Technical Guidelines for Quality Seed Production

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ICARDA
International Center for Agricultural Research in the Dry Areas (ICARDA)

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This manual of guidelines is intended to assist farmers who are becoming increasingly involved in the establishment of Village-based Seed Enterprises (VBSEs) for on-farm quality seed production. The manual should also prove useful for extension agents and staff of agricultural development agencies and NGOs who are supporting such local initiatives. It focuses on general principles. However, where necessary, specific examples have been used to explain the details.

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Introduction

For millennia, farmers selected plants from their local landraces and saved their own seeds for planting. Within the community, there are also reputable and knowledgeable farmers who manage their crops better, and provide seed in both good and bad harvest years. Moreover, farmers exchange seeds not only with relatives, neighbors and other farmers in adjacent villages, but also across large valleys and geographic regions. Different forms of transaction are used, from cash payment to free seed exchange, as part of social obligations.

The availability, access to, and use of quality seed of adaptable crop varieties, are important in increasing crop production and productivity. Given the absence of an organized seed sector in many marginal and remote areas, we intend to decentralize seed production and marketing at local levels by establishing village-based seed enterprises (VBSEs) with the particpation of farming communities. Such small seed enterprises are expected to be technically feasible and economically viable in producing and marketing quality seed within the local community. The degree of success and sustainability, however, depends on producing quality seed, getting farmers' trust, and convincing them to purchase seed regularly.

Within this context, farmers who are engaged in small seed enterprises need to focus on producing and marketing quality seed. They should differentiate between seed and grain production, and focus on (a) aspects of seed quality, (b) quality standards to be maintained, (c) proper agronomic management practices, and (d) a robust internal quality assurance system.

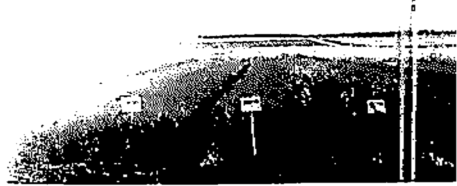
Defining Quality Seed

Seed is a primary input in crop production, whether agriculture is practised at commercial or subsistence levels, by large or small-scale producers, or in favorable or less favorable environments. Seed quality is one of the main factors affecting crop production potential. For seed to play a catalytic role in crop production, it should reach farmers in good quality. Therefore, '*high quality seed*' can be defined as '*seed of an adapted variety with high varietal, species, and physical purity; high germination and vigor; free from seed-borne pests; and properly cleaned, treated, tested and labeled*'.

In general, seed quality comprises many aspects, but four key attributes may be explicitly identified:

1. *Genetic quality*—Genetic quality is the inherent genetic make-up of the variety contained in the seed, which provides the potential for higher yield, better grain quality, and greater tolerance to biotic or abiotic stresses
2. *Physiological quality*— Physiological quality is the viability, germination and vigor of seed, which determines the potential germination and subsequent seedling emergence and crop establishment in the field
3. *Physical quality*—Physical quality includes freedom from contamination with other crops, common and particularly noxious and parasitic weed seeds, seed size, seed weight and seed lot uniformity
4. *Health quality*—Health quality includes the absence of infection/infestation with seed-borne pests (fungi, bacteria, viruses, nematodes, insects, etc)

A seed field which has been inspected and has met varietal purity and identity



will be harvested, cleaned, treated, sampled and tested before marketing, to ensure that it meets the minimum quality requirements prescribed by the quality assurance program. The seed is often properly packaged in attractive containers, labelled with necessary information regarding quality, and sealed before marketing to the users.

Figure 1. A bag of grain (left) compared with a properly cleaned, treated, tested, packaged and labeled bag of seed (right)

However, the environmental conditions under which the crop is grown and the cultural practices used for production can affect seed quality. Several environmental factors such as soil conditions, nutrient deficiency, water stresses, extreme temperatures and pest infestation may affect seed quality by reducing its viability and vigor by the time the seed reaches physiological maturity. Therefore, appropriate measures should be used to produce high quality seed.

Requirements for Quality Seed Production

In many agricultural crops, the general agronomic operations used in growing a crop for seed, are rather similar to those used in producing grain for consumption or feed. Such similarity of operations may discourage farmers from taking the extra necessary measures required to produce good quality seed. This could easily lead to the mixing of seed and grain during planting, harvesting, storage and transportation thereby reducing seed quality.

Seed is a living biological product, which requires special attention and care to ensure its physiological quality. Maintaining the varietal identity and purity of the seed is essential if it is to meet the expectation of farmers and consumers. Therefore, seed production should be strictly monitored throughout the entire crop growth period, from planting through to harvesting, cleaning, storage and marketing. Seed producers should understand the principles and procedures for growing a crop for seed, and ensure that all operations are carried out at the right time.

Seed production should be quality-oriented, compared with grain and forage production. Seed production must include the following considerations:

- (i) Site and field selection to find suitable area or land for seed production
- (ii) Isolation to avoid contamination
- (iii) Roguing to remove contaminants
- (iv) limited generations of multiplication to reduce contamination
- (v) Ensuring cleanliness of machinery to avoid admixtures during planting, harvesting, cleaning, treatment and storage
- (vi) Production arrangements using specialized growers, and
- (vii) Maintaining seed quality by applying rigorous quality assurance systems

These operations are elaborated in the following section.

Selection of Adapted Varieties

Selection of an adapted variety is the first step in the production of a good seed crop. The variety must be selected from a list of recommended varieties. Apart from its adaptation, the variety should have high yield potential, tolerance to biotic (fungal, bacteria, viral) and abiotic (cold, frost, heat, drought, salinity) stresses and have good marketability and consumer preferences. Unless the variety meets the requirements of farmers and consumers, it is less likely to be widely adopted and grown, and,therefore, there will be no demand for seed.

Figure 2. Selection of an adapted variety from a recommended list is a prerequisite for high quality seed production

The availability of improved varieties is a selling point for seed marketing. If recommended improved varieties are not available, the best local varieties may be used for seed production. The inclusion of high quality seed of local varieties in the product mix of the enterprise could be a profitable option, as demand for high quality seed may already exist for such varieties.

Selection of Source Seed

After selecting the varieties, choose the seed for planting from a good source. Good quality seed comes from a known source, where the field is inspected during the growing season, and the seed is cleaned and tested after harvesting. Basic seed purchased from the agricultural research center or certified seed from the formal sector, is recommended, since it assures good quality seed with high varietal purity, physical purity and germination.

Planting seed from an unreliable source may result in a crop which is varietally mixed, contaminated with noxious weeds (e.g. wild oats), may not germinate well, or produce a poor crop stand. It is important to link VBSEs to the formal sector from where they can purchase source seed regulalry to ensure quality seed production.

However, in case there is no reliable source, farmers should be trained on how to maintain their own seed source through mass selection in a field that is properly grown for such purpose, and where roguing and inspection are strictly practiced. The following are simple procedures for producing good source seed on the farm:

(i) Select source seed from a well rotated field
(ii) Rogue offtypes and other varieties
(iii) Rogue other crops and noxious weeds
(iv) Rogue plants infected with seed-borne diseases
(v) Bulk-harvest the entire seed field after inspection
(vi) Properly clean, treat, package and store the seed
(vii) Conduct simple purity and germination tests

It is important that these operations are strictly followed with great care and attention to produce good quality seed. Table 1 indicates the minimum standards for source seed, based on FAO Quality Declared Seed System. However, it is possible to set higher standards for germination capacity in legume crops than what is suggested in the table.

Table 1. Suggested field and seed standards for on-farm seed production based on FAO quality declared seed system

	Wheat	Barley	Maize	Rice	Faba bean	Chick-pea	Lentil
Genetic purity	98	98	98	98	98	98	98
Physical purity	98	98	98	98	98	98	98
Inert matter	2	2	2	2	2	2	2
Germination	80	80	80	75	60	60	60

Source: FAO, 1993

Figure 3. Simple informal tests for purity (top) and germination (bottom) before planting

Selection of Production Sites

There are variations in agricultural lands in terms of altitudes, topography, soil types, climate, etc., and these influence the geographic distribution of crop species and varieties. Apart from agroecological and climatic adaptation, the area selected for seed production should be free from natural hazards like floods, drought, frost, salinity, diseases and insect pests, etc., to prevent any damage to the seed crops. The area should be fertile, well-drained and leveled. Availability of irrigation facilities is preferable to ensure good seed harvest. Areas with dry and cool weather conditions during ripening and harvesting are ideal for maintaining seed quality. Accessibility and proximity of the land for supervision, and suitability for transporting the seed quickly and economically is also essential. The fields must be also suitable for the specific crop management practices required for high quality seed production.

Although selection of site for seed production is crucial for VBSEs, some shortcomings may also be corrected by adjusting the agronomic management practices. For example, a high disease incidence, heat or frost can be overcome by adjusting planting dates, practicing crop rotation, treating the seed or using tolerant/resistant varieties.

Selection of Production Fields

Most cultivated crops can be successfully produced on soil types that are well drained and productive. Selection of fields with the right cropping history and suitable crop rotation is necessary; and if possible these two should be combined. The right previous cropping is necessary to avoid genetic, mechanical and pathological contamination in seed production, whereas crop rotation is mainly practiced to maintain soil fertility and control soil and/or seed-borne diseases.

In seed production, previous cropping specifies the crops that should not be grown before the seed crop. A seed crop should preferably follow another crop species to avoid admixtures (e.g., cereals after legumes or vice versa). The land selected for seed production should be free from varieties of the same crop species for at least one or two years prior to planting unless the previous crop is of the same variety. Similarly, in cereal seed production, previous cropping with other cereal crops such as wheat, oats, barley or rye should be avoided, because a seed crop of wheat, for instance, is very difficult to purify by roguing if contaminated with excessive mixture of other cereals (Table 2). A field used for seed production should also be free of noxious weeds and seed/soil-borne diseases.

Table 2. Previous cropping for high quality seed production

Crop	Previous crop not allowed preceding the seed crop
Cereals	
Bread wheat	Barley, oats, durum wheat, rye, triticale
Durum wheat	Barley, oats, bread wheat, rye, triticale
Barley	Oats, wheat, rye, triticale
Rice	Barley, oats, wheat, rye, triticale
Rye	Barley, oats, wheat, triticale
Legumes	
Faba bean	Faba bean (small seeded), lathyrus, lupin (large seeded)
Faba bean	Faba bean (large seeded), lathyrus and lupin (small seeded)
Chickpea	Phaseolus bean, faba bean (small seeded)
Haricot bean	Lupin, chickpea, faba bean (small seeded)
Pea	Lathyrus, vetch

Source: Madarati and Bishaw, 2002

The seed production field should be properly isolated (in space and/or time) from other cultivars of the same species (to avoid mechanical admixture and/or cross-pollination) and free from stones to facilitate mechanical operations. Furthermore, availability of irrigation facilities and easy access are key factors for selecting fields for seed production.

Figure 4. Select seed production areas with less natural hazards (drought, top; bad terrain, bottom)

Land and Seedbed Preparation

Primary and secondary tillages are crucial for seed yield and quality. Proper tillage operations, and time, improve soil moisture conservation and physical property (aeration, filteration); reduce weed and volunteer plant population; reduce disease and pest inocula; and enhance germination, emergence and crop establishment.

Land preparation should start early to ensure suitable tilth at sowing. The seedbed should be thoroughly prepared and leveled to ensure that sufficent moisture is available in the soil. A finer tilth is necessary for small seeds than for large seeds. Sowing after enough rainfall or irrigation and proper cultivation would minimize such negative impacts.

Selection of implements and tillage practices should be based on soil types, amount of crop residues and the crop to be planted. In heavy soils that are covered with a large quantity of crop stubble but are less stony, a moldboard plough is preferable; otherwise a disc plough can be used. For both light and heavy type soils with limited crop residues, duck foot or chisel cultivators can be used.

Figure 5. Avoid fields which are stony (top) or with excessive noxious weeds (bottom)

Good practices for seedbed preparations include:

- Using appropriate implements—wrong implements may result in poor seedbed (clod formation, moisture loss, poor stubble incorporation)
- Avoiding late primary tillage—late planting will generally lead to lower seed yields
- Early secondary tillage—will help control weeds/volunteers and prevent soil compaction

Sowing Date, Sowing Rate and Method

The time of sowing depends on the variety and area of adaptation. A seed crop must be planted at its recommended time, otherwise growth and development may be affected, thus reducing seed yield. Matching cultivar maturity to the sowing date is a key element for maximizing seed yields in dryland farming, and it helps in reducing risks.

In general, late planting is not recommended because it can lead to substantial reductions in yield. Planting early, on the other hand, is beneficial, but may increase risks of early dry spells, frost damage, and weed infestation.

The optimum seed rates vary with crop, variety, location and method of planting. Seed rates may also differ among varieties depending on seed size and the method and time of sowing. The recommended seed rate should be used when a crop is sown at normal time to achieve the right plant population for adequate competition with weeds and for better yield. For a desired plant population, the actual seed rates can be calculated using the following formula: seed rate in kg ha^{-1} = [(plant density m^{-2} x thousand seed weight in g) % field emergence or survival] x10. For example, for a lentil variety with a thousand seed weight of 70 g, and 80% of field emergence, planted at population density of 12 plants m^{-2}, the seeding rate = [(12 x 70) 80] x 10 = 105 kg.

Figure 6. Stubble removal for land preparation (top), primary tillage for crop residue management (middle) and a good seedbed ready for sowing (bottom)

Many farmers in developing countries prefer to use a higher seed rate than recommended, because they perceive it as a good strategy to control weeds and reduce the risks of crop production. Planting at a higher than the recommended rate is not encouraged because of its negative impact on seed quality, particularly on seed size and weight. Instead of using higher rates, farmers must pay close attention to all recommended seed production practices.

On-farm seed priming, pre-soaking of seed with water and drying before planting, appeared to increase germination, seedling emergence and crop establishmnet in dry condtions for crops such as maize, sorghum, chickpea, etc. It is important that farmers are encouraged to adopt such techniques to improve seedling emergence and crop establishment, particularly in drier regions.

In seed production, planting in rows has advantage over broadcasting, as it requires less seed, facilitates mechanical weed control, pesticide spray access for roguing and field inspection, and prodcues better yield. Roguing lanes (empty rows at intervals) should be left, which could be used by the seed grower to walk through the field when roguing, as well as for inspecting the crop.

A comparison between seed broadcasting and row planting (using a seed drill) is presented in Table 3

Table 3. Comparison between seed broadcasting and row planting

Criteria	Consequences
Broadcasting	• Requires more seed • Difficult to adjust seed rate • Uneven planting depth and distribution • Difficult for mechanical weeding and fertilizer application • Produces lower yields
Row planting	• Requires less seed • Simple to adjust seed rate • Proper planting depth, good distribution • Easy for weeding and fertilizer application • Easy for inspection and rouging • Can combine planting and fertilizer application • Risk of mechanical mixing (in planters) • Produces higher yields

Planting with an automatic drill is recommended, but not essential. A drill assures uniform seeding at a proper depth with a good moist bed. The drill must be calibrated for the recommended seed rate and depth of planting to ensure uniform seedling emergence, good stand establishment and vigorous plants competing with weeds. The depth of sowing depends on the seed size, large seeds being buried more deeply than small seeds. It is important to clean the drill box between different varieties to avoid admixtures. Although mechanical planting is recommended when dealing with a large number of varieties and relatively small areas, hand planting is the most common option.

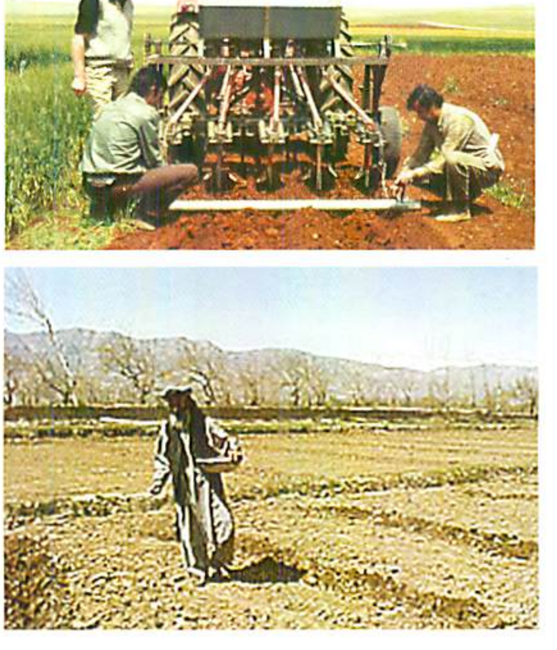


Figure 7. Row planting is preferred (top) over broadcasting whether the seed is planted mechanically or manually (bottom)

Isolation

Isolation, the growing of a seed crop separately from all sources of contamination, is one of the fundamental seed production techniques. An appropriate isolation distance should be maintained to prevent contamination due to the pollination habit of the crops. Self-pollinating crops need small distances while crops with high percentage of out-crossing require large isolation distances.

Although the field size, topography of the site, wind speed and direction, insect type and population, and cropping patterns influence the risks of contamination, standard isolation distances are usually recommended.

For example, wheat is entirely a self-pollinating crop with a very low percentage of cross pollination (1-4%), thus it has low risk of genetic contamination. It is sufficient to have a small strip of land of at least three meters between different fields as isolation distance to avoid mechanical admixtures. On the other hand, maize is a cross-fertilizing crop and much larger isolation distances (200-400 m) are recommended. Apart from distance isolation, time isolation can also be used for seed production, by growing the crop during the off-season.

Figure 8. Crop diversification and planting by alternating crops is useful for maintaining isolation distances in self-pollinated crops

Table 4. Suggested isolation distances for high quality seed production

Pollination habit	Crops	Species	Isolation distance (m)
Self-pollinating	Cereals	Wheat, barley, rice	2-5
	Legumes	Chickpea,lentil, beans	2-5
	Oilseeds	Groundnut, soya bean	2-5
Cross/partially	Cereals	Maize, sorghum, millets	200-400
cross-pollinated	Legumes	Faba bean	100-200
	Oilseeds	Rape, linseed	200-400

Source: Madarati and Bishaw, 2003; FAO, 1993

The problem of fragmentation because of land ownership can be solved by growing the same variety adjacent to each other and grouping farmer seed producers. Adjusting planting dates (time isolation) may also prevent outcrosssing and other types of contamination.

Irrigation

Availability of irrigation water is important for a good seed crop. The irrigation regime should be scheduled according to the crop growth stages. The seed crop must receive ample water at two critical stages of crop growth, i.e., during establishment/vegetative growth and early phase of seed development. Moisture stress at these two stages will adversely affect the yield and quality of the seed. Less water during flowering promotes seed setting while ample water after flowering will ensure the development of the greatest possible number of seeds, thus increasing seed yield. On the other hand, irrigation at physiological maturity will delay harvest maturity.

In seed production, surface irrigation is preferable because overhead irrigation may affect pollination and encourage foliar and seed-borne diseases. Sprinkler irrigation will wash off pesticides, resulting in poor pest control, therefore, it should not take place immediately after pesticide application. Similarly, irrigation before fertilizer application may result in foliar damage (burning of leaves).

It is important to avoid passing irrigation water through plots of different varieties because seeds of one variety as well as pathogens and nematodes may be carried to the next plot, thus causing contamination and/or infection. This can be avoided by separating fields with high ridges.

Fertilizer Application

A well-balanced supply of nitrogen, phosphorus and potassium is essential for seed production, as it has an influence on seed development, seed quality and yield. Fertilizer application to seed crops should be based on local recommendations.

The benefit of fertilizers is not always apparent. Fertilizers may increase disease incidence and trigger competition by weeds such as wild oats. High nitrogen levels may promote vegetative growth, cause delayed maturity, predispose the crop to foliar diseases, lead to severe lodging and reduced yield and seed quality. Phosphorus is essential for enhancing seed maturity, and potassium for enhancing seed development. Modern crop varieties are reasonably responsive to fertilizers and the yield potential cannot be fully realized without inorganic fertilizers. In view of the general deficiency of nitrogen and phosphorus (less so for potash) in most soils, a balanced use of these nutrients is essential. The extension service or the nearest research station should be consulted for the recommended packages.

Apart from the type of fertilizer, the time and method of application of the fertilizer is very important. Phosphorus and potassium are relatively stable in the soil and can be applied at the time of planting. However, nitrogen fertilizers are volatile, a minimum of two split applications is necessary, i.e., one at planting and the second during crop growth. It is preferable to use fertilizer spreaders during early vegetative stages, but at the later growth and reproductive stages, mechanical application will result in heavy damage to the crops.

Farmers should have access to soil testing services, and based on the test results, they should decide the types and rates of fertilizers to apply. Where this is not possible the extension service should be consulted for the recommendations.

Figure 9. Higher productivity and quality depends on balanced plant nutrition

Weed Control

Seed is one of the most important means of introducing common, noxious and parasitic weeds into agricultural lands. Moreover, increased use of fertilizers, inadequate rotations and ineffective control practices are major factors encouraging weed infestation. Hence, freedom from weed seeds is a very important seed quality attribute. In seed production, contamination of the seed crop with other crop or weed seeds of similar physical characteristics must be reduced to the barest minimum because cleaning alone will not sufficiently remove such contaminants.

Weed seeds can be classified into three: objectionable weeds (not permitted), noxious weeds (permitted with specified standards) and common weeds (no standards). *Avena, Bromus, Lolim* and *Phalaris* spp. in small grain cereals and *Orobanche* and *Cuscuta* spp. in food legume are considered noxious weeds and are often difficult to control once etsablished in the field.

A well designed integrated weed control package combining crop rotation, inter-row cultivation and hand pulling, coupled with herbicide application, is commonly used. Some crops, such as wheat and lentil, do not suppress weed sufficiently and need a clean and weed-free seedbed for planting.

Irrigation, followed by cultivation shortly before sowing, usually destroys germinated weed seeds, and favors vigorous plant growth with better competition with weeds. In double cropping, a seed crop may follow another crop, leaving no time for pre-planting cultivation, thus weeds may germinate and emerge at about the same time as the seed crop. Harrowing is the most appropriate method for controlling such weeds. Cultural practices such as delayed planting, hand pulling, rotations and use of trap/catch crops are the only means for controlling parasitic weeds. Special attention should be paid to controlling weeds on fence rows, corners, irrigation channels, field-paths, and patches of low plant population. In case of heavy weed infestation, herbicides may be applied. The herbicide must be selected for the weeds infesting the crop, and applied at the recommended rate, growth stage and method of application using the right equipment. Effective crop rotations, properly prepared seedbeds, and planting at a time that allows rapid and uniform crop establishment can increase effectiveness of the herbicides. Lack of knowledge of application techniques and equipment (sprayers) may result in inaccurate dosage, which is uneconomical, reduces efficacy and may lead to herbicide resistance.

Roguing

Roguing, the act of removing undesirable plants, is another fundamental aspect of seed production. Undesirable plants,

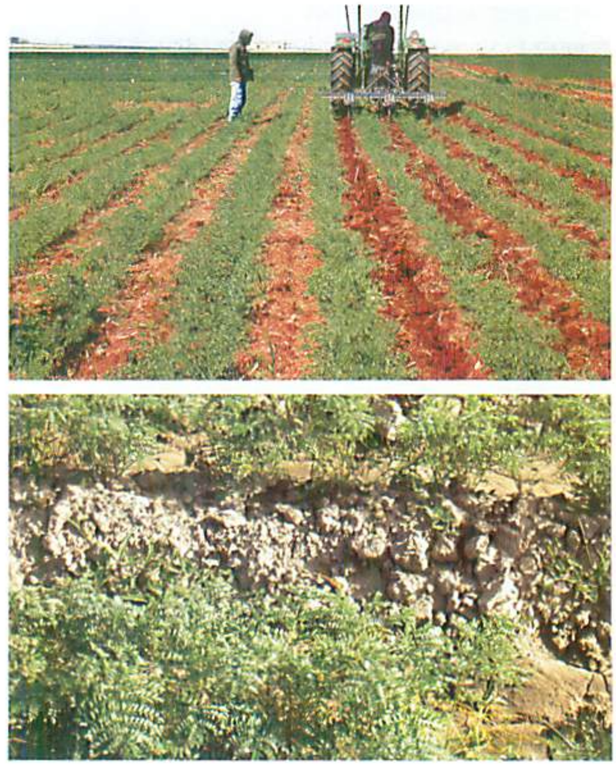


Figure 10. Inter-row cultivation to control weeds (top) and a chickpea field infested with Cuscuta (bottom)

commonly known as 'rogues', are:

(i) Offtypes genetic variants of the same variety
(ii) Pther varieties of the same crop species
(iii) Pther crops with similar growth habit and seed characteristics
(iv) Noxious weeds difficult to remove during cleaning, and
(v) Plants infected with seed-borne diseases

Roguing is carried out to maintain varietal purity and keep the seed crop free from contamination by other crop species and seed-borne diseases. Seed fields should be rogued before undesirable plants cause genetic or physical contamination, and during crop growth stages when the rogues can be identified visually. These growth stages vary with the crop, the undesirable species, stage and condition of growth. Roguing can be performed at various stages of crop growth, but the most effective stages are flowering, post-flowering or maturity, when it is easier to see important morphological characteristics (inflorescence type, flower color, ear shape) that will help differentiate between the variety and the rogues. During roguing, the whole plant with all lateral tillers should be removed, taken out of the field and burned. The roguing crew must be well-trained to examine the seed crop carefully and remove contaminants.

Figure 11. A four-member crew roguing wheat seed field, followed by a supervisor (top, Tel Hadya, Syria) and wheat field infested with oats (bottom, Afghanistan)

Roguing is expensive and not a solution for poor agronomic management. If varietally pure, clean and treated seed is sown in a properly rotated field, with sufficient isolation distance between crops and varieties, and proper cleanliness of machinery is maintained between seed lots, the need for roguing will be minimized.

Management of Seed-borne Diseases

Freedom from pathogens, especially seed-borne diseases, is one of the most important seed quality attributes and standards. Lack of proper disease management in quality seed production, may adversely affect the productivity, quality attributes and standards of the harvested seed. The production of a healthy seed includes a combination of a different practices, viz: (i) use of disease-free seed lots, (ii) zoning of seed production areas, (iii) off-season seed production, (iv) proper rotation and isolation of seed fields, (v) roguing of diseased plants, (vi) spraying to avoid disease build-up, (vii) field inspection and testing, (viii) efficient cleaning of lots, and (ix) seed treatment with chemicals.

The standards for field inspection varies from country to country on the basis of the crop, susceptibility of the cultivar, seed class and environmental factors. Seed treatment plays a crucial role in a well designed plant protection program. Isolation, field inspection, roguing of infected plants and application of chemical treatment are crucial in healthy seed production. For example, loose smut of barley and wheat is controlled through seed certification, which is based on isolation, field inspection, laboratory testing and treatment with a systemic fungicide.

Figure 12. Seed-borne diseases of wheat with worldwide distribution: common bunt (left) and loose smut (right)

Harvesting

Harvesting comprises cutting and threshing as separate or combined operations. At maturity the seed crop could be harvested and threshed manually, with stationary threshers or combine harvesters. Mechanical harvesting is a common practice for seed production particularly for larger fields. Whether the seed is harvested and threshed manually or mechanically, the most critical factors to be considered are the seed moisture content, mechanical damage, and cleanliness (of equipment). Dry weather during ripening and harvesting is necessary to maintain seed quality. Cereal and legume seeds reach physiological maturity between 35 and 45% and 45 and 50% moisture content, respectively. However, the seed needs to dry properly to safer moisture content for harvesting and storage. Low seed moisture content, resulting from delayed harvesting, increases shattering losses and excessive seed injuries. The moisture content of the seed can be used as an indicator of when the crop is ready for harvesting. The crop characteristics or electric moisture meters can be used to decide the time to harvest.

Manual harvesting and threshing practices may have a less damaging effect on seed quality. However, in the case of mechanical harvesting, proper adjustment of the concave clearance and drum speed of the combine harvester is essential to avoid damage to the seed crop. In general, cereals are less susceptible to mechancial damage than legumes and oilseed crops.

In traditional threshing, care must be exercised to keep the floor clean. There should be no leftover seed of previous variety and weeds on threshing floors. Where combines are used, the cleanliness of the harvesting machinery is important to avoid admixtures. The combine should be thoroughly cleaned before harvesting, as well as between different varieties. However, combine harvesters are often difficult to clean and may still harbour contaminating seed, even after thorough cleaning. Availability of compressed air is important. When harvesting the next variety, the first few hundred kilograms of seed may be discarded because contamination may still be present in the combine. For larger plots it is also possible to harvest and discard the outlying rows of the field. Keep different varieties separate to avoid admixture.

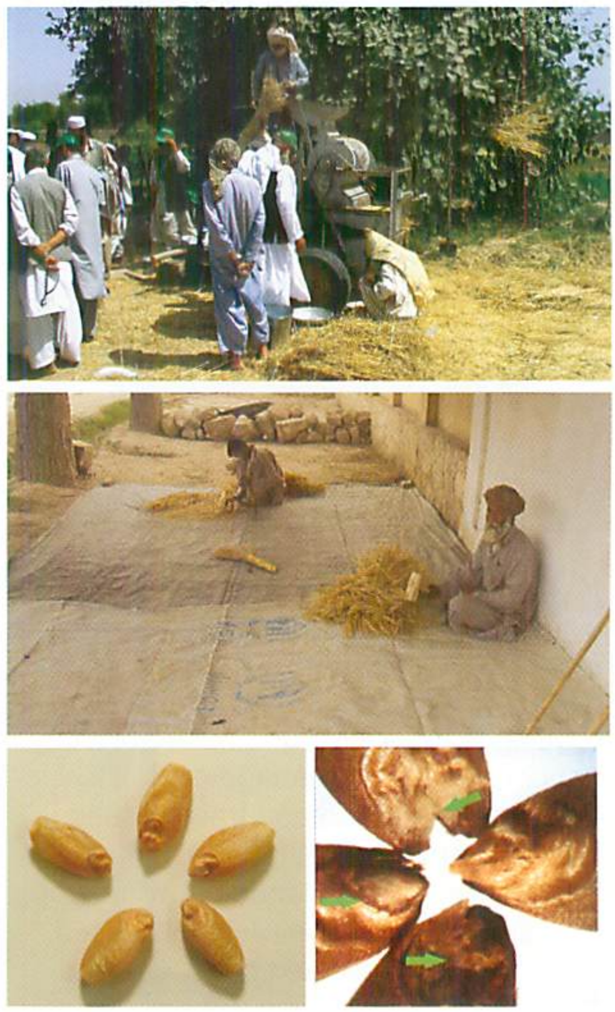


Figure 13. Wheat seed threshing at an agricultural research station in Afghanistan: mechanical (top) or manual (middle); and an intact wheat seed (bottom left) compared to mechanically damaged wheat seed (bottom right)

The following instructions must be followed when harvesting high quality seed:

- Start harvesting when the seed moisture content is reduced to approximately 12% (cereals and legumes) to avoid mechanical damage and maximize storability
- Set the concave clearance and speed of the threshing drum to reduce mechanical damage as much as possible. Mechanical damage influences physiological quality such as germination and vigor
- Adjust the air and screening system to minimize losses and maximize physical purity
- Harvest crops/varieties in a sequence that minimizes mechanical mixing between them

Seed Cleaning

Upon receiving the harvested seed, it should be inspected to guide and monitor seed processing operations such as the need for drying, fumigation, and cleaning, If the seed moisture is too high (above 12%), the seed should be (first pre-cleaned and) dried before cleaning or storage. If insects are present, the seed should be fumigated.

Cleaning includes the removal of inert matter; seed of weeds, other crops, other varieties and seeds of the same variety which are shriveled, damaged, deteriorated or diseased, to improve and upgrade seed quality. Traditionally, winnowing follows threshing, to remove chaff, straw and other light materials from the seed. Hand cleaning using sieves to remove seeds of different sizes and heavier materials (stones, soils) then follows. Mechanical cleaning is possible because seeds have differences in size (length, width, thickness), density, weight, shape, color, etc. The most important characteristics are seed size (length, thickness, width and diameter) and weight. Each crop requires a different set of machines and sequences where a combination of machines is used.

A complete list of equipment required for cleaning different crops is suggested in Table 5. However, a machine comprising an air screen cleaner, indented cylinder, and a treater is sufficient for on-farm seed processing. In an air screen cleaner, a combination of screens (sieves) and air blast are used for seed cleaning. Round screens separate on the basis of the diameter of the seed, while oblong screens separate on the basis of thickness. The upper sieves remove large seeds and plant materials while the bottom sieve removes broken, small, shrivelled seeds. Air separates seeds according to the behaviour in an air stream; light particles (dust, chaff, glumes, empty or partly filled seeds) will be lifted, whereas the heavier seed will fall down through the air stream. Indented cylinders make length separation; the cells, depending on the size, lift the seeds that fit into the indents.

In mechanical cleaning, the cleanliness of the machinery is very important between different varieties. The availability of air compressors is also essential.

Table 5. Seed cleaning equipment suggested for different crops

Machine	Wheat	Barley	Maize	Rice	Faba bean	Chickpea	Lentil
Deawner		•					
Scarifier					(•)	(•)	(•)
Air screen	•	•	•	•	•	•	•
Indented-cylinder	•	•		•			
Gravity-table	(•)	(•)		(•)	(•)	(•)	(•)
Grader			(•)				
Color-separator					(•)		
Treater	•	•	•	•	•	•	•
Bagger-weigher	(•)	(•)	(•)	(•)	(•)	(•)	(•)

Note: (•) = optional

Figure 14. A simple locally manufactured mobile seed cleaner and treater (top) and a sample of raw seed, clean seed and impurities removed during cleaning (bottom)

Seed Treatment

Seed health is an important attribute of quality, and seed used for planting should be free from pests. Seed infection may lead to low germination, reduced field establishment, severe yield loss, or a total crop failure. Seed production in disease-free areas, or under effective disease control and field inspection schemes, is very important for obtaining healthy seed. Thus, understanding the disease epidemiology, its transmission rate and economic threshold, combined with seed health testing, could help define the need for seed treatment.

In cereals, fungi (*Drechslera, Fusarium, Septoria, Tilletia, Ustilago* spp), bacteria (*Cornybacterium, Pseudomonas and Xanthomonas*) and nematode (*Anguina tritici*) are the most important seed-borne diseases due to their worldwide distribution and the losses they incur in crop production. In cool season food legumes, the most important seed-borne diseases of global signficance are ascochyta blight, chocolate spot, viruses in faba bean, ascochyta blight in chickpea, and wilt in lentil.

Chemical seed treatment is one of the most efficient and economical plant protection practices and it can be used to control both external and internal seed infections. It also protects young seedlings, or adult plants from attack by seed, soil or air-borne pests. It disinfects seed of pathogens, checks the spread of harmful organisms, promotes seedling establishment, improves seed quality and minimizes yield losses. Seed treatment is preferrable over other conventional methods because it is easy to apply, safer to handle, cheaper, better targeted against the organism, and less influenced by the environment. Selection of the proper chemcial depends on the target organism and its location, economic importance, infection level, as well as the efficacy of the chemical. The use of an effective broad-spectrum seed treatment fungicide, both for external and internal seed-borne diseases, is essential. However, routine seed treatment should be avoided as much as possible.

Although some farmers traditionally apply plant extracts to seed for disease control, wide-scale use of chemical treatment on-farm is less frequent. In situations where farmers practice seed treatment, the chemical (usually in powder form) is first diluted in water and then mixed with the seed manually, using shovels. The formulation of available chemicals, the method and rates of application, precautions on safety measures, and lack of adequate equipment and knowledge of handling are the main constraints of on-farm seed treatment.

For example, Vitavax 200 (Carboxin + Thiram) at the rate of 250-300g per 100 kg seed can be used for the control of loose smut and common bunt of wheat as well as ascohcyta blights and *Fusarium oxysporium* f.sp. *ciceri* of chickpea. Vitavax extra Carboxin + Imazalil + Thiabendazol at the rate of 200-300g per 100 kg of seed can be used against smuts and *Pyrenophora graminea* of barley. In legumes, Tecto (Thiabendazole) at the rate of 500 g per 100 kg of seed can be used against ascohcyta blight of faba bean, chickpea and lentil.

The introduction of simple and manually operated seed treatment equipment would be beneficial to farmers in increasing the efficacy, targeting organisms, improving safety, and reducing production cost and environmental pollution.

Figure 15. On-farm manual seed treatment (top, Syria) and locally manufactured motor-operated seed treater (bottom, Algeria)

It is important to:

- Use seed treatment chemicals with a strong dyeing color to discourage human consumption or use for animal feed
- Use simple seed treatment machines, which can be properly cleaned between varieties
- Adjust the rate and coating systems properly to ensure good pesticides application
- Treat seeds in a sequence that minimizes mechanical mixing of varieties and crops

Fumigation

Fumigants are insecticides used to control storage pests. In seed production, phostoxin (aluminum or magnesium phosphine) is widely used. It is popular because it is easy to handle, has no influence on germination, and the seed can be fumigated repeatedly. Fumigation is used as a curative measure and can be highly effective. In comparison with contact insecticides, fumigants have the advantage of penetrating different types of containers such as jute bags, boxes, paper bags, etc. Fumigants are active in the gaseous phase, and fumigation is effective only if applied under airtight conditions using special fumigation sheets. The disadvantage of fumigants is that they are not persistent, and re-infestation may take place as soon as fumigation is completed.

Therefore, fumigation should only be used under proper hygienic conditions. To avoid re-infestation, fumigation is often carried out after stacks are sprayed with a contact insecticide. This will give a long-lasting effect, because the contact insecticide will give a persistent cover to the stack, while fumigation will kill all stages of insects inside the containers.

Phostoxin is applied at the rate of 3-6 tablets per tonne of seed (2-4 tablets per m^3). For larger stacks, under sub-optimal conditions (i.e., low moisture contents), or when eggs or pupae have to be killed, the exposure time should be extended. The relative humidity of the air should not be lower than 30% because no gas will be released from the tablets. At 30% RH, exposure time should at least be 10 days. In very dry areas, insufficient moisture may be present, and it may be necessary to place a container of water under the fumigation sheet.

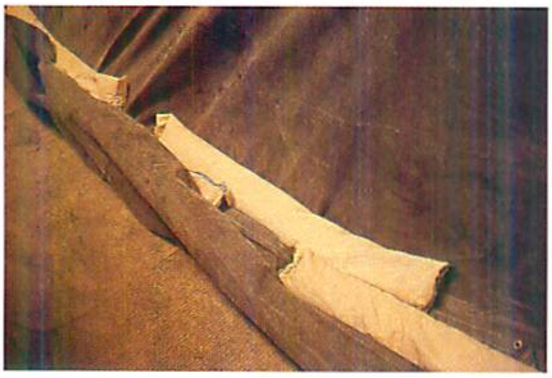


Figure 16. A protective mask (top) and sandsnakes to ensure airtight condtion (bottom) during fumigation

At higher temperatures, the chemical reaction is faster and the respiratory system of insects work better, resulting in a faster and better intake of the gas. It is generally recommended not to fumigate at lower than 15°C, but to adjust exposure dates to 10 days if the temperature is between 5 and 10°C; 5 days (11-15°C); 4 days (16-20°C); and 3 days (over 20°C).

Insects can develop resistance to the fumigants just as to other insecticides. This is a serious problem because there are no alternative chemicals. The main cause of resistance is the sub-lethal dosages, because fumigation is often not carried out under airtight conditions. To be more effective, increase the exposure time and not the dosage.

To sum up, the factors determining the success of fumigation are: (a) hygienic conditions, (b) proper dosage and exposure time, (c) adequate sealing, and (d) correct temperature and sufficient moisture.

Seed Packaging

Proper packaging is important for safe handling, storage, marketing and distribution. Use of proper packaging material contributes to minimizing quantitative and qualitative losses. Woven bags of strong material prevent damages that can lead to spillage and mixing. In recent years, polypropylene bags are becoming standard packaging materials for seed. Availability of different bag sizes enables the packaging of seed in quantities desired by farmers. Attractive packaging plays a crucial role in product promotion and marketing.

Figure 17. Seed in clean new jute bags and labelled ready for marketing

Seed Storage

The seed is in a state of 'transient storage' from the time it reaches physiological maturity on the parent plant, until it is planted. Germination is highest at physiological maturity and then declines inexorably until the seeds die. Good storage conditions can maintain the initial quality, but cannot improve the phsyiological quality of poor seed. Therefore, only high quality seed should be stored. Moreover, seed must be stored in new bags because old bags can be a source of contaminants and insect infestation.

The most important factors affecting storability are, the type of seed crop, mositure content, storage conditions (temperature, relative humidty) and storage pests. Most agricultural crops, with few exceptions, have a medium-, to long-term storage period with minimum loss of viability. Generally, cereals store better than legumes, and legumes store better than oilseed crops. The seed should be harvested when it reaches harvest maturity, dried to safe moisture content (if necessary), cleaned and stored under favourable conditions, and protected from damage and pests until planted. Keeping the store clean, cool and dry is the best management practice because this reduces physiological processes, fungal and insect activities.

The storage facilities should be cleaned and sprayed with suitable pesticides to protect the seed from insect pests. In cereals there are more than 20 different species of storage pests, of which grain borer (*Rhizopertha*) and weevils (*Sitophilus*) occur most frequently. The typical storage pests of legumes are *Callosobruchus* and *Bruchidius* spp. *Callosobruchus* is distributed worldwide, whereas *Bruchus* is most important in the Mediterranean countries and Asia.

Adequate planning and management are essential to avoid losses and keep seed free from insect pests during storage. The following preventive and remedial measures should be taken:

- Ensure that all seed storage structures are clean, cool and dry. Locate seed storage sites in cool and dry (low relative humidity) areas
- Clean and spray all storage structures thoroughly with insecticides, followed by a regular spray of residual insecticide
- Maintain proper sanitation in and around seed stores to deny insects any shelter for multiplication, and to control rodents
- Clean the seed and reduce its moisture content to a level that will allow safe storage for the required period
- Use new bags to avoid both insect infestation and mechanical mixtures. Seed should be bagged in a thick weave cloth bag without loose weaves
- Keep seed bags on wooden pallets at least 50 cm away from walls, with aisle space of 1 m, to ensure adequate aeration
- Inspect seeds upon entry. They must be free from storage pests. Check stored seed at least once a week, for insects, and if found, fumigate immediately
- Apply sound rodent monitoring and control program during seed storage.
- Store seed of high germination and vigor only. Immdeately dispose off poor quality seed
- Maintain seed identity by labeling each bag, keeping up-to-date records, and using stack cards

Seed Quality Assurance

Quality assurance system is a major component of seed production. Similarly, on-farm seed production should have an

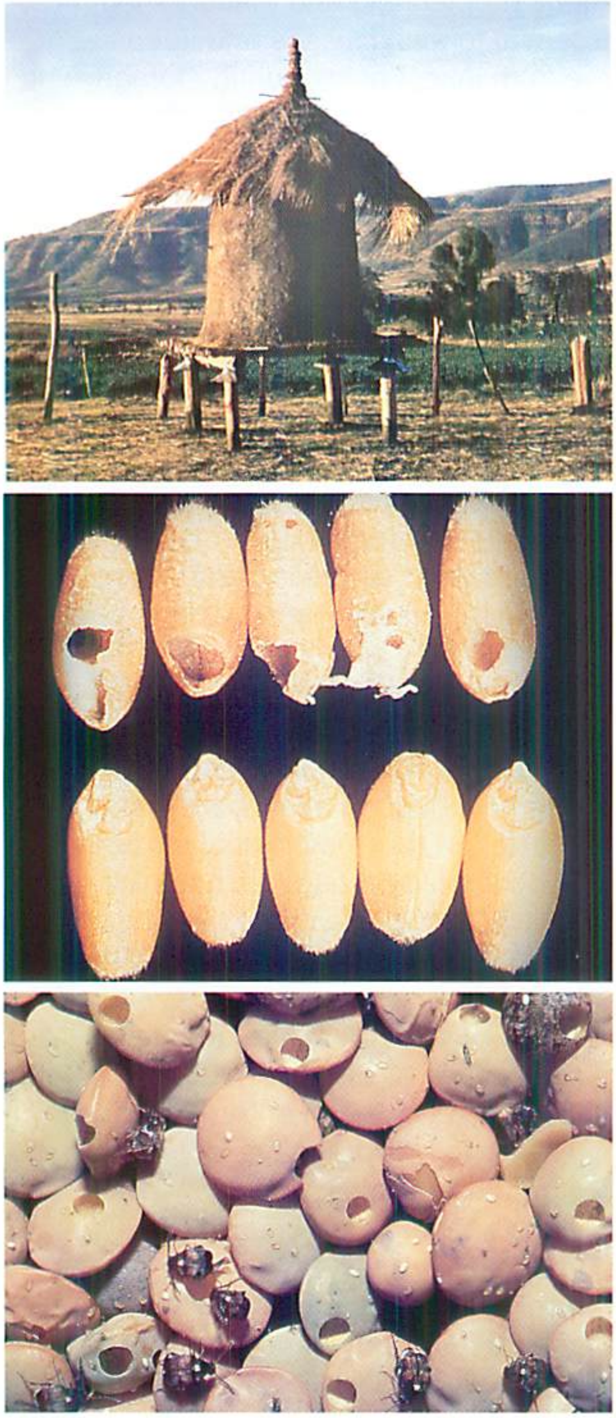


Figure 18. Providing adequate storage facilities and management maintains seed quality (top) and damage by storage pests (weevils in wheat, middle; and bruchids in lentil, bottom)

in-house quality assurance program to ensure that varietal purity and identity and other seed quality attributes (purity, germination, health) are maintained. Certain minimum standards need to be set and maintained, taking into consideration the relevance of the quality attribute and experience of seed producers. A seed crop should always be inspected on the field and the seed tested for quality.

The seed producers, with the assistance of extension staff or development agents, should carry out field inspections. They should ensure that the seed crop is free of rogues (offtypes, other varieties, other crops, noxious weeds, and infected plants) to their satisfaction, or take the necessary remedial action. After the seed has been harvested, cleaned and/or treated, a sample should be taken and simple tests conducted for purity and germination.

The two most important seed quality assurance activities relevant to VBSEs are field inspection and seed testing.

Field inspection

Field inspection is a systematic procedure to verify the levels of contamination with offtypes, other crops, seed-borne diseases, and noxious weeds in seed multiplication fields. During inspection, by comparing the results against prescribed set of standards, the seed fields can be approved to be harvested for use as seed or discarded for sale as grain.

Continuous and rigorous supervision is needed in quality seed production. The first thing is to verify the suitability of the site and field for seed production. The second is to check on plant density and need for weed control during seedling emergence and establishment. The third is to inspect the field to certify or discard the seed crop at full maturity. Regular field visits are necessary for proper crop management and monitoring.

Field inspection is one of the practices that differentiate quality seed production from grain production. It is a measure to ensure that the seed produced will meet the seed quality standards. It assesses the potential risks of contamination and remedial actions required.

Failing to inspect seed production fields may adversely affect all quality attributes and standards of the harvested seed.

Seed Testing

The first and most crucial step in seed testing is sampling of the seed lot. The objective of seed sampling is to draw a representative sample from seed lots to determine quality. It is important that the sample precisely represents the composition of the seed lot. Physical purity and germination are the two most common seed quality tests performed in the laboratory.

Seed Sampling

Sampling can be done by hand or by specially designed equipment. The equipment and procedure for sampling are described below.

Equipment

(a) Simple spears for taking primary samples from seed lots
(b) Simple seed containers for mixing primary samples, and
(c) Sample bags (paper, cloth) to store samples until testing

Sampling procedures

1. Take many small portions of seed (primary samples) from different parts of the seed lot or containers
2. Combine the small portions (primary samples) together into a composite sample
3. Thoroughly mix the composite sample and reduce the sample to the required weight
4. Conduct simple informal tests on the farm or send the sample to the seed testing laboratory

Physical purity test

The equipment and procedure for purity test are as follows:

Equipment

(a) Seed containers or trays
(b) Simple weighing balance

Testing Procedures

1. Take a minimum weight of seed based on crop (about 120 g for small-seeded cereals)
2. Divide the seed into three fractions: pure seed, other crop/weed seeds, and inert matter
3. Weigh each fraction separately
4. Calculate the weight of each fraction separately
5. The weight of pure fraction equals percentage purity.

For example, in wheat,120 g is used for purity testing. If the pure seed fraction is 110 g, other crop seed is 5 g, and inert matter is 5 g, the purity of the seed sample is calculated as follows:

Physical purity (%) = [110 x100]/120 = 91.67%.

If 100 g of seed is used, the weight of the pure seed fraction is equivalent to the physical purity (%) of the seed lot.

An alternative simple and quick method can also be used to assess the purity of the seed lot using a 'flotation' method. A small quantity of seed will be poured into a bucket that is half full of water, where the straw, chaff, common weed seeds, etc., will float to the top of water and the heavier and good seed will sink to the bottom of the bucket. The equipment and procedure for flotation method are as follows:

Equipment

(a) Bucket
(b) Water

Testing procedures

1. Pour 4-7 kg of seed into a bucket that is half full of water
2. Straw, chaff, common weed seeds, etc., will float to the top
3. Heavy and good seed will sink to the bottom of the bucket
4. Check 'floating' materials to either clean the seed or change the seed source

The procedure is very useful for wild oats and ergots in cereals.

Germination test

The equipment and procedure for a germination test are as follows:

Equipment

(a) Wooden/plastic germination boxes/trays
(b) Clean sand/soil, piece of paper or cloth

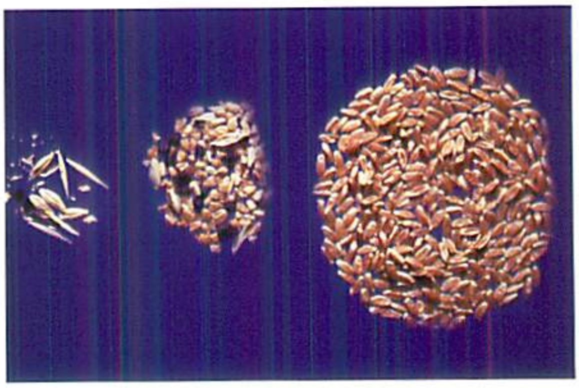
Testing procedures

1. Put clean moist sand/soil in at least two boxes (of 10-12 cm)
2. Make planting holes in sand/soil in each box (2-3 cm)
3. Plant seeds in boxes (minimum of 100 seeds in each box)
4. Keep boxes moist, not wet, throughout the germination period
5. Remove seedlings and observe germination (after 5-8 days)
6. Classify seedlings into normal/abnormal and seeds into ungerminated/dead
7. Calculate the average percentage of each fraction separately
8. Number of normal seedlings equals percentage germination

For example, if you have planted a total of 200 seeds, i.e., 100 seeds in each box, and get 95 normal seedlings in box 1 and 85 normal seedlings in box 2, the average germination capacity can be calculated as follows:

Germination (%) = [95 + 85]/2 = 90%

It is also possible to plant 100 seeds only where the number of normal seedlings is equivalent to germination capacity.



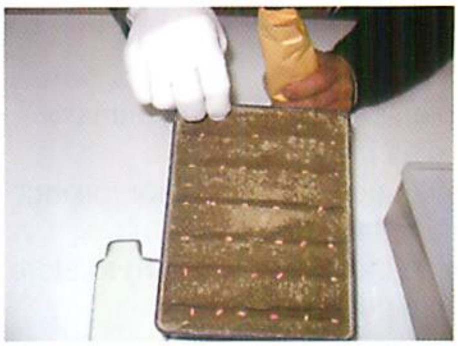


Figure 19. Fractions of a physical purity test (top), flotation method (middle), and planting seed for germination test (bottom)

Moisture test

Seed moisture is seldom a problem in dry areas, where the seed crops properly dry before harvest. In humid tropical and temperate climates, seed moisture is a problem, where on-farm drying is essential before storage. Although simple and portable moisture meters are available to check seed moisture before or after harvesting, it would be impractical to conduct accurate moisture tests at the farm level. Therefore, to assist farmers in avoiding damage to seed because of excessive sun-drying (if practiced) a simple alternative method called 'salt test' is suggested. The equipment and procedure for 'salt test' is as follows:

Equipment

(a) Glass jar with a lid
(b) Table salt

Testing Procedure

1. Put table salt in the jar (fill up to a quarter of the jar)
2. Add a sample of seed (fill up to one half of the jar)
3. Cover the jar with lid and shake for five minutes
4. Allow the seed to settle for 10 minutes
5. A moist seed shows damp salt stuck on jar, whereas in dry seed no salt will stuck on jar

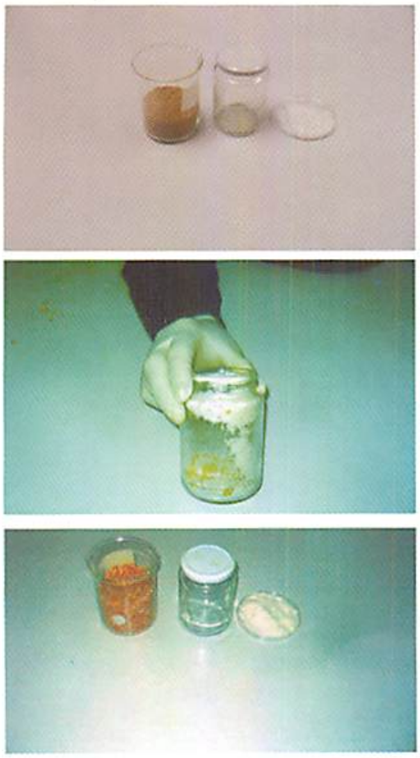


Figure 20. Moisture determination using salt method: equipment (top), dry seed (middle) and moist seed (bottom)

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