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2 Supporting informal seed supply

2.1 Supporting farmers in maintaining and selecting seeds of local varieties*

Conny Almekinders and Niels P. Louwaars

Maintenance and selection are important activities in crop improvement programmes. It is often assumed that variety maintenance and crop improvement are specialized activities that can only be performed by trained breeders. However, farmers too practise such activities, which are a critical part of the informal seed system for maintaining and improving local or adopted improved varieties. Methods of seed production practised within the formal setting can provide ways of enhancing the 'genetic quality' of seed produced by farmers within the informal seed system. This section presents some basic background and describes some techniques of variety maintenance and selection which may be used when supporting farmers' seed production.

Options for selection
Selection is an important aspect of seed production. Selection is done to:
- Improve seed vigour by selecting well-developed plants and plump seeds only (physiological and analytical quality);
- Reduce disease incidence by discarding obviously diseased plants or seeds (sanitary quality);
- Maintain the genetic quality of the variety (varietal identity);
- Continually adapt the variety to changing growing conditions; and
- Obtain better varieties.

There are different selection methods, realized during different phases of seed production. Before planting, in reverse order, these are:
1. Selecting healthy and 'true-to-type' seeds from the stored grain, i.e. seeds that resemble those of the mother crop and do not show obvious disease symptoms.
2. Selecting after harvesting, but before threshing and storage. This is a common method in maize and sorghum, where the best-looking ears and heads are kept

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* This section is adapted from: Almekinders, C.J.M. and N.P. Louwaars, 1999. Farmers' seed production. New approaches and practices. London, Intermediate Technology Publications: pp. 119-131.

separately for seed. An advantage is that for small amounts of selected seed, drying and storage conditions can be given more attention.

3. Selecting while harvesting a particular field or part of the field that performs well. The selected portion is harvested separately for seed. The advantage is that seeds from well-developed plants with few disease symptoms are expected to be more vigorous and healthy.
4. Picking of individual plants just before the harvesting of the whole field. The advantage over method 3 is that it is also possible to select for the genetic composition of the variety.
5. Marking of particularly healthy and good looking individual plants during the season, e.g. by tying a ribbon around the stem of the selected plant, and harvesting separately (positive mass selection). At the same time, clear off-type or diseased plants may be removed from the field (negative mass selection). Compared with method 4, this allows for selection based on characteristics that are no longer visible at the end of the season, e.g. susceptibility to leaf diseases.
6. Selecting a field for seed production, separate from the crop production field, taking into account some isolation distance. Combining this practice with the roguing of off-type and diseased plants during the season can increase the selection pressure.
7. Performing a specialized selection procedure to maintain or purify the variety (see following section on variety maintenance).
8. Selecting a totally different environment for seed production, e.g. producing seed potatoes at a higher altitude to reduce disease pressures, and producing ware potatoes in the valleys.

These options are listed in order of specialization, and in order of efficiency in terms of genetic selection. The options divide into two types: in options 1 to 5, seed production is part of the crop production process, while in options 6 to 8 it is specialized and separate from crop cultivation.

In the first option, selection does not necessarily relate to plant characteristics and therefore carries a risk of genetic degeneration of the variety. For example, when some trailing beans are mixed with seed of a pure bush type variety with similar seed characteristics, the numbers of trailing plants will increase with time because the trailing plants produce more pods. Seed selection before planting can however be helpful for sorting out obviously poorly developed or diseased seeds, e.g. brown-spotted bean seeds affected by fungus or viral disease.

Options 6, 7 or 8 may be useful in very special cases, i.e. where uniform varieties are needed or where disease pressures are high. In large scale seed production this is by far the most preferable option, but in common agricultural practice this is only done in very specific situations.

Ordinary farmers generally perform selection methods 1, 2, 3, or 4, or a combination of them. There are, however cases in which farmers have developed more sophisticated seed production and selection practices. This happens for example where farm conditions are particularly suitable for seed production, or where particular farmers or farmer groups have a special interest in producing superior quality seeds. In many situations, options 3 and 5 offer interesting opportunities to improve seed quality.

One effective refinement of options 4 and 5 is a method known as 'grid selection', in which plants are selected in relation to neighbouring plants. This means selecting plants that compare well with the neighbouring ones, rather than taking all the plants from a possibly more fertile part of the field. A good farmer will select outstanding plants from all corners of his field by comparing each plant with its neighbours.

Seed cleaning and removing diseased plants from the field is another form of selection. Even though such selection for non-genetic seed quality is important, selection is more commonly associated with variety maintenance or improvement. It is, however, important to realize that any selection for non-genetic seed quality may – perhaps unintentionally – affect the genetic quality of the seed. So the effects of selection can be unpredictable, and the effects of farmers' selection methods can be detrimental (see Box 2.1).

Box 2.1 The effects of selection

- Early in the season, when vegetable prices are high, farmers are tempted to sell their vegetable beans. Only at the end of the season do they start thinking about seed for the following season. Some pods which develop late are left on the plant to produce seeds. Such plants may have contracted all kinds of diseases, some of which may be seed-transmitted. Moreover, the last seeds on a plant are commonly smaller, producing less vigorous plants.
- It has been observed that tomato and melon growers may sell their best-looking fruits in the vegetable market at a premium price, while oddly shaped fruits are eaten or used for seed. If the malformation of the fruit is genetic, such methods increase the chances of producing more poor quality fruits in the next season.
- Farmers often have particular early maturing varieties that provide food for the hunger season, i.e. the period before the harvesting of the main food crops. They are under severe pressure to use such early varieties for food rather than for seed. In early maturing maize crops, the earliest cobs are commonly picked for cooking, roasting or selling. This is likely to result in the maturity period of this variety getting gradually delayed. Similarly, early maturing bean varieties such as 'Mesi Moja' in Kenya (one month) and 'saca pobre' in Costa Rica may be lost completely where the temptation is to consume or sell the whole early crop.

Variety maintenance

Maintenance of diversity

Farmers generally select in their fields and in their seed stores, thereby preventing natural selection from introducing weedy characteristics into the crop, such as shattering seeds, weedy plant architecture and other characteristics that may be positive for plant survival, but negative for crop production. Variety maintenance is thus an important aspect of seed supply.

Maintenance of local varieties is a dynamic process whereby the farmer often selects on the basis of a particular diversity within the variety which is characteristic for that particular landrace. This is different from modern plant breeders who have an idiotype, or ideal plant type, in mind: a strategy which leads to uniformity. In practice, farmers do not maintain the variety in a strict sense. They maintain the variety's major features, but at the same time they can continually adapt the variety to changing conditions, e.g. a gradual decrease in rainfall or soil fertility, or to specific changes in the market. The genetic diversity which is present in landraces gives the farmer the opportunity to respond to such changes, and such selection within a genetically diverse variety does not necessarily lead to marked changes.

When cereal farmers pick individual ears for seed before harvesting the food crop, they often take a wide range of samples, thus maintaining the diversity of their local variety. This remains the basic principle, and they rarely select only the very best looking and very similar ears, although they may discard obviously weak and diseased plants, thus exerting some selection pressure. Another example is women bean farmers in Rwanda, who have been observed to intentionally mix differently coloured seeds to arrive at well balanced varietal mixtures for planting in different plots of their farm: mixtures for good soils, for shaded plots, etc. They could easily select single coloured seeds which are likely to result in more uniform crops, but the diversity offers a buffer against various possible uncertainties during the coming season, such as disease outbreaks, drought etc. Maize farmers maintain their varieties by choosing the average ears, and not the large ones. The latter method would necessarily lead to changes, not only of ear size, but also of other characteristics (Box 2.2).

Box 2.2 Poor selection in formal systems: KWCA maize in Uganda

Kawanda Composite maize became very popular in Uganda upon its release in the early seventies. Poor selection during a number of years caused considerable changes in the variety that made it far less adapted to local conditions. Selection method 2 was applied over a number of generations. Large ears from a specially planted field were selected for maintaining the variety. Plant characteristics were not taken into account. The result was that after a number of years the average plant height and the maturity period had increased, and the number of ears had decreased to 1. That the crop had changed in appearance can easily be explained by the selection method. Plants with large, good looking cobs generally have one cob per plant, whereas plants with two slightly smaller cobs may have a higher yield. Similarly, plants with large cobs are very competitive: they must have intercepted more sunlight than their neighbouring plants: they were taller, and they remained green longer. The result was that the increased maturity period made it difficult to grow two crops per year and to get the harvesting done during a dry season. Tallness caused lodging problems at the end of the season. One cob per plant was considered inferior to two cobs. It took a number of years of very specialized selection procedures to re-select KWCA to look more like the original variety.

Selection of landraces is more effectively done using methods 1 to 5. Methods 6 and 7 are particularly aimed at strict selection, i.e. increasing the uniformity of a variety that is too heterogeneous. This should be done with great caution, with clearly defined objectives, and carrying out regular adaptation and yield stability tests. Too strong selection leads to genetic narrowing down of the variety, which may reduce yield stability and potential due to inbreeding depression (in cross-fertilizing crops).

Support to farmers in the maintenance of heterogeneous varieties should therefore be given with caution. It involves creating awareness about which types should be considered off-types (i.e. not belonging to the landrace), and removing such plants from the field, preferably before flowering. Selecting within a variety to adapt it intentionally to changing conditions or new needs is discussed in Chapter 4.*

Maintenance of uniformity

Selection is a different process for a modern (uniform) variety, where the aim is usually to avoid genetic degeneration, i.e. to maintain or to re-select the original variety. Regular selection is necessary in order to avoid the accumulation of off-types, which may not be optimally adapted to the conditions. Simple selection includes roguing of obviously off-type plants in the field, preferably before flowering of the crop, or during several rounds both before and after flowering (negative mass selection). Alternatively, a positive mass selection picks the best (true-to-type) plants out of a field, and then multiplies their seeds. With relatively pure varieties, this is effective and is enough to keep a variety sufficiently pure. Positive mass selection for uniformity in modern varieties of cross-fertilized crops is described in the section on cross-fertilizing crops.

When a good variety has become mixed during subsequent seasons of reproduction, it may be necessary to use method 6 to re-select the original variety. This may look like a very laborious and specialized task, but it can be a very effective way to assist farmers to improve their seed. Basic selection schemes are presented here in order to guide such specialist selection. A distinction has to be made between vegetatively propagated, self-fertilizing crops, semi-cross fertilizing crops, and cross-fertilizing crops. All these methods need separate fields to avoid unwanted cross-pollination, and close attention should be paid to avoiding inbreeding depression in cross-fertilized crops.

Self-fertilizing crops

When only little heterogeneity is observed in a uniform variety, simple mass selection can be used to maintain the variety. Mass selection can be done by removing the off-type plants (negative mass selection), or by positively selecting the preferred plants (positive mass selection); see Box 2.3 for an example from cowpea and sesame varieties.

When a uniform variety of a self-fertilizing crop shows considerable variation in the field, a so called pure line or ear-to-row selection can be performed. The latter name makes the method clear:

1. True-to-type ears (cereals like wheat or finger millet) or plants (pulses like beans or chickpeas) are selected and harvested separately.

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* See various sections in Chapter 4 on participatory crop improvement and supporting informal seed supply.

2. The seeds from each plant are then planted together in separate rows or small plots.
3. If the mother plant was genetically pure, the row planted will be very uniform. If the mother plant was not pure, the row will show segregation, i.e. clear differences between the plants within a row. In this case the whole row should be eliminated.
4. Only rows which are uniform and definitely true to the variety are harvested for seed.
5. The seeds from the uniform-looking rows can be bulked.
6. If an extra cycle of selection is still needed for more uniformity, the seeds from the different uniform rows are kept separately. They can be planted in blocks in the following season. The blocks will be larger than in the preceding season, allowing more precise evaluation. Blocks which are not uniform are eliminated.
7. Selected blocks are bulk harvested and multiplied for distribution to the farmers.
8. It is strongly advised not to keep only one uniform row or block for further multiplication. This particular row may have invisible faults, such as poor resistance to a disease that is not very prevalent during that particular season. It is better to select 10 or more similar-looking rows. Moreover, this favours a more rapid multiplication.

When different modern varieties of a particular crop have to be maintained in the same field, some rows should be planted around each selection block, separating the different varieties. These rows should not be harvested for seed, because some cross-fertilization or mechanical admixture may occur even in self-fertilizing crops.

Box 2.3 Recuperation of degenerated seeds of cowpea and sesame

Seeds of local varieties of cowpeas (self-fertilized) and sesame (semi-cross fertilized) have been grown with success for many years. Because of poor maintenance, the varieties have become too diverse: the variation in plant height among the plants increased after the introduction of some modern varieties of the crop in the area. The result is that the shorter plants do not develop sufficiently, they contract various fungus diseases, and the produce is of very poor quality.

The applied strategy for regeneration is to regain the original local variety by exerting a low selection pressure within the variety. One possible method would be to remove plants which are too tall or too short (negative mass selection); another option would be to select average size plants (positive mass selection). Inbreeding depression should not be feared in these crops, but the original level of diversity should be attained, so selecting a sufficiently large number of plants is a must.

If the original variety was already very diverse in plant height before the introduction of modern varieties, negative mass selection can be used. This removes the extremely tall and small types and maintains the original diversity. If the original variety was rather uniform in plant height and there was little variation in the degenerated variety, positive mass selection can be applied, and selection of a few plants of similar heights will provide the basis for further multiplication.

Vegetatively propagated crops

From a genetic point of view, variety maintenance of vegetatively propagated crops is easy. Single plant selection, alone or in combination with 'ear-to-row' multiplication, will eliminate off-types very effectively. The main problem of maintaining varieties (clones) of vegetatively propagated crops is to keep the stock free from diseases. Very strict selection for disease free plants in rows can be effective, assuming that measures are taken to avoid the spread of diseases within the selection field. This can be done by planting other crops between the lines or by early spraying with fungicide. Regular spraying of systemic insecticides against the spread of insect-transmitted viral diseases can be useful when applied in large areas.

A variety may be completely infested with viral diseases. If healthy plants cannot be found, it may be possible to eliminate the disease through tissue culture in a research station. This is a costly exercise which is only useful if there is some guarantee that re-infection with the disease in the field can be avoided. If the chances of re-infection are high, the best option may be a large-scale multiplication scheme in a 'clean' environment. Plants can then be distributed to replace all infested materials in a particular area (e.g. virus-infested cassava).

Cross-fertilizing crops

Maintenance selection of cross-fertilizing crop varieties is more complicated than that of self-fertilizing varieties. The main difference is that a cross-fertilizing variety may suffer from 'inbreeding depression', when it becomes too uniform. Also, selecting a small number of plants may result in genetic drift, i.e. a gradual shift in some characteristics of the variety. This means that selection does have its limitations: too strong selection will result in a gradual reduction in yield. A second problem is that apparently healthy plants may have been fertilized by very poor plants, so that although selection of their seeds multiplies the good characteristics of the mother plant, it also multiplies the poor characteristics of the pollinators. The simplest procedure is mass selection for which three methods exist:

1. In negative mass selection, off-types or bad-looking plants are eliminated; the harvest from the rest of the plants can be used as seed.
2. In positive mass selection, the best plants are selected for seed production.
3. In stratified mass selection or grid selection, seed is selected from plants distributed equally in the field, and plants which compare well with their neighbours are selected for seed. This method reduces the risk that differences in field conditions (soil fertility, irrigation) result in selection of plants from only one side of the field.

When using the latter method, one should guard against selecting too few plants, to decrease the risk of inbreeding depression or drift, which would be counterproductive. Many farmers use or are taught the principles of stratified mass selection as a means to support farmers' seed production. See an example of farmers practising stratified mass selection in Box 2.4.

Box 2.4 Farmers practising stratified mass selection in Brazil

Farmers in the municipality of Anchieta, Brazil, practise stratified mass selection in seed production, crop improvement and maintenance of local maize varieties. The seed production area is usually divided into equal areas with rows of 5 to 10 meters. In each row, farmers identify an equal number of plants considering the best exemplars, representing the variety (for maintenance and seed production) or the best performing individual plants (for crop improvement). A common practice is to plant a variety in an area of at least 800 m2 or 3000 plants, of which 400 are selected. At this density, farmers collect one ear every two meters in a row, thus maintaining the variety without any loss of variability, while selecting the best plants according to their preferences. Agronomic characteristics taken into consideration include plant height, ear position, ear diameter, diseases and pests. Harvesting is followed by selection at home.

For variety maintenance, the procedure is as follows: From the 400 ears selected in the field, 200 ears are selected using the criteria of grain type, ear appearance, colour, weight, healthy appearance, etc. The ears are kept in the husk, and further dried in the shed for 45 days before the seeds are removed from the ears. From each of the 200 ears, 18 grains are taken from the central part and germinated. If the germination rate is 85%, then 3060 plants will be grown the next season. In addition, farmers maintain another duplicate seed lot of 18 grains per ear. This is to secure the variety in case of crop loss during the next season. The maintained grains can be used for seed production. Farmers within the Local Maize Variety Producer Association in Anchieta (ASSO) maintain a range of local varieties, while at the same time engaging in commercial seed production of their local varieties. Some farmers in this group are also involved in farm-based breeding, and in participatory plant breeding projects with formal institutions.

A more advanced maintenance procedure is the following form of ear-to-row selection:

1. Select at least 200-500 healthy-looking ears (maize, pearl millet) or heads (sunflower), i.e. those which are well developed and have all the typical characteristics of the variety, but are not necessarily the biggest.
2. Plant rows with the seeds of each plant. These rows may consist of 10 to 50 plants (so called half sibs) depending on the available field size.
3. Remove the poor-looking rows, preferably before flowering.
4. Remove the most irregular rows, preferably before flowering, and harvest the other rows and bulk the seed.
5. Select the best plants or ears within the good rows to start a new selection cycle.

This selection is quite ‘soft’ and will be effective when executed for a number of seasons.

When a variety has been very ‘contaminated’ because of many years of production without selection, or a problem with isolation, the above procedure may be refined through two methods: the remnant seed method and the full sib selection. The remnant seed method is an ear-to-row selection. Seed is harvested from selected healthy and true-to-type plants; seeds of individual plants are kept separately. Only half the amount of seed harvested from a plant is sown in rows. If a row looks uniform, the seed that has been saved is bulked with seed saved from other rows. During the first stage, part of every ear or plant is kept in store because the plants of the selected lines in the field may be pollinated by neighbouring (non-selected) lines, which considerably reduces the selection efficiency. When the rows are planted, some seed from each plant/ear/head is kept in properly labelled bags and stored. In the field, off-types may remain in the rows, but poor plants are labelled during several selection rounds over the season. Only the best half sib lines (at least 50!!) are selected. The remnant seed is taken from the store, bulked and planted the following season. If less than 50 are selected, there is a serious risk of inbreeding and thus of reduced yields.

During full sib selection, two good looking plants may be artificially crossed. This is relatively easy with maize, but very difficult in many other crops. The crossed ears then provide the seed for the rows for selection (whether or not the remnant seed method is used). When a variety has become relatively pure, these selected lines may then be planted in the middle of a field planted with seed of a mixture of the selected heads. In the case of maize, the plants in the rows are detasseled in order to allow the surrounding plants to fertilize the selected ones. This reduces the risk of inbreeding and protects the selections from pollen blown in from other fields. Full sib 'rows' should be selected for the main characteristics of the variety and for uniformity. They should not be selected for yield because heterosis may 'blur' the observation.

It is virtually impossible to maintain different varieties of cross-fertilizing crops in the same field. The isolation distance between the fields has to be large in order to prevent pollen from one variety contaminating another. Planting tall crops between two varieties may reduce this risk in wind-pollinated crops (e.g. tall elephant grass surrounding maize selection plots), but this does not work for insect-pollinated crops (sunflower, radish, cabbage). In some conditions it is possible to stagger the planting of different varieties: planting the different varieties at different times prevents them flowering at the same time. If conditions permit, however, it is much safer to concentrate on one variety in one year and on another in the following year.

Semi-cross fertilizing crops

Selection of semi-cross fertilizing crops does have to take crossing behaviour into account, but these crops generally do not suffer from inbreeding depression. This means that maintenance selection looks like the method used for self-fertilizing crops (ear-to-row) when the important characters can be observed before flowering, i.e. before poor plants can contaminate the selected ones. When important characteristics cannot be observed before harvesting (e.g. seed colour in sesame) the remnant seed method presented above for cross-pollinators can be followed, to increase efficiency. There is no need to observe the minimum number of selected plants in this type of crops, because inbreeding depression is less likely. As with self-fertilized crops, however, selection of less than 10 plants should be avoided.

Conclusions

Farmers apply very different types of selection in their crops as part of their seed production processes. Varying levels of selection pressures and use of diverse criteria over many generations have resulted in the farmers' varieties that we know today. Maintaining the positive traits and improving on less desirable ones are important objectives in local seed management, which may benefit from various methods of maintenance selection derived from the formal seed system. The resources and knowledge of farmers, and their priorities with regard to their varieties largely determine which methods are most appropriate for their conditions.

2.2 Supporting farmers' practices in seed processing and storage*

Niels P. Louwaars and Conny Almekinders

Post harvest operations and storage methods have strong effects on seed quality. This section introduces general aspects of these operations, such as handling, seed drying, cleaning, treatment and the effects of temperature, moisture, and insects on the potential loss of seed quality during seed storage. These aspects can be taken into account when assessing and seeking ways to support farmers' methods of seed processing and storage.

Harvesting
Harvesting should be well timed to allow quick drying of the seed, and to avoid important losses due to shattering or field infestation of storage insects (e.g. weevils in maize, bruchids in faba bean). Farmers often delay harvesting because of the peak labour needs at the end of the season, and because drying of the crop on the plants reduces the need for drying floors. Harvesting and threshing have to be done with much care to avoid damaging the seed. Threshing when the seed is over-dried may cause the seed to crack, while threshing wet seed may cause (internal) damage and create subsequent germination and vigour problems.

Processing
Processing is the first post-harvest activity in farmers' seed management. It includes activities such as handling (transporting/receiving), seed drying, cleaning and treating.

Drying
Seed should be dried quickly, but high temperatures can damage the seed. Sun-drying can normally be completed in a few days. For some crops, such as maize or sesame, special racks or cribs are used to improve the ventilation and speed up drying. If seed is dried on the floor, regular turning will improve the balanced drying of the seed lot and avoid mould growth at the bottom of the layer. In humid climates, seed drying can be a serious problem. If harvesting cannot be done during a dry season, small scale wood-fuelled dryers can be used. These require a considerable investment and

* This section is adapted from Almekinders, C.J.M. and N.P. Louwaars, 1999. Farmers' seed production. New approaches and practices. London, Intermediate Technology Publications: pp. 112-118.