Agrodok 37

Small-scale seed production

with variety improvement of cereals and pulses

Harry van den Burg

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Foreword

Seed production and the maintenance of crop cultivars by small farmers is a subject that has attracted increasing attention over the past decade. The increasing dominance of large multinationals in the seed trade, the controversy over genetic engineering, and the recognition of farmers' rights over cultivars developed by them over the course of many years have all highlighted the importance of the maintenance of farmer capacity and capability in seed production.

This Agrodok hopes to contribute to the skills and references at the farmer's disposal. It has been written with frontline extension staff and skilled small-scale farmers in mind. It deals with the general principles and practices of cultivar maintenance and seed production, and makes reference to specific issues regarding cereal and legume seeds. It is hoped that follow-up booklets will deal with specific requirements of other important crop groups.

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Harry van den Burg

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1 Introduction

1.1 Reasons for producing one's own seed

Keeping seed from one's own crop was standard practice for farmers throughout nearly the whole history of agriculture. Swapping or passing on new types of seed between farmers must have been common, but only in the case of crop failure or other disasters would farmers have obtained all their seed from others. Occasionally, someone may have found a plant type that was better than the one normally cultivated, and some farmers may have been better at producing good seed than others. From these very early differences the modern seed industry slowly developed.

Nowadays, most technologically advanced farmers buy their seed every year. They recognize that specialized seed companies offer better quality seed of new, continually improved, cultivars than what they can produce themselves. The cost is more than offset by the benefits that they obtain.

But in many countries there is no modern seed industry. Or, if there is one, it concentrates only on certain areas in the country, or on certain, mostly richer, groups of farmers. It is also common for modern seed companies to concentrate on only certain crops, for which there is a steady, large market, and not on small crops with fluctuating market sizes. The *cultivars* (varieties) that these companies produce are often also only suitable for certain groups of farmers. The seed may be expensive, it may be hybrid (this often goes together), or the cultivars may not have the characteristics that the smaller farmers are looking for.

These are all good reasons for why farmers may want to keep their own seed. This booklet is meant to assist farmers and extension workers in applying the right methods to obtain the best possible seed quality. It explains the principles of seed production and indicates methods that can be used by resource-poor farmers.

Because of the history of on-farm seed production, there may well be individual farmers who have developed their own, different methods of seed production. These can be very valuable when developing locally adapted methods. By checking them against the general principles explained here, it will become clear whether and how they promote the same result: good quality seed of the right variety.

Likewise, the products of the formal, modern seed industry are not necessarily always wrong for the small farmer. The physical seed quality is often excellent, in most cases assisted by official certification schemes. The cultivars are designed to meet the demands of buyers other than the small farmer, but sometimes, quite by chance, these cultivars have characteristics that are of interest to the small farmer as well. It is therefore always wise to keep an eye on what the formal sector offers, and to try out what might look promising.

1.2 Seed production and cultivar development

Producing seed should always go hand in hand with *selection*, with choosing the best and discarding the worst. This can very easily have an impact on the characteristics of the cultivars, on the way they look and perform from year to year. The identity of cultivars may slowly change over time. This is in fact how our cultivars, and even our crops, have come to look the way they do now, starting thousands of years ago with plants taken from the wild. The farmer who wants to keep his or her own seed must bear this in mind. It is one thing to want to keep a cultivar the way it is, but improving it or developing new cultivars out of it is something else.

In the formal seed industry it is very important to maintain the identity of a cultivar, and official certification schemes are strictly applied for this purpose. This is because the buyers of the seed and of the end product want to know exactly what they are getting. If the buyer is a processor of potatoes for instance, it is essential that the processing characteristics of the cultivar do not change, otherwise his chips or potato flour will not look or taste the same. It is also important because other seed companies may have a very similar cultivar. By allowing a cultivar to change, it may 'turn into' somebody else's, and rules of ownership may be infringed.

The small farmer who produces seed for his own use does not need to worry about all that. In fact, he most likely will be actively looking to improve his cultivar all the time. But the situation changes if he chooses to sell some of the seed. An improvement for one farmer may be a disadvantage for a buyer who farms in a different area, or for a different purpose. It is important to always be aware of what the user of the seed is looking for. In such cases, it is often better to have separate fields for the maintenance of the cultivar and for trying out new improvements. We will look separately at the methods for producing seed and at those for improving cultivars.

1.3 Open-pollinated versus hybrid cultivars

Nowadays, for certain crops, modern seed companies market mostly *hybrid* seeds. Among the crops we deal with in this booklet, this practice applies mostly to maize and sorghum. Hybrid cultivars are made by planting two cultivars in the same field, allowing only one parent (the male parent) to produce pollen, and harvesting the seed only from the other (the female) parent. If the parents are chosen correctly, the offspring (the hybrid cultivar) will perform much better than the average of the parents, or even better than each of the parents. This is called *heterosis*, or hybrid vigour.

It is very difficult and time-consuming to develop and choose just the right parents, who together will produce the maximum hybrid vigour. This is why the seed is expensive. It is also very difficult to copy a hybrid. If the farmer keeps and plants seed from the harvest of a hybrid, the (worse performing) parent types will appear again among the following year's crop, and most of the hybrid vigour will be lost. Hybrid seed production is a job for professionals, and we will not deal with it in this booklet.

Farmers who keep their own seed normally work with non-hybrid or *open pollinated (OP)* cultivars. The plants are allowed to pollinate freely, and seed can be harvested from all plants. The only exception to this rule involves certain selection methods used in cultivar improvement, which will be described later.

2 What you must know about inheritance

2.1 Self-pollination versus cross-pollination

The offspring of a pair of parents, whether they are people, plants or animals, often look alike, and almost always have a number of things in common with their parents. We say that individuals *inherit* these things ('traits' or 'characteristics') from their parents.

Whereas with animals and people there are always separate male and female parents, with plants that is not always the case. The *pollen* (the fine yellow powder produced by flowers, which has the same function as sperm in animals) that fertilizes a flower can be produced by a flower on a different plant. These two plants then obviously are the two parents. But it can also be produced by a flower on the same plant, or even the very same flower! Figure 1 shows the three types of flowers that exist.

Figure 1: Schematic representation of a flower. a: Complete flower (impression), b: Complete flower (schematic), c: Male flower, d: Female flower

If a plant is able to pollinate its own flowers and does so most of the time, we say it is *self-pollinating*. If there is any reason why that is not happening, we say the plant is *cross-pollinating* (because the pollen has to come from a different plant). Figure 2 shows some examples of how self-pollination and cross-pollination work.

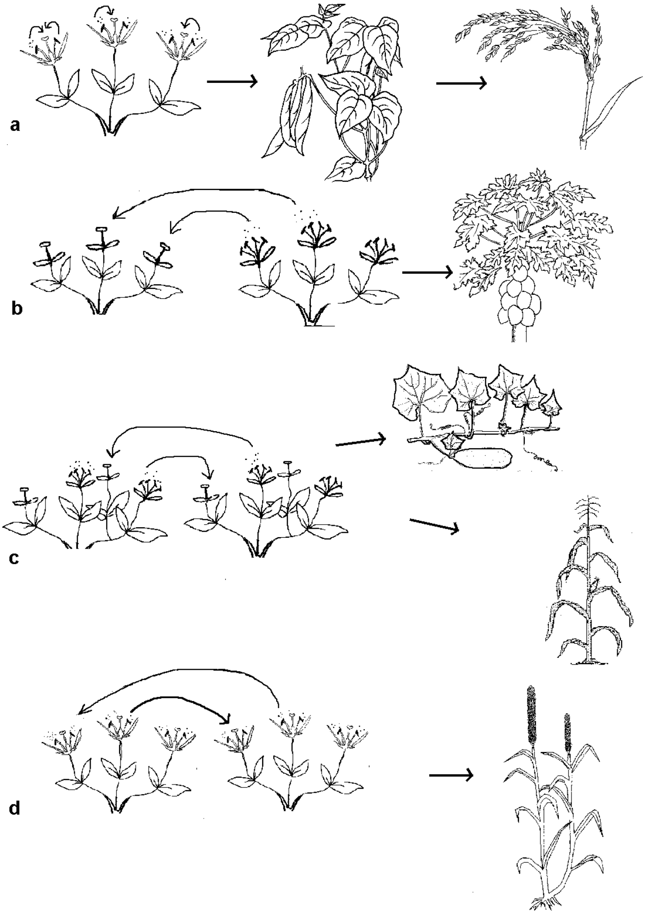

Figure 2: Self and cross-pollination between different types of flowers. a: Complete flower, self-pollinator, b: Dioecius, cross-pollinator, c: Monoecious, cross-pollinator, d: Complete flower, cross-pollinator

Examples of self-pollinators are most plants in the bean family, as well as wheat, rice, barley and finger millet.

There are also plants that usually do not propagate through true seed, that is, seed produced by flowers. These are said to propagate vegetatively. Examples are sugarcane, cassava, potato and sweet potato. We will deal with these in a different booklet.

There can be many reasons why a plant is a cross-pollinator. Some species have plants that produce only male or only female flowers, so self-pollination is physically impossible. These species are called *dioecious* (from a Greek word meaning: 'two houses'). Examples are date palm and many papaya cultivars. In other cases, the plant has both male flowers and female flowers, but they are in different parts of the plant, and tend not to pollinate flowers on the same plant. Such plants are called *monoecious* ('one house'), and examples are maize, adlay and oil palm. In many such cases though, self-pollination is in fact possible, and occurs to a limited degree. In yet other plants, there are complicated genetic mechanisms that prevent pollen from one plant from fertilizing its own flowers even if it lands on them, such as in cabbages. This is called self-incompatibility, and it always results in cross-pollination.

If under normal conditions less than 5 percent cross-pollination occurs, a crop is called a self-pollinator. The list in Appendix 1 shows which cereal and pulse crops are self-pollinators or cross-pollinators. It also deals with those crops that use both methods to a significant degree, i.e. between 5 and 20 percent cross-pollination. These are called intermediate pollinators. Any plant with over 20 percent cross-pollination is treated as a full cross-pollinator.

When producing seed, it is very important to know how your crop pollinates. Cross-pollinators as a rule are more difficult to handle if you want to keep cultivars separate, and if you want to improve cultivars through selection. You have to pay attention to pollen that may reach your fields from outside. It will also take longer to get rid of traits you don't want in your cultivar. With self-pollinators it is sometimes difficult to combine different characteristics into one cultivar. For most of this booklet, self- and cross-pollinators will be treated separately.

2.2 Genetic variation in cultivars

Farmers have different words for the types of seed varieties they can distinguish. They may talk about 'breeds', 'types', 'strains', 'lines', or any number of words in languages other than English. What they mean to say is that they can recognize different seed types or varieties by their outward appearance, or by the way they perform under given conditions. These differences are very often large enough for farmers to identify varieties by name, just as is done in the commercial seed sector. The word used throughout this book for such varieties is '*cultivar*', which comes from '*culti*vated *var*iety'. A cultivar is a group of plants within a crop, which retains its particular characteristics when multiplied in the way that is usual for that crop.

Although a cultivar as a whole will remain roughly the same from year to year when grown under the same or similar conditions, it does not always mean that all plants in it are the same. The degree of *genetic variation* within each cultivar, that is, the differences between plants that are caused by characteristics inherited from their parents, can be quite large. This is an important aspect of both seed production and cultivar improvement.

Often (but not always) the success of a cultivar in performing well under widely differing conditions is due to the genetic variation present within it. To put it simply, no matter what the conditions are, there are always some plant types within the cultivar that can perform well, while others lag behind, only to take over when conditions change. Such stability of performance is often of much more value to small farmers than the ability to perform exceptionally well under very specific and constant conditions. But please note that stability of performance can in most crops also be fixed in individual plants, through genes that make the carrier ecologically stable! So you don't always need genetic variation to achieve stability of performance.

On the other hand, when a farmer is able to purposely set about improving his farming operations, for instance by improving his tillage, using fertilizer or lime, perhaps even using chemicals or irrigation, then such genetic variation may hold back his progress. There may be too many plants in the cultivar that do not respond sufficiently to the inputs to justify the cost of applying them.

However, having a cultivar with large genetic variation as starting material offers many opportunities for cultivar development. By selecting certain types within such a cultivar, new cultivars can be created that may be suitable for specific purposes or conditions, and perform better in some respects. Often, such variable cultivars are found where farmers have been multiplying their own seed for many generations without applying much in the way of selection, or where they have actively encouraged diversity. The particular combination of soils, climate, other environmental factors, and farmer-imposed factors then determines which plants prosper and produce seed and which don't. Such a cultivar is called a *landrace*. Landraces are normally very well adapted to the soils, climate and farming system of a certain region, and have a lot of genetic variation in them.

As a general rule, the genetic variation within a cultivar of a cross-pollinating crop is usually larger than within a self-pollinator. Moreover, with self-pollinators you can identify and isolate the components of this variation more easily. This is because each individual plant inherits all its characteristics in a fixed combination from its one parent. Provided that all parents roughly produce the same amount of seed, this means that the same combinations of genetic traits are coming back unchanged from generation to generation.

With cross-pollinators the combinations of traits shift constantly, as individual plants inherit different traits from separate parents. As a whole within the cultivar though, the traits occur in the same ratios from generation to generation. It is just more difficult to 'catch' them within one plant. Box 1 on Mendel's peas elaborates this difference between self- and cross-pollinators.

Box 1: Mendel’s pea experiments

Mendel did most of his work with peas (Pisum sativum L.), which are self-pollinators. He cross-pollinated by hand (= crossing) several varieties that differed in many traits. Traits are characteristics that occur in two or more forms. In the case of Mendel’s peas, seed shape was ‘round’ or ‘wrinkled’.
When Mendel crossed two varieties that differed in seed shape, he found that all offspring resembled the one parent with the round seed but none resembled the other with the wrinkled seed. Therefore, Mendel called the ‘round’ form dominant and the ‘wrinkled’ form, which wasn’t present in the offspring, recessive. Which form is dominant is different for each trait and can also be different for different crops. Some traits don’t have a dominant form, like yield or seed size.
The parental plants are called the P (parental) generation or the F0 generation. Their hybrid offspring are called the F1 (first filial) generation. The offspring of the F1-generation are called the F2-generation, the offspring of the F2-generation are called the F3-generation, and so on. When Mendel produced such F2 generations, he saw both round and wrinkled forms present again. The wrinkled seed that seemed to have disappeared in the F1, reappeared in the F2 generation. Mendel repeated this experiment with many other traits which had a dominant and a recessive form and each time he found that one form disappeared in the F1, but was back in the F2 generation with a ratio dominant:recessive of close to 3:1.
Later it was found that each pea plant has two copies of the gene responsible for seed shape, but that pollen grains and ovules only have one of these two copies. After fertilization the copy of a pollen grain and of an ovule come together again and the resulting seed has two copies, one coming from the pollen parent, the other one coming from the ovule parent. Seed shape is regulated by one gene. Also seed colour is often also regulated by one gene, but it is not clear yet how many genes regulate yield.
The different forms of a gene are also called alleles. The dominant allele is indicated with a capital letter, while the recessive allele is indicated with a small letter. In the example of seed shape, round seed shape is indicated with an ‘R’ while wrinkled seed shape is given a ‘r’. If both alleles of the gene for seed shape are the same (either RR or rr), a plant is called homozygous for seed shape. If a plant has both a dominant and a recessive allele (Rr), the plant is called heterozygous for seed shape, but still has only round seeds, the dominant form.
If a homozygous pea plant self-fertilizes itself, it either produces round seed or wrinkled seed. If a heterozygous pea plant fertilizes itself, it produces round and wrinkled seed in a ratio of 3:1. By continued self-fertilization the number of heterozygous plants declines, and after 5-6 generations it will be very small.

If peas were a cross-pollinating crop (which they aren't), the ratios would be different. In that case the ratio of homozygous and heterozygous pea plants would remain stable over all generations. Also the ratio of round and wrinkled seed would remain 3:1 in all generations. Whereas a homozygous self-fertilizing plant always produces the same seed type, a homozygous cross-fertilizing plant can produce all seed types if the surrounding plants have different alleles.

The following figures give schematic illustrations of the inheritance of dominant and recessive alleles of the trait seed shape in a self-pollinator (Figure 3, showing that after several generations the heterozygous form decreases and the ratio of round to wrinkled seeds approaches 50:50) and a cross-pollinator (Figure 4, showing that after several generations the heterozygous form doesn't decrease and the ratio of round to wrinkled seed remains 75:25).

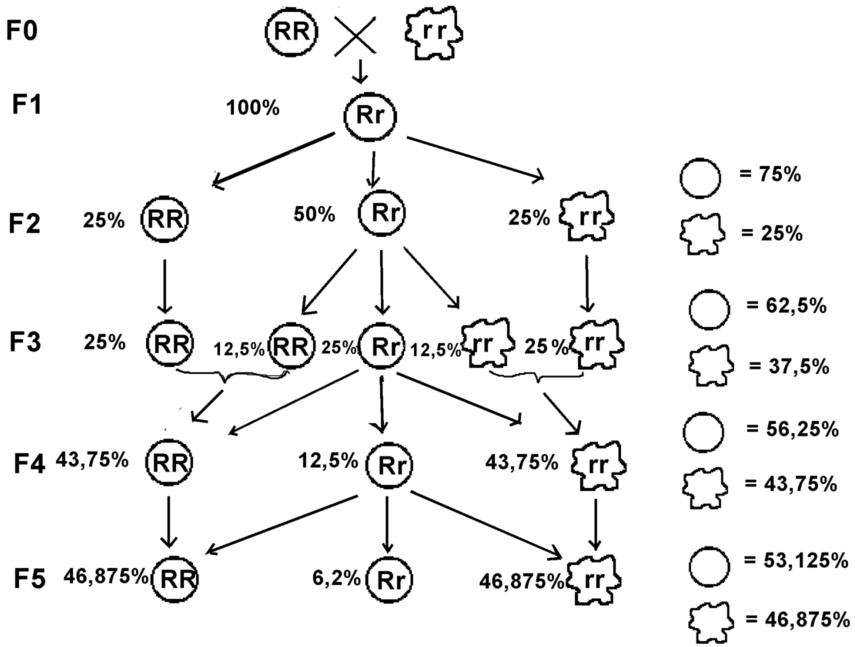

Figure 3: Inheritance in a self-pollinator

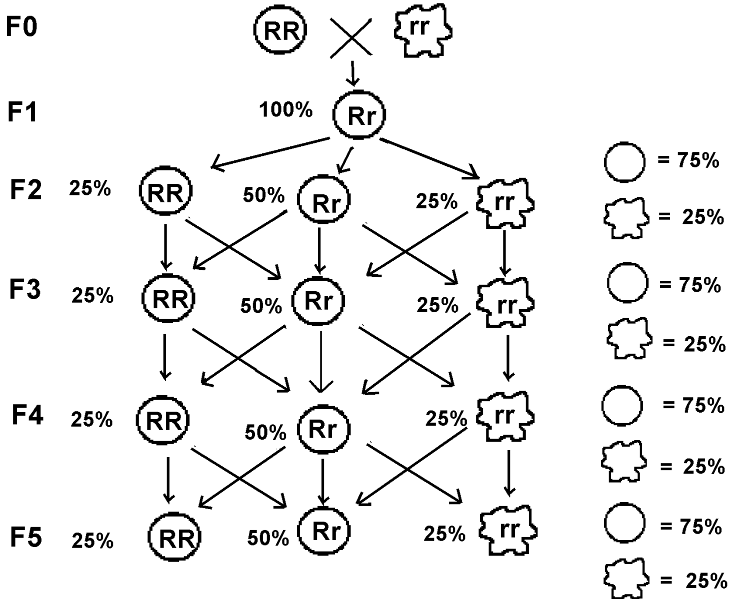

Figure 4: Inheritance in a cross-pollinator

2.3 Selection criteria

Whether you are producing seed and maintaining the cultivar as it is, actively improving your cultivar or developing new ones, you must be clear in your mind as to what you are looking for. What are your selection criteria? Ask yourself which traits are essential, which are important, and which are merely desirable, and write them all down according to importance. Try wherever possible to quantify them, for instance: ‘at least four tillers per plant’ instead of ‘good tillering’. Consider all aspects of the crop:

- strong seedlings
- quick early growth
- tillering
- reaction to diseases
- reaction to temperature extremes

- reaction to drought
- reaction to poor soil
- reaction to fertilizer
- time of flowering
- amount of seed set (number of pods/ears/cobs)
- time to maturity
- resistance to lodging
- drying off
- ease of harvest (shattering!)
- yield (remember by-products, e.g. straw!)
- storage characteristics (insect damage)
- processing and consumption quality
- consumers' preferences (size, colour, taste, etc.)

It is also important, especially with cross-pollinators, to distinguish between traits you can judge before or only after flowering.

When maintaining an existing cultivar you should concentrate on listing and maintaining its strong points and most important characteristics. A bit of progress can often be made in the weak points by selecting against them (i.e. eliminate those plants that show those weak points), especially if there is still a lot of genetic variation in the cultivar, but you should guard against losing the typical characteristics that define the cultivar.

Bear in mind that the perfect cultivar does not exist, and that being overly critical when selecting is not going to get you anywhere. Concentrate on the essential and the more important traits, and consider the rest a bonus. As you progress, and your cultivars improve in the essential aspects, you can then pay more attention to traits of lesser priority.

2.4 Selection methods

So far we have pretended that everything about a plant's performance is inherited. This is of course not true. When two plants in a field differ in yield the cause can be genetic (the yield potential inherited from the plant's parents), but it can also be a result of a difference in, for instance, soil fertility. We say then that the variation is environmental. Especially traits such as consumption quality and yield are often strongly influenced by the environment, and not so much by genetics. We say that they have a low *heritability*. Even very strong selection for a trait with low heritability will not give us much progress, unless it is done on a large scale and with scientific methods. Again, it is better in such cases not to be too critical. In chapter 4 we will look at selection methods that minimize interference from environmental variation.

The traits plants inherit from their parents are laid down in *genes*, tens of thousands of them. Even the largest selection programme will only focus on a fraction of these. The others are inherited pretty much at random (by chance), even the ones we are happy with. This opens up the risk of *random drift*, i.e. the statistical chance that we lose a gene because the group of plants we select to continue with by chance does not contain that gene. To guard against this loss through random drift it is essential to stick with minimum numbers of selected plants, particularly in cross-pollinators. Wherever it is appropriate, we will mention with each selection method the minimum numbers of plants needed to avoid random drift.

The simplest method to maintain an existing cultivar is to merely remove whatever is undesirable, and harvest the rest of the crop in bulk. This is called *negative mass selection*. Undesirable may refer to plants that belong to the cultivar but show unwanted characteristics, or they may be plants resulting from cross-pollination from outside, accidental admixture of seed, or *mutation* (the spontaneous changing of genetic information). Even untrained farmers who have been keeping their own seed for many years often instinctively practise this method. If only a part of the harvested crop is used for seed (as is often the case), it should be taken at random from the harvested crop. If this does not happen and further choices are made (for instance selecting nice-looking cobs of maize), this method becomes what we call positive mass selection (described below). This is not necessarily a bad thing, but the objective and method should be clearly defined ahead of time. Negative mass selection can be adequate to maintain cultivars of self-pollinators, but with cross-pollinators it is not very effective, especially with traits that are only visible after flowering. It is not a suitable method to improve a cultivar or develop a new one, only to maintain an existing one. With negative mass selection there is no risk of random drift.

Positive mass selection is going one step further. We select and mark individual plants that are as close as possible to the typical description of the cultivar we are maintaining, or to the ideal we have in mind. At harvest time, the yield of all selected plants is kept separate from the bulk and used as seed. Further selection sometimes takes place after harvest, for instance maize cob size and shape. Now the danger of random drift appears. It is very important never to use less than 50 plants of a cross-pollinator, or 30 of a self-pollinator for the next generation. You will have to select at least twice that number in the field while the crop is growing, to allow for ones that are lost or are discarded later for various reasons. If you still end up with too much seed for next year, then be sure to take what you need *at random*, without selecting further. Positive mass selection is the standard method for maintaining cultivars of both self- and cross-pollinators, as long as we are happy with the cultivar and the way it maintains itself, and there are no major problems.

There will come a time when we will want to correct flaws that have crept into our cultivar, whether through cross-pollination, admixture, or mutation, or for any other reason. Then it becomes important to know the parent (or parents) of the plants we have selected. Most of the time we can only do this by looking at their offspring. We then select plants as described above under positive mass selection, but keep the seeds of each plant separate at harvest. The next season we plant the seed of each plant in a separate row, as a family. In the offspring we can now see where the unwanted traits are. We then discard the entire row of plants (the whole family) where we found the unwanted trait, even if it only appeared in one of the plants in the row. This is because the others may very well have that trait too, even if they don't show it. In the end, you must still be left with your minimum number of families (50 or 30, as above) to mix for the new planting, so you must make sure you had plenty to start with! You then harvest all the remaining families, and mix the seed for next season's planting. Do not select further, even if you have too much seed! With self-pollinators this method is called *line selection*, with cross-pollinators *half-sib (HS) family selection* (Figure 5).

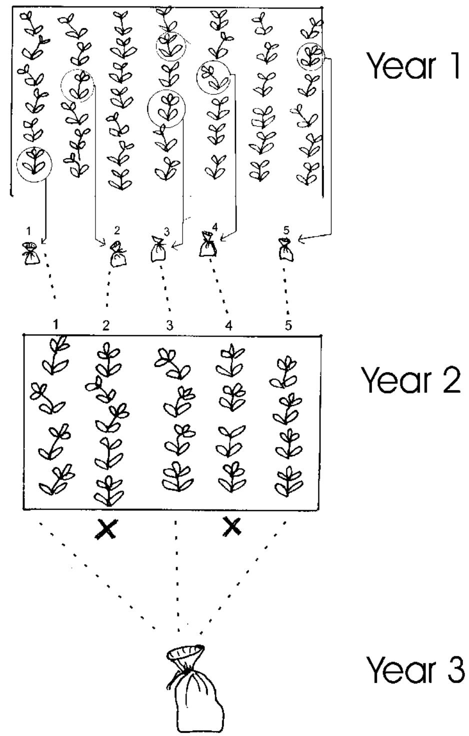

Figure 5: Schematic example of line or HS-family selection

For cross-pollinators, never use this method for more than two years in a row with the same material; after that go back to mass selection. It is quite a lot of work anyway, so you won't want to do it too often, and one year will normally be enough.

Line selection and half-sib family selection are also the methods to use if you spot a different plant in your field that looks as if it could be a good new cultivar. Harvest it separately and plant its seed in its own little row, so you can have a good look at it and see if the good traits show themselves again. You can again select individual plants from the family if you want to.

If you are trying to select for or against a trait that can only be seen after flowering, there is an additional problem with cross-pollinators. By the time you have spotted where the culprits are, they already have pollinated the rest and spread their unwanted trait. Or the good plants you want to keep have been pollinated by the bad ones. You can then use the *remnant seed method*. (See Figure 6.)

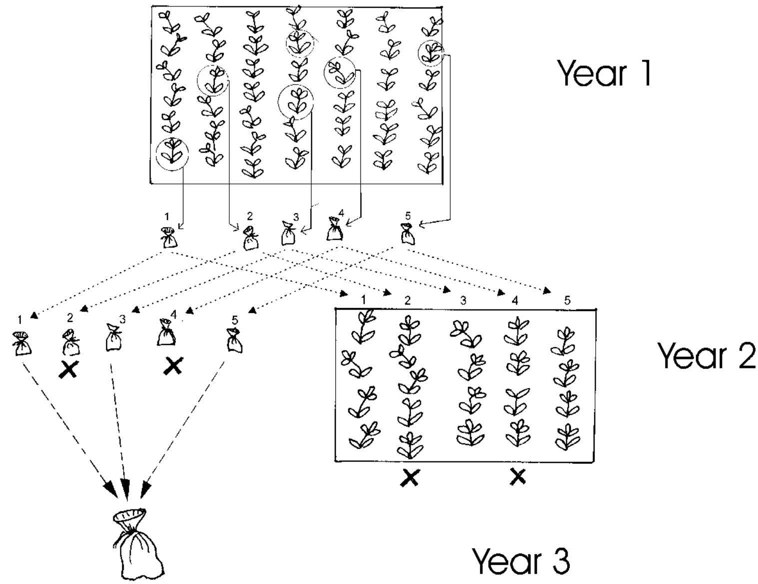

Figure 6: Schematic example of remnant seed selection

This is the same as half-sib family selection, except that you only plant half the seed of each separately harvested plant, and keep the other half in storage packets. Once you have worked out which families were the good ones, you go back to the seed you kept of them in the packets, and mix that together for next year's planting. The observation field with family rows is then not used for seed at all. With this method your record keeping must be very good (give packets and corresponding rows the same numbers), because you must be able to link each little family row in the field to the right packet of seed still sitting in your storage! And of course the storage must be good too – the remnant seed is kept for a second season. If used properly, you should only need to use the remnant seed method once before going back to mass selection. The remnant seed method should be used for serious problems only. Again, after having spotted and discarded the unwanted families, you must still be able to continue with at least 50 packets of remnant seed from your storage.
We will look further into these different selection methods and the ways to use them in sections 4.3 and 4.4.

2.5 Increasing genetic variation

All the above selection methods result eventually in reduced genetic variation within the cultivar. The line/half-sib family selection and remnant seed methods work faster, and maintain less variation than the mass selection methods.

There may come a time when you want more genetic variation, either for more 'choice' of characteristics to develop new cultivars, or more variation within your cultivar to withstand widely differing conditions. Or a new disease may show up, and you want to make your cultivar, with which you are otherwise happy, more resistant to it. Or your customers demand additional traits in the product. You will then need to introduce new characteristics.

The first step is to look for sources of genetic variation: seeds of other plants of the same crop that have the traits you want. Good sources are usually farmers in areas with similar conditions to yours but located far away. You can also try government or international research stations, certain NGOs or aid organizations, or commercial seed companies. If you are looking for sources of resistance to a new disease you may have to search for wild forms of your crop, if they exist. A list of some public institutions you can try is in Appendix 3.

Once you have seeds of promising new types, the new traits have to be incorporated into your cultivar(s). This can be done through either mixing or crossing.

Mixing

Mixing is by far the easiest way: you basically let the crop do the work! Before you mix new cultivar seeds with yours though, it is advisable to try at least a bit of the new seed out for a season, separate from but at the same time as your crop. In that way you can see if the growing periods generally coincide. Having parts of your crop ripen much earlier or later can give problems at harvest, and with cross-pollinators the time of flowering is also important if you want the two types to blend.

After the mixing of seeds of different origins, the cross-pollination will ensure that the new genes are spread throughout the population. All you have to do is look out for the individuals that combine the best of both original types. One round of HS family selection is usually enough to get these to the fore and lose most of the less successful combinations. The speed at which the mixing happens depends on the percentage of cross-pollination in the crop.

With complete or nearly complete self-pollinators this will not happen. You will continue to see plants of the different origins growing side by side in the field year after year. Whether or not this matters much depends on your objective. If your aim was for instance to make the cultivar more tolerant to weather fluctuations, this will work just fine. In a dry year the drought-tolerant ones yield better, in a wet year the flood-tolerant ones. Even disease pressure on susceptible plants will be reduced when there are resistant plants in the field, and the crop as a whole may be tolerant enough for your purpose. If, however, it is essential that the characteristics of the different sources are combined in the same plant, you have no alternative to artificial crossing.

Crossing

Crossing in cross-pollinators, as set out in the previous paragraph, is basically automatic. There are however exceptions, where certain genetic factors prevent some individuals from crossing with others. In the cereals and pulses this is rare, but it might surface when you attempt cross-pollination with wild forms of these crops. These crossing barriers are hard to overcome without resorting to fairly high-tech methods, so if you happen to run into one of these barriers, you have reached a dead-end.

It may sound surprising, but most self-pollinators cross quite easily when the right manual techniques are used. This normally involves opening a bud well before its normal time, removing the anthers (male organs), and applying pollen from your chosen male parent to the stigma (female organ). It would be too detailed to explain all these techniques here, but in the literature list you will find some references. In general: the larger the flower, the simpler the technique. Soya beans are quite difficult, but most bean (Phaseolus) species are easy.

You will need to label hand-pollinated flowers individually, showing which plant was used as male parent. Small paper tags with cotton yarn on them, such as often used for price tags in clothing or jewellery shops, are ideal. Seed from crosses should then be planted according to the line selection method. All seed involving the same two parent plants crossed in the same direction (i.e. with the same plant as mother) can be planted as one line, even if different flowers were involved. You can then assess the results, and decide with which ones you want to continue. You will also see that sometimes your cross was not successful, and your offspring is a copy of the mother plant!

Maize is a special case. (See Figure 7 and Figure 8.) Because this crop is monoecious, and the male and female parts are well separated, it is quite easy to make directed crosses. This means that you can choose the male and female parent individually and cross them by hand, rather than rely on the natural crossing in the open field. Again, mark your crosses carefully.

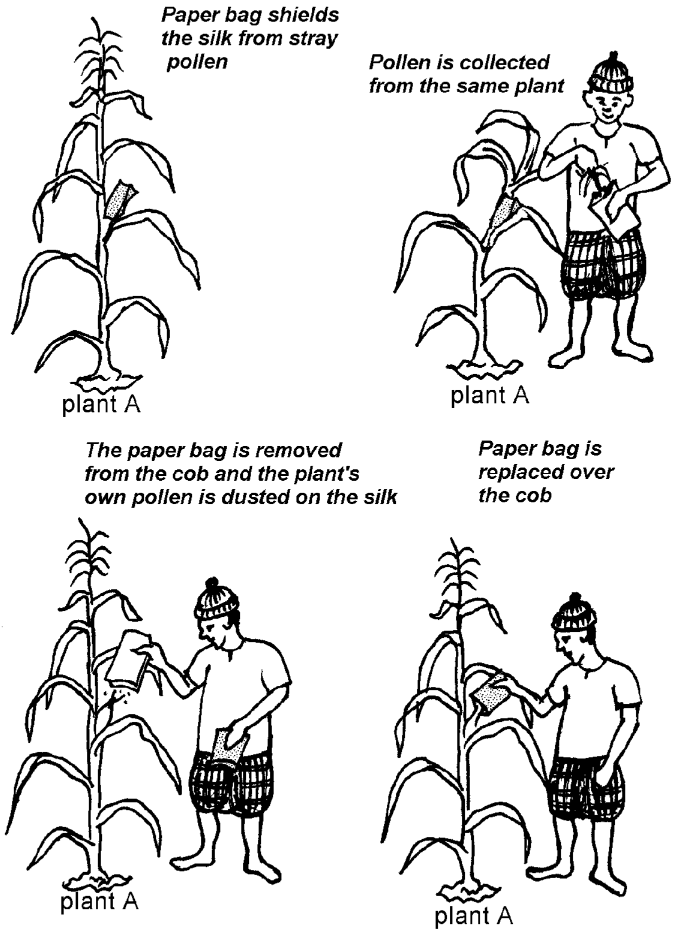

Figure 7: Self-fertilization of maize (adapted from Almekinders and Louwaars, 1999)

However, since individual plants of cross-pollinators contain a lot of genetic variation, your offspring will be even more variable than the parents. There is not much point in separating the single plant progenies. Rather plant them as a block, and do one round of HS family selection followed by positive mass selection in the following generation. You should then have the basis of the new, improved cultivar.

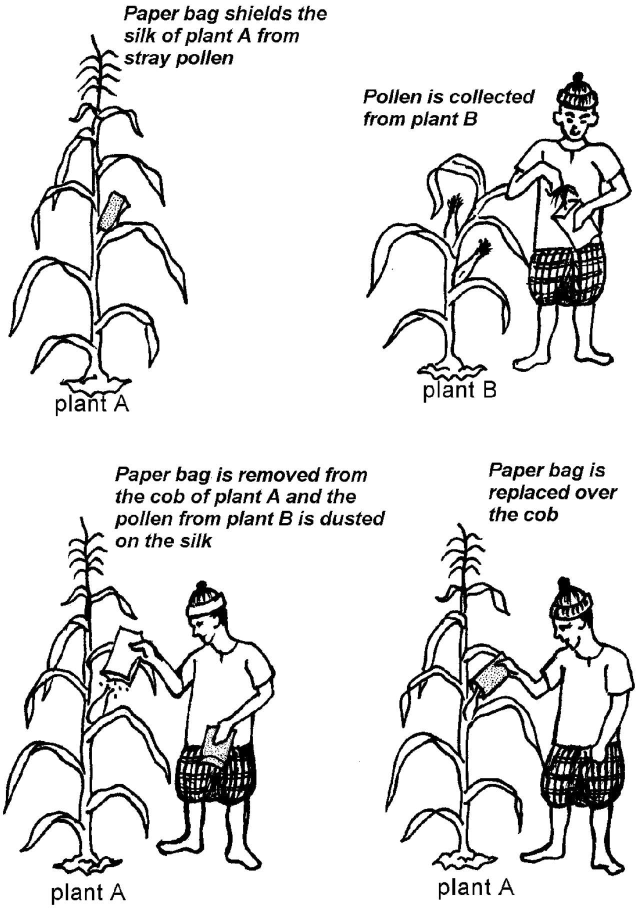

Figure 8: Cross-fertilization of maize (adapted from Almekinders and Louwaars, 1999)

3 Components of seed quality

3.1 Moisture

Through their seeds, plants are able to survive from season to season. One of the most essential functions of seed is therefore storability, which is determined by its moisture content. As a general rule, most seeds can be stored longer when they are drier. Exceptions to this rule can mostly be found among seeds of certain trees, including fruit trees such as mango and avocado, but also coffee, cocoa, rubber and oil palm, which die very soon no matter what you do. Because such seeds seem to resist storage, they are often referred to as *recalcitrant seeds*. Also some non-recalcitrant or *orthodox seeds* do not keep very well. The most important of those treated in this book are soya beans and groundnuts, including Bambara and Kersting's groundnuts.

For most cereals the maximum safe moisture content for storage is around 12 to 13 percent, for pulses it can be around 2 percent higher. It should never be more. The drier the seed is, the longer you can keep it. Very dry legume seed poses other problems though: it becomes very brittle and very easily damaged when handled. The practical moisture content of legumes is therefore between 11 and 14 percent. Assessing moisture content is often one of the largest problems faced by the small-scale seed producer. There is no accurate method to judge moisture other than with small electronic moisture meters, and they are usually quite expensive. However, if you can afford them, it is definitely worthwhile investing in one. Some experienced farmers and seed handlers can judge seed moisture content by biting the seed. If they crack, rather than cut, they are dry enough for storage.

If the seed is not dry enough for storage, the first casualties are germination potential and vigour. The drier the seed, the longer it will maintain a good germination potential and strong seedling growth. Roughly, for every 1 percent reduction in moisture content the seed stores approximately twice as long.

If seed is very wet when put into storage, it provides an ideal food source for moulds and insects. The activity of these storage pests raises the temperature in your stockpile or bags, and within quite a short time the seed is totally spoiled, both by direct damage (rot and feeding) and by destruction of the germination capacity through high temperature. Ensuring that your seed is dry is therefore the first and most important measure to achieve quality.

Most crops will dry sufficiently if left in the field, provided the weather is suitable. However, long periods of field drying may expose the seeds to other dangers such as lodging, unseasonable rain resulting in sprouting on the plant, attack by insects or other animals, or even theft. It is often better to harvest a little earlier, and use some form of on-farm drying.

More information about moisture content, drying and safe storage of seeds can be found in Chapter 6, and in Agrodok no. 31: 'The storage of tropical agricultural products'.

3.2 Cleanliness

An important benefit of good, clean seed is the reduced spread of weeds. Crop seed should not contain any weed seeds, soil, stones, chaff or other bits of plants or broken pieces of seed. If the farmer produces seed for his own use he may not mind a little dirt, but nobody who buys seed wants to pay for rubbish! With some tall, large seeded crops (e.g. maize) cleanliness is quite easy to achieve, but with shorter plants and smaller seeded grains and pulses the seeds of wild grasses and legumes can cause problems, as can soil clods and stones. Some diseases that normally only survive in the ground can be spread to other fields too, if disease-carrying soil or plant debris is mixed with the seed.

In official certification schemes the minimum required seed purity (cleanliness) is almost always 99 percent. That means there must not be more than 1 percent of all the above impurities, by weight, mixed in with the seed. In addition, seeds of certain troublesome weeds are often listed, and 100 percent freedom from these is required. It is good even for the small seed producer to strive for these kinds of standards. The benefits to the user of the seed will be very great.

A weed-free field is the best guarantee for a weed-free seed crop. This is especially important with cereals such as sorghum, wheat, barley, rye and oats, because closely related weeds such as Johnson grass, shattercane and wild oats can cause big problems. Even unrelated weeds, such as morning glory and bindweed, can give problems in small-seeded cowpeas, soya beans and other crops with nearly round seeds. Careful handling during harvesting, threshing and winnowing will minimize the percentage of broken seed as well as the amount of soil and stones that get mixed in with the seed.

In section 4.2 we will pay further attention to achieving seed cleanliness in the field, and in chapters 5 and 6 to methods to improve seed cleanliness during and after harvest.

3.3 Germination

The most important job of the seed is, of course, to germinate! Good quality seed has a high percentage of seeds that are capable of germination. For cereals this should be a minimum of 85 or 90 percent, depending on the crop. For pulses the minimum is usually 80 percent. Again, these are official seed certification standards which the small-scale producer would do well to try and achieve.

A small seed producer can test the germination of his seed quite easily. Any type of plastic, steel or enamel container with a tight-fitting lid can be used. (Figure 9 shows an example.) Avoid aluminium, cast iron or anything with signs of rust, or anything that cannot be thoroughly cleaned, such as unglazed pottery or calabashes. Clean one or more containers, depending on their size, with boiling water and soap. Line the container with a few layers of tissue paper (preferably without any printing). Even toilet tissue can be used. Moisten the paper, and lay out at least 100 seeds, well spaced. Use more than one container if necessary. Cover with another layer of tissue, moisten again, close the lid and put the container away in a cool place, out of direct sunlight. Do not overwater, the seed must be able to breathe air. For very small seeds, the top layer of tissue can be left out. Check every day, and add a bit of water if required. After one week, count how many seeds have formed a complete, normal-looking seedling that shows no sign of disease. Those are then said to have germinated. Anything that looks strange, diseased, has parts missing, or is just very far behind the rest does not count. You can then calculate your germination percentage. Instead of tissue, plain river sand can also be used, but it should be sifted first, and then sterilized by boiling it in a pot with water. Let it cool before using, and plant the seed to the depth of the thickness of one seed.

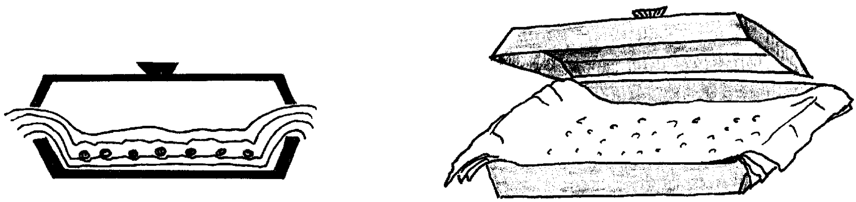

Figure 9: Example of seed germination testing on tissue paper

A less exact way is by planting at least one hundred seeds in a properly tilled piece of ground with adequate watering near the house. You will however not be able to control things like excessive rain, disease, insects, or animals. Your soil must also be suitable, not too heavy and without stones or too much manure.

3.4 Vigour

When talking about minimum germination, we normally refer to the germination percentage under a set of favourable conditions (soft soil, the right amount of water, optimum temperature). In the field the conditions are not always ideal, and even good seed can show less germination. The ability of seed to germinate even under less than ideal conditions, and form a strong seedling, is called *seed vigour*. Fresh, healthy, well-grown seed almost always has a high vigour. Even if the seed has been infected with disease, if it was produced on weak parent plants, or if it has been kept for a long time, it may still show a good germination under ideal conditions. However, as soon as the going gets tougher, lack of vigour will clearly show in greatly reduced emergence. Sound production methods are the best way of ensuring that vigorous seed is produced. If you starve your plants, you can't expect them to produce a strong seed!

Maintaining good germination percentage and vigour is the most important function of seed storage. This requires a dry, cool environment that is out of direct sunlight, and free from insects, rats, and any other storage pest. You can find more information about these in Chapter 6, and in Agrodok no. 31: 'The storage of tropical agricultural products'.

3.5 Seed health

Compared to vegetative propagation methods (cuttings, shoots, tubers, etc.), cultivation from seed is a good way to raise healthy plants as most plant diseases are not carried with the seed.

Nevertheless, a number of important diseases are transmitted through the seed, and a seed producer should be on his guard for them. Healthy seed is the first requirement if you want to produce a healthy crop, and the battle will be half lost already if the farmer starts off with disease in the seed.

Diseases can be transmitted either inside the seed, or by riding along on the outside. As mentioned in 3.2, soil mixed with the seed can carry disease too, but the disease is then not considered to be 'seed-borne'. If the disease is on the outside of the seed it can usually be eliminated by chemical seed dressings. Chapter 6 will explain more about these. You must realize, though, that treated seed can no longer be used for consumption when the germination percentage drops or when you have produced too much. In the case of pulses for dry grain production, seed treatment is often not done for this reason. In many pulses germination can drop quickly if storage conditions are not right. Treatment just before planting can sometimes be a solution.

The most problematic diseases are those which are contained inside the seed, where common chemicals can't reach them. They are mostly transmitted by fungi but sometimes by bacteria or viruses. Some of the fungi and bacteria can be controlled by *systemic* chemicals. These are chemicals that are sprayed on the seed crop, and that are taken up by the plants and work inside the seed. They tend to be quite expensive. The only way of controlling viruses, and the best way to control fungi and bacteria without the use of chemicals, is through strict disease control and sanitation practices in the field. In section 4.2 we will go more deeply into husbandry methods to assist with disease control.

Table 1 shows a list that includes seed-borne diseases that are either widespread or cause large amounts of damage in certain areas only. Local diseases with relatively low impact are not listed.

This list looks positively frightening! Bear in mind, however, that it covers important seed-borne diseases from all over the world. Fortunately, there is no country (yet?) where they all occur at the same time, and although some may be very widespread their level of damage is not all that high. An example is ear-cockle of wheat (which also happens to be a nematode disease). And large parts of the important maize growing area of Southern Africa are free of maize downy mildew.

The list does show, however, that it is very important that prospective seed producers learn as much as they can about the important seed-borne diseases that can affect their seed crops in their area. It would go beyond the scope of this booklet to describe all of the possible diseases. The list of further reading includes a number of handy booklets that will help you with identification. Try to get more information from extension officers and any other people experienced in the crop you are dealing with.

Table 1: Important seed-borne diseases by crop

Crop	External	Internal
Barley	smut	loose smut *) downy mildew barley stripe mosaic virus
Foxtail millet		green ear
Maize	Diplodia cob rot several seedling wilts and blights	downy mildew *) Stewart's wilt
Pearl millet	ergot grain smut	green ear *)
Rice	brown spot foot rot	bacterial blight blast
Sorghum	bacterial streak bacterial stripe target spot covered smut loose smut	downy mildew anthracnose
Wheat	common bunt ear-cockle flag smut scab Fusarium rot	loose smut *) spot blotch tan spot
Broad bean	Ascochyta	Fusarium
Chickpea	Ascochyta blight (gram blight)	
Cowpea	anthracnose Ascochyta	blackeye cowpea mosaic bacterial blight bacterial pustule brown blotch cowpea aphid-borne mosaic cowpea mottle virus cowpea severe mosaic cucumber mosaic southern bean mosaic
Groundnuts	crown rot yellow mould	Fusarium seed rot
Lentils	Ascochyta	Fusarium wilt viruses
Peas	Ascochyta	
Phaseolus bean	Ascochyta angular leaf spot anthracnose charcoal rot halo blight	bean common mosaic virus common bean blight
Pigeon pea		anthracnose
Soya bean	anthracnose downy mildew sclerotinia stem rot	soybean mosaic virus wildfire bacterial pustule bacterial blight

*) = Internal disease that is treatable with systemic fungicides

4 Seed production of cereals and pulses

4.1 Choice of field

Uniformity

The most important thing to consider when choosing a field for seed production is uniformity. The reason is that you will be selecting individual plants for different stages of the multiplication process. If you select (or reject) a plant, you want to be sure that you do so based on its inherited characteristics, and not because it is standing in a much better (or worse) spot in the field. A poor plant in a fertile spot could then be selected without you noticing it! This is especially important with cross-pollinators, which tend to adapt to the environment faster than self-pollinators. A uniform field will be as level and even as possible (lower spots tend to be wetter, higher ones will be drier), does not lie on a slope, has the same type of soil throughout, and does not have tall trees close to it. It would also have the same degree of fertility throughout. A perfectly uniform field is almost impossible to find, but try to guard against extremes of all of the above.

Note carefully that we did not say it has to be a very good field! Remember that selection of seeds will make your cultivar more suitable to the place where it is being selected. If that is the best field in the village, the cultivar will eventually be less suited to poorer conditions. An average field, not too fertile, not too poor, not too dry, not too wet, etc., is your best bet. This also applies when you are producing seed for use on your own farm only: don't use your most fertile field, unless it is also the most uniform. Of course a very poor field is also not suitable: poor fields and weak crops produce weak seeds.

If you produce seed as part of your normal crop, and don't want to get involved with selection for genetic improvement, you can choose a corner of the field where plants look strong and healthy to harvest for seed. This is better practice than choosing from the grain bulk after harvest. The seeds will most likely be stronger and healthier than if they were taken from other parts of the field.

Crop rotation

Growing one crop on the same field year after year is not good farming practice. With some crops (e.g. rice) it can sometimes be done for a number of years without apparent difficulties. With most crops you will run into problems with diseases accumulating in the soil, as well as with exhaustion of soil fertility. Some of the diseases may be seed-borne, and reduce the quality of your seed. For crops that have such diseases rotation is essential.

An additional problem when growing seed is formed by the volunteers that grow from seed spilled the year before. If you are trying to keep a cultivar pure this can be a problem, especially if you were growing a different cultivar or related crop last year. If you are maintaining your own seed it is less important, but it can still undo some of your painstaking selection work! It is recommended that you rotate your seed crop with a different, if possible totally unrelated, crop. Cereals rotated with legumes is a common combination. If rotating is not possible, then try to use one field for the same cultivar.

If you have a problem with unwanted weeds that are related to your crop and look very similar to it, rotation will also give you the chance to properly eradicate them. Examples are Johnson grass (also called shattercane or wild sorghum) in sorghum, wild oats, and red rice. Weeds like these should also be controlled around the fields.

Isolation

An extra complication comes up with cross-pollinators (see appendix). Because wind and insects can carry pollen over considerable distances, your seed crop may be pollinated by a neighbour’s crop or by a different cultivar on your own farm. If you want to keep your cultivar pure, or if you are selecting in it to improve it, you may want to avoid this cross-pollination. You must then ensure that your seed field is isolated from other fields of the same crop. This can be through distance (*spatial isolation,* see Figure 10) or through a difference in planting time (*time isolation*).

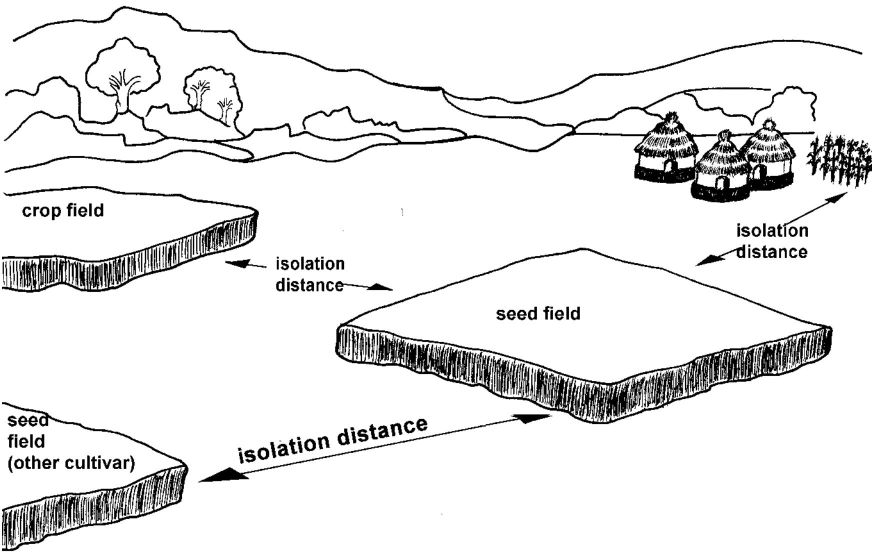

Figure 10: Isolation of seed production

Different crops have different safe distances for isolation, both in space and in time. Table 2 gives you an indication of some of these distances. They are not absolute, and many field factors can make greater distances necessary. These isolation distances also apply to wild plants in the vicinity that are related to your crop and can cross with it. Remember that even a few plants can already be a danger! With some of these distances the reduction of disease transmission and the risk of accidentally mixing the harvest are also taken into account (see also 4.2).

Table 2: Isolation distances for seed production of various crops

Crop	Distance	Crop	Distance	Crop	Distance
Cross-pollinators		Intermediate		Self-pollinators	
Maize	300 m	Road bean	100 m	Chickpea	5 m
Pearl millet	300 m	Cowpea	100 m	Finger millet	5 m
Kidney bean	400 m	Pigeon pea	100 m	Groundnuts	5 m
		Sorghum	100 m	Lentils	5 m
				Rice	5 m
				Soya beans	5 m
				Wheat	5 m
				Barley	25 m
				Phaseolus beans	25 m
				Bambara groundnut	50 m

With time isolation you try to avoid a situation in which an outside field is producing pollen while the female flower parts in your seed field are receptive to pollen. This is very weather- and crop-dependent, and you will have to make an estimate based on your own experience in your area. Remember to build in adequate safety margins in case of unseasonable weather, and bear in mind that tillers and side shoots flower later. The less uniform the crop or the cultivar, the longer the safety period has to be.

If space or time isolation did not work for one reason or another, and you suspect that you got some contamination, you can still reduce this by harvesting only the centre of the field for seed, or by harvesting only the part that is furthest removed from the source of foreign pollen.

Apart from cross-pollination, planting seed fields too close to other fields of the same crop can also introduce the danger of admixture, of accidentally mixing seed from different origins. This applies to both self- and cross-pollinators. Therefore a certain minimum distance is always required, even with strict self-pollinators, and even with crops that propagate vegetatively!

4.2 Crop husbandry for seed production

A good seed crop needs all of the same care as a normal crop. Ordinary cereal and pulse crops (grown for food) are grown for the same product as seed crops for sowing, so there are many similarities. A healthy and strong crop will give the best quality seed, a weak crop will produce poor quality seed. There are, however, certain aspects that need more care when you produce seed, and in this section we will concentrate on those.

Planting

The foundation of a good crop is laid by proper planting. Moreover, most mistakes made at planting cannot be corrected, so it is very important to get it right.

Use healthy and strong seed. You will probably already have done some sort of selection against poor quality seed at harvesting, but you can still remove any seed that has rotted in storage or has insect damage on it, or any poorly developed seed that you missed the first time. More information on seed selection is given in Box 4A and Chapter 5. If you buy seed to start your own seed program, buy the best you can get. It should be at least Government Certified, or sold by a very reputable company or farmer.

You should again strive for uniformity at planting, for the same reasons as given under section 4.1.1. Till your soil as evenly as possible, to ensure that seeds germinate easily and evenly. Plant seeds at uniform depth and distance, to ensure that each plant has the same amount of space available. It is best to plant in rows: to promote uniformity, to make access and weeding easier, to slow down the spread of disease between rows and to be better able to recognize volunteers.

Planting at a lower density than normal may help to reduce the spread of diseases, especially in pulses. It can also result in larger and more vigorous seeds, although the total yield may be reduced. But reducing plant density is not always an option: wider spacing results in almost all cereals in increased tillering, or multiple cobbing. This can cause problems at harvest time, when the ears on the tillers may not yet be ripe while the one on the main stem is near to shattering. In groundnuts wider spacing may increase the occurrence of rosette virus. You will have to make your own decision based on your conditions.

If soil pests such as cutworms are often a problem, it is a good idea to use an insecticide to control them. Simple and cheap granular baits are available in many places to control cutworms.

If for some reason germination was disappointing there is the temptation to go in and fill gaps. Unless the problem is severe, this is not recommended. It usually takes at least a week before you can even tell that there is a problem with the germination. Having plants of different ages in the field is what we were trying to avoid in the first place! Gap-filled plants tend to be shaded out and dominated by their older neighbours anyway, and rarely reach their full potential. Even if they do grow well, they are likely to contract diseases more readily than the earlier plants. If there are large sections where a lot of gap-filling is needed, they could be marked with sticks, to remind you to be alert when selecting. But in such cases you should consider whether it is not better to plough or harrow them in and start afresh.

Fertilization

Seed crops require broadly the same amounts of fertilization as crops for grain, so you can use the normally recommended fertilization rates for your conditions, if there are any. It is important, though, to guard against over-use of nitrogen (N). This leads to excess vegetative growth (stalks and leaves) at the expense of flowering, and produces in general a weaker plant, with less vigorous seeds. Especially when using fresh animal manure or other not properly composted organic material you can expect problems. The best method is to apply nitrogen in at least two instalments, one at or shortly after planting, and one halfway between planting and flowering.

On the other hand, phosphorus (P) and potassium (K) are, if anything, more important than in normal crops, because they stimulate flowering and the production of more and hardier seeds. Be careful with K when your soils are acidic, since you can also overdo things, upsetting the soil's calcium/potassium balance. P is very important in pulses, and helps them to fix their own N from the air!

Weed control

All farmers are aware of the dangers that weeds pose to crops. They steal water and food from the crop, they grow faster, create shade, and can smother a crop completely.

In seed production weeds are even bigger villains. When the seed crop is weakened by weeds, it produces weaker seeds too. At harvest, the seeds of weeds can get mixed with the seed crop, which will give you a lot of work in cleaning it, or a big problem the following year if the weed seed is planted together with the crop. Some weeds, or their seeds, even look a lot like a crop, and distinguishing them can be difficult. An example is red rice.

Normal methods of weed control can be used in seed crops. It is just much more important to ensure that your crop is as clean as possible.

Lastly, some weeds are related to crops and can at times cross with them. You will not notice that this has happened until the following year, when some of your crop plants look very different, and usually perform much worse than the rest. This is especially a problem in sorghum and pearl millet. It can be difficult to establish whether troublesome weedy or wild crop relatives exist in your area. If you cannot find a botanist (a specialist in wild plant species) to consult, you can use Table 3 to see if a problem is likely. The table lists the *centres of origin* of crops. These are the parts of the world where scientists believe that farmers first started taking certain plants out of the wild and farming them (this is called *domestication*). In these areas, there are usually a lot of wild plants still around that are related to the crop, look like it, and can cross with it. Unfortunately it does not mean that you are completely safe anywhere else, but it will at least give you an idea of the danger.

Table 3: Areas of presumed origin for various crops

Crop	**Area of origin**
Adlay	East & South East Asia, tropical Africa
Adzuki bean	Japan, China
Amaranth	Andes, Central Mexico, SouthWest Rocky Mountains
Bambara groundnut	West Africa
Barley	Libya to Afghanistan
Black gram	India (not known in wild state)
Broad bean	Mediterranean & South West Asia
Buckwheat	North India to Siberia
Chickpea	West and South Asia (not known in wild state)
Common bean	Central and South America
Common millet	Central to Eeast Asia (not known in wild state)
Cowpea	Africa and Asia
Finger millet	Africa
Foxtail millet	Origin China? Naturalized as weed almost in all warm regions
Groundnuts	South America
Kidney bean (scarlet runner bean)	Central America
Lentils	South Europe, West Asia, India
Lima beans	Central and South America
Maize	Mexico to Central Andes (not known in wild state)
Mung bean (green gram)	India, Burma (not known in wild state)
Oats	Central and SouthWest Europe, Mesopotamia, Ethiopia
Pearl millet	West and Central Africa
Peas	Europe to West and Central Asia, Ethiopia (not known in wild state)
Pigeon pea	Africa, Madagascar, India
Quinoa	Central Andes, Central Mexico
Rice	Pakistan to North Australia
Rye	North Africa to Afghanistan
Sorghum	Central and East Africa
Soya bean	East Asia, mainly China
Teff	Ethiopia
Wheat	South Balkan to Afghanistan, Ethiopia

There are fortunately also advantages to having wild crop relatives around. They are a valuable source of genetic variation, in case new problems such as diseases show up. If you are so far advanced with your seed program that you can start improving your cultivars with introduced traits, the wild crop relatives are one of the places to start looking. This is a long-term process, however, since crosses with wild plants don't only bring you the desired trait, but usually a lot of undesired ones as well. Constant selection among the crossing products will then slowly take you back to your original type, enriched with the new trait. See also section 2.5 on this subject.

Irrigation

If you are able to irrigate your crop, a lot of new options become available. Not only can you improve your yields by helping the crop through dry spells, and generally making sure that there is no drought stress, but you can also plant in different seasons, thereby reducing or eliminating the danger of cross-pollination from other fields as well as avoiding times of the year with high disease pressure. However, if the seed is for use under non-irrigated conditions, you should not use your irrigated field to do any selection.

Large areas of irrigated seed production may in certain cases lose their pest and disease advantage. This is because a crop planted off-season could offer the insect pest or the disease organism a way of overcoming the constraints of the unfavourable season (which can be severe enough to wipe out the pest or disease), and allow it to attack the main crop even more severely. So be on your guard.

Furthermore, you must ensure that your irrigation water does not carry any diseases. Check where it comes from, and make sure it does not come in contact with crops of the same type at a higher elevation.

In seed production the same irrigation methods can be used as for normal crop production. Flood or furrow irrigation has an important advantage in that it keeps the plants themselves dry, and thereby reduces the chances of the spread of diseases. That is why it is often preferred over sprinkler systems for seed production. Micro-irrigation (drip and sub-surface drip) is also preferred for this reason, in addition to its greatly increased water use efficiency. Drip systems used to be very expensive, but the simpler versions are slowly becoming more affordable.

Pest and disease control

The importance of seed health has already been mentioned in section 3.5. In order to control diseases the first and foremost step is for the seed producer to familiarize himself with the symptoms of the most important diseases in the area, and which of them are seed transmitted. Even the non-seed-borne diseases are important, as they can reduce yields dramatically, and can hide symptoms of the seed-transmitted ones. Try to get advice from knowledgeable people, such as government extension staff, teachers at colleges or universities, or even technically trained employees of chemical companies. Consult the booklets listed in Further Reading.

Pests are sometimes important as carriers and transmitters of crop diseases, and sometimes they cause damage on their own. Such damage can reduce yields, but is not usually a danger to the health status of the seed. Examples of disease carriers are mostly sucking insects like aphids and leafhoppers (see Figure 11), which spread viral diseases in many cereals and pulses.

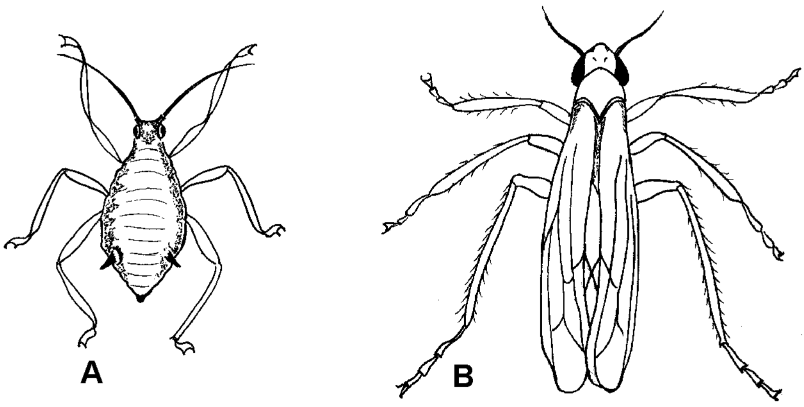

Figure 11: A: Aphid, black or green, B: Leafhopper or cicada, light green with transparent or white wings

As with all diseases, prevention is better than the cure. This requires proper crop hygiene. Start with healthy seed, as mentioned in section 3.5. Bear in mind that even if the seed itself looks healthy and clean, spores or other propagation bodies of diseases can be carried in apparently harmless material such as straw and soil. Do everything to make the situation on the land as unattractive to diseases as possible. This includes a clean start, with crop residue ploughed under (diseases often survive on the remains of crops), clean weeding (weeds often host the same diseases as crops), irrigation methods that keep the leaves dry, and the control of all movement of people and machines in the crop. Viral diseases in particular can be easily transmitted on boots, hoes, wheels and even hands. Never enter seed fields in the morning when the plants are still wet. If you have more than one field of a crop, make sure that workers always start in the healthiest one, and then move to the less healthy ones, never the other way around. If you can, use a cheap disinfectant such as bleach or carbolic acid ('Jeyes Fluid') on tools, boots and hands when changing fields.

Chemicals can be sprayed both as a prevention and, with fungal diseases, to stop diseases from spreading once they are present. They become essential when certain seed-born diseases appear. Many of these seed-borne diseases do not cause much damage to the seed crop when they arrive during the season, but can be devastating when the next user plants infected seed. Some of them can be controlled with chemical seed dressings, which are usually more effective and reduce the amount of chemical sprayed in the fields. See section 6.2 for more information on seed dressings.

Bacterial diseases are difficult and viral diseases impossible to control chemically once they have gained a foothold. In those cases *rogueing*, or pulling out infected plants, is the best option. Workers should be trained properly in recognising symptoms by just looking at the plants. In many cases, especially with viruses, they will need an umbrella or a broad-rimmed hat to throw shade on the plants to help them see the symptoms. They should not touch the plants when looking for symptoms, as that may spread the disease. Any uprooted plants should be put into a plastic bag immediately, to avoid insects or pieces of the plant from dropping off and continuing the spread. The collected plants should be taken away from the field and destroyed, preferably burned or buried.

Insects must be controlled if they cause damage by themselves or transmit diseases. Standard control methods can be used, as in non-seed crops. To reduce the incidence of storage pests, such as weevils, early harvesting and artificial drying is useful (see section 3.1, Chapter 6, and Agrodok 31). The longer the crop stands in the field, the more time the weevils have to invade.

4.3 Selecting self-pollinators in the field

Once the crop reaches a stage in which one or more of your selection targets (see section 2.3) become visible, it is time to start selecting. Sometimes this can be quite early already, for instance if you want strong seedlings or rapid early growth, but most of the time this will be after a month or two, depending on the crop, once the plants show more clearly what they are made of!

Selecting for cultivar maintenance

With self-pollinators, using either negative or positive mass selection (see section 2.4) is adequate to maintain a cultivar. If you opt for negative mass selection, simply remove the plants you don't like. Carry them out of the field in a plastic bag and destroy them. Remember that you can transmit viral diseases with your hands, so do not touch other plants if the ones you remove are virus infected (see 4.2). You will have to make several selection rounds throughout the field, depending on your criteria and the crop's different stages of development.

Positive mass selection requires marking the plants that in your view best represent the cultivar. You can mark them using whatever method is convenient to you. Bear in mind that the markings must still be clearly visible at harvest time, so they should be able withstand all the vagaries of the weather. Tying small pieces of string (preferably nylon, cotton may rot away) around the stem is one way. Some input supply companies sell very convenient tie-on plastic labels (see Figure 12), on which you can also write. Alternatively, with certain cereals you can simply tie a knot in one or more leaves! Just be careful that you don't damage your prize plants too much, or that the leaves don't drop off before harvest.

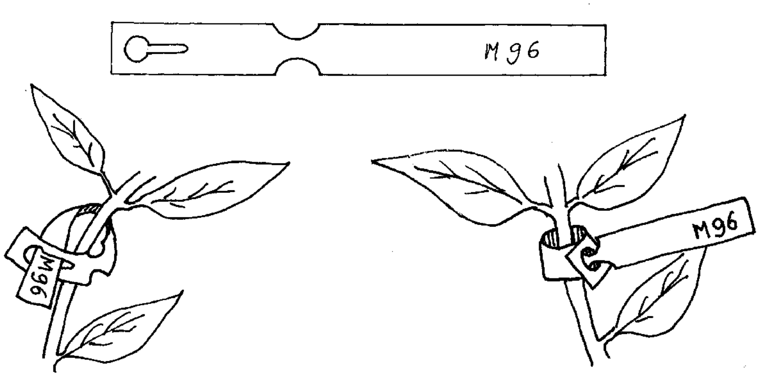

Figure 12: Tie-on label

If you intend to do several selection rounds, you must make sure that in your first round you make far more selections than you will need. Your later rounds will then mostly concentrate on the plants you have selected already, removing the initially selected ones that show wrong traits later on. Bear in mind the minimum number of 30 plants that must be left over in the end, including any selection you may still do after harvest! Remember also that the fewer plants you select, the more uniform your cultivar becomes. If you want to maintain a wide genetic variation, negative mass selection would be more appropriate.

Another method would be to only concentrate on certain sections in the field, and call those your seed production squares. This is especially important if your field is not very uniform. You can then eliminate any patches that show poor growth to start with. But be careful: you don't want to select plants only because they are in a good spot in your field! In that way you might end up with genetically mediocre plants while you're actually looking for the best plants. A thorough knowledge of your field and cultivar is necessary if you do this.

At harvest time you carefully harvest each selected plant individually, and bag and thresh the seeds separately from the rest of the crop. The seed of these plants together then becomes your seed for next year.

If you see any plant that seems exceptionally good and different compared to the rest of the cultivar, you have two choices. Either you select it as you would any other plant for seed, and combine it with your other selections, or you mark it in a different way to keep it separate. In the first case, you are improving the cultivar. This is fine if you produce for yourself, or if your customers buy seed from you because of your own reputation. But if they want seed of a particular, clearly defined cultivar (usually when it has a name) it may be better to keep such a plant separate, and multiply it apart from the rest. This then becomes a possible new cultivar, and you should proceed with line selection as in the next section.

Selecting for cultivar improvement and development

Methods employed for this purpose are positive mass selection (with relatively small numbers of plants selected, but never less than 30) or line selection. The aim is to improve the characteristics of the cultivar by getting rid of inferior plants, to remove any contamination that may have come into the cultivar, or develop a new one. The stricter you apply these methods, the more uniform your cultivar will become.

Positive mass selection is described in section 2.4 and the previous section. For line selection you proceed the same way up until harvest. Then you harvest the selected plants, but keep each one separate throughout threshing and storage. The following year you plant the seeds of each selected plant in its own little family plot. You should have at least 30 separate plots or rows, one for each plant. During selection, you will now discard every plot in which there is an undesirable plant, even if there is only one! The remainder together will then form your seed for next year. If you want, you can select further by taking the ten or twenty best plants out of each remaining plot, depending on how much seed you are going to need and how many plots you have left.

Remember to observe the isolation distances around the block of 30 plots as listed in section 4.1. Internally, between the plots themselves, this is not necessary.

With a new plant type found in a field as mentioned above, you would begin with one little block containing all the plant's seeds. Select individual plants that resemble the parent the most, and harvest and store these individually. No strict rule applies as to the number. The following year plant them in bulk. You should then have enough seed to check if it is indeed better than other cultivars.

For the introduction of genetic variation from outside, see section 2.5.

4.4 Selecting cross-pollinators in the field

To select efficiently in cross-pollinators, it is important to make a distinction between traits you can already observe before flowering, and those that only appear later. Negative mass selection can still be used on the former. After flowering though, negative mass selection is futile, and positive mass selection is the only option, short of family selection.

Selecting for cultivar maintenance

Positive mass selection is the method of choice in this case. It has been discussed in detail in sections 2.4 and 4.3. One important difference compared to self-pollinators is that the minimum number of plants in a cross-pollinator crop that has to be selected to avoid random drift is 50.

Progress with mass selection in cross-pollinators is always slower than in self-pollinators. This is because we only know the mother plants of each seed. The father could be one of the plants that we are not happy with. The only relatively simple way to avoid this problem and make quicker progress, and which can be used in any crop, is HS family selection as mentioned in section 2.4, with or without remnant seed. If you think that your cultivar needs cleaning up and mass selection is not doing the job well enough, you can perform one round of HS family selection. In stable, established cultivars this should only occasionally be necessary.

Selecting for cultivar improvement and development

If you have a cultivar with a lot of genetic variation, whether it was already like that or you created it yourself through introduction of other material (see section 2.5), you have two options: using it as it is and gradually shaping it into something more uniform and specialized, or developing more than one cultivar out of it. If your aim is to make significant changes or to develop new cultivars, mass selection alone is inadequate. You will then have to use HS family selection, with or without the remnant seed method, and possibly more than once. Be sure, however, that you always allow for at least one season of random pollination (i.e. planting all your seed in one block to re-mix it) between two rounds of HS family selection. Otherwise you will likely reduce the vigour of your cultivar and consequently also its yield potential.

In some crops it is possible to completely exclude pollination from other plants by simple means. Examples are maize and sorghum. By enclosing the cob (maize) or the panicle at the top (sorghum) in a paper bag fastened with a paperclip, pollen from outside will not be able to enter. Sorghum will then pollinate itself, but with maize we have to do it by hand. This gives us the opportunity to decide whether to use the plant's own pollen, or to cross it with another desirable plant in the field. A more detailed description is given in Figure 6. In this way you can work towards your target type of cultivar much faster. Again, don't work with too few plants, but always make at least 30 to 40 different crosses with the same aim in mind, and mix the resulting seed into a new population from which you can select.

4.5 Selecting intermediate crops

For crops like sorghum that can both self- and cross-pollinate, the selection methods for self-pollinators can be followed, especially when the plants or flowers can be bagged to ensure self-pollination. The result will then be a uniform variety that can be maintained as a self-pollinator. It may however need a round of line selection more often than real self-pollinators, since the chances of foreign pollen coming in are higher.

4.6 Examples in seed production

This chapter contains a fairly complete general overview of all the factors involved in field production of seed for sowing. In the following sections examples are given in a step-by-step approach of how these principles translate into practical seed production for a self-pollinator and a cross-pollinator. Box 2 summarizes all the steps, and can also serve as a checklist for other crops.

Box 2: General checklist for seed production

1 Area selection
2 Crop rotation
3 Isolation
4 Soil
5 Planting time
6 Plant population
7 Seed
8 Fertilization
9 Weed control
10 Hygiene
11 Insect control
12 Disease control
13 Selection

Seed crop husbandry of common bean

Example of a legume and self-pollinator

Please note that in Mexico and the West Indies certain insects can cause a lot of cross-pollination, to the extent that seed production practices for cross-pollinators must be followed.

The main issue in the production of quality bean seed is seed health. Being a strict self-pollinator, beans can be kept genetically sound fairly easily. More than in most other crops, off-season production of bean seed is a preferred method to ensure seed health. Areas that have a dry season with mild temperatures and sufficient irrigation water are ideal.

1 *Area selection*

An area that is warm and dry, with irrigation water is ideal. The more rain received, the higher the risk of transmission of seed-borne diseases. Rain at harvest time can easily cause discolouration of the seed. When irrigating, avoid sprinkler systems.

2 *Crop rotation*

A minimum of 12 months should elapse between harvesting the last bean crop and planting a seed crop. If the previous crop was completely free of disease you can risk a shorter period, but if the straw of the previous crop was ploughed in, a longer period would be advisable. Cowpeas and mung beans count as beans in this regard: they share several diseases.

3 *Isolation*

Cross-pollination is not a problem in most Phaseolus species, but disease transmission is. Keep a seed field 25 m away from any other bean crop. Be careful of fields that may harbour volunteers from an earlier crop. Check the direction and origin of run-off water that may enter your seed field and carry disease.

4 *Soil*

Avoid extremes of high and low clay content. Heavy soils can cause germination problems, tend to waterlog, and slow down drying of the crop in windrows. Very light soils are usually low in nutrients and can harbour high numbers of nematodes, to which beans are quite vulnerable.

5 *Planting time*

Choose the planting time in such a way that you can be reasonably sure of dry weather at harvest. Avoid extreme heat at flowering time, which can cause the flowers to abort.

6 Plant population

A compromise has to be sought between high plant density, which boosts yields, and low density, which slows down the spread of disease. A final population of between 140,000 and 200,000 plants per ha is recommended. Do not plant closer than 7.5 cm in the row. 60 to 75 cm between rows is practical, 80 cm gives more protection against the spread of diseases.

7 Seed

Use the best seed you can get. Inspect the seed coat – although you cannot see everything, stains, discolouration of the navel and any malformations are usually signs of internal problems. Remove any suspect seed by hand. It is recommended to treat the seed before planting to give it some protection against diseases, using captab, thiram or Vitavax. Very effective insecticides are available to protect against soil pests, leafhoppers, aphids and bean fly, but they are quite expensive. An example is imidacloprid ('Gaucho'). This will protect your crop for the first four to six weeks. Handle seed with great care, bean seed is fragile. If you use mechanical planters, check carefully that they do not damage the seed.

8 Fertilization

Phosphorus (P) is the most important element, and if you can only afford small quantities of fertilizer the application of superphosphate, MAP or DAP would be best. If your soil is not too acid and beans have been grown there before, the plants are likely to form small, round, pinkish tubers on the roots, called nodules. Inside these live Rhizobium bacteria which can bind nitrogen (N) from the air and provide the plant with it. If this happens you will need to apply little or no nitrogen, except a little at planting to get the crop going. Potassium (K) is less important in beans than in other crops, but shortages can occur. It is best if you can have your soil analysed to see what it needs.

9 Weed control

This is very important, especially in the young crop. But for disease control purposes we want to limit all movement in the crop. Also, bean types with a semi-climbing plant are hard to weed by hand later in the season. So if you can, use herbicides. Good ones to use are bendioxide ('Basagran'), for broadleaf weeds, and fluazifop-butyl ('Fusilade') for grasses. If weeding by hand, remember to always start working in the healthiest field, and to disinfect your tools at the end of the day.

10 Hygiene

Try to limit all movement in the field. For optimal protection against the spread of diseases, disinfect implements, tools and boots before going into a field. Good and cheap disinfectants to use are bleach or carbolic acid. Wash your hands too: even dry consumption beans can carry viruses! <u>Never enter the field when the plants are wet</u>. Always start working in the healthiest field. Ensure that no disease is brought in with irrigation water.

11 Insect control

The most dangerous insects for seed production are aphids and white fly, as they can transmit viral diseases. Learn to recognize them, scout for them, and apply a suitable insecticide when they are seen. Other insects that can damage the crop (but do not transmit diseases) are bean fly, American bollworm, loopers, thrips and red spider mite. Cutworms can reduce the stand by attacking seedlings; cheap baits are available in many places.

12 Disease control

Viruses: mainly bean common mosaic virus (seed-borne). Follow hygiene practices and rogue infected plants (see 4.2). There are no chemical control methods.

Bacteria: mainly common bacterial blight and halo blight (both seed-borne). Handle as with viruses. Copper-based chemicals are available that have some preventative action.

Fungi: seed-borne ones include Anthracnose, angular leaf spot and Ascochyta. Important non-seed-borne diseases are brown rust and Sclerotinia (white mould). Spraying against rust is often necessary, and this will then also control most of the others. If the cultivar is resistant to rust, decisions on whether or not to spray should be based on scouting for the important seed-borne diseases. Plants with seed-borne diseases should be rogued.

Do NOT harvest your seed from later pods after having harvested the early ones for fresh consumption! This is a sure way to collect diseases in the seed.

13 Selection

Any number of selection rounds can be included during the season, depending on your aims.

Seed crop husbandry of maize

Example of a cereal cross-pollinator

In maize seed production the most important issue is maintaining the identity of the cultivar. Diseases play a minor role, and come mostly to the fore at harvest time (see chapter 5).

1 Area selection

Few restrictions apply. Off-season production is not a great advantage from a disease point of view, although it may offer other benefits such as reduced risk of cross-pollination and reduction of the storage time before sales.

2 Crop rotation

If the previous crop was maize, there is a potential problem with volunteers. You can try to get them to germinate earlier by pre-irrigating, or waiting a bit after the first rains, and do another round of harrowing. There is little danger if the previous crop was the same variety. Rotation also reduces transmission of diseases through crop debris, and is, as always, advisable.

3 Isolation

To prevent outside pollen from entering your crop, keep a distance of 300 m from any maize likely to flower at the same time. A difference of around four weeks in planting time also provides enough protection. If a source of outside pollen is suspected to have contaminated the crop, only the central part and/or the part furthest removed from the source of contamination should be harvested for seed.

4 Soil

No special requirements for seed crops over and above those for normal maize.

5 Planting time

Choose a planting time that will ensure dry weather at harvest.

6 Plant population

Follow the standard for the location. Do not plant too widely apart, to avoid problems with late flowering and late drying of second cobs.

7 Seed

Use the best you can get. Inspect and if necessary sort for stained, decayed, malformed or otherwise damaged seed. If Diplodia ear rot or downy mildew is a problem you could treat the seed with a suitable fungicide before planting. They are expensive, however, and the cheaper ones don't work against all diseases. Examples of cheaper ones, effective against soil diseases in the seedbed and some seed-borne diseases, are captab and thiram. Very good but expensive ones are Apron and Ridomil.

8 Fertilization

Fertilize as for normal maize. If you can, have your soil analysed. Guard against over-application of nitrogen.

9 Weed control

Weed as for normal maize.

10 Hygiene

Never enter the field unnecessarily. Ensure that no disease is brought in with the irrigation water.

11 Insect control

Stalk borers are a serious pest. Not only can they reduce yield through damage to stalks and cobs, but removing damaged grain at harvest is time-consuming. In addition, tunnelling by stalk borers provides an entry for cob diseases, some of which are seed-borne. Effective chemical controls for stalk borers are available. Cutworms, for which baits are available, can reduce the stand. Leafhoppers transmit streak virus (not seed-borne), but can only be controlled by systemic insecticides applied at planting time in the furrow (Temik and carbofuran, both of which are highly poisonous and not recommended) or on the seed (Gaucho and Cruiser, which are expensive but very effective). Streak is usually not a problem in the main planting season, but it can be very serious in off-season production.

12 Disease control

Few important diseases are seed-borne. Most (such as Diplodia ear rot and downy mildew) can be controlled by applying seed dressing with fungicides, removing infected cobs after harvest (Diplodia), rogueing in the crop (Stewart's wilt, downy mildew, viruses), and following proper rotations.

13 Selection

Any number of selection rounds can be included during the season, depending on your aims.

5 Harvesting seed crops

5.1 Timing

The keyword for harvesting seed is timeliness. Harvesting must not take place too early, when a high moisture content will make safe storage of the seed impossible, nor too late, which will result in losses through disease and insect infestation, birds, shattering, spoilage through rain, and increased brittleness of the seed (which makes for high breakage when handling the crop).

Because of the higher value of a seed crop, it can be worth the extra trouble to harvest a little early and dry the seed artificially. This will eliminate most of the dangers mentioned. Some simple and good methods of drying and drying equipment are described in Agrodok 31, pages 29 to 37, in the UNIFEM Source Book *Drying*, and in the IT/CTA book *Tools for agriculture* (see Further Reading). When you research drying methods that have not been specifically designed for seed, bear in mind that too much heat is the surest way to kill the seed! Seed drying temperatures should never be over 40˚C for cereals or 35˚C for pulses, and seed should not be dried in the sun. A well ventilated place in light shade is best, and the seed should be regularly turned. You should also be careful to stop in time, and not let the seed get too dry (see Chapter 6 for safe moisture levels).

If you want to rely on field drying, you must have planned your planting time so that harvesting can take place in the dry season.

In most crops, the seed reaches maturity a while before normal harvesting time. The grain has been filled, the germ is complete, and all that happens from then on is removal of water. We say that the seed is *physiologically mature*. In theory, it can be harvested any time after this time, provided you are equipped to deal with the high moisture content.

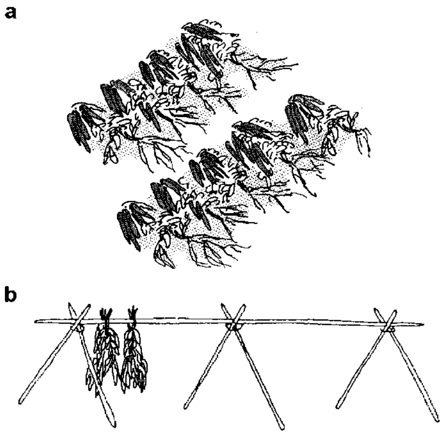

Figure 13: Drying bean plants (a) in windrows, and (b) on racks

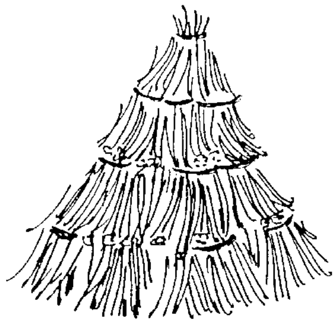

Figure 14: Drying pulses in stacks or cereals in sheaves

In most pulses, physiological maturity is reached when the pods start to change colour. The plants can then be pulled up and put in windrows or on racks to dry (see Figure 13). This helps to ensure that all pods are ready for threshing at about the same time. In cultivars with a long flowering period and pods of widely differing ages, you will have to compromise between losing seeds from the oldest pods due to shattering and harvesting the youngest pods too early. The first set pods are usually the best quality, so it's worth saving them rather than the youngsters. Windrowing works less well if the soil is heavy and remains moist for a long time. Building simple racks or tripods onto which the crop is then piled can be a solution.

Common and Bambara groundnuts do not allow for simple inspection of the pods. There is no alternative to digging up a few plants when you think the time is nearing, and checking if the seeds are free in the pod, and if the skin on the seeds (in the case of peanuts) has turned colour. They are also normally dried or 'cured' on racks or in stacks or windrows in the field. If there is a chance of rain, it is very important to construct these stacks in such a way that water cannot get in (see Figure 14). The pods should be on the inside, and the leaves form a kind of thatch on which the water runs off, like the thatch of a house. A small piece of tarpaulin or plastic on the top (like a hat) also helps.

In maize, physiological maturity is reached when the 'black layer' is formed. You can see the black layer by breaking a seed off the cob, removing the bits of fibrous and papery tissue at the top, and looking as it were 'into' the seed from the point where it was attached (see Figure 15). The crop could be harvested at this point and will yield very good quality seed, but only if some form of forced drying (drying with fans) is available. Drying will have to be done on the cob, before threshing, since threshing is not possible at high moisture content.

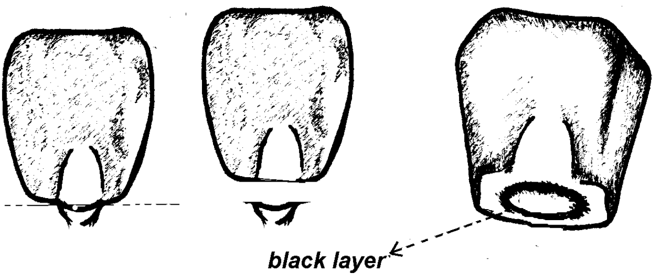

Figure 15: By removing the fibrous tissue you can find the black layer

Physiological maturity is not a useful indicator in rice and other short straw cereals (wheat, barley, rye, oats). It already occurs at around 50 percent moisture, which is far too early to harvest. The best time to harvest is, as with pulses, when the ears turn colour. Drying can then be done in the field in sheaves, or with various artificial methods.

Remember to harvest your individually selected plants first, before the rest of the crop comes off.

5.2 Threshing, cleaning, selecting

There are few, if any, specific threshing methods for seed. We just have to ensure that the local standard method used is as gentle as possible, to avoid breakage. Especially pulses are sensitive. Here the value of harvesting a little early really will show, as seed with a slightly higher moisture content stands up better to handling. However, too wet is also not right, since handling can then cause internal damage. Additional drying will take place after threshing, but before winnowing and cleaning.

If the crop is field-dried, remove the windrowed or sheaved crop from the field early in the morning, when there will be a bit of dew on the pods or ears, or dampness in the air, which will limit shattering. Threshing can begin later in the day. The simplest way of threshing pulses for seed is by stuffing the pods in bags and hitting these with sticks. Do not trample pods or run vehicles over them, as that is likely to cause too much damage. The groundnuts are again an exception: firstly, because they are better stored in the pod until planting time, and secondly, for seed there is no good alternative to threshing ('shelling') by hand.

Threshing of cereal seed is done with the same methods as when harvested for food. If you have enough space and suitable facilities, maize seed can also be kept very well on the cob. Small quantities of cobs can be bundled and hung indoors, but for larger qualities a crib must be built (see pages 45 and 46 of Agrodok 31).

Threshed seed will generally need to be cleaned of soil, stones, chaff and other pieces of plants, as well as insects and weed seeds. Smaller quantities can be cleaned by hand, through winnowing, sieving and/or sorting. But if you have large quantities of seed, this will soon become a job that will have to be mechanized. A wide range of machinery is available, from simple to very advanced. Some versatile and simple machines are listed in *Tools for agriculture* (see Further Reading).

Whether sorting by hand or by machine, pay special attention to weed seeds and to crop seeds that do not look healthy. This may include discoloured, broken, stained, shrivelled or malformed seeds, or seeds attacked by insects. Box 3 explains how to do this for maize. Even though many of these may already be taken out during winnowing or sieving, visual inspection and if necessary a last hand sorting before putting the seed into storage must always be done. Box 4 explains how to sort maize seed to make it suitable for mechanical planters.

Box 3: Sorting of maize seed on the cob

The shape and structure of the maize cob allows for hand sorting of the grain before threshing. Damaged or diseased grains can usually be identified easily by inspecting the cobs. Individual grain can then be removed by hand, making use of a tool such as a screwdriver. If you don't want to waste your best screwdriver, a simple cob-cleaning tool can easily be made from a five or six inch nail. Hammer the sharp end flat to resemble a screwdriver tip, and insert the head into a piece of wood or a cork.

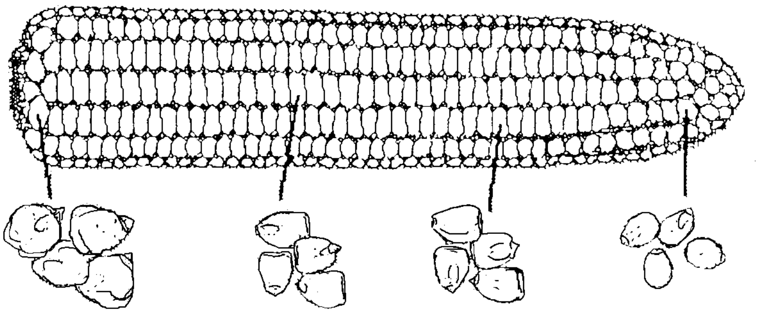

Figure 16: Maize cob and loose seeds from different parts of the cob, to show shape and size differences

Box 4: Maize seed sizes and mechanical planters

If you produce maize or other seed for sale, your customers may want you to separate seed sizes. You will have to do that also for yourself if you use a mechanical planter. Mechanical planters work most commonly with plates that have holes in them. Each hole takes one seed and drops it in the exit hole.

For a mechanical planter to work properly, it is important that the seed is of a uniform size and thickness. In theory a mechanical planter can take any size or thickness, provided the farmer has a wide range of plates. But in practice, a new planter comes with a few plates only, and most farmers never buy additional ones. So usually, only a few seed sizes are plantable with a mechanical planter. They are mostly the medium size flat ones. Large rounds and flats give problems with skipping (the hole does not pick up a seed), jamming (a seed gets stuck in the hole and blocks further use of it, causing more skips, or it gets stuck in the exit hole and the whole bin stops working) or crushing (the seed gets ground up by the plate). Sizes that are too small for the plate cause double planting, with more than one seed being picked up by the hole.

There are many different shapes and sizes of seeds on a maize cob. The larger ones are at the bottom of the cob, while smaller seeds are at the top. Top and bottom seeds tend to be round, while the ones in the middle are flat, at least on a well-filled cob (Figure 16).

To be able to offer customers graded seed, only work with well-filled cobs. The ones that are poorly filled have all sorts of different shapes and sizes of seed, making the job much more difficult. First remove the seeds at the bottom and the top of the cob. This is called 'topping and tailing'. After that, the flat seeds in the middle can be threshed. For more accuracy, separately thresh the top and bottom half, giving you large flat and small flat. Try to remove individual round or thick seeds if you find them.

The seeds from the top are usually too small. Very small seeds will be at a disadvantage when conditions are less than ideal (e.g. a dry or rough seedbed) due to the slower start they get in life. The smaller the seed, the less energy it has to grow quickly. The size of the seed does not affect the genetic quality of the plant that grows out of it!

Seeds from the bottom can still be used. Don't throw them away. Round seeds can be sold for hand planting. Because they tend to be heavier, they normally germinate and emerge better than lighter seeds in fields where the soil tillage is rough with large clods of soil. Often it is the farmers who plant by hand that have a lesser standard of soil tillage.

It may be useful to remember again the rules about the numbers of individually retained selected plants under the selection methods other than negative mass selection. Remember that you should have the yield of at least 30 plants of a self-pollinator, or 50 of a cross-pollinator available for planting the following year. Given that you will probably still throw away a bit of seed before planting, after taking the seed out of storage, you should put a bit more than that into storage. Exactly how much more depends on the crop, your area, and the quality of your storage. Try to err on the safe side in the beginning, and after a few years you will know more exactly.

A last subject to consider before storage is seed dressing. This will be further discussed in Chapter 6.

5.3 Avoiding admixture

Throughout the entire harvesting and post-harvest operations, pay careful attention to keeping different cultivars and selections separate. It is very easy in all the excitement and activity of harvest time to make mistakes and accidentally combine seed lots that should have been kept separate, or to spill seed of one cultivar into another.

Ensure that all types of containers, vehicles and storage are thoroughly cleaned before being put to new use. Bags can be turned inside out and given a good shake. Drums, tanks, and tins should be swept or wiped. Wheelbarrows, carts and sleds, as well as cribs and storerooms should be likewise cleaned, swept and checked for cracks and chinks. When changing from handling one cultivar to another, the whole cleaning process must be performed again. Any machinery you use can be especially tricky, and often partial disassembly is necessary to remove all grains left inside the machine.

Make sure that all containers are properly labelled or marked throughout, with at least the name of the cultivar and the harvest date. Any other information that may be useful later on can be added.

Store or stack different cultivars separately as well. If the seed is in bags, make separate stacks for different cultivars. Loose grain obviously must be in separate tanks or rooms.

6 Post-harvest care and storage of seed

An excellent summary of general drying and storage methods for crops is given in Agrodok no. 31: *The storage of tropical agricultural products* (see Further Reading). A separate section deals with seed for sowing, and covers this subject very well. In this chapter we will look at some additional issues only.

6.1 Safe moisture content

A low moisture content is the key to safe storage of seed. Insects, fungi and bacteria need moisture to grow and develop, and the drier the seed is, the better it is protected against these problems. In addition, the life processes of dry seed itself are also slowed down a lot, meaning that the process of ageing goes slower and germination capacity is better maintained. You could say the seed lives slower, and so stays young longer! But it is alive, it breathes, it needs oxygen and produces water vapour, even though these quantities are extremely small. Seed can therefore never be kept forever without any deterioration.

It is not too difficult to dry seed enough to prevent growth of fungi and bacteria, and the moisture content required for this purpose can be reached by both field drying and artificial drying. A moisture content of 13 to 15 percent offers enough protection against the most important fungal diseases in most crops. However, the most important storage insects can still grow and multiply on a large scale at a moisture content as low as 11 to 12 percent, and they are not stopped completely until you reach 8 to 10 percent moisture. This is often not practical, and is certainly difficult to achieve without investing in major drying equipment. Some form of additional protection is therefore necessary, and the most commonly used methods are chemical (see section 6.2).

Once you have reached a safe moisture level it has to be maintained. If the seed is in contact with outside air, it will exchange moisture with the air and become drier or wetter again, depending on how dry or humid the air is. In most cases, whenever air humidity is higher than around 60 to 70 percent, dried seed will become wetter again. If this is the case in your area during the storage season, you will have to use some form of (semi-)airtight storage. This is not as difficult as it sounds, and can be achieved with many types of packaging and sealing materials. Because of the respiration that is still taking place, producing water vapour, it is advisable to dry the seed as far as you can if you want to keep it airtight. Further protection can be given by including some material that will absorb water, such as silicagel, charcoal, or ashes. Agrodok 31 gives a number of other examples.

Table 4: Recommended moisture contents for storage of seed

Crop	Moisture content
Barley	12-13.5%
Broad beans	15%
Buckwheat	12.5-14%
Chickpeas	14%
Cowpeas	15%
Groundnuts (in pod)	8.5-10%
Groundnuts (shelled)	6.5-7%
Lentils	14%
Maize	13-13.5%
Millet	14%
Oats	12-13.5%
Peas	12-14%
Phaseolus beans	13-15%
Rice	12-13.5%
Rye	12-13.5%
Sorghum	12-14%
Soya beans	9.5-11.5%
Wheat	12.5-14%

Table 4 gives the most commonly used values for safe moisture content in a number of crops. These are guidelines only, since these values are also influenced by the storage temperature, the length of the storage period required, the germination percentage of the seed when it was put into storage, air humidity, insects and diseases present, and even the crop cultivar involved. For these reasons, you can find almost as many safe moisture content figures as you can find books on the subject.

These values refer to the main production climates of the crops for short-term storage (i.e. from one season to the next, or about 20 weeks). For cool weather crops, such as oats and barley, in warmer climates these figures could be as much as 2 to 3 percent lower. For longer-term storage lower values would also be necessary, and also for storage in airtight containers. As a rule of thumb, every 1 percent decrease in moisture content doubles the possible storage time (and of course the reverse is also true).

Seed that is not dry enough can also be kept safe under low temperatures. But generally it is easier to dry seed than to refrigerate it, so drying is preferred. However, all seed should be kept as cool as possible, to better maintain germination capacity. Another rule of thumb: every 5˚C decrease in temperature doubles the possible storage time (and vice versa).

6.2 Chemical protection and seed dressing

The use of chemicals in seed storage is widespread, but can be avoided in many cases. Agrodok 31 gives some suitable non-chemical methods. Where there are practical difficulties in applying these, there could be broadly two reasons why we would want to use chemicals to store seed.

The first is to protect stored seed from insects (see section 6.1). This use could only be avoided by drying the crop very thoroughly, and packing it in such a way that it does not pick up moisture again, nor allow entry to insects. There are other ways to reduce insect infestation, such as mixing the seed with certain types of clay or ashes, which makes it difficult for insects to move around amongst the seed and reduces available oxygen, or with dried leaves that repel insects. With pulses, certain types of cooking oil can be used. Regular turning or moving of the seed also can help in disturbing the insects' development. These methods all have their drawbacks (e.g. you have to separate the maize and sand again before planting), but they can be useful in certain cases.

The second reason is to protect the young seedlings after germination. In the seedbed there are usually many diseases present that can attack the seedling and cause ‘damping-off’, or seedling mortality. Treating the seed with fungicides can help avoid this. These fungicides can assist in storage too, but it is better to rely on proper drying. Fungicides can be applied before storage, or after storage and just before planting. Some insecticides and fungicides can even provide the growing plant with protection against insects and diseases for several weeks when applied on the seed. Examples are imidacloprid against bean fly and leafhoppers, and metalaxyl against downy mildew. These types of chemicals reduce the need for spraying in the field, so they save chemicals, they save costs, and they are less harmful to the environment.

Table 5: Recommended insecticides and fungicides for use against seed-borne factors, and for protection in storage and in seedbeds for cereals and legumes

	Seed-borne factors	**Protection in storage**	**Seedbed factors**
Cereal insecticides		chlorpyrifos-methyl pirimifos-methyl mercaptothion pyrethrum pyrethrins	Imidacloprid, mercaptothion, gamma-BHC
Cereal fungicides	captab, thiram, carboxin, metalaxyl		captab, thiram, mancozeb, metalaxyl
Legume insecticides		pirimifos-methyl mercaptothion pyrethrum	Imidacloprid, gamma-BHC, mercaptothion
Legume fungicides	captab, thiram, metalaxyl, tolclofos-methyl		captab, metalaxyl, thiram, tolclofos-methyl

Table 5 lists some chemicals that are recommended and their uses. With the exception of gamma-BHC these are relatively low-toxic chemicals. But you should still use them carefully: all pesticides are toxic, otherwise they would not kill! Always read the label very carefully, and follow the instructions on it regarding the quantity to use and the way to apply it, whether dusted, mixed with water, etc. Wear overalls and rubber gloves when using the chemical, and preferably a respirator too, especially with powders. Wash your clothes and yourself thoroughly after use, and do not eat, smoke or drink before having washed.

These chemicals are often sold under different trade names, but the name of the above active ingredient will also be on the label. Some trade names and their active ingredients are given in Table 6.

Table 6: Active ingredients and trade names

Active ingredient	Trade name
Captab	Captan, Orthocide
Carboxin	Vitavax
Chlorpyrifos-methyl	Reldan
Imidacloprid	Gaucho
Gamma-BHC	Lindane
Mancozeb	Dithane M45
Mercaptothion	Malathion, Merkaptotoks
Metalaxyl	Apron, Ridomil, Emerald
Pirimifos-methyl	Actellic, Cooperfos
Pyrethrins	Numerous, most ending in '–thrin'
Thiram	Thiulin, TMTD
Tolclofos-methyl	Rizolex

Treating seed can be done in various ways:
- Spread the seed on a tarpaulin or a concrete floor, sprinkle the chemical over it, and mix with a shovel (for powder forms only).
- Put seed and chemical in an oil drum fixed on a stand, and turn with a handle (see Figure 17).
- Use a concrete mixer.

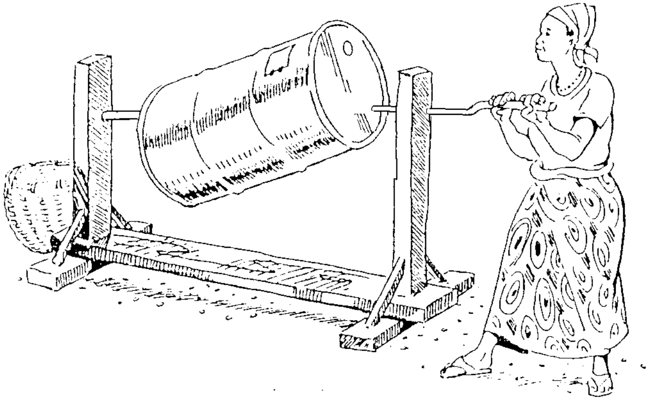

Figure 17: Simple treating machine for seed

Any seed treated with a liquid mix (a ‘slurry’) must immediately be allowed to dry before packing or using it.

When you plant by hand seed that has been treated with a chemical, you should be just as careful as when treating the seed in the first place. And so, of course, should your customers. Wear overalls and rubber gloves, wash these and yourself after use, and do not eat, smoke or drink before washing. It is good to have a clear warning on the pack when selling treated seed, and in many countries this is in fact compulsory.

6.3 Difficult cases

Some seeds are quite difficult to keep, and they lose their viability quickly. The most difficult among the cereals and pulses is no doubt the soya bean. Other tricky examples are groundnuts (including Bambara and Kersting’s) and wheat.

Wheat can be stored relatively well, but careful moisture management is crucial. The seed must be dried properly, and during storage it must be carefully prevented from picking up moisture again. If this can be managed, there should not be too much loss in germination.

With groundnuts, careful drying and curing is also essential. However, most further problems can be avoided by keeping the seed in the pod, and shelling only just before planting.

Everything has to be just right with soya beans, otherwise storage will be a failure. This includes harvesting the seed at exactly the right time, drying immediately to the right moisture content, and packing it air-tight in sealed plastic bags or drums. Refrigerated storage is also very good, but expensive. Storage in normal air can only be done if the air humidity is less than 45 percent, and there are not many situations in which this can be achieved. The only other way is to plant a bit of seed again within a month, if necessary under irrigation, and harvest your actual seed crop just before the planting time of the commercial crop. In fact, you are then storing in the field.

6.4 Good housekeeping

All your efforts to prepare the seed for storage will be useless if the storage environment is unsuitable. The three keywords here are dry, cool and clean.

Apart from through roof leaks, moisture can enter the storage area through walls and floors, as well as through flooding or by being blown by the wind through windows. An overhanging roof gives sideways protection. A threshold will repel surface runoff from entering under the door. Proper plastering on the in- and outside will reduce the amount of moisture coming through the walls. As a last precaution, seed should never be stored in direct contact with the floor or walls. The stack should be away from the wall, and off the floor on a wooden pallet or platform made from poles. Old sheets of corrugated iron on bricks also make excellent platforms, if you first hammer flat any sharp bits.

To keep the storage area cool, any windows should be whitewashed. If storage is in a metal tank it must be shaded completely. Setting the storage container in a windy place also helps.

Cleanliness reduces the chances of any spilt material attracting moisture, fungi or pests. It includes keeping the storage area or container in good repair, closing any entry points for rats and mice, and sealing cracks in which insects can breed. Keep the seed stocks tidy as well, by keeping different batches separate to avoid admixture and confusion.

If seed is stored for a prolonged period, regular baiting against rodents as well as fumigating against insects may be necessary.

7 Seed sales as a small business

7.1 Business potential

Once you have attained some success in improving your cultivars and producing clean and vigorous seed, neighbours and other farmers will start wanting to buy from you. The question is then: are you going to specialize in seed production and make a business out of it? The answer to that question requires some careful consideration.

Market potential

Selling some seed to your neighbours every now and then is one thing, but having large surpluses every year for which you have to find a market is quite another. The first step is to ensure that you know as accurately as possible how big the market for your type of seed is, and exactly what seed and cultivar characteristics it demands. Market size will be the more difficult of the two; you will most likely have to rely on your own judgement as in many cases there will be no figures available. If you have the time, or know someone who can do it, a formal survey would be most helpful.

In considering this option, it is useful to ask the question: what reasons do farmers have to buy seed? The answer can fall in one or more of the following categories: genetic, physiological, physical or sanitary reasons, or plain availability.

- Genetic: A new cultivar has been introduced and farmers want to get hold of it, or the farmer's own seed of an existing cultivar has deteriorated genetically through admixture, outcrossing or mutation and has to be replaced. Opportunities exist if you can regularly offer improved cultivars, or when it is difficult for the farmer to keep seed of a crop genetically pure (cross-pollinators). You will have to have good contacts with breeders, or with researchers who try out a lot of new cultivars from within or outside the country.

- Physiological: If the farmer's seed has deteriorated physiologically and does not germinate any more, it usually has to do with storage. Some crops (soya beans, groundnuts, in certain situations wheat) are inherently poor keepers, and they can offer business opportunities if you have better storage or can produce in the off-season. In other crops it can be just a matter of having better storage than most farmers, or better control over harvesting methods.
- Physical: Producing seed of good physical quality that is free of dirt, crop remains, broken seeds, and above all weed seeds can be a problem with certain very small-seeded crops, like grasses. It is not usually a problem with cereals and pulses.
- Sanitary: Some crops suffer more from seed-transmitted diseases than others, and if you can consistently produce healthy seed you have a business opportunity. This might be through better field practices, through chemical seed treatments, or through off-season production or production in a different area.
- Availability: Farmers may also need seed because they don't have farm-saved seed. However, this is usually a result of poverty, and of not being able to afford to buy any. That is unfortunately not much of a business proposition. There may, however, be possibilities for barter trade, if you can make use of the products they offer.

In general, one can say that the more difficult it is to produce good seed of a crop, the more likely it is that there will be a market for it (see Table 7).

You may think that as an experienced farmer you have a good idea already of the type of cultivar characteristics that farmers want, and you may be right. But it is always advisable to keep an ear to the ground for any changes in preferences that may occur. Visit field days, fairs, markets or other gatherings of users of seeds as well as of their end products, and talk to as many people as possible, to keep abreast of and anticipate needs.

Figure 18: Plan your multiplication stages to obtain the right quantities of seed

Producing seed for a market means that you have to be able to anticipate the quantities required, since it may take some time to build up your volumes. The important thing is that crops differ in their *multiplication rate*, that is, the amount of seed harvested for every kilogramme planted. Low multiplication rates are a feature of mostly large-seeded self-pollinators like beans and groundnuts, and also barley and wheat under certain conditions. The lower the multiplication rate, the longer it takes to reach a given quantity from a fixed starting weight, or from a certain limited piece of land. The more seasons it takes, the longer the lag time to respond to demand, and the more difficult it will be to predict requirements. This puts you at the risk of either being seen as unreliable because you don't have stock, or having to get rid of excess stock at commercial grain prices. It is easier to start a seed business in crops with a high multiplication rate (sorghum, maize, millet, pigeon pea, lentils).

Table 7: Seed enterprise potential of different crops

Crop	Potential	Reasons	Remarks
Barley	Poor	Seed easy to grow, low income farmers, low multiplication rate.	Potential good when grown for brewing, if a pure cultivar is demanded by the industry.
Finger millet	Poor	Same as barley (except multiplication)	New cultivars could find a market.
Maize	Good	Cross-pollinator with high multiplication rate.	New selections with added value can be made relatively easily.
Pearl millet	Medium	A lot of scope for cultivar improvement, some for seed treatment against disease.	Cross-pollinator, needs cultivar maintenance.
Rice	Poor	Seed easy to grow, self-pollinator.	Some limited potential in cultivar development.
Sorghum	Medium	Some scope for cultivar improvement and seed treatment against disease.	
Wheat	Good	Off-season production, storage, and seed treatment.	
Chickpea	Poor/good	Seed easy to grow, self-pollinator.	In many places seed diseases are a problem and can create business opportunities.
Cowpea	Poor	Seed easy to grow, self-pollinator.	In a few places virus diseases may create opportunities.
Groundnut	Medium	Crop often commercialized and seed shortages are common.	
Phaseolus bean	Poor/good	Seed easy to grow, self-pollinator, low multiplication rate.	In many places seed diseases are a problem and can create business opportunities.
Soya bean	Good	With good disease control and storage conditions a very high potential.	

For many crops the market size fluctuates. This is most apparent with those crops for which farmers easily keep their own seed. In normal years, only a small percentage of farmers will want to replace their seed. If the previous season was bad, and many farmers have lost their seed stock or have obtained low yields, the demand will be high. But a seed producer is then also likely to have small stocks available! Conversely, a good season will give you a high seed yield, but demand will be reduced because everyone had a good year. This difficulty is not easily overcome, and crops that exhibit this type of market size fluctuation are not good candidates for a commercial seed venture. This applies to most self-pollinators without serious disease or physiological problems, such as rice.

Price

What price must you charge to get a return on your costs and efforts, and how much is the customer willing to pay or can the customer afford? The answers to these questions will determine the commercial viability of a seed enterprise. The figures will differ from place to place and crop to crop, and have to be calculated carefully, but we can give some rules of thumb.

If you produce your seed from a normal crop field through setting aside part of the crop or doing simple selection, you can value the product at 5 to 10 percent above the value of the grain crop. If you set aside special seed production fields, to which separate management and input standards are applied and separate attention is given, the value could be up to 20 percent higher than that of grain from similar fields or farms. Further specialization, post-harvest handling with machines, treating and packaging could add anything from 50 to 100 percent to the value of the crop. On top of these values would then come a percentage for your return, as well as that of any other party involved in the chain, such as transporters, distributors and retailers. The end result could well be seed costing three to four times the price of commercial grain.

Are farmers able and willing to pay this? That depends to a large extent on what they get for their money, and what the alternatives are. If the product addresses a major problem in one of the areas listed under 'Market potential', chances are that it is very much worth their while. Any extra cost of seed compared to using one's own, or compared to buying consumption grain for example, has to be measured against the increase in value of the final crop, and will weigh more heavily in crops with a low multiplication rate. Two examples are shown in Box 5.

Box 5: Two examples of decisions to buy or not to buy seed

Let us say that to plant a hectare of maize a farmer needs 20 kg of seed, and he harvests 2000 kg of maize. The multiplication rate is 100. The price of maize grain is 10 money units per kg, so using his own seed costs him 200 units. Buying improved seed will cost him 40 units per kg, or 800 units per hectare. To pay for this, the improved seed must give the farmer a yield increase of 600 units, or 60 kg, or 3 percent. This is in most cases quite a feasible proposition, so farmers are likely to buy.

On the other hand, to plant a hectare of groundnuts a farmer would need 100 kg of seed. His harvest could be 800 kg (multiplication rate: 8). With the same prices per kg as in the first example, improved seed will cost him 2900 units per ha more than keeping his own, and to pay for that he will need a yield increase of 36 percent. It is easy to see that seed alone is not likely to give such a jump in yield. This means that the seed producer will either have to have an exceptional product, or will have to cut his costs and margins severely, to have any chance of selling at all.

If there is a large-scale commercial market for a crop, there is a better chance that farmers will be able and willing to pay more for seed. An example could be a commercial extractor of soya oil. Farmers producing soya beans for sale to a factory will be more aware of seed quality and uniformity issues, since the factory will refuse substandard product. The guarantee of monetary income may also make the availability of cash for inputs easier.

Production planning

In the section about market potential we already referred to the lag time in production due to different multiplication rates. This has financial and technical repercussions for the seed production enterprise.

A considerable amount of money will be tied up in stocks of seed under multiplication, especially for crops with low multiplication rates.

Even the crop that will be sold in the next planting season has to be bought from the producers at the end of the last season. This often covers a period of several months to half a year, and it is the biggest strain on working capital in a seed enterprise. For example, to increase the volume of bean seed from a few kilograms to several tens of tons takes three to four growing seasons. All that time, the stock ties up money. If there is only one growing season per calendar year this can become an insurmountable obstacle.

Figure 19: For maize one or two rounds of multiplication will do.

There is also a technical problem with long multiplication sequences. Every extra round of multiplication increases the chances of changes in the genetic make-up of the cultivar. Tight supervision on the genetic integrity of the cultivar is essential. The best system is to have a continuous positive mass selection programme running separately from the seed production programme. The selection programme is meant to maintain the cultivar true to type. Any bulk seed coming out of the selection programme enters the seed production programme.

Other business issues

Like any other product, seed needs to be presented to the customer in an appealing way at the right time, quantities and places. The customer must also be made aware of its characteristics and availability.

Packaging must bear in mind the normal quantity required by the farmer. In small-scale farming that might mean 10, 5 or 2 kg bags instead of the 25 to 50 kg bags common in the commercial sector. Small farmers also buy with their eyes, so plastic bags that show the seed, with an attractive and informative design, will sell much better. This also offers good opportunities for the development of brand recognition.

Distribution can be a major problem. It is important to get the seed close to the farmers in time, that is, near the start of the rainy season. But as many small farmers buy inputs with money earned by family members who are in paid employment, it is equally important to have the seed available where the money is earned, i.e. in town. It is impossible for the seed producer to handle all this by himself, so linking up with reliable partners in the distribution and retail business will become essential.

Advertising and promotion is the last important element. Most small farmers can be reached most effectively by radio, and radio advertising is a very powerful tool. It avoids the illiteracy problem, and in most small farmer cultures the oral tradition is strong. The radio moreover often carries an aura of authority, and people tend to doubt the truthfulness of radio far less than that of newspapers. Posters hung up in strategic places (shops, meeting halls, bus stations) and flyers handed out at community events can also have a strong impact, with text for the educated and pictograms for the illiterate.

Demonstration fields are another powerful tool. Try to find farmers with fields in strategic places, such as near road junctions, bus stops, or other community gathering points with a lot of traffic. Try to convince them to plant your seed there (hint: giving it away is often not the best idea; try instead to sell it 'at a big discount'), and put up a sign once the crop looks good. Holding a farmers' field day, if possible with the help of the local extension worker, is also a good strategy. You will hear farmers' comments first hand!

Figure 20: Different buyers have different needs: make sure you can provide the quantities of seed they need

7.2 Regulatory issues

Most governments have over time become aware of the importance of the seed industry to the overall performance of agriculture. Their reactions have been varied, but generally restrictive. In most cases this is motivated by a desire to protect farmers against the risks of purchasing inferior quality seed or seed of unsuitable cultivars. Before setting out to market seed on a wider scale than among your immediate neighbours it will be prudent to investigate what, if any, regulations will apply to you. There are various possibilities.

Many governments require seed producers and traders to register with an appropriate authority. This may include submitting your premises to inspections and your stocks to regular sampling for quality testing. It may also involve various regulations regarding the control of repacking of seed.

One or more Variety Lists may be in operation. This involves the conducting of variety trials by the government or an authorized institution, procedures to evaluate the trials, and a procedure to place cultivars on the List. Only seed of cultivars on the Variety List may be sold.

A Seed Certification Programme may also be in operation. Under such programmes, seed production fields have to be registered and will be visited by inspectors. Quality standards are set out, and only seed that passes all tests may be sold. Often the seed producer has to pay for such services.

Besides protection of the seed buyer, there may also be regulations that protect the seed producer. The most important ones are Plant Breeder's Rights (PBR) or Plant Variety Protection (PVP) legislation, and recently also patenting. Not many developing countries have implemented these yet, but their numbers are increasing. Under PBR or PVP legislation the owner of a cultivar on the Variety List has the exclusive rights to that cultivar, and any propagation of it by unauthorized persons is prohibited. In exchange, the owner has the obligation to make adequate quantities of seed available for sale, either by himself or through a licensing agreement, under which he will be entitled to receive royalties. So if you want to multiply such a cultivar, you should reach an agreement with its owner. It is important to note that cultivars protected under PBR/PVP laws can be freely used by others in breeding programmes to develop new cultivars. New cultivars that cannot be distinguished from ones already on the list cannot be registered and sold.

With the advent of biotechnology and genetic modification this protection was not deemed adequate any more, and in many countries cultivars and genes can now be patented. This means that any unauthorized use of such a patented gene is now prohibited, even if the cultivar that carries it is clearly distinct from all others. Even if the gene ended up in a new cultivar unintentionally, for instance through natural cross-pollination, it still constitutes a patent infringement which is punishable by law. You will have to find out if this could pose a danger to you.

The rights of farmer communities to traditional cultivars are now also almost universally recognized, if not yet everywhere under formal legislation. This means that in some cases it may not be possible to use traditional cultivars in a breeding programme without first reaching an agreement with the community in question.

List of cereal and pulse crops by pollination type

Table 8: List of cross-pollinators, self-pollinators and intermediates

1. Cross-pollinators	**2. Intermediate**	**3. Self-pollinators**
- Cereals:		
Adlay (Job's tears, Coix lachryma-jobi)	Amaranth	Barley
Amaranth	Common millet (Panicum miliaceum)	FInger millet (Eleusine coracana)
Buckwheat	Foxtail millet (Setaria italica)	Oats
Maize	Sorghum	Quinoa
Pearl millet (bulrush millet, Pennisetum glaucum)		Rice
Rye		Teff
		Wheat
- Pulses:		
Kidney bean (scarlet runner bean, Phaseolus coccineus)	Adzuki bean (Phaseolus angularis)	Bambara groundnut
	Broad bean (Vicia faba)	Chickpea
	Cowpea (in humid climate)	Cowpea (in dry climate)
	Lima bean (Phaseolus lunatus)	Groundnuts (peanuts)
	Pigeon pea	Kersting's groundnut
		Lentils
		Peas (Pisum sativum)
		All Phaseolus beans (except kidney, adzuki and Lima)*
		Soya bean

* = in Mexico and the West Indies certain insects can cause considerable cross-pollination in common beans (*Phaseolus vulgaris*)

A crop can be either a cross-pollinator or self-pollinator (see Chapter 2), but a small percentage of the other type of pollination usually occurs as well. When this is very little (less than 5 percent) we disregard it for seed production purposes, and the crop is treated as a complete self- or cross-pollinator.

There is also a category of intermediate pollinators. This contains crops that have, next to their main method of pollination, a significant amount of the other type as well. For practical seed production purposes a cross-pollinator with a lot of self-pollination is still a cross-pollinator, even if self-pollination is more than 50 percent. You will get poor results with these crops if you use methods designed for self-pollinators. However, when a self-pollinator has between 5 and 20 percent cross-pollination it becomes an intermediate type. For the selection of new cultivars you can treat it as a self-pollinator, but for seed production it becomes a cross-pollinator and you will have to maintain proper isolation.

Further reading

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In the near future the Agromisa website will provide more information on small-scale seed production and links to other sites that deal with crop development and seed production.

Useful addresses

AVRDC: Asian Vegetable Research and Development Center, P.O. Box 42, Shanhua, Tainan, 741 Taiwan ROC; Website: www.avrdc.org; E-mail: avrdcbox@netra.avrdc.org.tw

CGIAR: Consultative Group on International Agricultural Research, 1818 H Street NW, Washington DC 20433, USA; Website: www.cgiar.org; E-mail: cgiar@cgiar.org. The website also provides access to the websites of all CG institutions like: CIMMYT, CIAT, CIP, ICARDA, ICRISAT, IRRI, ISNAR and WARDA.

FAO: Food and Agriculture Organisation of the United Nations, Seeds and plant genetic resources service, Via delle Terme di Caracalla, 00100 Rome, Italy. Website: www.fao.org

HDRA: Henry Doubleday Research Association, Website: www.hdra.org.uk; E-mail: enquiry@hdra.org.uk

IPGRI: International Plant Genetic Resources Institute, Via della Sette Chiese 142, 00142 Rome, Italy; Website: www.ipgri.org.

ISTA: International Seed Testing Association, Reckenholz, Postfach 412, 8046 Zürich, Switzerland; Website: www.seedtest.org; E-mail: ista.office@ista.ch

UPOV: Union Internationale pour la Protection des Obtentions Vegetales, 34 Chemin des Colombettes, 1211 Geneva, Switzerland; Website: www.upov.int; E-mail: upov.mail@wipo.int

Glossary

at random	By chance, without selecting, blind.
centre of origin	The part of the world where a plant was first taken out of the wild by farmers to start farming with. In the centre of origin of a crop you usually find a lot of different forms of the crop, as well as many wild relatives.
characteristic	(= trait) Anything that makes an animal, plant or thing different from other similar ones.
cross-pollination	Fruits and seeds are formed when pollen from one plant lands on the female parts of flowers of another plant.
cultivar	(= cultivated variety) A uniform group of plants within a crop, which retains its particular characteristics when multiplied in the manner that is usual for that crop.
dioecious	Each plant has either male flowers or female flowers, but not both, and cannot pollinate itself.
domestication	The process of taking a plant out of the wild and through continuous selection adapting it to the needs of man, whether for cultivation or for another usage.
gene	A unit of inheritance. All genes that determine the looks and functions of an organism are present in each cell of the organism, and are passed on to offspring through egg cells and pollen or sperm.
genetic variation	The total of all differences between plants within a group that are caused by characteristics inherited from the parents of the plants in the group. The group can be a cultivar, a crop, a species, or the whole flora of an area, but the term is most often used for groups of plants that can cross with each other.

half-sib family selection The equivalent to line selection (see below) for cross-pollinators. Because the seeds harvested on each plant have only one parent in common in cross-pollinators, the resulting offspring are half-siblings.

heritability The proportion of total variation observed in a cultivar that is due to inherited factors, as opposed to environmental ones.

heterosis (= hybrid vigour) The superiority in performance of a hybrid cultivar over the 'average' of the parents. The word is often only used when the hybrid even exceeds the best of the parents, not just the average.

hybrid A cultivar which is made by the controlled crossing of two different parents. Unless you have the exact parents, you cannot copy or reproduce a hybrid cultivar.

inherit To receive characteristics form one's parents or ancestors.

landrace A cultivar developed by farmers under influence of their farming system and their physical environment (soils, weather). Landraces are characterized by high genetic variation.

line selection A selection method that uses the whole offspring of one plant (a line) to identify wanted or unwanted traits. Normally the term is used only with self-pollinators.

monoecious Each plant has both male and female flowers, either next to each other or on different parts of the plant, but no flowers with both male and female organs. Self-pollination is usually possible.

multiplication rate The number of units of seed harvested for every unit planted. Important if you want to determine how long it will take to build up a large quantity of seed supplies.

mutation Changes occurring independently in the genetic information of an individual. Mutation can be spontaneous (a natural process) or induced by environmental factors or by man.

negative mass selection Selection method whereby only unwanted individuals are removed and the rest is harvested in bulk for seed.

open-pollinated (O.P., or O.P.V., from Variety) Propagated through random spread of pollen. Normally only said of cross-pollinated crops.

physiological maturity The point at which the ripening seed is fully developed and no further growth or storage of food reserves takes place. At physiological maturity the seed is theoretically ready to germinate, but is usually too wet to thresh or to keep for any length of time.

pollen A (most often yellow) coloured powder produced by the male flower or male part of the flower. It contains the cells which are the male 'vehicle' of genetic information, and serves to fertilize the egg cell in the female flower parts. Its function is the same as that of the sperm of an animal.

positive mass selection A selection method where individuals with desired characteristics are selected and kept separate from the bulk for further multiplication.

random drift The risk that a gene or group of genes disappears from a population, because the group of individuals selected does by chance not contain them.

remnant seed method A modification of half-sib family selection (see section 2.4), whereby half of the seed of a selected plant is kept behind for re-planting.

rogueing The pulling up and destroying of unwanted plants. These can be either plants that are infested with disease or genetically unwanted.

selection The process of improving the genetic characteristics of a cultivar through retaining the best and/or discarding the worst plants and their progenies.

seed vigour The ability of the seed to germinate and form a strong seedling under less than ideal conditions.

self-pollination Fruits and seeds are formed when pollen from a plant lands on the female parts of flowers of the same plant.

spatial isolation The practice of planting a seed crop at a large enough distance from another field of the same crop to prevent cross-pollination or accidental mixing.

systemic chemicals Chemicals that are capable of entering the plant through various means, and that are spread throughout the plant's tissues. They work against their target disease or pest from the inside of the plant.

time isolation The practice of planting a seed field before or after another field of the same crop. The difference in planting time should be large enough to prevent cross-pollination or accidental mixing.

trait (= characteristic) Anything that makes an animal, plant or thing different from other similar ones.

vegetative propagation Multiplying plants without the use of true or botanical seed formed by flowers. Many different parts of the plant can be used for vegetative propagation.