Wheat seed production

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WHEAT SEED PRODUCTION IN DEVELOPING COUNTRIES

The future for wheat seed production appears to be mixed. Wheat is a high-volume, low-profit seed crop and has been produced primarily by heavily subsidized government seed programmes. With privatization and liberalization, many of these programmes are at risk of being closed down. The private sector, however, may not focus on wheat seed due to its characteristics (self-pollinating, high-volume and low-profit). If private seed enterprises exist, they consider wheat seed to be of secondary importance. Furthermore, in most countries there has been no ongoing effort to promote the use of improved seed by wheat farmers, and no significant breeding developments have recently taken place to increase yield and quality. Since wheat is a self-pollinating crop and the grain can be used as seed, farmers tend to replant their own seed. It is, therefore, expected that in the future the large majority of resource-poor, small-scale farmers in many developing countries will have to rely on seed saved from the previous harvest.

In the developed world, declining world market prices for grain do not encourage farmers to produce wheat. Moreover, there have been no widespread disease outbreaks, which make seed treatment (and thus purchase of certified seed) necessary. Countries in Europe and the United States are attempting to reduce subsidies, which will result in further unwillingness to invest.

On the other hand, there are possibilities in developing countries for major increases if significantly improved varieties appear on the market, disease outbreaks occur and organized promotional efforts emphasize maximum production efficiency including improved seed. Introduction of Plant Variety Protection and/or sophisticated technologies, such as Genetic Use Restriction Technology (GURT), may also induce the private sector to invest in wheat seed.

In Australia, Europe and the United States, there is a possibility of increased use of seed of higher yielding varieties if subsidy reductions and/or market trends cause a decline in production area, with only the more efficient farmers remaining in production and attempting to produce more (or the same total amount) and more efficiently from less area as a result of trying to diversify crop production.

SEED

Seed is a means of dispersal for plant populations in space (spatial) and time (temporal), representing continuity and change, and thus adaptation to the local environment. Seed has played a critical role in agricultural development since prehistoric humans domesticated the first crops.

In modern agriculture, seed is a vehicle to deliver almost all agriculture-based technological innovations to farmers so that they can exploit the genetic potential of new varieties. The availability, access and use of seed of adaptable modern varieties is, therefore, determinant to the efficiency and productivity of other packages (irrigation, fertilizers, pesticides) in increasing crop production to enhance food security and alleviating rural poverty in developing countries.

For seed to play a catalytic role, it should reach farmers in a good quality state, i.e. high genetic purity and identity, as well as high physical, physiological and health quality. In contrast to fertilizers and pesticides, farmers select and save seed to plant the next year's crop, and any off-farm seed from the formal sector should be of a better quality for farmers to invest in it. Therefore, the best production techniques need to be followed to produce good quality seed.

For wheat, seed and grain production follow rather similar operations but different strategies. Apart from good agronomic management of the crop, seed production differs from grain production on the following key issues: land requirement, isolation, roguing, prevention of contamination and limitations of generations. Another difference is that seed crops must meet specific quality standards prescribed by the national seed regulations. The technical, administrative and legislative control by the certification agency provides guidelines that have to be followed to produce good quality seed that meets the standards.

VARIETY DEVELOPMENT, EVALUATION AND RELEASE

Modern varieties are the backbone of the formal seed industry. National Agricultural Research Systems (NARSs) have a major responsibility for variety development and for generating appropriate technologies to better utilize the yield potential of new varieties. The new varieties must pass through a series of evaluation, release and registration tests and procedures before farmers can use them. Basically two type of tests are carried out: Distinctness, Uniformity and Stability (DUS) and Value for Cultivation and Use (VCU).

A DUS test is a descriptive assessment that establishes the identity of the new variety, by using morphological characters, as well as its uniformity and stability. It is a useful tool for the purposes of seed production, certification and plant variety protection. The DUS tests usually run for two years. The new variety is compared with existing varieties to establish its distinctness. A variety description is prepared, and differences with other varieties noted.

The VCU trials focus on the benefit of the variety to the end users, farmers and consumers. National multilocation variety trials enable identification of superior varieties that meet diverse agronomic and consumer requirements. The VCU tests usually run for three years. In some countries, the variety is tested in on-farm verification trials under farmers' management conditions during the last year.

Based on DUS and VCU test results, a variety may be released and registered for farmers' use. Many developing countries give priority to agronomic (VCU) trials rather than descriptive (DUS) tests. While both tests are important, the benefits of the two tests must be considered based on the immediate need of the country to use available resources efficiently and economically.

SEED CLASSES

Seed production follows a generation system to ensure that all seed that is marketed to farmers originates from a known source (breeder seed). When a variety is officially released, the small amount of breeder seed received from the breeder (agricultural research centre) is multiplied through a number of generations before it becomes available to the farmers in larger quantities as certified seed. Each generation is produced under strict supervision and must meet seed quality standards. The number of generations that are allowed after breeder seed depends on the mode of reproduction of the crop, risk of contamination, multiplication ratio and quantity of the seed required. For wheat, four to five generations are commonly used.

Different generation schemes exist (Table 28.1), which vary very little, particularly in nomenclature. The procedures followed are essentially the same. For the purpose of this chapter, the Organisation for Economic Co-operation and Development (OECD) generation scheme is used as

TABLE 28.1
Comparative seed nomenclature in selected countries of West Asia and North Africa

Definition	OECD[a]	AOSCA[b]	Ethiopia	Egypt	Jordan	Algeria
1st generation supplied by plant breeders	Breeder	Breeder	Breeder	Breeder	G_1	G_0 (G_1, G_2)
2nd generation	Pre-basic	Foundation	Pre-basic	Foundation	G_2	G_3
3rd generation	Basic	Registered	Basic	Registered	G_3	G_4
4th generation	Certified 1	Certified	Certified 1	Certified	Certified 1	Registered 1
5th generation	Certified 2	-	Certified 2	-	Certified 2	Registered 2

[a]OECD = Organisation for Economic Co-operation and Development.
[b]AOSCA = Association of Official Seed Certifying Agencies.
Source: FAO, 1975; van Gastel and Hopkins, 1988.

outlined below:

- Breeder seed is the initial source of seed and is usually produced by the breeder. It is the source for the production of pre-basic or basic seed.
- Pre-basic seed is the progeny of the breeder seed and is usually produced under the supervision of a breeder or his designated agency. This generation is commonly used for crops that have low multiplication ratios and where large quantities of certified seed are required.
- Basic seed is the progeny of breeder or pre-basic seed and is usually produced under the supervision of a breeder or his designated agency and under the control of a seed quality control agency.
- Certified seed is the progeny of basic seed and is produced on contract with selected seed growers under the supervision of the seed enterprise, public or private. Certified seed can be used to produce further generations of certified seed or can be planted by farmers for grain production.

Breeder seed production is not monitored by the seed certification agency, while basic seed and certified seed are covered in the seed certification scheme. The seed quality control agency verifies the quality both in the field and in the laboratory and certifies that the seed meets the national standards. Such classes of seed are known as certified. It is important to note that all certified seed classes relate to a breeder seed through one or more generations.

Some developing countries, where natural disasters such as drought are a common phenomenon, recognize a ‘commercial seed’ class to meet seed shortages in emergency situations. In such cases, the standards for certified seed are often lowered and accepted for distribution to farmers to overcome seed shortages. In other situations, commercial seed is simply a grain used as seed after laboratory testing for some quality attributes, such as purity and germination.

Variety maintenance and breeder seed production

Upon release of a new variety, a breeder will make available a small quantity of seed stock that is very pure and represents the variety. This stock is referred to as parental material and forms the basis of any future maintenance and seed multiplication of the variety (Laverack, 1994). Laverack defines maintenance as “the perpetuation of a small stock of parental material through repeated multiplication following a precise procedure”. For wheat, an ear-to-row (Plate 74) method is recommended, where a number of ears (depending on the total quantity of certified seed required) that are true-to-type are selected, threshed separately and then planted in individual rows. During the entire growth period, the rows are inspected regularly, and any row with off-types or deviants is discarded. Ears are selected from the remaining rows to repeat the cycle, which is usually referred to as maintenance. The remaining rows are bulk harvested, and the seed is called breeder seed. In India, for example, 1 000 plants are used for wheat variety maintenance (Singh, 1985).

Each year the cycle is repeated to provide a regular supply of breeder seed for further multiplication to basic seed and then to certified seed. Maintenance and breeder seed production is the responsibility of the breeder or the institution that developed the variety. In many developing countries, maintenance is seldom carried out properly, and the responsibility is often taken over by seed production organizations. Some national seed programmes (e.g. Ethiopia) have established special farms to produce early generations (pre-basic and basic seed) to maintain quality and availability.

Laverack (1994) described different arrangements and management approaches for breeder seed production that can be useful and adopted in developing countries. In Morocco, a separate Seed Unit has been established within the Institut National de la Recherche Agronomique to maintain and produce breeder seed of public varieties.

PRODUCTION PLANNING

New improved varieties developed by NARSs should be multiplied and made available to farmers in the shortest possible time to realize the benefits of investments in agricultural research. Appropriate seed production techniques coupled with strict quality control measures ensure that varietal purity and identity is maintained, which is the cornerstone of the entire seed programme. The rate at which the variety is multiplied and accessed restricts the availability of seed and its adoption and rapid diffusion through formal or informal channels.

Most farmers have a tendency to save their own seed of self-pollinating crops such as wheat compared to open-pollinated crops or hybrids where the risks of contamination and decrease in yield are higher. The seed renewal rate, the frequency in which farmers purchase certified seed of the same variety from the formal sector, varies between the type of seeds, crops, production environments and socio-economic factors.

The multiplication factor can be defined as the amount of seed harvested from each quantity of seed sown. It differs from crop to crop, but is largely dependent on climate, physical factors (soil fertility, etc.) and agronomic management.

New varieties, after they enter commercial production, may lose their genetic potential or become susceptible to pests over time, which requires their replacement. Moreover, the varieties may also be exposed to genetic, mechanical and pathological contamination during the seed multiplication process. There is a practical need to limit the number of generations that the seed is multiplied after breeder seed.

For each generation, it is important to make an accurate estimate of the seed that needs to be produced every year. The total requirement depends on: (i) crop area planted; (ii) seed renewal rate; (iii) seed rate; (iv) multiplication ratio; and (v) number of generations. When planning seed production, the rates of rejection during field inspection, processing and laboratory testing should also be considered. Furthermore, a certain amount of carry-over seed should be taken into account, particularly for early generation seed. Precise estimates of seed demand are difficult because several factors, such as weather conditions and socio-economic factors, influence farmers' decisions on which crop to grow the next year. In case of wheat, farmers may prefer to keep own-saved seed for a longer period than the anticipated seed renewal rates of four to five years. The seed demand of new varieties is even more difficult to estimate and depends on the adoption rate, which in turn is influenced by several technical, institutional, economical and sociological factors.

PRODUCTION ARRANGEMENTS

Generally, early generations (breeder and prebasic seed) are produced on agricultural research farms and basic seed on specialized seed farms, while certified seed is more conveniently and economically produced by farmers who are contracted by the seed enterprise (public or private). Farmers' cooperatives and associations are often involved in certified seed production. The seed enterprise provides technical guidance and advice to growers on various aspects of seed production, such as planting, roguing and harvesting, as well as monitoring and supervising field operations. The seed quality control agency inspects the fields and tests the seed in the laboratory.

In wheat, seed and grain crop production follow rather similar operations. The end product can either be used for consumption or for planting. Such similarity can easily lead to mixing seed and grain during planting, harvesting, transportation and storage. Seed production should be strictly monitored, and seed producers should be quality conscious. In developing countries, farmers are rigorously selected before they become seed growers.

In many developing countries, the availability of experienced seed growers is limited, and seed organizations provide considerable support. A village seed production scheme, which groups adjacent fields for seed production, will help to overcome problems of isolation distances and supervision when contracting smallholder farmers for seed production.

The cost of seed production is higher than the cost of producing grain for consumption because it involves extra operations to maintain quality. Thus seed growers incur additional costs in field operations and management and must be paid a premium. In case of wheat, the additional premium paid over the grain price ranges from 10 to 20 percent.

Land selection

Wheat can be successfully grown in most parts of the world, both in tropical and temperate environments and on all soil types that are well drained and productive. Seed (certainly breeder seed) should be produced in areas: (i) where the variety is adapted; (ii) where soil conditions are optimal (to achieve a high multiplication ratio); and (iii) where climatic conditions are reliable to avoid loss due to natural hazards (flooding, drought, frost, etc.). The early generations should possibly be planted at two different locations to reduce the risk of losing the complete generation.

In some tropical countries, there is a high risk of rain coinciding with harvest time. Rainfall at maturity delays harvesting, causes sprouting and predisposes the crop to fungal attack, resulting in poor seed quality, i.e. reduced viability and vigour. Selection of appropriate sites is very essential to produce quality seed.

Previous cropping

The crop should be planted on a field with a known history to avoid contamination from volunteer plants, noxious weeds and soilborne diseases that are potentially seed transmitted. The minimum number of years that is allowed between the planting of two seed crops (or seed and grain crop) is usually prescribed by the national seed regulations. Examples of requirements for previous cropping in countries in West Asia and North Africa are provided in the WANA Secretariat (1995).

A wheat seed crop should never immediately follow wheat, unless the wheat crop in the previous season was of the same variety and of the same or higher generation. For basic seed, it is often recommended that the field should not have been planted with wheat or other small grain crops for at least two consecutive years. For certified seed, no wheat crop should have been grown in the previous year.

A suitable crop rotation plays an important role in pure seed production. For example, a two-year rotation for flag smut and seed gall nematode is suggested where applicable. For wheat, previous cropping could be legumes, vegetables or clean fallow, but other cereals (barley, oat, rye and triticale) and forage crops (oat) should be avoided.

Weeds

Seed contaminated with weeds could be the means for introduction and dissemination of noxious weeds. Mohamed (1996) mentioned that the introduction of wild oats in wheat in Egypt is attributed to contaminated seeds. Therefore, heavily infested fields with noxious weeds should be avoided. Unfortunately, fields in many countries are infested with wild oats (*Avena fatua*, *A. sterilis* and *A. ludoviciana*), noxious weeds that are spread almost all over the world and are difficult to eradicate. *Avena fatua* has no resistance to frost, and it is only problematic in summer wheat. In West Asia and North Africa (WANA), the problem is mainly *A. sterilis*.

Worldwide, a 10 percent potential yield loss in cereals is due to weeds, even with currently used control measures (Koch and Hess, 1980). In wheat, Tanner and Sahle (1993) cited that the use of clean seed had a significant effect on grain yield compared to weeding by hand or hoe.

For land selection, the most essential prerequisite is the selection of clean fields that are properly rotated and known to be free from contaminants.

Planting

Seedbed

Seedbed preparation is the same as for a grain crop. Wheat does not suppress weeds sufficiently and needs a clean, weed-free seedbed for planting (Doerfler, 1976). In Sudan, weed competition studies on wheat showed that if weeding is not carried out between two and four weeks after sowing the yield is reduced by 20 percent (Mohamed, 1996).

Planting method

Planting with an automatic drill is recommended but not essential. However, row-planting has an advantage over broadcasting, as it requires less seed and facilitates mechanized weed control, roguing and field inspection (Galanopoulou *et al*., 1996). Roguing lanes (empty rows at intervals) should be left, which could be used by the seed grower to walk through the field when roguing and inspecting the crop, as well as for spraying the crop.

Deep sowing delays emergence, resulting in weaker seedlings, reduced emergence and poor tillering and yield. Varieties with short coleoptile length, particularly semidwarf varieties, suffer most compared to varieties with longer coleoptile length (Perry and Hillman, 1991).

Seed rates

The optimum seed rates for wheat vary with variety, location and method of planting. For seed production fields, a lower seed rate may be recommended because lower seed rates lead to higher multiplication factors (Nelson, 1986) but to lower yield per unit area (Table 28.2). Higher multiplication factors lead to rapid seed increase (more seed harvested per kilogram of seed planted), and farmers will benefit from the improved variety earlier. Low seed rates do not only increase the multiplication factor, but also often improve seed quality because a lower number of plants per unit of land receive better nutrition, thus producing better quality seed.

In practice, very low seed rates are not used. Lower seed rates may be used when planting early generations, but certified seed is planted at the normal or slightly lower seed rate. For

TABLE 28.2
Effect of seed rate on multiplication factor of wheat

Seed rate (*kg/ha*)	Yield[a] (*kg/ha*)	Multiplication ratio
25	4 081	157
50	4 907	98
75	5 176	69
100	4 949	49
125	5 574	44

[a]Yield is average of two varieties.
Source: FAO, 1975; van Gastel and Hopkins, 1988.

certified seed, acreage becomes too large to be closely monitored and thus the risk of reduced yield is too high.

Seed size

In wheat, seed size is positively correlated with seed vigour: larger seeds tend to produce more vigorous seedlings (Ries and Everson, 1973). Larger seeds of spring wheat produced higher yields than smaller seeds under late-sown conditions (Singh and Kailasanathan, 1976), but not under optimum management conditions (Kalita and Choudhury, 1984). Similarly, Khah *et al.* (1989) found that low-vigour spring wheat seed produced lower yields only when it resulted in low plant populations or when planting was later than normal. However, Mian and Nafziger (1992) have found that seed size has little effect on emergence of soft red winter wheat.

Fertilization

Fertilizer application to seed crops should be based on local recommendations. A well-balanced supply of nitrogen, phosphorus and potassium (NPK) is essential for seed production as it has an influence on seed development and thereby on seed quality. Phosphorus is essential for enhancing seed maturity and K for seed development. Ascher *et al.* (1994) concluded that seed nutrition combined with soil nutrition gave better yields and better seed quality. For example, cereals (wheat, barley and oats) grown from seed with a high P concentration gave 20 percent more yield than with low P, with a critical concentration of 0.30 percent for wheat seed (Perry and Hillman, 1991). Ngugi (1992) reported that the use of compound fertilizers with sulphur (S) and calcium (Ca) gave higher grain yield and better seed quality (higher bushel weights) in non-traditional wheat-growing areas of Kenya.

The benefit of fertilizer is not always apparent. Fertilizer may increase the disease incidence and competition of weeds, such as wild oats. High N levels may promote vegetative growth, delayed maturity, predispose the crop to foliar diseases and lead to severe lodging and reduced yield and seed quality. In Ethiopia, both N and P increased the incidence of stripe rust, though the effect of P was less pronounced (Tanner *et al.*, 1992). In a similar study, the density of wild oat panicles increased with N fertilizer, but decreased with P fertilizer. Top dressing wheat crops with high levels of N will make the crop lodge, which makes it difficult to be field inspected by the seed certification service.

Cleanliness of machinery

Cleanliness of machinery upon planting is very important. Seed drills should be cleaned with compressed air when changing between varieties and other crops of similar seed characteristics. Vans and trailers used for transporting the seed should be completely clean to avoid contamination.

Isolation

Isolation, growing a seed crop separate from all sources of contamination (genetic, physical and pathological), is one of the fundamental seed production techniques. In practice, such contamination can be reduced by not planting a seed crop in the vicinity of a similar crop that may contaminate it. Small, long and narrow fields need larger isolation distances than large or wide fields. Long and narrow strips are more prone to

TABLE 28.3
Examples of isolation distances for wheat in West Asia and North Africa

Country	Isolation distance (*m*)		
		Seed class	
	Pre-basic	Basic	Certified
Cyprus	-	2	2
Egypt	5	5	5
Iran	5	5	5
Sudan	4	4	4
Syria	2	2	2
Tunisia	1	1	1

Source: WANA Secretariat, 1995.

contamination than square fields. The minimum distance required for a particular crop is usually prescribed by the national seed regulations and depends on the seed class. Minimum isolation distances are larger for the early than for the later generations.

Wheat is entirely a self-pollinating crop with a very low percentage of cross-pollination, from 1 to 4 percent (Doerfler, 1976). Therefore, the risk from genetic contamination through out-crossing is small. Appropriate isolation is, however, required to minimize physical contamination.

For wheat, it is usually sufficient to have a small strip of land between different fields to avoid mechanical admixtures. Minimum isolation distances (in metres) used in some Middle Eastern and North African countries are presented in Table 28.3. In India, an isolation distance of at least 3 m is required to separate a wheat seed field from the same variety not conforming to the standard (Randhawa, 1983).

Early generations, such as breeder seed, can be located in the middle of a field with the same variety, which is a common practice in some North African countries. Breeder seed (G_1) is grown in the middle of a pre-basic (G_2) field and G_2 in the middle of a basic (G_3) field (Plate 75) of the same variety to reduce risk of genetic and mechanical contamination (for names of generations refer to Table 28.1).

For wheat, isolation distances are more important when dealing with smut-susceptible varieties. In India, Agarwal (1983) reported that basic and certified seed fields of susceptible wheat varieties should be isolated by 150 m from fields infected with loose smut in excess of 0.1 and 0.5 percent, respectively. In Morocco, a 150 m isolation distance is required from other wheat fields if infection with loose smut is beyond 0.1 percent for pre-basic, 0.2 percent for basic, 0.3 percent for certified 1st generation and 0.5 percent for certified 2nd generation seed (WANA Secretariat, 1995).

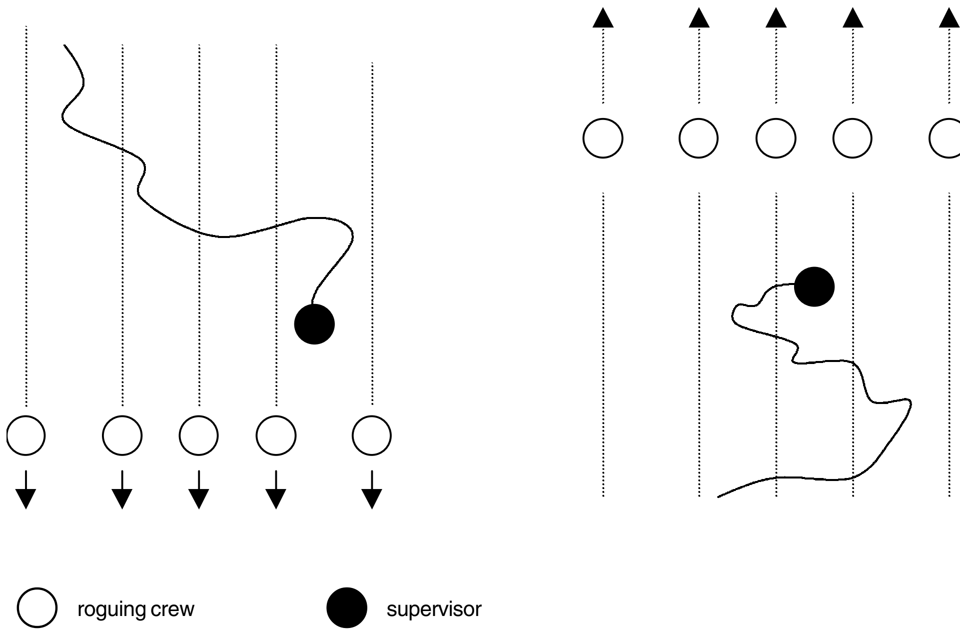
Restricting the number of varieties grown for seed multiplication per farm will reduce the chances of contamination. For example, in Tunisia only one wheat variety can be multiplied on a farm.

Crop management

Agronomic management should be optimal and is similar to that for a grain crop. Small differences do, however, exist:

- using lower seed rates to increase the multiplication factor;
- leaving lanes to facilitate roguing and inspection;
- applying slightly less than optimum amount of N to reduce lodging;
- maintaining the species and variety purity;
- controlling diseases that are seed transmitted.

FIGURE 28.1
Diagram of how a five-member roguing crew follows roguing paths through a seed field, followed by the supervisor



Roguing

Roguing, removing undesirable plants, is another fundamental aspect of seed production. Undesirable plants, commonly known as rogues, are: (i) off-types or genetic variants of the same variety; (ii) other varieties of the same species; (iii) other crop species of similar growth habit and seed characteristics; (iv) noxious weeds; and (v) infected plants with seed-borne diseases. Roguing is carried out to maintain the variety and species purity of the crop and to keep the seed crop free from seed-transmitted diseases.

Roguing follows a systematic procedure (Figure 28.1) and should be carried out at the time when rogues can be most easily identified and before any contamination occurs to the seed crop. The best periods for roguing a wheat seed crop are at heading and at maturity because off-types and other varieties of the same species are most easily identified. In wheat, all off-types, including those that appear due to residual segregation, should be removed. For example, the inherent problem of tall off-types in semidwarf wheat varieties due to aneuploidy, arising from chromosome pairing failures at meiosis, has been discussed by Storlie and Talbert (1993) and Worland and Law (1985). Similarly, other crop species whose seed is difficult to separate during processing (barley, oats, triticale, rye), noxious weeds (wild oats, lolium) and infected plants with seed-borne diseases (i.e. *Fusarium*, *Helminthosporium*, *Tilletia*) are usually easily distinguished at these stages. It may be necessary to rogue the field several times, and all tillers and roots should be removed (pulled) to prevent regrowth. Rogues should be removed from the field and disposed of far away from the field or burned.

Roguing loose smut (*Ustilago tritici*) infected plants has no effect (except in reducing the disease inoculum) because the spores have already been spread and infection of the seed crop has taken place by the time the symptoms become visible. Therefore, certification schemes often do not allow the removal of smut-infected plants. However, reports from India indicated that loose smut-infected plants do head earlier and that flag leaves of smutted tillers exhibit yellow chlorotic streaks, yellow patches or yellowing at tips, even before ear emergence, and can thus be rogued before flowering. However, plants without streaks were also smutted (Agrawal and Gupta, 1989).

Seed certification schemes set minimum standards for each class of contaminants that are permitted in a seed crop. Roguing aims at ensuring that these standards are met. Roguing should be carried out only when the seed fields do not meet these standards; roguing fields that meet the standards is not economical.

While roguing, no selection should be carried out to ensure that the genetic make-up of the variety remains the same. Therefore, roguing of early generations should preferably be carried out by the breeder or under the breeder's supervision. Roguing in early generations can be most effective.

HARVESTING

Mechanical harvesting is a common practice for seed production fields. Breeder and pre-basic seed are harvested by plot combine and do not constitute many problems. Basic and certified seed, however, have to be harvested with commercial combine harvesters.

The most critical factors to be considered are seed moisture content, mechanical damage and cleanliness of equipment. For seed crops, dry weather during ripening and harvesting is essential.

Moisture

Cereal seed reaches physiological maturity between 35 to 45 percent moisture content, but it needs to dry down to a safer moisture content for harvesting and storage (Boyd *et al*., 1975). The seed moisture content can be used as an indicator of when the crop is ready for harvest. Electric moisture meters or the crop characteristics can be used to decide when to harvest. For wheat, threshing or combine harvesting at 16 to 19 percent moisture content reduces mechanical damage (Thompson, 1979).

Mechanical damage

Proper adjustment of the concave clearance and drum speed of a combine is essential to avoid damage to the seed crop. Mechanical damage becomes a serious problem for durum wheat seed production in Algeria (Lakhdar *et al*., 1998) and Morocco (Grass and Tourkmani, 1999). In Algeria, seed harvested by a single ear thresher or combine showed low germination and increased fungal attack (Lakhdar *et al*., 1998).

Cleanliness

Combine harvesters are often difficult to clean and may still harbour contaminating seed even after thorough cleaning. The availability of compressed air is important. The combine should be thoroughly cleaned before harvesting, as well as between different varieties. 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 of certified seed, it is also possible to harvest and discard the outlying rows of the field.

After harvesting, the seed should be packaged in new and clean bags to avoid contamination.

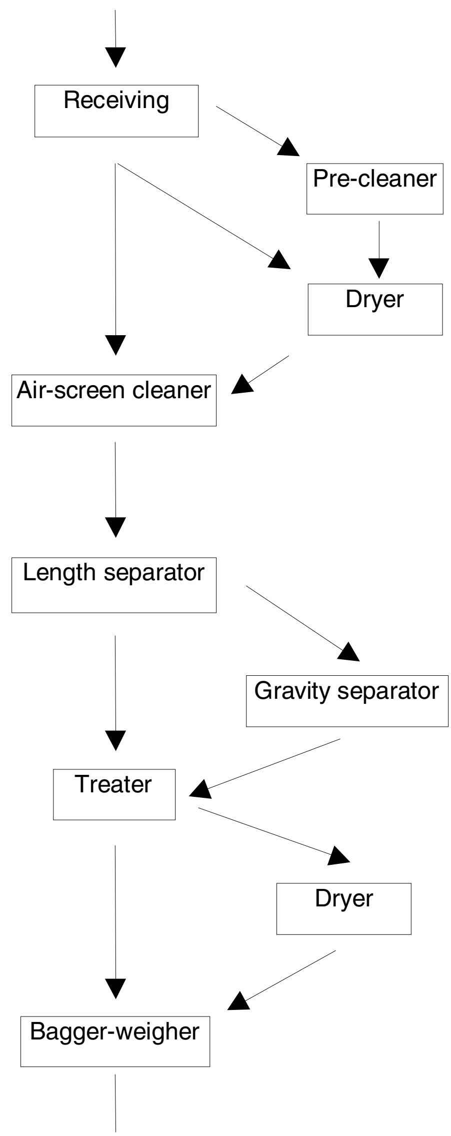
PROCESSING

After a seed crop has been harvested, the seed, if necessary, has to be dried and cleaned, i.e. removal of inert matter, seed of weeds, other crops and other varieties, and seeds that are diseased, damaged and deteriorated. Cleaning can be done because wheat seeds differ in length, width, thickness, density, weight and shape.

For wheat seed cleaning, mainly screens, indented cylinders and air are used. Screens separate based on the width and thickness; a width (or diameter) separation is obtained by round screens, while for thickness separation oblong screens are used (Plate 76). Indented cylinders carry out length separation; the indents (cells or pockets) in the cylinder will, depending on their size, lift the seeds, which fit in the indents. Air separates seeds according to their behaviour in an air stream. The most important characteristic is the weight; light particles (dust, chaff, glumes or empty or partly filled seeds) will be lifted, whereas the heavier seed will fall down through the air stream. Each crop requires a different set of machines.

The raw (unprocessed) wheat seed is received from growers in bags or bulk and sampled to evaluate the need for fumigation, drying and cleaning, as well as to guide and monitor processing operations. If seed moisture is too high, the seed is first (pre-cleaned and) dried. If insects are present, the seed should be fumigated. After the raw seed has been received and where necessary fumigated, processing operations (and sequence) are as outlined below (Figure 28.2).

FIGURE 28.2
Flow diagram of wheat seed processing



Pre-cleaner

Wheat seed often contains considerable plant material trash, and it is often pre-cleaned. A typical pre-cleaner is similar to an air-screen cleaner, except that it has only one air channel to remove light material, one top scalping screen to remove large particles and one bottom grading screen to remove small particles.

Dryer

If wheat seed is above 11 to 12 percent moisture, it is dried before it goes into bulk storage or processing.

Air-screen cleaner

This is the basic cleaner, usually with two air channels and, preferably, four screens. The first air channel (head aspiration) removes dust and light materials as the seed falls from the feed hopper. The second air channel (tail aspiration) removes light seed and materials after the seed passes through the last screen. Although screen configurations vary considerably, one or two top or scalping screens remove particles larger than the good seed, and one or two bottom or grading screens remove particles smaller than the good seed. Because the average size of wheat seed varies according to the growing conditions, standard screen sizes cannot be recommended. Hand testing screens should be used to determine the exact screen perforations.

Length separator

A length separator is almost always used to clean wheat seed. By using the proper machine configuration, shorter or longer undesirable materials (such as broken grains, weed seeds, oat, barley, etc.) are removed. Broken grains and weed seeds, which are shorter than the good seed, are removed by using cylinders with smaller indents. Larger impurities can be removed by using a cylinder with indents that lift all good seed, but contaminants (wild oats, oats or barley grains and unthreshed glumes) remain in the cylinder.

Gravity separator

After the seed is cleaned by the air-screen cleaner and indented cylinder, it may be necessary to use a gravity separator. The gravity separator classifies a seed mixture mainly according to density or specific gravity. It can be used to remove unthreshed glumes and soil particles, which have similar sizes to wheat but different weights. Another application is the removal of weevil-infested grains from the seed lot and upgrading seed (in order to improve germination). Furthermore, wild oats and some barley may be removed from the wheat seed lots, but at the expense of substantial amounts of good seed and only after recycling the material a number of times on the gravity separator.

Treater

Wheat seed should, if necessary, be treated with the appropriate fungicide to protect the seed and seedling after planting. Insecticides are sometimes applied to protect seed in storage and in the soil. Treatments may be applied to protect the seedlings or adult plants against pathogens carried on or in the seed.

Dryer

In humid and hot climates, seeds may be sealed in vapour-tight plastic bags to maintain viability over longer periods. In such cases, wheat seed moisture content must be below 9 percent, preferably not over 8.5 percent. Usually, a dehumidified, closed-circuit dryer is used after the seed treatment is applied.

Bagger-weigher

The final step is to weigh the proper amount of seed into the proper kind of bag. Wheat seed bags should be of a size that fits local farmer needs (seed rates and field size).

During processing, strict attention should be paid to the cleanliness of the processing machines and any admixture should be avoided. Every processing plant should have a complete set of hand screens, a small air-screen cleaner and an indented cylinder to help determine the proper processing requirements. It is also essential to have an internal quality control laboratory attached to each seed plant with a small seed testing facility. This laboratory unit should constantly monitor the quality of the seed and the efficiency of processing operations.

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. For example, severely infected wheat grains with Karnal bunt either fail to germinate or produce a greater percentage of abnormal seedlings (Singh and Krishna, 1982; Singh, 1980).

In wheat, fungi (*Fusarium* spp., *Tilletia* spp., *Drechslera* spp., *Septoria* spp. and *Ustilago* spp.), bacteria (*Corynebacterium*, *Pseudomonas* and *Xanthomonas*) and nematodes (*Anguina tritici*) are the most important seed-borne diseases due to their worldwide distribution and losses they incur in crop production (Mamluk and van Leur, 1986; Diekmann, 1996a).

Chemical seed treatment is one of the efficient and economic plant protection practices and can be used to control both external and internal seed infection. It protects young seedlings or adult plants against attack from seed-borne, soil-borne or airborne pests. It disinfects seed from pathogen, checks spread of harmful organisms, promotes seedling establishment, maintains and improves seed quality or minimizes yield losses. Selection of the proper chemical depends on the target organisms. A wide range of chemicals (Diekmann, 1993) and equipment (Jeffs and Tuppen, 1986) are now available for such purposes. Some recent literature gives detailed information on the management of bunts and smuts (Wilcoxson and Saari, 1996) and bacterial (Duveiller *et al.*, 1997) seed-borne diseases of wheat.

Meisner *et al.* (1994) indicated that Vitavax 200 (Carboxin [37.5 percent] and Thiram [37.5 percent]) is an effective broad spectrum seed treatment fungicide, both for externally and internally seed-borne diseases of wheat. Moreover, pre-harvest foliar application of chemicals can also reduce the internally seed-borne fungi and can be combined with seed treatment to produce healthy seed. Sinclair (1983) cited that foliar spraying of wheat with benomyl, methyl benzimidazole carbamate or benomyl plus mancozeb reduced *F. graminearum*, whereas capatafol and mancozeb reduced *S. nodorum*.

Apart from disease control, seed treatment also has a positive effect on crop growth and yield. Ahmed (1996) reported that wheat seed treatment with systemic fungicides, such as Baytan, Raxil and Vitavax, significantly increased crop stand, grain yield and yield attributes. Meisner *et al.* (1994) reported a 10 percent increase in wheat yield due to seed treatment with Vitavax 200 against smuts.

Seed production in disease-free areas or under effective disease control and field inspection schemes is very important to obtain disease-free seed. Thus, understanding disease epidemiology, its transmission rate and economic threshold, combined with seed health testing, could help to define the need for seed treatment.

STORAGE

Seed is 'in storage' from the time it reaches physiological maturity on the parent plant until it is planted by the farmer. Germination is highest at physiological maturity, and viability then declines inexorably until the seed dies. Deterioration of seed viability cannot be reversed once it has occurred. Good storage cannot improve the quality of poor seed; therefore, only seed with high germination and high vigour should be put into storage. Storage conditions should then be as favourable as possible to maintain quality. Unfavourable conditions at any time during storage may reduce or destroy viability.

Seed should be harvested when it reaches harvest maturity, dried to a safe moisture content (if necessary), stored under favourable conditions and protected from damage and pests until it can be planted. Conditions that cause the loss of seed viability in storage include:

- immature or damaged seed cannot survive long storage periods. Seed should be harvested when properly matured;
- mechanical injury to seed during harvest or handling makes it more susceptible to deterioration in storage;
- seed should be properly dried before going into storage and protected from moisture and high relative humidity. Fungi (*Aspergillus* and *Penicillium*) cause

damage to stored seed if seed moisture is high;

- high storage temperature has a damaging effect on seed. Stores should be designed so that low temperatures are maintained;
- some seed treatments cause seed to die if it is stored too long; therefore, seed should only be treated when it is certain that it will be sold for planting;
- rodents, mainly rats and mice, can be most destructive to seed. Effective rodent control (traps and poison) is essential in all seed stores. A complete programme of exclusion, sanitation and control should be used;
- insects should be controlled by a combination of insecticides and fumigants. Use safest fumigants (e.g. phostoxin) because some fumigants (e.g. methyl bromide) will reduce germination.

Keeping the seed as dry and cool as possible in clean stores is the best management practice. If seed is dry and cool, physiological processes, fungal activity and insect activity are low. Select a seed storage site that is cool and dry (low relative humidity). O'Dowd and Dobie (1983) described the design of open seed stores, and Ellis (1988) suggested a practical guideline in choosing alternative sites for short- and medium-term seed storage.

Clements (1987) discussed the problem associated with wheat storage under tropical conditions. Wheat seed is storable for medium to long periods if kept under safe storage conditions. For wheat, high seed moisture (above 11 to 12 percent) is the most damaging, and seed must be kept as dry as possible in storage. The response of wheat seed to high atmospheric humidity (RH) in storage varies with temperature. Clements (1987) reported that at 25ºC and 75 percent RH the equilibrium moisture content for wheat is 15 percent, and at 90 percent RH this may increase to 19.7%. He also stated that the critical moisture content for wheat that increases the rate of respiration is 14.6 percent. In general, stored wheat seed should be kept at moisture content levels below 12 percent and relative humidity should not exceed 50 to 60 percent.

Diekmann (1996b) indicates that in cereals there are more than 20 different species of storage pests of which grain borer (*Rhyzopertha*) and weevils (*Sitophilus*) occur most frequently. Some insects, such as the khapra beetle (*Trogoderma granarium*), are quarantine pests in some countries. In India, it is reported that the rice weevil (*S. oryzae*), lesser grain borer (*R. dominica*), khapra beetle and flour beetle (*Tribolium castaneum*) are important seed storage pests of wheat (Singh, 1985). In Bangladesh, farmers traditionally use natural insecticides, such as neem (*Azadirachta indica*), biskatali (*Rumex obtusifolius*) and tobacco leaves, as insect repellents for farm-saved seed (Ahmed, 1985).

SEED QUALITY CONTROL

The seed quality control and certification agency is responsible for ensuring variety purity, identity and other seed quality attributes, such as physical purity, germination and health. The official seed quality control agency carries out inspection in the field and tests the seed in the laboratory to confirm that the seed meets the national certification standards.

Variety purity and identity of seed is ensured through field inspection of growing crops. Land requirement, isolation distance and seed source are confirmed, and the presence of off-types, other varieties, other crops and seed-borne diseases are determined based on inspection of representative samples that are compared with the standards. Seed crops that meet minimum field standards are accepted for harvesting and processing.

After processing, the seed is tested for purity, germination, health, etc. These tests are carried out in a seed testing laboratory based on samples taken from cleaned seed lots. After a seed crop has been field inspected and laboratory tested, and standards have

TABLE 28.4
Field and seed standards for wheat in Morocco

Standards	Seed classes			
	Pre-basic	Basic	Certified 1	Certified 2
Field standards				
Rotation (*minimum, years*)	1	1	1	1
Isolation (*minimum, m*)[a]	10	10	10	10
Other varieties (*maximum, %*)	0.05	0.1	0.2	0.3
Other species (*maximum, number*)[b]	1/15 000	1/10 000	1/5 000	1/2 000
Noxious weeds	-	-	-	-
Infected plants (*maximum, number*)[c]	1/10 000	1/5 000	1/2 000	1/1 000
Seed standards				
Pure seed (*minimum, %*)	99	99	98.5	98
Other varieties (*maximum, number/1 000 seeds*)	1	1	2	3
Weed seeds (*maximum, number/kg*)	6	8	20	30
Cereal species (*maximum, number/kg*)	1	2	12	15
Wild oats (*maximum, number/kg*)[d]	0	0	1	1
Noxious weeds (*maximum, number/kg*)[e]	3	4	6	8
Infected seeds				
Loose smut and common bunt (*maximum, %*)	-	0.02	0.05	0.1
Insect infestation				
Live insects (*maximum, number*)	0	0	0	0
Insect damage (*maximum, %*)	0.1	0.1	0.1	0.1
Germination (*minimum, %*)	85	85	85	85
Moisture content (*maximum, %*)	14	14	14	14
Specific gravity (*minimum, hl/kg*)	79	79	79	79

[a]Isolation for the same or higher category of the same species; 2 to 4 m for other species and 150 m for a field of the same species with 0.1 percent of smut for pre-baisc seed, 0.2 percent for basic seed, 0.3 percent for certified 1 seed and 0.5 percent for certified 2 seed.
[b]Impurities of other crop species refers to all cereal species other than the crop in question (e.g. in bread wheat: barley, oat, durum wheat, rye and triticale).
[c]Plants infected with *Ustilago* spp., *Tilletia caries* or *Helminthosporium gramineum* where applicable.
[d]Maximum permitted for wild oats in cultivated oats are 1, 2, 3 and 4 seeds/kg for pre-basic, basic, certified 1 and certified 2, respectively.
[e]Noxious weeds refers to *Astragalus* spp., *Emex spinosa*, *Galium tricornitum* and *Vaccaria pyramidata*.
Source: WANA Secretariat, 1995.

been met, labels can be attached to each sealed seed bag, and the seed is officially certified.

Seed standards need to be rationalized, taking into consideration the relevance of the quality attribute, the experience of the seed growers and the level of agricultural development in the country. Excessively high standards that are copied from developed seed programmes may frustrate the growth of the seed industry and should be avoided. An example of field and seed standards for different classes of wheat seed used in Morocco is given in Table 28.4.

In many developed countries, there is a tendency to give more importance to the internal quality control by the companies that are producing and marketing the seed. In developing countries, seed quality control agencies often lack resources and are not able to carry out proper seed quality assessment. In view of this, the Food and Agriculture Organization of the United Nations (FAO) proposal *Quality Declared Seed* is particularly relevant to developing countries because it aims at a system that requires fewer resources and still provides sufficient guarantee for the farmers (FAO, 1993).

MARKETING

Seed marketing is the final step in a seed programme; it takes the seed to farmers and gets them to buy it and plant it. Seed marketing is time-sensitive and sensitive to factors affecting rural marketing. Seed must reach the farmer at the right time, at the right place, at the right price, in the right amount and must be of the highest quality. Because seed marketing is sensitive to many factors, it is often considered a high-risk business. Seed marketing requires:

- convincing farmers that the seed quality is high and ensuring that only high-quality seed is sold;
- convincing farmers that the seed quality means a benefit to them that is worth the extra cost they must pay for the seed. All possible means of promoting the seed must be used;
- making the seed available in locations close to the target farmers. The seed must be readily available when the farmer needs it. It must be available in bag sizes that fit the farmers' needs.

Effective seed marketing is a specialized operation, as described by Gregg and van Gastel (1998). Wheat seed marketing has the same requirements, problems and needs as the marketing of other crop seed. Farmers' variety and seed replacement is influenced by their perception of the yield gain of a new variety, the yield loss of an old variety and the risk in changing the variety (Brennan and Byerlee, 1991). In wheat, decline in variety purity and yield from retained seed is expected to be low. An estimated yield reduction of 0 percent in dry areas of Australia, 0.25 percent in Pakistan and 1.6 percent in Nepal from retained seed is reported (Heisey and Brennan, 1991). As a result, farmers can save their own seed for planting for quite a long period of time once they have purchased seed of the new variety.

Few farmers are willing to spend more money to purchase improved seed of wheat. On average, wheat farmers typically purchase a relatively small amount of improved seed.

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