more tied to the growth phase than the open-pollinated varieties. A comparison of the two varieties Locarno (F1) and Halo (OP) using picture forming methods (Balzer-Graf 1998) confirmed the 1996 results (Balzer-Graf 1998).

The works discussed here support the criticism of hybrid breeding prevalent in biodynamic circles. They also show that there is still a considerable need for research.

For the sake of completeness we shall add two (translated) quotes which show that the fundamental issues of quality are not limited to hybrid breeding: “However, one must not overlook the fact that it is the prevailing breeding aims which have led to the method [hybrid breeding] being favoured. If the value-defining criteria remain unchanged, then breeding efforts will develop open-pollinated varieties in the same direction as it is happening with the hybrid varieties today, albeit much later and over a longer time-period.” (Müller 2000).

“According to current scientific knowledge, the breeding aims realized for hybrids on the basis of heterosis are based on the accumulation of dominant traits. Therefore it should be possible, given the already intense breeding efforts, to realize the same aims for self-fertile species such as wheat with homozygous varieties. The concept of pureline varieties in self-pollinating plants and the breeding aims pursued in this work should therefore always be questioned in the same manner and should be examined with regard to their impact on quality-defining characteristics going beyond processing traits.” (Müller 1996, 218).

In the long term breeders should therefore also pursue higher intrinsic qualities in open-pollinated varieties as a defined objective of breeding. Alternatives to pureline varieties in self-pollinating crops would have to be found.

At present, however, the primary need for action is to slow down the advance of the hybrids and to give a clear signal to interested breeders, in order to prevent the last open-pollinated varieties from being irretrievably lost from the seed catalogues.

6.2.2 Farmers’ dependence

In 1979 the Canadian Pat Roy Mooney published the study “Seeds of the Earth – a private or public resource?” which for the first time clearly and urgently set out the impact of the monopolization of the seed market for the future world food supply. On account of its monopolistic character, hybrid breeding is also critically examined in the study.

Saving and replanting the seed of a hybrid variety results in a non-uniform crop. The various traits segregate. It is therefore unlikely that such seed will give a similar yield and quality to the bought-in F1 seed. This is the reason why it is recommended to purchase new hybrid seed on an annual basis. The seed basically has a built-in product protection for the breeder. From the very beginning this was an important argument for the “fathers of hybrid breeding” in the US where at the time there was no plant variety protection, which meant that a breeder had no way of living off the fruits of his labour. Only a few years after the scientific introduction of the idea, commercial maize breeding companies were set up (*e.g.* Pioneer Hi-Bred). Breeding thus turned from an honourable hobby or pure research into big business. This was the beginning of today’s largely complete division of labour between variety breeding on the one side and propagation and cultivation on the other side.

The expensive groundwork required by every hybrid breeding programme has often been done by public institutions such as universities, *i.e.* the development of inbred lines, the search for pollen sterile lines, the development of useful statistics programmes for test cross matings and much more – so the division of labour is also evident in this field: expensive and time-consuming (publicly financed) research and practical breeding (privately financed and with private returns). This whole development has been impressively researched and put together by Kloppenburg (1988).

The concurrent division of labour between farmer and seed producer would probably have happened anyway but one aspect that has repeatedly been criticized is the farmers’ dependence on private industries (Mooney 1981, Steinbrecher & Mooney 1998, Henatsch 2002).

At present the dependence of farmers on breeders and seed producers in Switzerland is not seen as a problem. Few farmers save and replant seed in Switzerland (the situation is, however, quite different in Germany). The dependence would only be seen as a problem if the political and economic context changed. If at such a point only hybrid seed was available it is conceivable that the seed could be used to pressurize farmers. Seed sales could, for example, be tied to supply contracts which would allow for control over quantities and prices. Another possible scenario would be that political conditions were attached to seed purchased: only those who please politically are allowed to grow food.

6.2.3 Ethical issues

Chapter 3 has shown that hybrid breeding requires major interventions into the plants’ flowering biology. This renders hybrid breeding a doubtful practice in particular for those who advocate a greater degree of “naturalness” in organic farming.

The fact that they are “throw-away varieties” (Henatsch 2002) or “end of the line” (Lammerts et al. 1999) as they have been termed, makes some farmers and growers reject them, especially those who farm biodynamically.

In vegetable varieties where the generative parts of the plants are not harvested, it is not necessary to restore the hybrid variety’s fertility. For this reason vegetable varieties exist which are no longer able to set seed. Lammerts et al. (1999) have proposed that in order to assess the different breeding techniques, three basic tenets of organic farming (closed production cycles, natural self-regulation, biodiversity) be also applied to the plant level. The authors list the following guidelines for organic plant breeding: (i) the plants' natural ability to reproduce, (ii) adaptability to environmental conditions, and (iii) genetic diversity including respect for the authenticity of species. From this point of view hybrids without restorer genes are at variance with the basic tenets of organic agriculture (Lammerts et al. 1999, 21f.).

For many plant species hybrid breeding is not yet feasible today because of a lack of workable hybridizing mechanisms. It is likely that, with the aid of biotechnology, significant progress will be made in this regard in the future (mutagenics, protoplast fusion, gene transfer) (Geiger 1990, 65ff.).

In order to achieve high seed set in the production of certified seed, father plants of species with unfavourable pollinating traits should grow as close as possible to the mother plants, preferably in mixed cultivation. To use this method and yet be able to harvest pure hybrid seed the pollinating plants must be removed from the mixed crop or selectively killed off. This would be possible if the mother plant had an in-built herbicide resistance as the father plants could then simply be sprayed with a herbicide after flowering (Geiger 1990).

These examples demonstrate that hybrid breeding is particularly susceptible to the new developments in biotechnology and genetic engineering and that many problems which are being addressed in the biotechnology field originate in hybrid breeding.

Some people reject hybrid breeding for ethical reasons on account of its intervention into the plants' flowering biology and fertility (Assoziation biologisch-dynamischer Pflanzenzüchter 2003).

The protection of plant variety rights in the future is also an ethical problem. Who should "own" the crop plants? Is it right to support a breeding process which turns the breeder effectively into the owner? With the US as the vanguard, work done all over the world is pointing in that direction. Organic farming, however, advocates an agriculture sector which is in the hands of the farmers and increasingly tries to define itself not only in the biological-ecological sense but also by setting social and economic standards (Schäfer & Sherriff 2005). In this respect it is important to acknowledge the central importance seed has in agriculture. "Seed is more than a mere means of production. In the form of cultivated species and varieties seeds are also an inalienable cultural asset" writes the association of biodynamic plant breeders in their mission statement, and Henatsch (2002) emphasizes: "Seeds and the diversity of varieties are an expression of mankind's cultural achievements, his cultural and geographical diversity. Patenting and hybrid breeding … turn cultural assets into private property. A cultural asset and intellectual property has become an economic asset and power factor …". Many seed and breeding initiatives associated with the organic farming sector try to present alternatives to this development by maintaining threatened varieties on a voluntary basis (Oppermann et al. 2001, 19) or by searching for new ways of financing plant breeding (Müller 2004).

The inability to save seed and replant hybrid varieties, *i.e.* the "built-in product protection" which assures the breeder's income leads down the same path as the patenting of life forms which is being rejected as unethical by all ecologically and socially motivated movements. The development of agriculture towards a production centre for patented life forms is contradictory to the objectives of organic farming.

If organic farmers grow hybrid varieties because they want to utilize their advantages, they support, contrary to their declared aims, this questionable development.

6.2.4 Genetic depletion and vulnerability

According to SHULL (1908) every population of self-sterile plants can be regarded as a mix of complex hybrids. Hybrid breeding aims at discovering the one superior hybrid in this mixture in order to produce a whole field of identical copies of this hybrid. To this end it breaks up the original population into inbred lines that are as homozygous as possible. This is followed by test cross matings in order to find the best hybrids that can be produced by the inbred lines, after which the selected hybrids are produced as homogenous varieties.

The uniformity of the hybrid varieties is a decisive reason for their success, especially where vegetables are concerned (see p. 9f).

When a hybrid variety is grown all plants in the field share the same genotype. This uniformity makes the variety genetically vulnerable, *i.e.* in the case of a resistance breakdown an epidemic can affect all plants in the field in the same manner. In such cases organic farming does not have the means to intervene using agrochemicals. Therefore its declared aim is to maintain and enhance diversity as a type of prophylaxis, wherever possible.

Moreover, in the case of rye, all the hybrid varieties produced by a breeder (or possibly even those produced by a number of breeders) share the same cytoplasm since male sterility is inherited through the cytoplasm. This means that all varieties, no matter how different they may be regarding many of their traits, are absolutely uniform in terms of their cytoplasm.

Open-pollinated varieties, in contrast, are well buffered against epidemics through their diversity in the field.

As was set out at the start of this paper (p. 10) hybrid breeding, through inbreeding, entails a loss of recessive genes such as are always present in open-pollinated varieties and passed on without manifesting themselves. Therefore the well-known heterosis researcher F.W. Schnell (1997) of the University of Hohenheim concludes in his self-critical appreciation of hybrid breeding that in self-sterile plants the transition from population breeding to hybrid breeding “has merely provided the possibility of ever sharper selection” (p. 5) while heterosis had already been utilized prior to hybrid breeding by means of heterozygosity in the varieties.

If open-pollinated varieties are grown agriculturally, they represent – in addition to their current use – a large-scale genetic reservoir for the future, grown out under field conditions. In other words, their production combines current use and future potential (Müller 1996). If hybrid varieties replace open-pollinated varieties, higher yields and greater uniformity often entail greater current benefits (at least at a superficial level). However, the aspect of future development is much diminished and the reservoir of genetic diversity is limited to breeding gardens and the gene banks’ freezers and is thus removed from the context of life in farming.

6.2.5 Summary of criticism of hybrid breeding

- **Loss of intrinsic quality:** There are concerns, especially in the biodynamic movement, that continued inbreeding and pollen sterile maternal lines as part of the breeding process may lead to a loss of more subtle quality traits.
- **Inability to save and replant seed:** To the farmer the seed is “economically sterile” (Berland and Lewontin 1986); he can not bulk it up and maintain it and thus becomes dependent on the breeder/seed producer.

- **Ethical issues**: The hybrids' "throw away" character and the breeders' intervention into the flowering biology of the parental lines are at variance with the objectives of organic agriculture. The fact that the hybrid seed can not be saved and replanted effectively constitutes "patent protection" and promotes the ethically questionable change in meaning from a cultural asset to a mere means of production.
- **Loss of diversity:** As a result of strict inbreeding, recessive genes are eliminated during the breeding process. When a hybrid variety is grown all plants in the field share the same genotype. All the hybrid varieties produced by a breeder (or possibly even those produced by a number of breeders) share the same uniform cytoplasm.

All these arguments have future repercussions, as breeding of course always does. They are all relevant, regardless of the circumstance that the first point has not yet been satisfactorily clarified. Today's decisions on selection give us tomorrow's varieties. This is also true of selection decisions taken in the marketplace.

7 Conclusions

Hybrid breeding utilizes the advantages characterizing F1 plants in a targeted manner: Vigour, uniformity, and a combination of all dominant traits of the parental lines. It gives breeders secure licences, as farmers can not save seed from hybrid varieties with a view to replanting.

Regarding rye, the current advantages of hybrid varieties are primarily the higher yields but also improved resistances to lodging and sprouting. However, farmers can only benefit from higher yields if the limited market for organic rye in Switzerland can be expanded. The currently available hybrid rye varieties have higher susceptibility to leaf rust and ergot infections.

The criticism of hybrid breeding and hybrid varieties concerns four areas:

Firstly, the area of intrinsic quality: There are concerns, especially in the biodynamic movement, that continued inbreeding and pollen sterility as part of the breeding process will lead to losses regarding the more subtle ripening and nutritional qualities. This poses the question of adequate research methods. There is still considerable need for research.

Secondly, the area of socio-economics: The fact that seed from hybrid varieties can not be saved and replanted leads to greater dependence on breeders and seed producers on the part of the farmers. At present this is not regarded as a problem in Switzerland as most farmers purchase new seed every year in any case but in the long term it renders agriculture liable to corruption.

Thirdly, the ethical field: Some people have concerns regarding the breeders' intervention into the flowering biology of the relevant cereal species. These interventions are at variance with the basic ethical-philosophical tenets of organic agriculture. Moreover, the fact that the hybrid varieties can not be saved and replanted effectively constitutes “patent protection” and promotes the ethically questionable change in meaning of seed from a cultural asset to a mere means of production.

Fourthly: Hybrid varieties of self-sterile plants (*e.g.* rye) are genetically more vulnerable to environmental influences which were not considered during selection. This point is less relevant as regards self-fertile plants (oilseed rape, barley, wheat) as even today's pureline varieties are already very uniform. It must be noted that amongst all hybrid varieties which are based on male sterility many so-called “different” varieties may share the same cytoplasm.

As the criticisms regarding dependencies and genetic vulnerability only concern the future and the ethical concerns are not shared by everyone, it is the quality issue which is of particular relevance regarding the pending decision on whether or not to ban hybrid varieties in organic bread cereal production in Switzerland. Further research is essential. However, if one is to wait for the relevant results before taking a decision, this will certainly be too late. It would be more realistic to integrate a review clause into a potential decision to refrain from the use of hybrid varieties.

Abstaining from the use of hybrid varieties in organic bread cereal production in Switzerland would give a clear signal to upstream and downstream sectors (breeders/trade and consumers respectively) that organic farming strives to consider long-term and future aspects of independence, quality, and diversity and that it would be ready to forego current agronomic advantages to this end. This would need to be clearly communicated to the trade sector when it comes to discussions on market prices.

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9 Photo/figure captions

Cover page:

Image on left: Stigmas and anthers of male fertile (left), partial male sterile (centre) and fully male sterile (right) rye. Source: Geiger (1990), p. 48.

Image in centre: Winter rye in organic farming. Source: www.oekolandbau.de / Copyright BLE 2002-2005 / Thomas Stephan.

Image on right: Ears of rye. Source: Den virtuelle floran. Copyright: Naturhistoriska Riksmuseet, Sweden. Source: http://linnaeus.nrm.se/flora/mono/poa/secal/secacer3.html. Foto: Anna-Lena Anderberg.

Main text:

Fig. 1: FiBL (2001), p. 9

Fig. 2: Becker (1993), p. 146.

Fig. 3: Image: Christine Arncken and Claudia Kirchgraber, FiBL

Fig. 7: Hansueli Dierauer, FiBL

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