Commercial Hybrid Seed Production

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Hybrid vigor has been recognized as a widespread phenomenon in plants and animals for many years. Corn breeders first recognized its potential for increasing yields and developed procedures for commercial production of hybrid seed. Commercial hybrids now are used extensively in many crops, including corn, sorghum, sugarbeet, and sunflower. Research is being conducted on many other crops that may permit the widespread use of commercial hybrids in the future.

Commercial hybrids have the greatest potential for crops in which the hybrid seed can be produced reliably and economically. Three biological requirements for successful hybrid seed production include the presence of hybrid vigor, elimination of fertile pollen in the female parent, and adequate pollination by the male parent (Chapter 4). If the biological requirements have been met in a species, a practical program of seed production on a large scale must be developed before hybrids can be used by farmers.

The purpose of this chapter is to describe practical aspects of commercial production of hybrid seed. The principles will be illustrated with four crop species whose biological characteristics necessitate the use of different techniques for some aspects of seed production. Corn is a monoecious species that is naturally cross-pollinated by wind. The flowers of sunflower are perfect, but the stamens develop before the stigma is receptive and it is cross-pollinated by insects. Sorghum is a self-pollinated species that has been successfully adapted to commercial hybrid seed production. Wheat is a self-pollinated species that has been studied extensively for hybrid production, but has not yet been adopted as a commercial hybrid on a large scale.
I. TYPES OF HYBRIDS

The most common type of commercial hybrid is a single cross between two unrelated inbred lines (A × B). Single crosses provide the greatest opportunity for expression of hybrid vigor and usually have higher yields than other types of hybrids. They also provide maximum uniformity for seed characteristics that are important in use of the crop and for height and maturity that can facilitate harvest. The main disadvantage of a single cross for corn and sunflower is that the inbred line used as the female parent usually produces lower seed yields than the types of females used for producing other hybrids (Fick, 1978). Inbred lines of sorghum and wheat have good seed yields and single crosses are used almost exclusively for those crops.

The primary purpose of modified single cross, three-way cross, modified three-way cross, and double cross hybrids is to reduce seed cost by use of a more productive noninbred female parent in the seed field. A modified single cross hybrid (A' × A) × B is produced by crossing two closely related inbred lines (A' and A), and using the related single cross as female parent for hybridization with an unrelated inbred (B). The closely related inbreds are progeny from the same breeding population or they may be developed by backcrossing (Chapter 5). A three-way cross (A × B) × C is produced by crossing two unrelated inbred lines (A × B) and using the single cross as female parent for hybridization with an unrelated inbred (C). A modified three-way cross (A × B)(C' × C) and double cross (A × B)(C × D) involve crossing two single cross hybrids in the seed field. One hybrid of the modified three-way cross is a single cross between two related inbred lines (C' × C), whereas all four inbreds of a double cross are considered unrelated.

II. OBTAINING SEED OF PARENT LINES

A basic requirement for production of hybrid seed is an adequate supply of foundation seed of the parents. Foundation seed is referred to as basic seed in many countries. A specialized department for foundation seed production is maintained by major seed companies. This department obtains a small quantity of seed of parent lines that have been developed by plant breeders and is responsible for increasing seed of the parent lines to the quantities required for commercial hybrid production. Seed companies that do not maintain complete research and foundation seed departments obtain their foundation seed from seed producers who increase and maintain seed stocks of publicly and, in some cases, privately developed lines.

The key to good foundation seed production is to secure a pure source of the parent from the plant breeder and to maintain a high degree of purity during its increase. Production of pure seed depends on careful selection and isolation of a field, roguing off-type plants, and careful harvesting and seed conditioning.
A. Types of Parents

The types of parents that must be increased as foundation seed depend on the system used to eliminate fertile pollen in the female parents. The cytoplasmic-genetic system of male sterility requires three lines to produce a single cross hybrid; the A line (male-sterile), B line (male-fertile maintainer), and R line (male-fertile with restorer genes) (Chapter 4). Foundation seed production of the A line resembles that of a hybrid, with the A line being the female and the B line the male. Factors considered for optimizing seed set in a hybrid seed field must be considered for production of the A line (Section IIC). Low ratios of A line (female) to B line (male) often are used. For example, a 1:1 ratio is used in sorghum to assure adequate pollination and minimum contamination from undesired pollen (Quinby and Schertz, 1970). Synchronization of flowering dates usually is not a problem because the A and B lines are nearly identical, except for their cytoplasm. Foundation seeds of the B and R lines are produced by open-pollination in isolated fields.

Three-way crosses produced with cytoplasmic-genetic male sterility involve maintenance and production of four lines, an A and B line of one inbred and male-fertile inbreds of the other two. Double crosses involve six lines, A and B lines of two inbreds and male-fertile inbreds of the other two (Chapter 4).

Artificial emasculation (detasseling) can be used for hybrid seed production of corn (Section VI). In such cases, all parents are male-fertile and foundation seed of each is produced by open-pollination in isolated fields.

Both cytoplasmic-genetic male sterility and detasseling are used to produce certain hybrids of corn because hybrid plants produced with the male-sterile method may not shed enough pollen in some environments to obtain maximum seed set (Craig, 1977). To avoid risk for the farmer, about 25 to 50% of hybrid seed produced by detasseling can be blended with 50 to 75% of the identical hybrid produced by the male-sterile method. Hybrid plants from the detasseled fraction will shed enough pollen in the farmer’s field to supplement any deficiency in pollen shed of the other fraction.

B. Field Selection and Isolation

Certification standards for purity and isolation are closely followed to assure production of foundation seed that is acceptable in commercial seed production areas, including countries that require seed certification labels. Genetic purity of parent lines is critical because it reduces the cost of roguing in large hybrid seed fields.

Contamination from volunteer plants of the same or different species is avoided by the use of fields that produced a crop in the preceding season that is easily identified or of no problem in the foundation field. For ex-
ample, volunteer plants of soybean do not have to be removed from a seed field of corn.

Foundation fields require isolation from sources of pollen from other lines, hybrids, or weeds that can cause undesired cross-pollination. Proper isolation can be a major problem in areas where a crop is grown commercially because wind and insect-borne pollen can be carried considerable distances. The isolation distance used for foundation seed fields of corn, sorghum, and wheat is a minimum of 200 m (Craig, 1977; Quinby and Schertz, 1970). Isolation distances used for sunflower seed production vary among producers, and range from 0.8 km to 6.4 km (Smith, 1978).

Different planting dates can be used for some species and locations to achieve isolation by differential time of flowering. A 30-day difference in planting date has been used to obtain isolation between sunflower fields that do not have adequate distance between them.

Some weed species can produce contaminating pollen and can be a problem in achieving proper isolation. Wild sunflower can be a problem for sunflower seed production (Smith, 1978). Sudangrass, shattercane, and Johnsongrass can be a source of contaminating pollen for grain sorghum (Quinby and Schertz, 1977).

C. Roguing

Off-type plants must be rogued from the field, preferably before pollination. Off-types can result from volunteer plants of a previous crop grown in the field; undesired cross-pollination in the previous seed crop; mixing of seed from different genotypes during planting, harvest, or conditioning; or mutation.

Roguing in large foundation wheat fields is not practical because they are seeded in narrow rows with high plant populations. The problem is minimized by preparing a pure source of seed each year. Individual heads representative of the line are selected each year and seed from each is sown in an individual row the following year. Off-type rows are discarded, individual heads are selected from uniform rows, and the remainder is harvested in bulk. The bulk seed is sown on 1 to 2 ha at about one-third normal plant density in rows spaced 0.3 m apart. This small field is the last phase in the increase program in which roguing is practical; therefore, foundation and hybrid production fields seeded at normal plant densities do not have the benefit of roguing.

Roguing for male-fertile plants in a male-sterile line requires special care. For example, wheat must be rogued daily during the 7 to 10 days of blooming. The most effective roguing is done in the early morning or late evening when wind velocity usually is low and the sun is at a lower angle. Winds greater than 15 km/hour cause the plants to move excessively and reduce roguing effectiveness significantly. Heavy rain may cause delays in roguing of up to 24 hours by washing away extruded anthers from male-fertile plants.
D. Harvest and Seed Conditioning

Harvest and seed conditioning must be completed without mixing seed of different lines. Foundation seed is harvested and processed in the same manner as commercial hybrid seed (Sections VII, VIII and IX). Small, specialized threshers that can be cleaned readily are used to harvest small increases of pure seed of wheat, but conventional combines are used for large foundation seed fields.

III. FIELD SELECTION

Desirable fields are important contributors to purity, yield, and quality of hybrid seed. Hybrid seed fields are selected that are best suited for a particular crop, and generally are located in areas of commercial production. Fields are avoided that produced the same crop in the preceding season. It is important that the farmer-cooperator be concerned about proper soil fertility, tillage operations, control of plant pests, and harvest procedures.

The field must be isolated from sources of undesired pollen using distance or time isolation similar to that of foundation seed (Section IIIB). Isolation distances may be reduced by planting a barrier of the male parent between the source of contamination and the seed production area (Fig. 1).

Fig. 1—A hybrid seed field of corn in which the female parent has been detasseled. A barrier of rows of the male parent on the edges of the field produces an abundance of pollen that has a greater chance of pollinating the female parent than does contaminating pollen from adjacent fields.
The purpose of the barrier is to produce an abundance of pollen that has a
greater chance of pollinating the female parent than does pollen from the
source of contamination. Reduction in the isolation distance and width of
the barrier varies with production conditions and the hybrid being pro-
duced. In corn, isolation distance may be reduced at least 7 to 8 m for each 1
m width of the barrier.

IV. OPTIMIZING SEED SET

Proper selection of fields and farmer-cooperators is a key factor in ob-
taining high seed yields. Maximum seed set also requires management of the
crop to obtain an adequate amount of pollen when the female flowers are
receptive. Adequacy of pollen production is a primary consideration in de-
termining the ratio of the female to male parent (female: male ratio) planted
in the field. The female: male ratio depends largely on the abundance and
duration of pollen production by the male parent. Ratios for sorghum vary
from 3:1 to 6:1, corn from 2:1 to 4:1, sunflower from 2:1 to 7:1, and wheat
from 1:1 to 3:1 (Craig, 1977; Fick, 1978; Miller et al., 1974).

The width of each strip of the female and male parent is strongly in-
fluenced by the size of the available equipment for planting and harvest.
For example, in corn and sorghum, 6:2 or 12:4 ratios of female to male
rows are less complicated and less costly to handle with conventional
planters and harvesters than are narrower strips in a 3:1 ratio (Fig. 1 and 2).

Interplanting male rows between evenly spaced rows of the female has
become increasingly popular for hybrid corn production, especially with
crosses involving a vigorous male parent with abundant pollen. For example,
female rows would be planted in rows spaced 1 m apart and the male rows
would be planted between them at a 50 cm spacing. The number of inter-
planted male rows would be a function of the female: male ratio. The male
rows are destroyed after pollen is produced to avoid the accidental harvest-
ing of seed from the male parent.

Crops that are insect-pollinated must have adequate pollen vectors
present at flowering to optimize seed set. Hives of honeybees are placed in
sunflower fields during flowering at a rate of 0.5 to 2.5 hives/ha (Smith,
1978).

Synchronization of flowering of the parents is essential for optimum
seed set, and may require special techniques at planting or during the grow-
ing season (Chapter 1). Parents that differ widely in flowering date should
be avoided in hybrid combinations whenever possible because hybrid seed
production becomes more complicated, costly, and unreliable.

When parents differ in flowering date, one parent must be hastened or
delayed to obtain pollen shed when the female is receptive. Planting parents
on different dates, commonly referred to as delayed or split planting, is the
most common procedure for altering flowering dates (Fig. 3). Two planting
dates for the male parent also may be used to extend the pollen shedding
period of some crops. The number of days in delay for planting the earlier
parent of corn and sorghum can be estimated from the number of growing
degree-days required for each parent before flowering begins. The equation
used by the U.S. National Oceanic and Atmospheric Administration to compute growing degree-days for a 24-hour period is \( \frac{([\text{Daily maximum temperature} + \text{daily minimum temperature}] + 2) - 10}{10} \). The maximum temperature used is 30 C and the minimum is 10 C. For example, if the maximum temperature for a 24-hour period is 28 C and the minimum is 15 C, there are \( \frac{(28 + 15) + 2 - 10}{10} = 11.5 \) growing degree-days. If the maximum is 32 C and the minimum 7 C, there are \( \frac{(30 + 10) + 2 - 10}{10} = 10 \) growing degree-days. Number of growing degree-days is a useful indicator of flowering dates, but flowering also may be altered by soil temperature, soil moisture, fertilizer, hours of sunlight, and other growing conditions.

Fig. 2—A hybrid seed field of grain sorghum with a ratio of four rows (light colored) of the male parent to 12 rows of the female parent (dark colored).
Flowering of sunflowers is strongly influenced by photoperiod. Planting date studies in which the parent lines of sunflower are planted at regular intervals during the growing season are helpful in establishing the need for and timing of split plantings. Drought and unusual temperatures do not affect time of flowering of sunflower as much as they do corn and sorghum.

Alteration of flowering date by split planting is not reliable in species that require vernalization (Chapter 1). A 10-day delay in fall planting of winter wheat results in approximately a 1-day delay in blooming. Results can be inconsistent among years because of variation in the length and severity of the cold period.

Clipping or burning leaves of young plants has been used to delay flowering of corn, sorghum, and wheat. Additional techniques used to cause small changes in flowering date are fertilizer application, irrigation, and variable planting depths.

More than one technique can be used to synchronize flowering in a field. The choice depends on what is practical as well as effective. When treatments are needed, injury to the female parent that will reduce its seed production should be avoided. Delayed planting, clipping, burning, and moisture stress should involve only the male parent, whenever possible (Fig. 3).

Fig. 3—Rows of the male parent in a hybrid seed field of corn were planted later than the female parent to synchronize their time of flowering.
V. ROGUING

The removal of off-type plants from both the female and male parents is necessary to maintain the genetic purity of hybrid seed. Female parents with cytoplasmic-genetic male sterility must be rogued for male-fertile plants before pollen is produced. The frequency of roguing is determined by the number of off-types and rate of development of flowering. Early in the growth of the crop, removal of the entire plant is advisable. Cutting below the flower primordia may be adequate when plants are more developed. Sunflower heads, however, continue to shed pollen when removed from the stalk; therefore, the detached head is placed face down on the soil to prevent contact with pollinating insects (Smith, 1978).

Unique characteristics of a crop can influence the roguing procedure. Fields of sunflower planted north-south are more easily rogued than those planted east-west. The heads of sunflower usually face the east after the ray flowers are fully developed (Smith, 1978). Planting rows north-south permits the rogues to look westward at the heads, whereas rows planted east-west are difficult to rogue when walking eastward. Roguing large fields in hybrid wheat production is hampered by use of solid seeding (Section IIC), thus the only plants removed are the occasional off-type wheat plants or those of other crops, such as rye.

VI. ARTIFICIAL EMASCULATION

Hand emasculation of the female parent is not economically feasible for commercial production of hybrid seed of most crop species. Corn is an exception because of its monoeicious reproductive structure. Removal of the tassel (detasseling) by hand or machine eliminates pollen from the female parent of a corn hybrid (Fig. 4 and 5).

The time of detasseling is based on the percentage of tassels shedding pollen relative to the percentage of receptive female silks. Standards used by some companies are illustrated in Table 1. Another common standard calls

<table>
<thead>
<tr>
<th>Percent of tassels in the female parent that are shedding pollen</th>
<th>Percent of silks in the female parent that are receptive</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 to 0.24</td>
<td>Blue  Blue  Blue  Blue  Blue</td>
</tr>
<tr>
<td>0.25</td>
<td>Blue  Blue  Blue  Blue  Green</td>
</tr>
<tr>
<td>0.26 to 0.50</td>
<td>Blue  Blue  Green  Red  Red</td>
</tr>
<tr>
<td>0.51 to 1.0</td>
<td>Blue  Green  Red  Red  Red</td>
</tr>
<tr>
<td>Over 1.0</td>
<td>Blue  Red  Red*  Red*  Red*</td>
</tr>
</tbody>
</table>

† Blue = Hybrid seed from the field will have minimal contamination from self-pollination of the female parent. Green = Hybrid seed from the field may be blended with seed from a field designated as blue to reduce the percentage of contamination from self-pollinated seed. Red = Hybrid seed from the field may be discarded or blended with seed from a field designated as blue to reduce the percentage of contamination from self-pollinated seed. Red* = Detasseling operations are suspended in the field and no seed is harvested because of excessive self-pollination of the female parent. Seed from fields are candidates of grow-out plots.
for removing the tassels so that the percentage of female plants shedding pollen at any one time is never in excess of 1%, or that the total percentage of females shedding pollen on any 3 successive days is never in excess of 2%. A tassel is considered to be shedding when 2.5 cm of the center spike has exposed anthers.

Hand detasseling is performed by persons who walk through the field or who ride on a tractor-mounted platform (Fig. 4). Hundreds of workers, primarily young people, are required to cover the extensive hectarage of hybrid seed corn production. Hand detasseling causes little or no damage to the plant, is unaffected by nonuniform height of the female parent, and can be done when fields are too wet for mechanical equipment. Its disadvantages are the lack of adequate labor in some production areas and high labor costs.

Fig. 4—Hand detasseling in a hybrid seed field of corn.
Mechanical detassellers have been developed to reduce the need for hand labor (Fig. 5). Two common types of mechanical detassellers are cutters and pullers. One type of cutter removes tassels with a rotating blade operated on either a horizontal plane or tilted in the direction of operation. A second type of cutter removes tassels with two revolving small-toothed circular saw blades placed in a V mounting with the cutting edges offset. One blade revolves five to six times faster than its counterpart. The puller types use either rubber rollers or pneumatic rubber tires that are mounted in a V position and tilted in the direction of operation. All of these machines have guides to direct the tassel into the cutting or pulling mechanism.

A primary disadvantage of mechanical detassellers is that they remove the top leaves of the plant with the tassel (Fig. 5). The average number of leaves removed ranges from 1.5 to 2.5, and is dependent on uniformity in height of the female parent, amount of tassel extrusion from the plant whorl before pollen is shed, and skill of the operator in adjusting height of the cutting or pulling mechanisms.

Female parents respond differently to removal of leaves. Seed yields of some parents decrease significantly as the number of leaves removed increases, and the percentage of the desirable flat size kernels of these parents usually decreases and percentage of less desirable round size kernels increases. Growing conditions influence the amount of reduction in seed yield and quality caused by leaf removal. Greater loss occurs during periods of high temperatures and limited soil moisture.

Machine detasseling currently is supplemented by hand detasseling to remove missed or late maturing tassels.

Fig. 5-Mechanical detasseling of corn with a rotary cutter. There is a ratio of six female rows (detasseled) to two male rows (with tassels).
VII. HARVEST

Harvesting of foundation or hybrid seed requires proper timing, adjustment of equipment, and control of moisture to avoid yield loss, seed mixtures, and damage to the seed. Moisture content of the harvested seed varies among crops.

Corn seed is harvested as soon as the kernels reach physiological maturity, which occurs when kernel moisture is approximately 30 to 38%. Craig (1977) indicated several advantages of harvesting corn seed at that moisture level. Harvest of the seed crop as soon as it is mature 1) reduces risk of freeze injury, 2) avoids excessive field losses from mechanical pickers, 3) reduces risk of delays due to adverse weather conditions, 4) reduces losses from insect damage, and 5) reduces losses from ear and stalk rots and other diseases. All of these factors contribute to the quality of the seed crop not only in appearance but in physical damage.

Ears of corn usually are harvested with pickers that leave a part of the husks intact, instead of with combines that shell the grain. Machines (huskers) in the field or seed conditioning plants are used to remove husks before ear sorting and drying. The advantages of ear harvest are that (a) seed can be harvested at a high moisture level without excessive seed damage, (b) damaged, diseased, and off-type seed can be removed by sorting ears before drying, (c) ears can be dried more uniformly than shelled seed, and (d) harvest of ears results in higher seed quality.

Sorghum, sunflower, and wheat seeds usually are harvested at moisture levels that are safe for storage without drying. Sorghum and wheat seed are safely stored at 13% moisture or less, and sunflower seed is stored at about 9.5% in the northern U.S. and 11% in the western U.S. (Smith, 1978). Seed of the three crops can be harvested at higher moisture and dried artificially, but such a practice is cumbersome and expensive, and can result in reduced seed quality. The seed is harvested with commercial combines equipped with rasp-bar cylinders that are set at the lowest threshing speed possible to avoid mechanical injury to the seed. Seed damage also can be minimized by avoiding the use of augers for moving seed within the combine and during transportation to the storage bin. Combines must be thoroughly cleaned with brushes, air pressure, and vacuum cleaners between the harvest of different parents. It is difficult to gain access to all parts of the combine for cleaning; therefore, the first several bushels of seed harvested of a new parent usually are discarded.

Seed of all crops must be handled gently to avoid seed damage during harvest, drying, storage, and conditioning. Dropping seed excessive distances to hard surfaces can cause considerable reduction in germination percentage. The use of seed ladders, rubber pads, slides, conveyor belts, and similar equipment often determines the difference between high and low quality seed.
VIII. SEED DRYING

Drying of seeds is necessary when they are harvested at moisture levels that are too high for direct storage. The length of time seed may be held between harvest and drying depends on the percentage of moisture in the seed and the air temperature. For example, ear corn at 25% moisture or higher should be placed in a drier within 6 to 8 hours after harvest when the air temperature is above 21 C. Reduction of seed moisture within the shortest time after harvest will avoid deterioration of germination and seedling vigor.

Drying temperatures should not exceed 44 C for most seed. Unheated outside air can be used for limited drying, if it is warm and dry. There are three prerequisites for effective and efficient drying of seed.

a) The drier should be filled to a capacity that will allow seed to be dried in 4 days or less.

b) Air should move uniformly through all sections of the drier. Excessive foreign material such as husks, silks, straw, and hulls can impede drying. The top layer of seed should be flat and parallel to the floor of the drier, not in a cone-shaped pile.

c) Air movement should be reversed periodically to avoid layers of extremely dry or high moisture seed.

IX. SEED CONDITIONING

Preparation of seed for marketing may include cleaning, sizing, treating, and bagging. The number of these operations used and the equipment involved varies among crops.

Corn seed that was shelled by harvesting with a combine may require cleaning before drying. Ear corn is shelled after drying and cleaned for immediate sizing and treating or for storage. Cleaning involves air removal of light-weight foreign material. It also may include the removal of large foreign material by passing seed through an upper round hole screen of 10.4 mm (26/64 inch) or 11.2 mm (28/64 inch) and removal of small seed by passing it over a lower round hole screen of 6.0 mm (15/64 inch).

Corn seed is separated into different sizes to improve the accuracy of seed spacing with plate-type planters and to a lesser extent with plateless planters. The screens used to obtain various sizes of seed are presented in Table 2. The seed is passed over a suction cleaner (aspirator) after drying to remove broken and light weight seed that was not removed during cleaning. Heavy cob particles occasionally present in the large seed sizes are removed with a gravity separator. Seed usually is treated with a fungicide to protect it from various soil organisms. An insecticide treatment may also be applied for protection against storage insects.
Table 2—Sizes of hybrid corn seed as determined by kernel thickness and width.

<table>
<thead>
<tr>
<th>Kernel thickness†</th>
<th>6.4-6.8</th>
<th>6.8-7.2</th>
<th>7.2-8.0</th>
<th>8.0-8.8</th>
<th>8.8-10.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through 4.8</td>
<td>Flat size</td>
<td>Flat size</td>
<td>Flat size</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Through 5.2</td>
<td>--</td>
<td>--</td>
<td>Flat size</td>
<td>Flat size</td>
<td>Flat size</td>
</tr>
<tr>
<td>4.8-5.2</td>
<td>Round size</td>
<td>Round size</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Over 5.2</td>
<td>Round size</td>
<td>Round size</td>
<td>Round size</td>
<td>Round size</td>
<td>Round size</td>
</tr>
</tbody>
</table>

† Size dimensions in mm.

Corn seed may be packaged by weight in bags containing 22.7 kg (50 lb) or 25.5 kg (56 lb), or by number of kernels, usually 80,000 kernels/bag. Sale of seed on the basis of kernels per bag has become common because farmers can determine readily the number of bags needed based on their intended planting rate and hectarage.

Conditioning of sunflower seed is similar to that of corn. Seed is cleaned with round hole screens ranging in diameter from 4.0 to 9.5 mm, then it is sized based on thickness and width (Smith, 1978). Four common sizes are 11,000 seeds/kg, 13,250 seeds/kg, 15,500 seeds/kg, and 17,600 seeds/kg. Seed usually is not treated with a fungicide before bagging. Bags of seed may weigh 11.4 or 22.7 kg or may be based on 80,000 or 120,000 seeds per bag.

Seed of sorghum and wheat is cleaned with air and screens, but is not sized. Sorghum seed usually is treated with a fungicide and insecticide and bagged in units of 22.7 kg. Hybrid wheat seed usually is treated with a fungicide, and an insecticide treatment also is used by some seed producers. Hybrid wheat seed is sold in bags weighing 22.7 kg.

X. QUALITY CONTROL

Inadequate genetic purity or seed quality can influence the performance of a hybrid in commercial crop production. Proper quality control involves inspection and records for production and handling of both foundation and hybrid seed. Major areas of inspection and records are the source, quality, and purity of foundation seed; field isolation; field diagrams and planting procedures; plant populations of female and male parents; roguing; detasseling corn fields; harvesting; sorting or cleaning immediately following harvest; drying; storage; sizing; treating; bagging; analysis and germination of seed; and approved labeling for state and federal regulations.

Samples of seed harvested from foundation or hybrid fields may be planted in grow-out plots to verify genetic purity. Grow-out plots of corn, sorghum, and sunflower may be grown in a winter nursery for rapid verification. Winter wheat is sown only 2 to 3 months after harvest; therefore, grow-out plots usually cannot be used to eliminate inferior seed lots.

A special type of wheat grow-out plot includes only male-sterile lines grown in isolation from self-pollinated wheat. The plots provide information on sterility in addition to readings made by the field inspector at pollination time. The plots also allow the seedsman to make accurate readings of
self-fertility at maturity. Bagging of individual heads before blooming can be an additional aid, especially if some partial self-fertility is suspected.

Germination tests are made on seed from all fields. This information is used to eliminate seed of inferior quality and for packaging seed on the basis of viable kernels per bag. Seed analyses are conducted to determine the amount of weed seeds and foreign material.

XI. STORAGE

Storage of large volumes of hybrid seed requires systematic records. Warehouse records include location of each hybrid and the quantity of various sizes. Warehouse equipment must be adequate to handle seed without loss or damage.

Seed that is used for planting the following year does not require special storage facilities, except in tropical climates with high temperature and humidity. It is a common practice, however, to store foundation seed of parents for more than 1 year, and some companies prefer to store surplus quantities of hybrid seed. A common rule for safe storage is to maintain the sum of relative humidity and temperature (C) below 60. Relative humidity of 50% at 10 C frequently is used for long-term storage.

XII. MARKETING

Companies use several methods for merchandizing their hybrid seed. A common method in the northern U.S. is to utilize farmers as salespersons. In the southern U.S., various agricultural stores include hybrid seeds as part of their merchandize. A very small proportion is sold by mail.

Educational programs and demonstration plots are used to provide information to the farmer. Agronomists are available in many companies to assist the farmers in planning and in remedying special production problems.

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