

### 5.3 Plant breeding and seed production for agricultural intensification and biodiversity conservation

Plant breeding has an enormous impact on agrobiodiversity. After long periods of enriching the diversity of cultivars that are used by man, the agrobiodiversity has been increasingly narrowing in the last 150 years. To counteract this menacing development, two promising breeding methods have been developed within recent decades:

1. Evolutionary plant breeding and
2. Breeding with farmers

Within this chapter these approaches are introduced and discussed.

#### 5.3.1 Development and consequences of plant breeding

Plant breeding has existed since the advent of crop domestication. For more than 10,000 years farmers have selected plants for higher yields and health; uniformity in germination and ripening became important traits allowing better harvesting. Plants were exposed and adapted to various environments. Gradually, a rich, man-made diversity of agricultural crops developed. Thousands of plant species were utilized and each crop exhibited major diversity.

During the past 150 years, agricultural development has reversed this trend – biological diversity in

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agriculture is dwindling. Today, only some 150 species are cultivated, and no more than three of them (rice, maize and wheat) supply almost 60% of global food. Not only are fewer and fewer plant species used for food and agriculture, but plant breeding and commercial seed production have contributed to the reduction of genetic diversity within individual species. The number of varieties of a crop is constantly decreasing and varieties are becoming increasingly uniform. This is worrying, because plant genes represent potential traits. Their loss – also called genetic erosion – is receiving increasing attention as it

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coincides with two global challenges: to ensure global food security and to adapt to climate-induced environmental changes. It is becoming increasingly clear that plant genetic resources are crucial for both. Reconciling agricultural intensification with the conservation of agro-genetic resources is becoming a key concern. Plant breeding and seed production are key to that endeavour.

**... also called genetic erosion ...**

#### 5.3.2 Evolutionary plant breeding – a new method that increases genetic diversity

The search for alternatives started 50 years ago and led to the method of evolutionary plant breeding. This method can be described as follows:

- In order to generate new varieties, breeders systematically utilize genetically diverse and ecologically adapted local varieties. Landraces of different evolutionary origin are assembled and recombined by cross-pollination; such mixtures are named “composite cross populations”.
- Over several generations, the progenies (genetic off-springs) are propagated as bulk, and the bulk is subjected to natural and artificial selection under various ecological conditions, which ultimately results in a “modern local variety”.

Mainly with barley and also with wheat, composite cross varieties can become superior in comparison to “leading” high yielding varieties, because they perform well under various ecological conditions. Obviously, yield stability and a high yield over a range of environments require genetic diversity.

Better disease resistance of composite cross populations is another important result. Not only can disease-induced yield reductions be limited by increasing genetic diversity, but genetically diverse populations also adapt well to changing disease patterns. The co-evolution of plants and diseases in genetically diverse populations is a well functioning, self-regulating mechanism that maintains the plant’s disease resistance – a characteristic which generally is not found in genetically homogeneous crops.

In summary, evolutionary breeding with composite cross populations is a very promising method for the intensification of land-use systems and for future

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adaptation of crops to environmental change. This applies in particular to marginal environmental conditions and may become increasingly relevant to farming in general.

### 5.3.3 Breeding with farmers – a new organizational approach (handout 11)

Another innovation is called Participatory Plant Breeding (PPB). In contrast to classical approaches, PPB is not done by breeders alone and hardly takes place on experimental fields or, as practiced nowadays, in laboratories. Throughout the whole process of breeding – the generation of variability, selection and testing of cultivars' phases – farmers are fully included in decision making.

Secondly, most of the process takes place on farmers' fields, not in research stations. In doing so, the bias of genotype-environmental interactions from research stations can be avoided. Whereas research stations have better soils, and possibly irrigation facilities, etc., farmers' fields represent the full range of environmental (and management) conditions for cropping.

Participatory Plant Breeding emerged within the past ten years, mainly promoted by the research centres under the Consultative Group on International Agricultural Research (CGIAR) and by a number of NGOs. The process is now practiced worldwide in developing countries, with outstanding results in three

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regions: barley in the Middle East, rice in South Asia and sorghum in West Africa. In all three programmes, the improvement of drought-tolerant cereals in low rainfall environments has been a main objective. Now the method extends to other crops such as vegetables and maize.

Considering the impact of the method, there are at least three strong arguments in favour of it:

- The effectiveness of breeding can be improved as farmers' experience, agronomic knowledge and preferences are included in the entire breeding process. All this gives varieties bred by this method high acceptance and accelerated adoption rates, lending a demand-driven approach to breeding.
- Research efficiency can be improved and farmers' selections can be as high-yielding as breeders' selections.

- Time for breeding can be reduced. Normally it takes about 15 years to release a variety. As under PPB site-testing on-farm is included in the breeding process, the release of superior bulks requires only half the time, and if pure lines are necessary, 3 - 4 years can still be saved. This is an important aspect in times of rapidly changing climate and the need for fast adaptation.

### 5.3.4 Alternative breeding approaches that complement classical breeding

The method of evolutionary breeding and the organizational approach of participatory breeding interlock. Together they can provide an important complement to classical plant breeding. They have several advantages:

- Scientifically, they have broadened the understanding of appropriate breeding technologies. Complementing formal breeding, evolutionary breeding offers a methodology that focuses on crop-environment interaction and makes use of it. Secondly, it has stimulated discussion on genotype-environment interaction and new methods have been developed that allow breeding under local conditions with various environments.





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- Socially they help to empower farmers to regain control of their seed systems, and to safeguard their interests after decades of marginalization due to trade liberalisation. Secondly, small scale farmers in marginal areas are now receiving benefits from agricultural research and development, as well as recognition that greater efforts must be made to develop technologies that are better suited to improving their livelihood.
- Economically it provides an answer as to how the potential of marginal areas and the large range of minor crops can be exploited and made more productive. This is one key aspect of increasing global food production.
- Ecologically the new approaches provide an answer to sustaining the diversity of agro-genetic resources and further developing it in accordance with environmental change within a shorter period of time. The challenge of global warming is to adapt to difficult environments as fast as possible.

An interesting example for the understanding of the described approaches is the Bingenheim Initiative in Germany, a farmer initiative with the objectives to stay independent from the seed industry and to achieve a higher food quality in their crops (see handout 11).

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**Literature cited and recommendations for further reading:**

**Bingenheimer Saatgut AG:**

[www.bingenheimersaatgut.de](http://www.bingenheimersaatgut.de)

**Ceccarelli, S. (2006):** Participatory Plant Breeding: Lessons from the South – Perspectives in the North. In: Desclaux, D. and M. Hédont (eds.): Proceedings of the ECO-PB Workshop: “Participatory Plant Breeding: Relevance for Organic Agriculture?”, 11-13 June 2006, La Besse, France, pp. 8-17. ITAP, Paris, France.

**Kotschi, J. (2009):** How can Local Varieties Contribute to Agricultural Intensification? [www.agrecol.de](http://www.agrecol.de)

**Kultursaat e.V.:** [www.kultursaat.org](http://www.kultursaat.org)

## Main Message 13

### Plant breeding and seed production for agricultural intensification and biodiversity conservation

- *Plant breeding spawned a rich diversity of cultivated plants over thousands of years. Strong selection on uniform criteria all over the world, however, reversed this trend in the last 150 years and led to a decreasing diversity in agricultural cultivars.*
- *Evolutionary plant breeding to create new local races is an alternative to the mainstream breeding procedure. With this practice landraces of different evolutionary origin are assembled and recombined by cross-pollination. Progenies of this cross pollination are propagated as bulk, and the bulk is subjected to natural and artificial selection under various ecological conditions. This ultimately results in a “modern local variety”, which can compete with high yielding varieties in many situations.*
- *Breeding with farmers and in their fields is an organizational approach, which is often combined with evolutionary plant breeding. This provides several advantages:*
  - *Socially it helps to empower farmers to regain control of their seed systems.*
  - *Economically it provides an answer as to how marginal areas and minor crops can be made more productive.*
  - *Ecologically the new approaches answer the need to sustain the diversity of agro-genetic resources.*



## Handout 11

# An example of breeding for a broader biodiversity – the case of Bingenheim in Germany

The Bingenheim Initiative started in 1985 as a network of mainly vegetable growers with the objective to supply seed among themselves. Their objectives were manifold. Some wanted to take responsibility for the conservation of endangered seeds, others to maintain independence from the seed industry, a third group aimed to achieve a higher food quality of crops, and all of them wanted to comply with the standards of organic agriculture.

### Organizational structure

Today the initiative comprises of three organizations:

- An informal network of farmers, doing mainly seed multiplication
- A registered association (NGO) that supports breeding: “Kultursaat e.V.”
- A shareholder company that produces the seeds: “Bingenheimer Saatgut AG”

### Farmer network

The farmer network is an informal association. It has around 120 members – mainly vegetable growers, mostly from Germany, some from neighbouring countries (Switzerland, France, Austria, Italy, Spain and the Netherlands). They multiply seed, and some do breeding as well. The farmers meet twice a year to exchange experiences on seed multiplication and develop future strategies. The network is the central foundation for the project.

The purpose of the group is to produce seed for biodynamic agriculture and its members mainly do maintenance breeding. The farmer network has a fairly loose and informal organizational structure and no legal status.

### Registered association

The second entity, called “Kultursaat e.V.” is a registered association – public and non-profit oriented. It was founded in 1994 to coordinate and combine already existing breeding initiatives of individuals and to support them financially and professionally (e.g. through training). In addition, the idea was to bring together people from various backgrounds that are motivated to support the maintenance and further development of agricultural crops, and who see in them a cultural heritage. Today, the association has around 400 members – not only breeders but also an interested public. In an annual general assembly, the members make decisions on strategic questions.

The association supports breeders financially and logistically; breeders apply for funding via project proposals to the association and the board of the association decides over the distribution of funds. The association coordinates breeding activities, and raises funds for breeding. Today 21 breeders at 18 locations do breeding on behalf of the association. Breeding is done on organic farms. Each breeder has two “godfathers”, members from the association and breeders themselves, who accompany and supervise the breeding work. This comprises a visit and inspection of the breeding

fields each year and discussion about the progress of work. In doing so, the association takes care of each single breeding activity.

The materials may be the work of an individual breeder within the initiative, but they are considered the result of a collective effort. Accordingly, promising materials developed by single breeders are handed over to the association. In its capacity as the legal owner, the NGO formally presents the materials for variety registration and takes care of the costs and responsibilities involved. This situation is ideal, considering the fact that the breeders consider private ownership of varieties as inappropriate. Therefore, the association is the owner of new varieties and the varieties are considered collective property.

The annual budget of the association is small. It comes from membership fees and mainly from donations. Kultursaat has registered approximately 30 varieties of different vegetables. Kultursaat, as the owner, is responsible for maintaining the varieties and giving licences to third parties for seed multiplication, for use and for commercialisation. So far, only Bingenheimer Saatgut AG has licences for varieties registered to the name of Kultursaat.

### **Seed enterprise**

The “Bingenheimer Saatgut AG” is basically a seed enterprise. Its purpose is to organize and coordinate seed processing and distribution in a professional manner. It contracts organic farmers (from within the farmer network) for the multiplication of seeds of vegetables, herbs and flowers. The company itself does seed processing and marketing of the seeds.

The new company has the following objectives

- To distribute organically produced varieties
- To conserve and promote genetic diversity in agriculture and in horticulture
- To maintain and enhance seed production as a cultural task of the society
- To develop an economy that allows participation of all stakeholders in production and use of seeds

The shares of the company are held by the members of Kultursaat (3%), the farmer network (20%), the Bingenheim Community (20%), a foundation (49%) and other single donors. Shares can only be sold after approval of the company.

### **Three types of seeds are produced**

- Initially, the company produced only seeds of free varieties, e.g. varieties that were not protected by plant breeders’ rights and were, therefore, freely available to the public.
- Later on, it produced also seed under licence from a number of varieties from other independent seed companies (mainly vegetables).
- Today, the company also produces seeds of varieties that have been developed by members of Kultursaat and that are registered under its name.

## Breeding strategy

Breeding for organic agriculture differs significantly from conventional breeding. Mandate and role of plant breeding are perceived differently. Organic agriculture can be described as the management of agroecosystems with the objective of sustainable supply to the regional market with safe and healthy food and non-food products, while maintaining a largely closed system. Central are the agro-ecological sustainability at plant and farm level, the socioeconomic sustainability, and the interaction between these. Diversity within and between varieties and crops and management thereof play an important role in the sustainability of agroecosystems. Whereas in conventional agriculture the genetic basis of crop production has narrowed considerably, organic agriculture aims at maintaining genetically diverse production.

This objective fits the perception that breeding has to play a role in maintaining the availability of diversity and in keeping this diversity in 'good condition'. This is in contrast with conventional breeding where the continuous introduction and replacement of varieties seems a necessity for breeding companies and farmers to survive.

In the organic sector, farmers and vegetable growers are not only considered end-users of breeding products: they also form the environment in which breeding is integrated. The organization of breeding activities on-farm does not necessarily imply direct participation of farmers in the breeding activities.

An important element in organic agriculture is the recognition of the specific character of the farm and the region. In breeding terminology this can be translated as the objective of aiming at specific adaptation to farm and environment.

## Breeding methodology and technology

In general, plant breeders distinguish four phases in the development of varieties:

1. The recombination of genetic variation
2. Selection
3. Variety maintenance
4. Production of foundation seed

The differences in breeding for organic agriculture are most relevant in 1) and 2). Conventionally, breeding is applied at plant or population level, cell and meristem level, and DNA level. In bio-dynamic agriculture the technologies at DNA and cell levels are not acceptable. If, like now, the majority of the organic breeding activities are taking place in the bio-dynamic domain, these technologies are likely to remain irrelevant for breeding in the organic sector. Another discussion is the acceptability of hybrid varieties. On this point the opinions among bio-dynamic practitioners vary. It is possible that in the future hybrids will not be acceptable anymore in the bio-dynamic sector. At present, hybrids are widely used in the organic sector, including the bio-dynamic sector.

The breeders of Kultursaat develop lines and populations according to the guidelines of bio-dynamic agriculture. As parental material they use free varieties and other commercially available varieties. They also evaluate a range of materials from gene bank collections, but so far these have hardly been used in their crossing work.

Rejection of various gene technologies has important repercussions for the flow of genes between organic and conventional breeding. At present, organic breeding can tap from the conventional sector. If in future, varieties developed with gene technology will dominate in the conventional sector, then the materials from this sector will be largely unusable as source material for organic bio-dynamic breeding.

## Main features of breeding

### Breeding generates diversity

For crossing, breeders use conventional varieties as sources of new genes, including hybrid varieties. The segregation of hybrid varieties in following generations is also used to develop new lines through selection. This forms a genetic link between the breeding programmes of the conventional and the organic sector.

### Variation in selection

Crossing and segregation can be considered as the means to generate genetic variation (recombination) at plant level. Selection can be seen as the way to generate a diverse portfolio of varieties. This means that selection should not only be seen as an activity that reduces available variation. The Bingenheim group selects in different environments and by different selectors.

### Exploitation of variation in environment and time

Variations in climate, mineral supply, and planetary constellation represent forms of variation in environmental conditions. They are the result of variation in time and place. Variation in environmental conditions leads to different materials being selected.

### Variation in selectors

Involving more selectors leads to more variation in selection preferences. This means that variation can be better evaluated and exploited, which may result in more variation being selected. One way to have more selectors is by involving farmers and vegetable growers. In a number of cases in the Bingenheim Initiative, the role of the breeder and producer are combined in the same person. When the breeder is also producer, it is assumed that the breeder selects 'with the eyes' (preferences) of a producer.

### Exploiting location-specific adaptation

The selection under different conditions and by a larger number of people contributes to a larger portfolio of varieties with region-specific adaptation. In breeding this is also referred to as 'exploitation of location-specific adaptation'. In addition to identifying the best variety for different conditions, this strategy contributes to a broad genetic base in agricultural crop production. It has, however, disadvantages, too. For example, varieties that were selected on the sandy soils usually perform less well on clay soils, and vice versa. This also explains that varieties developed for specific conditions are often low producing in the variety trials when presented for registration.



## Results and conclusions

### General observations

Bingenheim and other similar initiatives have created an alternative seed sector in Europe that provides mainly vegetable seeds and increasingly also grains for the organic market.

### Breeding methodology

Decentralised breeding offers opportunities to exploit region-specific adaptation, and close interaction with producers and with end-users. Breeding is based on the use of licence free varieties and varieties from the conventional sector. This may become a problem if genetically modified (GM) seeds gain increasing importance in the conventional seed sector, as non-GM parent material may become scarce in future.

### Seed production and marketing

The initiative addresses clients that appreciate diversity of crops. This concerns the organic sector in general and organic small scale vegetable growers and farmers in particular. The prices are based on normal market prices.

### Financial aspects

Financial resources from gifts and foundations create "external" benefits that do not pay directly and that help farmers tolerate reduced revenues from seed sales. Therefore, the initiative does not depend entirely on market mechanisms.

### Social aspects

Breeding is carried out by a network of breeders, and all parts of society are included in the financing of breeding. Broad participation and full transparency make breeding a socially widely supported activity.

### Legal aspects

The Bingenheim Initiative practices collective ownership of varieties. Property rights of the varieties lie with Kultursaat e.V. This emphasises their perception that the availability of the varieties is a public task.