A Guide for Faba bean and Field pea Seed Producers

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Introduction

In terms of acreage and production, pulses are the major crops in Ethiopia next to cereals. They are cheap sources of protein when consumed with cereals, which are deficient in essential amino acids. Pulses play significant role in restoring soil fertility and in export market. However, pulse production and productivity are far below the potential due to insufficient supply of seeds of improved varieties. Faba bean (*Vicia faba* L.) and field pea (*Pisium sativum* L.) have the largest share of area and total national production of all pulses grown in Ethiopia.

So far, a number of improved faba bean and field pea varieties have been released. The current national Extension Package Program has made farmers aware of the importance of improved seeds. However, seeds of improved faba bean and field pea varieties are not sufficiently available to farmers. It is believed that more varieties will be released from research and the demand for high quality seed is expected to increase, because more farmers will realize the benefits of quality seeds.

In Ethiopia, where the use of improved crop production technologies and improved seeds is limited, the lack of technical skill is one of the most important limiting factors in seed production. Thus, young breeders, seed technologists, farm management units of research centers, extension workers, private seed producers and trainers hardly find suitable guide and appropriate source material to faba bean and field pea seed maintenance and production. This technical manual will hopefully fill the gap.

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Favorable Agro-ecologies

Table 3. Important morphological descriptors for faba bean

Morphological descriptors	Explanations
Plant	• Height (from the ground level to the tip top of the plant) at maturity • Number of stems (the main stem and tillers above half of the length of the main stem) • Growth habit (determinate, semi-determinate or indeterminate)
Stem	• Number of nodes (across the main stem of the plant starting from the first flowering node) • Stem color at physiological maturity (light or dark) • Stem thickness (measured as width of one side of stem at mid-height from ten single representative plants at early podding stage) • Anthocianin color (absence or presence of anthocianin stem pigmentation at flowering time)
Foliage	• Color before flowering (green, light green or dark green)
Leaflet	• Size of basal pair of leaflets at full expansion stage (small, medium or large) • Number of leaflets per leaf (mean of five leaves each of them taken from the median flowering nodes of five separate plants at full expansion stage)
Raceme	• Number of flowers at the second and the third flowering node (mean of five representative plants)
Days of flowering	• Number of days from emergence to 50% of the plants with at least one flower
Days to physiological maturity	• Number of days from emergence to 90% of dried pods
Flower	• Flower color of petal (white, violet or brown) • Length (cm) • Melanin (spotted or non-spotted) • Number of flowers per node
Pods	• Number per plant • Angle at maturity of second or third pod bearing node (erect or horizontal pendent) • Length (mean of 5 random dry pods) • Median width (cm) • Pod curvature at green shell stage (present or absent) • Shape (sub-cylindrical, flattened constricted or flattened non-constricted) • Pod color (light green, green or deep green) • Number of ovules per pod including seeds • Thickness of pod wall (low, medium or high) • Reflectance (matte or glossy)
Seed	• 100 seed weight (average weight of two samples of 100 random seeds) • color of testa immediately after harvest (black, dark brown, light brown, light green, dark green, Grey, white, violet or yellow) • Helium color (black or color less) • Seed shape (flattened, angular or round)

Table 4. Important morphological descriptors of field pea

Morphological descriptor	Explanations
Plant	• Height (length from the ground level to the tip of the plant measured at maturity) • Growth habit (determinate and indeterminate). Determinate is with terminal inflorescence and Indeterminate is Without terminal inflorescence.
Stem	• Number of nodes (across the main stem of the plant starting from the first flowering node) • Stem color at physiological maturity (light green or dark green) • Stem angulation (erect, semi-erect or fully horizontal) Number of branches Texture (ribbed or smooth)
Foliage	• Color before flowering (green, light green or dark green
Leaflet	• Size at full expansion stage (small, medium or large) • Number of leaflets per leaf (mean of five leaves each of them taken from the median flowering nodes of five separate plants at full expansion stage) • Petiole length (cm) • Arrangement (opposite or alternate)
Flower	• Number of flowers at the second and the third flowering node (mean of five representative plants) • Days to flowering (number of days from emergence to 50% of the plants with at least one flower) • Flower color of petal (white, violet or others) • Length (cm) • Pubescence (absent or present) • Bracts (absent or present)
Days to physiological maturity	• Number of days from emergence to 90% of the pods have dried
Pods	• Number per plant • Size (cm) • Type (beaked or non-beaked) • Reflectance (matte or glossy) • Pod color (light green, green or deep green) • Number of ovules per pod including seeds
Seed	• 100 seed weight (average weight of two samples of 100 random seeds) • Seed color of testa immediately after harvest (greenish, dark brown, light brown, gray, white) • Helium color (black or color less) • Seed texture (rough or smooth)

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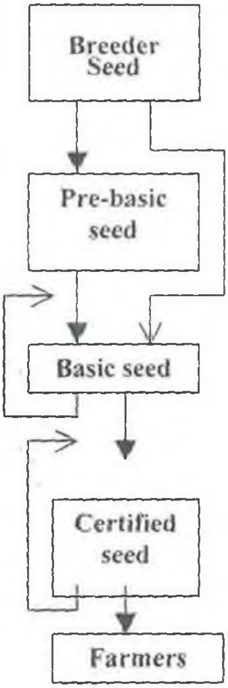
The Seed System and Seed Multiplication

The seed system

One of the sources of improved seeds to Ethiopian farmers is the formal seed supply system. This system comprises seed multiplication, processing, quality control, marketing and distribution units. The only formal organization in the seed sector is the Ethiopian Seed Enterprise (ESE). With its limited capacity, the ESE cannot produce seed which meets the national demand. Therefore, the involvement of private investors in seed multiplication would be profitable and supportive.

Under the formal system, breeders are expected to generate a small amount of seed called breeder seed. This small amount of seed is once more multiplied to produce large quantities of certified seeds needed to satisfy the national seed requirement. The breeder seed is first multiplied to produce the pre-basic seed, which is, in turn, multiplied to produce the basic seed. The basic seed is again multiplied to produce certified seeds, which is sold to farmers for commercial production. These different classes of seeds have to meet certain requirements *viz.* purity, quality, health and uniformity before they have to be advanced to the next generation or distributed to farmers (Fig 1).

The flexibility of these requirements increases as we proceed from breeder to certified seed i.e., the standards are more rigid for the early generations than for the later. Some of these requirements are examined before planting; some when the seed crop is in the field and the rest require analytical examination in seed laboratory on seed samples taken from basic and certified seeds in the storage, marketing and distribution units. Formal seed systems are usually interested in producing seeds of uniform varieties because certification procedures are based on genetic uniformity.



i. Produced by a breeder in a research center
ii. Quality controlled by a breeder

i. Progeny of breeder seed
ii. Produced at research centers or basic seed productio fields under the supervision of a breeder for quality
iii. May be omitted if there is adequate amount of breeder seed

i. Progeny of breeder or pre-basic seeds
ii. Produced at basic seed production fields under the supervision of seed agencies

i. Progeny of basic seed
ii. Produced by commercial enterprises or by progressive farmers
iii. Quality control by an official seed agency
iv. Distributed to farmers for commercial production

Fig 1. Steps of formal seed multiplication scheme

The second system is the informal seed supply system where farmers themselves produce seeds and sell to or exchange with their neighbors. This system needs to get some technical assistance from seed agency, research centers and relevant governmental and non-governmental development organizations. Faba bean and field pea require relatively higher seed rates per unit area of land. Thus, the informal seed system should support the formal seed system to fulfill the national demand.

This could be accomplished by providing progressive farmers with certified or basic seeds and the necessary technical back-ups annually or biannually. Proper training on seed production and the necessary facilities like mobile seed cleaners should be made available to the farmers until they are both technically and materially capable to carryout all tasks by themselves. Informal seed system also plays an important role in producing and distributing seeds of varieties i.e. improved landraces, populations and mixtures, developed by farmers (Fig 2).

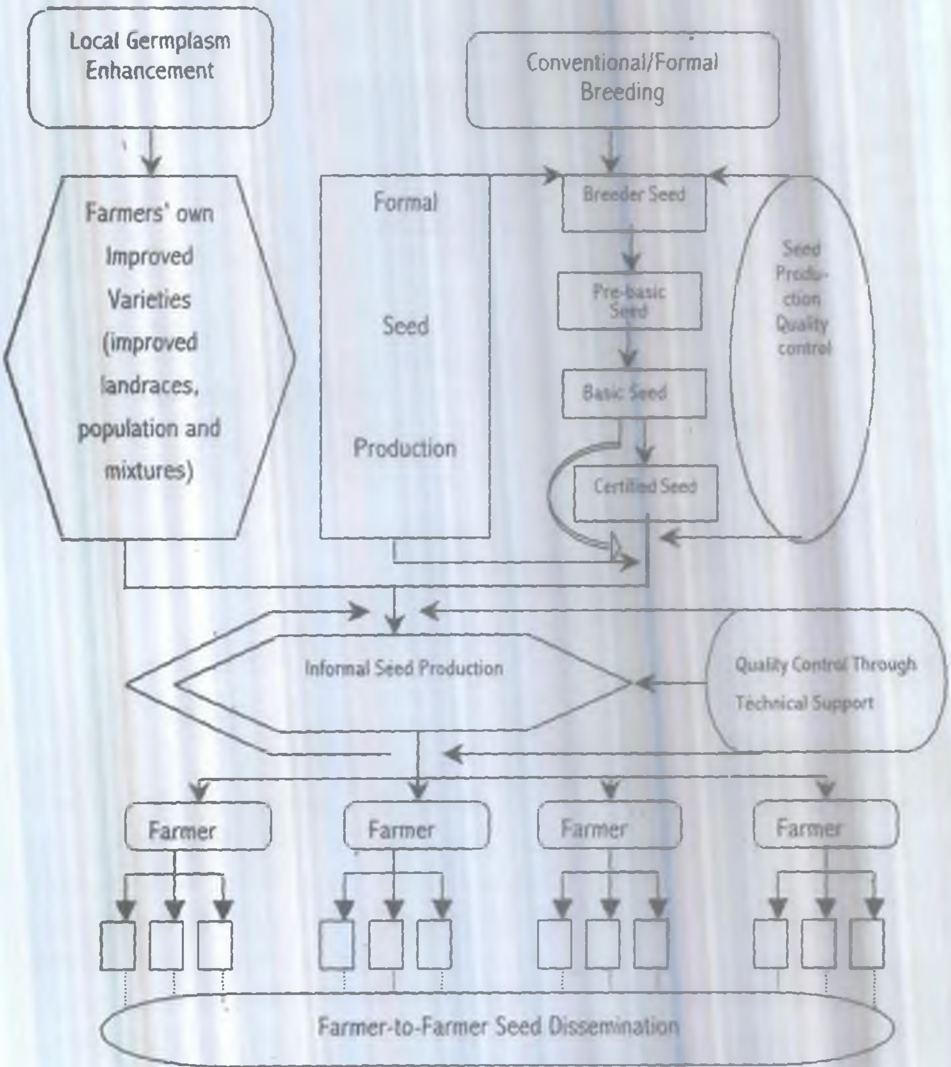


Fig 2. Hypothetical steps in an informal seed multiplication scheme

The formal system may serve in production and distribution of improved seeds to potential farmers, while the informal one may serve poor farmers who cannot benefit from the formal system. Potential farmers can also use the output of informal seed system when the formal one fails to supply improved seeds in sufficient amounts.

The amount of seed to be produced must be demand-driven. Thus, seed demand assessment is very crucial in planning seed production. The requirement for a breeder, pre-basic and basic seed depends by the demand of farmers for certified seeds. Theoretically, the demand for certified seed depends on the proportion of improved seeds utilized in a given country, seed rate per unit area and the period required for seed renewal or generation control. Average seed replacement rate for self-pollinated and cross-pollinated crops is 4–5 and 3–4 years, respectively. Assuming that all farmers regularly use improved varieties based on standard renewal rates, the annual seed requirement (SR) per year can be estimated as:

$$SR = \frac{\text{Total annual grain production area of a given crop (ha)} \times \text{seed rate (kg)}}{\text{Seed renewal rate (years)}}$$

However, seed requirement is a complicated phenomenon influenced by several factors. The economic background of subsistence farmers is not stable and the cropping pattern changes with the actual climatic condition of a given season. In such cases, seed requirement of farmers is determined by external factors like rainfall pattern and farmers' purchasing power. The stability of market price for grain and grain products and social services like credit system are also decisive for farmers' decision-making. Experienced professionals who have good knowledge of updated social, economic and climatic situation should, therefore, assess and predict the demand for seed.

Seed multiplication

Maintenance of breeder seed and the initial increase

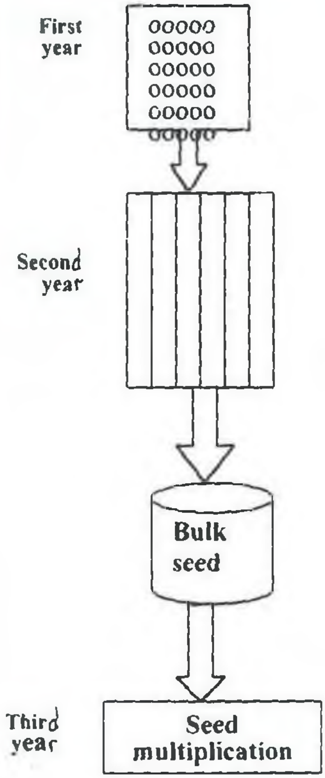
Since the variety is targeted for commercial production, maintenance of original materials and the initial increase of breeder seed are essential to sustainably produce certified seed. Breeder institutions, that develop the varieties, have the responsibility to maintain released varieties and to produce breeder and pre-basic seeds. The initial breeder of a variety has a responsibility for maintaining the breeder seed and for its adequate supply for subsequent steps in the seed multiplication process.

Maximum care must be made to maintain the genetic purity of original materials. As breeder seed is the earliest generation, any mistake made at this stage will be difficult to correct later. Moreover, the lose of breeder seed would result in the lose of certified seed source material for a complete generation. Some of the main causes of genetic deterioration during seed production are mechanical mixtures and natural out-crossing with different varieties of the same species.

The purity and original genetic composition of breeder seeds of self-pollinated crops like field pea should be maintained by sufficient isolation, mass selection and thoroughly roguing off-types both during maintenance and initial increase. Varieties of these crops may become impure, at certain interval of period, due to cumulative effects of the minimum natural out-crossing that may exist, off-types and mechanical mixtures. This necessitates varietal purification at certain periods.

To purify the breeder seed of field pea, a representative amount of seed (≥ 2500), typical for the variety, should be sown in bulk. It also needs to provide enough space between and within rows to easily observe individual plants. Representative amount of phenotypically similar plants (≥ 500) with the characteristics described for the cultivar should be selected and sown in progeny rows during the succeeding year. This helps to observe and reject any progeny that does not confirm to the original variety.

During the entire growing season progenies are carefully observed for any deviation from an official variety description. When off-types are found, the complete progeny is discarded. The progeny rows could be located at the middle of pre-basic or basic seed fields of the same variety so that any rare cross-pollination or a mechanical mixture that may take place will be between the progeny rows and pre-basic or basic seed fields. Individual plants for the next generation of breeder seed should be selected and kept. Seeds that prove to be similar to the original variety for qualitative and quantitative characters and resistant to major stresses should be bulked to make pure seed of the cultivar (Fig. 3). However, care should be taken to maintain the initial genetic make up of the variety when selection pressure is applied.



i) Plant a representative amount of (≥2500) seed in a bulk plot with enough spacing
ii) Select representative amount of phenotypically similar plants (≥500) with the characters described for the cultivar

i) Grow selected plants in progeny rows
ii) Reject progeny rows which do not confirm to the description of the cultivar or in which off-types are found
iii) Select and keep individual plants similar to the original description for the next generation of breeder seed

i) Bulk seeds from selected plants that confirm to the original description of the cultivar to make pure seed of the cultivar

i) Put the bulk seeds in the seed multiplication cycles
ii) Repeat the above when it is felt that the seed is contaminated

Fig 3. Procedures of field pea breeder seed purification and maintenance

Maintenance of parental materials in faba bean needs very strict attention as compared to field pea, because the crop is more liable to genetic deterioration from foreign pollen. Though the procedure is similar to field pea, more care should be taken to avoid out-crossing. The common way of breeder seed maintenance and production in faba bean is to extract parental materials from a well-isolated breeder seed increase field (at least 800m). At least 500 representative plants should be selected based on distinguishing quantitative and qualitative characters of the variety, which are resistant to major stresses. Each plant should be threshed separately and examined for its distinguishing characters, to discard those that do not confirm to the characters of the variety.

The next maintenance cycles of parental materials should be grown from the seeds of selected plants in progeny rows under isolation. The individual progeny rows should thoroughly be examined before and during flowering, and when it matures physiologically. This helps to identify and discarded off-types, deficient and diseased plants. At least 500 individual plants should be selected to grow the next cycle breeder seed and the remaining progeny rows should be harvested in bulk to constitute the breeder seed that is going to be multiplied into basic see (Fig. 4).

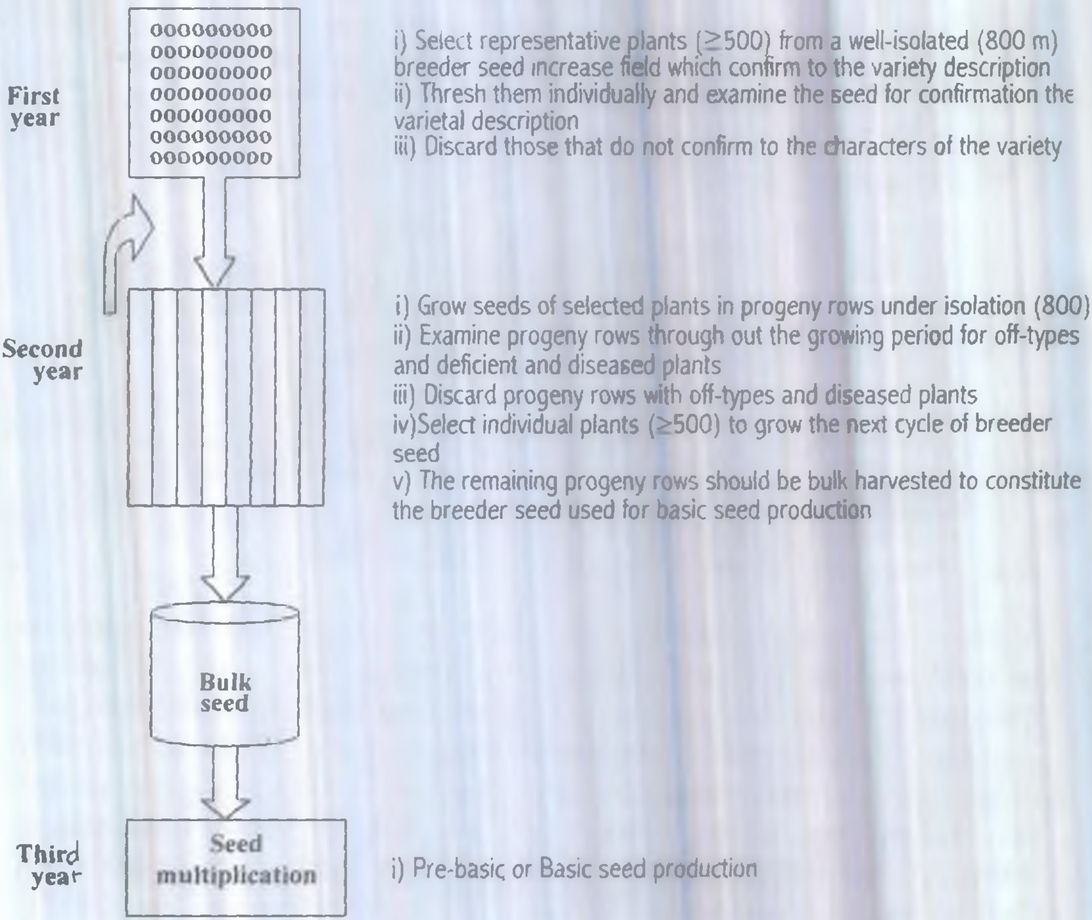


Fig 4. Procedures of faba bean breeder seed maintenance

Because of their seed size, faba bean and field pea require relatively large quantity of breeder seeds. When land is scarce, the second or third increases of breeder seeds need to be arranged for the pre-basic seeds. The sites should be different with the breeder's nursery and this needs a frequent supervision of the breeder and seed specialist.

Where natural calamities like hail damage and drought are frequent, risk aversion strategies such as producing adequate amounts of breeder and basic seeds during good seasons and keep reserve stocks for use during bad seasons are important. Because, there is less work than producing each year new lots of breeder and basic seeds and the variety will not be subjected to genetic shift especially in faba bean. The more the generation of cross-pollinated crops are grown, the more they lose their genetic identity.

The effect of inter-crossing is minimized by reducing generation advance using medium or long-term maintenance of breeder or basic seed and using its sub-sample for multiplication. Equally important is to spread risks by planting seed crops in several areas. Using irrigation in off-season and avoiding initial, mid-term and terminal moisture stresses during main season are the other risk aversion strategies.

Field requirements

Site selection

To harvest quality seeds, each variety should be produced in areas where its adaptation areas. Seed production fields should have easy access of transport and possibly near to seed processing plants. Irrigable land and irrigation facilities are also important to avoid risks of moisture shortage at any stage of crop growth. Seeds should be produced under uniform fields to attain full genetic expression and uniform stand of the crops so that an easy identification of off-types is possible.

Faba bean and field pea seed production should not be undertaken on a farm where different varieties of the same crop had grown in the previous year. Such fields need to be free of volunteer plants by allowing an interval of one crop of another species. A land to be used for seed production also needs to be free of volunteer plants introduced by hand-pulling. The other option is to irrigate the field 2-3 weeks before planting. This practice stimulates early germination of seeds of volunteer plants, which could easily be up-rooted.

Careful selection of land minimizes the work of rouging off-types. Planting in a field crossed by roads and close to seed warehouses or other installations is not advisable. A seed production field should not be located on the bottom of a sloppy field.

Large farms are favorable for seed production than small farms because, large farms are easily manageable in terms of equipment and supervision.

Managing seed production fields

There is no specific crop management recommendation for faba bean and field pea seed production, which differs from grain production. Full genetic expression of the plant is necessary to identify desirable ones and eliminate off-types. This is possible under good crop management condition. Therefore, available recommendations should strictly be followed in seed production.

Faba bean and field pea are sensitive to soil layers and surface compaction. They do not require a fine seedbed. Only 2-3 times plowings with a local plow or one disc-plowing followed by two disc-harrowing is enough. Preparing the farm before the usual time is also advantageous, because it encourages weed seeds to germinate so that they can be destroyed in subsequent cultivations.

Since lately sown crops can run into the periods of low moisture and heavy aphid infestation in mid altitude and frost areas of high altitude, timely sowing is essential for optimum yields. In a main season, the recommended sowing date is from mid to the third week of June for mid altitude and last week of June to first week of July for high altitude areas. These recommendations are based on the onset of rainfall. Where lodging is suspected, it is advisable to use 10% less fertilizer and less seed rate than the recommended. The desired population is about 0.5 million plants for faba bean and 1.0 million plants for field pea per hectare and this can be achieved by setting the seed rates. Seed rates can be calculated by considering the size of the seed, germination percentage and expected field loss due to birds, soil born diseases, insects etc as indicated below:

$$\text{Seed Rate (Kg/ha)} = \frac{10\,000 \times \text{required plants}/m^2 \times 100 \times 100}{\text{Number of seeds/kg} \times \%\text{germination } 100 - \text{expected field loss}}$$

For example, given that 50 plants (assuming a space of 40cm between rows and 5cm between plants) of faba bean are required per m², 3 500 seeds make a kilo and the seed have a germination rate of 85% with an expected field loss of 20%; then:

$$\text{Seed rate} = \frac{10\,000 \times 50}{3\,500} \times \frac{100}{85} \times \frac{100}{100-20}$$
$$= 142.86 \times 1.18 \times 1.25$$
$$= 210.72 \text{ kg/ha}$$

It should be noted that the type of soil influences the seed rate required in that higher germination capacity and vigor are required for good population density in heavy soils.

Though blanket application of 100 kg DAP/ha is recommended to soils of poor fertility groups for faba bean and field pea, the results of fertilizer trails so far are not consistent as these crops are very sensitive to environmental changes. Therefore, seed producers should undertake subsequent fertility trials to determine the most accurate and site-specific fertilizer requirement.

During their critical competition period, weeds can cause substantial losses to faba bean and field pea. The critical competition period of weeds for both crops varies from 3 to 8 weeks after emergence. Faba bean is more sensitive than field pea to weed competition. The common weeds affecting these crops are broad-leaved and both annual and perennial grasses. Major weeds in faba bean and field pea are manageable by hand weeding or by spraying herbicides. Faba bean needs hand weeding for twice; the first weeding could be applied three to four weeks after emergence (WAE) and the second 6 to 8 WAE. For field pea single hand weeding is enough during three to four WAE.

Chemical weed control gives the desired effect in large-scale faba bean and field pea seed production. Effective pre emergence herbicides against annual and broad-leaved weeds are: Terbutryn (Igram 500 FW) at the rate of 2 kg a.i./ha and mixture of Terbutryn + Terbutlazine (Topogard 500 FW) at the rate of 2 kg a.i./ha. Fluazitop-butyl (Fusilade 250 g/l EC) at 0.25 kg a.i./ha applied as post-emergence treatment controls late emerging annual grass weeds in both crops.

Pre-emergence herbicides are advantageous because they do not require incorporation after spraying. But favorable soil conditions like good tilth and soil moisture are necessary for optimum performance. Pre emergence herbicides often fail to work when the soil is too dry after the time of application or when dry spell follows the application made on moist soil.

As compared to other crops, insect pests that attack faba bean and field pea are few. Major insect pests, which attack both crops in a field, are pea aphid *Acrythosiphon pisum* and pod borer *Helicoverpa armigera*. Cypermethrin (Cymbush 10% EC), at the rate of 150g a.i./ha, can effectively control pod borer when it is sprayed at a time of infestation. On the other hand, Pirimicarb (Primor 50% WP), at the rate of 0.5 kg a.i./ha, can effectively control pea aphids. Using herbicides is economical when 35% of plants are infested.

Faba bean is mainly affected by chocolate spot *Botrytis fabae*, rust *Uromyces viciae-fabae* and black root rot *Fusarium solani* while field pea is affected by aschochyta blight *Mycosphaerella pinodes* and powdery mildew *Erysiphe polygoni* diseases. Currently, most of our improved faba bean varieties are moderately tolerant to chocolate spot infection. Therefore, if quality seed is the target, they need some protection with fungicides under sever infestation. Good yield and quality seeds can be obtained by foliar application of Chlorotholonil (Bravo 500 or Daconil 2787) at the rate of 2.5kg a.i/ha every 10 days when infection reached 30% and Mancozeb (Dithane M-45) at the rate of 3kg a.i./ha every week at the same thresh hold level. In addition, to remove or bury all old faba bean trashes that harbor spores, and a practice of crop rotation reduces primary inoculums that starts infection in a new crop.

Mancozeb (Dithane M-45), at a rate of 2.5 kg a.i./ha at weekly intervals can effectively control rust in faba bean. The application should be started when about 5% of the crop is infected. It is beneficial to spray the crop when it is at flowering or at early pod setting. Rust does not affect crops that are in late grain filling stage. Warm and humid weather is favorable to the disease.

Black root rot in faba bean can be controlled by proper water drainage. Water logging aggravates and initiates black root rot development. Therefore, proper drainage is a must where camber beds, broad beds and furrows may serve the purpose.

Chlorotholonil (Bravo 500 or Daconil 2787), at the rate of 2.5kg and 1.0 kg a.i./ha, can effectively control Ascochyta Blight in field pea. Metalaxyl (Ridomyl MZ), at the rate of 1.0 kg a.i./ha, can effectively control the same disease. The chemicals are effective when the weather two weeks after an application is expected to be wet and warm, and when the crop is before and/or at its flowering stage. Late spray may result in poor yield.

Benomyl (Benlate), at the rate of 2kg a.i /ha every two weeks, can control Powdery mildew in field pea. It is effective when the infection reaches about 5%. When infection starts early in the season, all plant growth stages are vulnerable to the disease and the yield lose is heavy. Removing all old field pea trashes and residues from the field before sowing and a practice of crop rotation reduces the primary inoculums that start infection in a new crop.

Maintaining physical and genetic purity

Seed production fields could be subjected to the following contaminations:

- genetic contamination caused by cross-pollination with other varieties of the same species growing in the field or surrounding area; and
- mechanical contamination caused by mechanical mixture with seeds of other varieties of the same crop.

The contaminants may genetically derive from the crop of previous seed production field, mechanical mixture of undesirable seed in the prior production fields or in the seed lots. They may also derive from volunteer plants resulting from seed left by the prior crop and seed brought to the field by water, birds, animals, people or agricultural equipment.

The effects of genetic and physical contamination can be reduced by appropriately and distantly isolating and rouging off-types and by avoiding mechanical mixtures.

Distantly isolating: The way fields should be distantly isolated varies depending on the type of crop and stage of seed production. In basic seed, faba bean and field pea require isolated distance of 400m and 20m, respectively, from other fields of different varieties of the same crop on each side of seed production field. This method is effective to prevent out crossing in faba bean and mechanical mixtures in field pea. Similarly, isolated distances of 200m for faba bean and 10m for field pea is required in certified seed production (Table 4). However, the distance for faba bean could be reduced if there are physical barriers between two fields cropped with different varieties of the same species that prevent easy movement of pollen from one field to another variety of the same species through pollinators. Faba bean production field can also be surrounded with species like rapeseed that does not intercross with faba bean but attracts the same pollen-transferring insects. The assumption is that the pollen-transferring insects first visit border plants and lose their atypical faba bean pollen to them.

Rouging: Off-type field pea plants should be removed from the seed production field when they can easily be identified. Identification could easily be done at flowering stage. However, off-types should be removed from faba bean fields before they shed pollen to prevent out-crossing. They can be identified by their deviation from the genotype i.e., plant type, size, pigmentation, flower color, etc. Their size and position out of rows can also help to trace and identify volunteer plants. Generally, the proportion of maximum permissible off-type plants to both crops is 0.1% in basic seeds, and 0.2% and 0.5% in certified seeds of faba bean and field pea, respectively (Table 4). Equally important is to rogue plants that look diseased and defected.

Mechanical mixtures: Machineries and equipment should be cleaned during planting and vegetative stages to avoid mechanical contamination by seeds of weeds, other crops or other varieties of the same species.

Harvesting and threshing

Late harvesting may cause shattering and, shedding and rotting of pods if untimely rain is encountered. Therefore, harvesting should be done when leaves and pods dried and the grain moisture content is significantly reduced. Under the climatic condition of Ethiopia, where the time of harvesting usually coincides with the commencement of dry season, it is possible to easily achieve low moisture contents while the crop is in a field.

Faba been and field pea are not suitable for combine harvesting. However, simultaneous harvesting and threshing may cost-effectively be executed using manual labor where labor is available and cheap. Canvases and polythene sheets also can protect the crops in the field from rain after harvesting. Faba bean and field pea are indeterminate in growth habit; the lower pods mature earlier while the upper pods are immature. Therefore, the freshly cut crops should be left on ground for about three–four weeks after harvesting. Then, after the crop get dried, it should be fed to a stationary thresher to get clean seeds. The threshing floor, for both formal and informal seed production, should be clean and preferably cemented to avoid contamination by inert matter, weed seeds and other crop or variety seeds.

Seed processing

Raw seed may comprise physically and genetically unwanted and impure substances. Therefore, a seed processing plant, which processes the crop-drying activity to its optimum moisture level for storage, cleaning and grading, testing for purity and germinability, treating for storage pests and seed borne diseases, and bagging and labeling, is a big investment by itself.

The initial moisture content of seed highly influences the viability of the seed. Thus, drying must be started a few hours after harvesting and threshing and this should continue until the required optimum moisture level is achieved. Optimum moisture content reduces the deterioration rates during storage; prevents damage that may happen due to moulds and insects' attack and, it facilitates the process. Improved seeds of highland pulses should be dried until the moisture content lowered to nearly 9%. This could be done by thinly spreading the seeds on a tray or floor out in an open sun before storage. Seeds may also artificially be dried by passing heated or unheated air through the seeds. However, this is more expensive than the ordinary drying method, although it is an obligatory especially under warm, rainy and humid environments.

Seed moisture content is basically determined by the water content of seeds in percentages. It is measured either by drying seed samples in an oven or with the help of moisture testers. The oven method involves weighing the seed samples and drying them to a constant weight in an oven. The dried seeds are weighed again and any loss in weight represents the weight of water lost due to drying. Then the percentage moisture content is estimated as:

$$\text{Moisture content (\%)} = \frac{W_1 - W_2 \times 100}{W_1}$$ Where:

W_1 is the weight of the seed sample before drying, and
W_2 is the weight of the seed sample after drying.

The use of moisture meters may require calibrations and correction factors which may need some technical skill. However, it is the most efficient and faster method.

After harvesting, seeds have to be cleaned to remove inert matters, weeds and other crop seeds, seeds of other varieties and diseased and damaged seeds. Where an appropriate machine and a right operation is employed, cleaning enhances seeds' quality like purity, germinability and health. Seed cleaning is based on differences in physical properties between the desired seed and contaminants. Cleaning is possible because seeds are different in physical properties like size, weight and shape. Sieves, mainly made of iron, are used for cleaning; they mainly sift based on the width and thickness of seeds. There are also air-pressure-based separators which take-apart seeds in relation to their weight. Hence, unnecessary particles such as dust, chaff, empty or partially filled seeds and husks would get away while heavier seeds fall down escaping the air pressure. Use of graded seeds is also important where sowing is done using seed drills and planters. Therefore, seeds should be properly graded before being distributed to farmers.

Seed storage

Faba bean and field pea seeds should be stored in a dry, cool and free-of-pest place and protected from any moisture on a floor. Stored seeds also need to be treated with a proper pesticide. But care must be taken because, improper chemicals may impair the ability of the seed to germinate. Treating seeds immediately after harvest and fumigating a store before storage keeps the quality of the seed. The most important destructive store-pest of faba bean and field pea in Ethiopia is bean Bruchids (*Callosobruchus chinensis*). Currently, the effective pesticide recommended to control bean Bruchids is to use 40g/100kg (6 to 8 ppm) rate of Primiphos-methyl (Actelic 50% EC).

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Field and Seed Inspections

Field inspection

In several countries, field inspection for basic and certified seeds is carried out by authorized agencies. Though this practice is at its infancy in Ethiopia, it is possible to train growers at least the basic seed production principles. For high quality faba bean and field pea seed production, inspectors must have a thorough knowledge and experience about varietal characteristics, common diseases and weeds of the crop. Adequate methodologies of field sampling and specific tolerance levels for contaminants are also important. Inspections should be made without any previous notification to the seed grower. The main objective of inspecting faba bean and field pea fields is to examine and determine its suitability for the task. The inspection includes knowing that the source of the crop is:

- from an approved seed supplier;
- the field meets the prescribed requirements as to the previous crop;
- in compliance with the prescribed isolation distances; and
- free of off-type plants and objectionable weeds and plants of other crops and diseases.

The field also needs a thorough assessment to assure that there are no volunteer plants. Field inspection must be carried out at crop development stages when contaminants are clearly identifiable.

Basic and certified seeds have different quality standards, which are more rigid in basic seeds for maximum permissible off-types, isolation distance and maximum permissible percent of other crop seeds (Table 4). The recommended time for faba bean and field pea certified seed inspection is thrice (before flowering, at flowering and before or during harvesting) and twice (before and during flowering), respectively. Inspection before flowering is advantageous because it gives a chance to assure that the required isolation distance is in effect and that volunteer and off-type plants are non-existent; while the one during flowering is to identify and avoid off-types having different flower colours from the described target variety. It is also essential to inspect the seed before or during harvesting to assure that it has maintained its originality as described for the variety.

Field inspection can be accomplished in two steps. First, the inspectors are required to undertake "Field Overview", whereby the inspectors walk through the field to see the general condition of the whole field. Equally important is to roughly estimate the field size and shape before inspection. If the field is regular in shape, the standard patterns of walking through the field should be followed (Fig. 5).

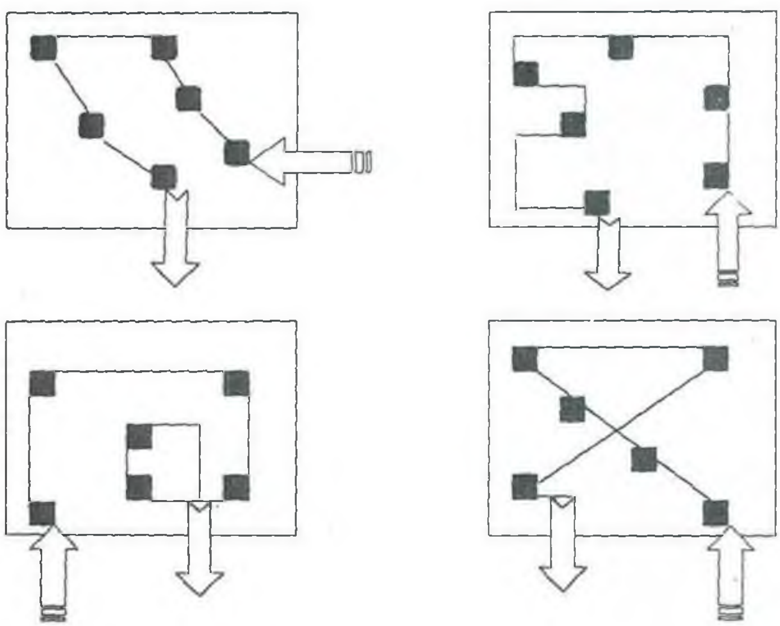

Fig 5. Possible travel patterns for field inspection

However, inspectors should modify the standard walking patterns for an irregularly shaped field in such a way the walking patterns fairly represent the whole field. The inspector should walk through the field in such a way that the sun's position helps him to clearly observe the general condition of the field.

The first and foremost requirement in seed production is that the seed to be multiplied must be officially released variety. The inspector should, therefore, identify the actual variety grown in the field. He has to carefully compare the morphological characters with the variety descriptors to assure varietal identity. If the varietal identity does not confirm to the varietal descriptors, it should automatically be rejected. When more than one-third of the crop lodges and/or causes difficulty to evaluate, the whole field may be rejected without further inspection. However, this principle may not work for prostrate crops like field pea.

The second step, Field Inspection Sample (FIS), is inevitably essential to determine the number of statistically representative plants from the field. Given the standard for tolerance level to each contaminant, the FIS should include three times the number of plants in which one contaminant is allowed. Since different generations have different standards for different types of contaminants (Table 5), the size of the FIS is also expected to vary with contaminants and seed class. However, to simplify the inspection, one standard FIS size is suggested to be used for all contaminants in each seed class.

The size of the standard FIS is determined by the strictest standard for each seed class. After, successfully inspecting faba bean basic seed field, the inspector may wish to determine the FIS size for more detailed inspection. In such case, the strictest standard for faba bean basic seed production is 0.1% which is the value for maximum permissibility of off-type plants, i.e., it allows one contaminant plant in 1000 desired plants. The standard FIS size in this class of faba bean seed production field is suggested to be 3000 plants. To assure that the FIS accurately represents the total field quality, the whole field inspection sample needs to be divided into five or six smaller areas called Field Counts, randomly located in different parts of the field.

Table 5 Recommended field practices and analytical seed quality requirements to ensure quality of basic and certified seeds in faba bean and field pea.

Parameter	Faba bean		Field pea	
	Basic seed	Certified seed	Basic seed	Certified seed
Maximum permissible off-type plant (%)	0.1	0.2	0.1	0.5
Maximum number of field inspection	3	3	2	2
Number of objectionable weed plants	nil	nil	nil	nil
Minimum isolation distance (m)	400	200	20	10
Minimum percent of pure seed (on wt. Basis)	95	95	98	98
Maximum permissible percent of other Crop seeds (on wt. basis)	nil	0.05	nil	0.05
Maximum permissible percent of other Variety's seeds (on wt. Basis)	nil	5/kg	0.1	0.5
Maximum permissible percent of inert Matter (on wt. basis)	2	2	2	2
Maximum moisture content (%)	9	9	9	9
Minimum Germination including hard seeds (%)	85	85	85	85

The numbers of field counts are statistically demonstrated to accurately represent field quality, provided that they are located in different parts of a uniform field. Field counts are calculated by dividing the total FIS size by five or six, depending on the number of field counts selected (3000/5 = 600 **or** 3000/6 = 500 plants per field count), respectively. Provided that the number of plants per unit area is known, these 600 or 500 plants can easily be translated into an area to be inspected for each field count. The higher the number of plants per unit area, the smaller the FIS and the field count sizes should be. Once the field count size is determined, the site of the first field count should randomly be selected and the appropriate distance between subsequent field counts should be set in random locations in different parts of the field.

Sometimes, the field may meet the standards and automatically be accepted, or it may not meet the standards and automatically be rejected. However, field counts should be taken and rates of contaminant occurrences must be recorded. The inspector should carefully examine and count all plants in each field counts and should separately take records of all contaminants until all field counts are covered. When field inspection is completed, the total number of each contaminant plants in all field counts should be added and the proportion of contaminants should be determined. If the proportion of each contaminant plants is less than the rejection level, the field is accepted. However, if more contaminant plants than the tolerance level are found, the field is rejected, or correction measures like rouging should be carried out. When the level of contaminant plants is exactly equal to the level of tolerance, an additional five or six field counts should be taken to confirm acceptance or rejection.

If there are pockets with excessive contaminants, non-uniform or different from the rest of the field, they should be marked off and recorded in the map of a field inspection report. The amount of weed plants whose seed is difficult to eradicate, plants diseased with pathogens and any occurrence that is not specified in the standards should be recorded. Volunteer plants in all sides of the field that may contaminate the seed crop within the isolation distance should be examined. Also roadways and field edges should be free of plants that may cause contamination at harvest.

Seed inspection

Seed should satisfy certain requirements such as genetic and physical purity, germinability, being free from weed seeds and seed-borne diseases and optimum moisture content. Setting an internal seed quality control system by seed producers is very important. Seeds coming from each field should be identified from one another by a lot number and if harvesting could not be undertaken under the same condition due to bad weather, it is also advisable to have even sub-lots. Systematic moisture determination is important before and after drying and during harvesting.

Equally important is to confirm that the originality of the seed is as described for the variety. In this case, standards for basic seeds are more rigid in relation to some parameters (maximum permissibility, of other crop seeds and variety's seeds in percentage) as compared to certified seeds.

Analytical tests are undertaken from representative bulk samples taken randomly from the seed lot. Sample seeds should be taken at least from three different spots of a single bag and bulked. But, for bags of more than one, at least a sample should be taken from each and be blend into one mass. The bulk sample should thoroughly be mixed and sub-divided into "working samples" by repeated quartering. The weight of a working sample may reach 25–100g depending on the type of crop, level of accuracy and number of replicates desired. For faba bean and field pea certified seeds, contamination of 0.05% (on weight basis) by seeds of other crop species is permitted. As faba bean is partially open-pollinated, contamination by other variety of the same crop is not totally permitted in basic seed, because it will deteriorate the genetic performance of the seed.

Seeds should be free of inert materials such as sand, stones, straw, soil particles and defected seeds that are broken, rotten, insect-attacked, shrivelled and not able to germinate. Assuming that the embryo is not damaged, a broken seed larger than half of the normal seed size is not considered defected. The maximum total amount of permissible contamination of inert material and defected seeds in basic and certified seeds of faba bean and field pea is 2%. It should be free from weed seeds and seed-borne diseases. It also needs to be dried till the optimum moisture content is only 9% (Table 4).

Seeds contaminated with pathogens should thoroughly be treated with proven disinfectants or protectants before distributing them to farmers. Seeds should be tested for important seed-borne diseases, namely chocolate spot and aschochyta blight, in faba bean and field pea, respectively. The information on quality control tests should be strictly considered to decide the necessity of seed treatment and the seed rates for optimum population density. Generally, genetical or physical purity is calculated on weight basis as follows:

$$\text{Purity (\%)} = \frac{\text{Weight of pure seed} \times 100}{\text{Total weight of working sample}}$$

$$= \frac{\text{Weight of pure seed} \times 100}{\text{Weight of (pure seed + seeds of other varieties + seeds of other crops + weed seeds + inert matter)}}$$

Faba bean and field pea seeds should have a minimum of 85% germination percentage and real values which are estimated as follows:

$$\text{Germination (\%)} = \frac{\text{Total number of seeds germinated} \times 100}{\text{Total number of seeds planted}}$$

$$\text{Real value (\%)} = \frac{\text{Purity (\%)} \times \text{Germination(\%)}}{100}$$

8

Seed Certification

Seed certification work could be carried out in a field and/or by inspecting seeds in a laboratory. Field inspection verifies the seed source, identity of variety, previous cropping, isolation distance, off-types, weeds, other crops, other varieties, diseases, etc. Seed inspection at a processing plant and in a seed store verifies for seed standard. The producer should request field and seed inspections and certification preferably before the sowing date.` The seed is rejected if the requirements mentioned in Table 4 are not fulfilled

Seeds should be put into bags of appropriate size for distribution and each bag should be labelled and sealed to prevent admixture of other substances. The label should include the following information:

- Kind of seed,
- Name of variety,
- Percent purity,
- Percent germination,
- Date of germination test,
- Percent weed seed,
- Percent inert matter,
- Supplier's address,
- Validity period of certification, and
- Any other information pertinent to the seed

Glossary

Anther: The portion of the stamens that contain pollen grains.

Anthocyanin: A water-soluble blue, purple or red pigment which occurs in a cell sap.

Basic Seed: Basic seed is the 2[nd] or the 3[rd] generation produced either from breeder or pre-basic seeds under the direct control of plant breeders or seed specialists. It is used to produce certified seed.

Bract: A modified leaf subtending a flower or the branch of a flower.

Breeder Seed: Produced by a breeder or institution, which develop a particular variety. Also it could be produced by other agricultural organizations under the direct supervision of the breeder when a large quantity of breeder seed is required. It is the source of basic seed.

Certified Seed: Commonly produced from basic seed by progressive farmers, private investors and seed producing governmental organizations and to be distributed for commercial crop production farmers. Certified seed is the final stage in seed multiplication.

Character: An attribute of a variety resulting from the effects of the genotype and environment; e.g. plant height or flower color.

Cross-pollination: A transfer of pollen grains from anthers of flowers of one plant to stigmas of flowers of another plant.

Determinate Growth: A type of development in which a plant ripens all its seeds at approximately the same time.

Distinctness: Behavior of a variety for being clearly distinguishable by one or more important characteristics from any other released variety.

Generation Control: The process of re-supplying farmers with the original variety in place of the old contaminated seed of the same variety.

Genetic Purity: Refers to the absence of seeds of other varieties of the same crop species and ensures that the seed is the target variety.

Genetic Shift: Change in genetic composition from generation to generation with no tendency to revert to its original condition.

Genotype: Genetic constitution of an organism.

Germination: The resumption of growth by the embryo in a seed.

Germination Test: A test is the test undertaken to determine the proportion of seeds that produce healthy seedlings.

Heterozygous: Lacking genetic uniformity. Plants that breed not true-to-type for the character in question.

Hilum: A scar on a seed which marks the point of its attachment to the pod or seed stalk.

Homozygous: Having genetic uniformity. Plants that breed true-to-type for the character in question.

Indeterminate Growth: A type of development in which seeds of a plant ripe at different times. Ripen seeds, blossoms and vegetative shoots may be present on a plant at the same time.

Inflorescence: The flowering portion of a plant.

Isolation Distance: A minimum distance that should separate a seed production field from a field of other strain of the same species to prevent contamination.

Landrace: A diverse plant population developed in a specific geographical location by farmers themselves.

Leaflet: One part of a compound leaf.

Longevity: Ability of seeds to stay viable.

Mass Selection: Identification of desirable plants to be bulked for next generation.

National Variety Trial: A final stage of multi-location variety evaluation by breeders to identify varieties for release after verification and evaluation by the NVRC.

Off-type: A plant or seed that deviates in one or more characteristics from which the plant breeder described as being usual for the strain.

Often Cross-pollination: The level of cross-pollination in crops is intermediate between that of self-pollinated and cross-pollinated crops. Such crops are known as often cross-pollinated crops and the phenomenon is called often cross-pollination.

Out-crossing: Natural crossing between two different genotypes.

Ovule: An immature embryo which develops into a seed after fertilization.

Petiole: A stem to which a leaf or flower is attached.

Phenotype: External appearance of an organism.

Physical Purity: Implies of seeds being free from inert matter (sand, stones, straw etc) and defective seeds (broken and shrunken seeds).

Pollination: The transfer of pollen grains from the anther to the stigma of flowers.

Pollinators: Agents like wind, water and insects that facilitate cross-pollination in crops.

Pre-basic Seed: The progeny of breeder produced under the direct control of the originating breeder. It is used to produce basic or certified seed.

Progeny: Offspring in any generation.

Pubescent: Covered with fine, fuzzy or short hairs.

Qualitative Characters: Characters showing little or no change due to changes in environment; e.g. Flower color.

Quality Seed: A seed of an improved variety that is officially released and that meets certain crop specific requirements related to genetical and physical purity, freedom from weed seeds and diseases, germination, moisture content...etc is called quality seed. In the Ethiopian context, quality seed can be categorized under breeder seed, pre-basic seed, basic seed and certified seed.

Quantitative Characters: Characters showing higher changes due to changes in environment; e.g. Grain yield.

Raceme: An inflorescence in which spikelets are pediceled on a rachis.

Real Value of Seed: The real value of seed is the proportion (percentage) of a seed sample that produces seedlings of the variety under consideration.

Rouging: A removal of off-types from the seed production field.

Seed: Any grain produced for raising a crop. Harvested seed that has not been cleaned and graded is also called *raw seed*.

Seed Certification: A process of certificates issuance that ensures genetical and physical purity and good level of germination of seed lots after a thorough field and seed inspections.

Self-pollination: Movement of pollen grains from an anther of the flower of a plant to stigma of the same flower.

Stability: Consistency of a variety from one generation to another for one or more important characters.

Stigma: The part of a female flower that receives pollen from anthers.

Testa: The external coating of a seed. It is also called *seed coat*.

Tiller: An erected, secondary stem which grows from the ground level of a plant.

Trier: A device for sampling seeds in bags or in bulk.

Variety: A crop strain officially released for commercial cultivation by the National Variety Release Committee.

Variety Maintenance: A production of small quantity of very pure and disease–free and initial material for further multiplication.

Volunteer Plant: Unwanted plants of the same species grown from seed that remained in a field of a previous harvest.

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