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Seed production of hybrid maize

Objectives. This guide is intended to enable you to

- describe the principles of hybrid seed production
- manage the field operations of hybrid seed production
- control pests
- manage detasseling
- harvest, process and store hybrid seed
- multiply foundation seed

Study materials

- Maize plants at different stages of inbreeding and hybridization
- Seed fields, equipment and material for land preparation, planting, and agronomic management
- Seed fields at tasseling, silking and harvesting stage
- Drying and storage facilities
- Fields of foundation seed

Practicals

- Visit farmers and ask about their experiences with maize seed
- Visit seed companies and contract seed growers, and study their production procedures
- In the field, discuss isolation of seed fields
- Practice land preparation, planting, pest management, weed control, detasseling, emergency procedures, field inspection, harvesting, seed processing, and storing

Questions

1 What was the first commercially available F1 seed?
2 How is 'seed' different from 'grain'?
3 How can high-quality seed of hybrid maize be best produced?
4 What are the effects of self-pollination, or 'selfing'?
5 What is the effect of hybridization between two inbreeding lines?
6 Why is Tx gaining popularity in developing countries?
7 What are the ecological requirements for a hybrid seed industry?
8 What region in West Africa is most suitable for maize seed production?
9 How can you 'isolate' seed fields?
10 At what time should you plant maize?
11 Why should seed multiplication fields be weed free?
12 At what time should you weed?
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14 How can you avoid detasseling?
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16 In the forest of West and Central Africa, why is seed production in the second season not as problematic as in the first season?
17 Why should you select ears carefully before shelling?
18 What criteria should you use for ear selection?
19 What is foundation seed?
20 Where can foundation seed be multiplied?
21 What is the viability and purity requirement for certified seed?

Seed production of hybrid maize

1 Principles of hybrid seed production
2 Hybrid seed agronomy
3 Pest and disease management
4 Detasseling
5 Harvesting, processing, storage
6 Foundation (parental) seed multiplication
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Abstract. Hybrid maize seed was the first commercially available F1 seed. Inbred lines serve as parents for commercial production of single-cross hybrid seed. Cooperation between seed companies, research institutes, and government institutions is essential to the successful development of productive hybrids. Commercial hybrid seed production requires proper ecological location, agronomic practices, pest and disease control.

Additional elements necessary for a successful hybrid seed industry include seed handling, treatment, and packaging equipment and materials, appropriate seed storage environment, and an efficient seed distribution and marketing infrastructure. Seed production in the savanna is often better than in the forest area of sub-Saharan Africa. The role of governmental seed certification agencies is to test seed viability and purity and to issue certificates to seed companies for seed marketing.

1 Principles of hybrid seed production

The discovery of hybrid maize has revolutionized maize production. Hybrid maize production increased dramatically in the USA between 1940 and 1950 because of the performance exhibited by hybrids in the severe drought of 1934 and 1936.

Similar expansion of hybrid maize production occurred in Europe beginning from 1984, and in east and southern Africa from the end of the early 1960s and early '70s. Among agricultural and horticultural crops, hybrid maize was the first commercially available F1 seed. In West and Central Africa, however, agriculture has not fully exploited the benefits of hybrid maize.

Seed is different from grain. While grain is used as human food, animal feed, or in numerous commercial processes, seed is used as planting material. Seed must therefore be specially handled and maintained under conditions that protect the living embryo and maintain the capacity of the seed to germinate when planted. Seed contains the genetic potential of the crop including superior plant characteristics. Seed must be handled with care to maintain genetic purity from generation to generation.

Seed production, especially hybrid seed production, requires specific guidelines and standards that vary according to the class of seed. Seed classes depend on the stage in the seed multiplication chain:

- Breeders' seed. Seed of the variety as produced by the breeder.
- Foundation seed. The progeny from breeders' seed.
- Certified seed. The progeny from foundation seed.

Usually, contract growers obtain foundation seed from which they produce certified seed. Farmers grow certified seed for grain production. To ensure farmers' interest in hybrid maize, seed must be of high quality with high yield potential and resistance to major pests and diseases.

Experiences of national programs, international agricultural research centers, private seed companies and farmers show that high-quality seed of hybrid maize can best be produced by private seed companies regulated by governmental seed certification agencies. Collaboration between private companies and governmental agencies is the most efficient way to achieve the benefits of hybrid maize.

All agencies and individuals involved in hybrid seed production must follow specific rules and regulations. For example, field and postharvest inspections are necessary to ensure quality standards. High-quality certified seed is not possible if foundation seed was not also properly produced. A certification label, issued by an impartial regulatory agency (usually governmental), should be stitched to every seed bag and serves as the farmer's guarantee that he or she is purchasing quality seed and not just grain.

Maize is naturally a cross-pollinating species, and each plant is genetically different from all others in non-hybrid cultivars, such as landraces and traditional varieties. To develop hybrids, however, breeders self-pollinate individual plants to produce 'pure lines' or 'inbred lines'. Self-pollination, or 'selfing', results in inbreeding depression manifested in reduced vigor, lower plant height, delayed flowering, low crop yield, and so on.

Hybridization between two inbred lines restores vigor and yield in the F1 plants because of the heterosis effect (precisely the opposite of inbreeding depression). This heterosis effect can be more, or less, for specific inbred line combinations. Therefore, in searching for an outstanding, commercially viable hybrid, breeders cross agronomically superior lines with several other inbred lines, and then test the resulting F1 hybrids in yield trials.

Only a few best experimental hybrids are advanced to multi-location trials for an additional 2–3 years. Inbred lines of the best hybrids serve as parents for commercial hybrid seed production.

The procedure described above of selfing to develop elite inbred lines and crossing to identify outstanding hybrids has disadvantages. Because inbred lines are lower yielding than hybrids (due to inbreeding depression), seed production for F1 hybrids derived from inbred parents will have reduced seed yield resulting in increased seed cost to farmers. A hybrid involving two inbred lines as parents is called a single-cross hybrid.

An alternative is to cross two different single-cross hybrids to each other, thereby obtaining double-cross hybrid seed which can be commercially marketed. In double-cross hybrids, four different parental inbred lines are involved. Seed production is easier: both F1 parents are already hybrids, and produce abundant pollen and plenty of seed.

Over time, breeders are able to develop more vigorous inbred lines, which improves the likelihood that production of single-cross hybrids will be commercially profitable.

Table 1 shows the different types of hybrids. A, B, C, D represent inbred lines.

- A single-cross hybrid (Sx) involves two inbred parents A x B, or C x D, or A x C, and so on.
- A double-cross (Dx) hybrid involves two Sx parents (A x B) x (C x D).

In a **modified single-cross hybrid** (MSx), A_1 and A_2 are related (sister) lines. Both of them are crossed and their F1 crossed to another line, B, to produce the commercial seed (A1 x A2) x B.

Table 1. Different types of hybrids, their cross combination, and number and type of parents.

Hybrid	Abbreviation	Cross combination	No. and type of parents
Single cross	Sx	(A x B)	2 inbred lines
Modified single cross	MSx	$(A_1 \times A_2)$ B	3 inbred lines
Three-way cross	3x	(A x B) x C	3 inbred lines
Double cross	Dx	(A x B) x (C x D)	4 inbred lines
Top cross	Tx	variety x line	1 OPV, 1 line
Varietal cross	Vx	variety x variety	2 OPVs

Three-way cross (3x) involves three unrelated lines. Sx (for example, A x B) is crossed to a third inbred, C to produce 3x. To maximize seed yield of the 3x hybrid, Sx is used as the female and the third inbred is used as the male.

Top-cross hybrid (Tx) is produced by crossing an open-pollinated variety (OPV) with an inbred line.

When two OPVs are crossed, a **varietal hybrid** (Vx) is produced.

Generally, Sx produces the highest grain yield and uniformity, followed in descending order by MSx, 3x, Dx, Tx, and Vx. Most popular hybrid types are Sx, MSx and 3x. The female parent of an MSx produces 20–50% more seed than the inbred parent of an Sx. Therefore, many commercial companies market MSx instead of Sx. Tx is gaining popularity in developing countries because of high seed yield and ease of production.

The cost of seed production, and hence the price which farmers must pay for commercial seed, generally decreases from Sx to MSx, 3x, Dx, Tx, and Vx successively.

This generally reflects increasing ease of production and increasing seed yield of certified seed production fields. Conversely, however, crop uniformity and grain yield generally increase from Vx to Sx, making purchase of the more expensive Sx seed sometimes profitable to the farmer.

Development of hybrids requires substantial investment. Cooperation between private (for example, seed companies) and public (for example, research institutes) institutions is essential to the successful development of

productive hybrids. The International Institute of Tropical Agriculture, for example, has developed many inbred lines and hybrids, which are distributed to public and private institutions on request.

Hybrid seed in commercial quantities is most effectively produced by seed companies either by direct management of the company or by contract seed growers. Most seed companies distribute hybrid seed produced by contract seed growers. Since hybrid seed production involves some risk, contract seed growers in West and Central Africa require:

- good knowledge of maize cultivation
- location in a favorable seed production ecology, such as the savanna region
- farm of sufficient size: at least 20 ha to allow 10 ha for seed production and the rest for isolation distance and other crops
- good access road, for transport of inputs to the farm, and of the produced seed to the seed company or directly to the market

Ideally, the seed company guarantees a standard base income to each contract farmer. Guaranteed prices may vary depending on hybrid types. Sx seeds have a 2–4 times higher price than 3x and Dx seeds. Contract seed growers and the seed company jointly sign a legal agreement before implementing any seed production procedure.

2 Hybrid seed agronomy

Site selection. A hybrid seed industry requires proper ecological location for seed production. Desirable characteristics of a production site include:

- well-drained fertile soil; avoid water-logged areas
- sufficient and reliable rainfall; at least 1000 mm per year, well distributed over the season
- abundant sunshine during the cropping season
- low incidence of diseases and pests
- dry weather at harvest

The moist savanna region of West Africa with a growing period of 140–180 days is very suitable for maize seed production.

In the humid forest zone, high rainfall, relative humidity and disease pressure make seed production difficult during the first season. Unreliable rainfall patterns and stem borer attack also render seed production risky in the second season.

To select an appropriate site within the chosen agroecological zone, consider two major criteria:

- ability to obtain proper field isolation
- availability of infrastructure

Distance between the seed production site and neighboring maize fields is known as isolation distance. Isolation distance should be at least 200 m and greater distances may be required in some countries. Border rows and natural barriers, wind direction and planting intervals can also improve field isolation. Planting dates may also be used to effect isolation, referred to as isolation in time. A three-week interval in planting two varieties with the same maturity allows for adequate isolation, but delayed planting often reduces seed yield.

Land preparation. Prepare land by:

- conventional tillage
- minimum tillage

Conventional tillage. Start land preparation after a good rain. Use either ridge or flat land preparation. In waterlogged soils, plant seed on top of ridges to minimize the effect of excess water on the plants.

Minimum tillage. Apply a preplanting, broad-spectrum herbicide such as paraquat or glyphosate. Repeated use of herbicide, especially paraquat, favors the spread of certain vegetatively propagating perennial weeds including *Cyperus rotundus* and *Imperata cylindrica*. Rotate minimum tillage (three years) with conventional tillage (one year). Alternatively, combine minimum tillage with weed-suppressing cover crops. *Mucuna* spp., *Pueraria* spp. and *Centrosema* spp. are examples of cover crops grown before maize.

Use minimum tillage combined with a cover crop for fragile soils on slopes of more than 3%. Preference for one system over the other depends on the relative cost of land preparation and herbicides.

The amount of fertilizer to be applied depends on the soil fertility of the seed production site. Select appropriate fertilizer types and rates for cost effectiveness according to soil analysis. It is also helpful to understand and observe deficiency symptoms in the plant (Table 2).

Table 2. Nutrient deficiency symptoms in maize.

Nutrient	Deficiency symptoms
Nitrogen (N)	Leaves turn yellow at the tip and along the middle areas. Older leaves are most affected.
Phosphate (P_2O_5)	Leaves initially have bluish-green color, with subsequent development of reddish-purple edges. Base of leaves turns reddish.
Potash (K_2O)	Firing or drying along tip and edges of leaves.
Magnesium (Mg)	Chlorotic (yellowish) stripes along veins and often a purplish color on the underside of lower leaves.
Zinc (Zn)	Yellow to whitish stripes on whole or part of leaves. Younger leaves are most affected.
Sulphur (S)	Pale buds and yellowish top leaves, turning white in extreme cases.

If soil test results are not available, general recommendations for fertilizer rates can be obtained from the local extension service.

A maize crop with a yield of 3–4 t/ha requires in general, approximately 120 kg nitrogen, 60 kg phosphate and 30 kg potassium per hectare.

Apply about 50% of the nitrogen and all of the phosphate and potassium fertilizers during land preparation, using for example, eight bags of 15-15-15 (NPK) compound fertilizer (400 kg) per hectare.

Apply an additional 4 bags (200 kg) of calcium ammonium nitrate (CAN) or 2 bags of urea per hectare near the maize plants (at least 5 cm away), 30–40 days after planting (side dressing).

Urea must be incorporated into the soil to avoid losses by volatilization.

Some soils in the savanna belt are deficient in magnesium (Mg), sulfur (S), or zinc (Zn) and require special fertilizer treatments. Do not use ammonium sulphate on sandy loams or on loamy sands in the savannas, because ammonium sulphate acidifies the soil.

Planting. Test seed viability before planting. Good quality seed should have at least 95% germination. Dress all seeds with a fungicide-insecticide mixture. Apron Plus, Aldrex-T and Fernasan D are examples of chemicals used for seed dressing.

Where there is a risk of soil insect or bird attack, apply an additional insecticide or a bird repellent.

Plant as soon as rains become reliable. Planting maize too early may cause stand losses and lower optimum plant densities. Remember that replanting may not be a viable option because of the need for male and female parents to flower simultaneously. If there is inadequate rain after planting, the entire field may require replanting.

Follow specific instructions provided by seed production specialists on dates for planting female and male parents. Depending on the hybrid being produced, both parents may need to be planted either on the same date or on different dates.

Flowering time of parental lines dictates the time to plant female (seed) and male (pollen) parents. Both parents must flower about the same time in order to crossbreed. If there is any uncertainty about flowering dates in your area, or if the female parent is variable (Tx or Vx), you may wish to spread planting of male parents over a few days (3–5 days) to increase duration of pollen production.

Plant seeds at a depth of 5–7 cm, cover with soil and press down. Do not press soil down when wet.

Parental lines for single-cross seed production should be planted at a density of about 66 666 plants per hectare. With 75 cm spacing between rows, planting 1 seed/hill at 20 cm spacing or 2 seeds/hill at 40 cm will achieve the desired planting density.

Parents of 3x, Dx, and Tx hybrids need a lower plant density of about 53 333 plants per hectare. Using 75 cm spacing between rows, this density can be achieved by planting 1 seed/hill at 25 cm or 2 seeds/hill at 50 cm.

Other plant spacings can also be used to attain the desired plant density. For example, when planting on ridges, row spacing may be increased to 90 cm between plants within rows.

Row arrangement of female (seed parent) and male (pollen parents) varies depending on:

- type of hybrid
- pollen productivity
- duration of pollen production of male parent

Sx seed is best produced at a row ratio of 2 female : 1 male. You can use a row ratio of 4 : 2 but a ratio of 2 : 1 is better for effective pollen distribution.

Plant three-way crosses (3x) in ratio 4 : 2 not 2 : 1. The 2 : 1 planting could reduce pollen production due to shading by the tall single cross (A x B) used as the seed parent over the less vigorous male inbred line. Modified single cross (MSx) and top cross (Tx) can be planted like a three-way cross (3x). If the male parent produces large amounts of high-quality pollen for a long duration (5–7 days), a row ratio of 6 : 2 may also be used for 3x, MSx and Tx.

Plant double cross (Dx) seed in row ratio 6 : 2 or 8 : 2 depending on pollen productivity and duration. The higher number of female rows increases seed yield per hectare. It is desirable to plant additional male rows around the field in order to dilute any pollen carried in from other fields.

3 Pest and disease management

Hybrid seed production requires pest and disease control. Parental lines resistant to pests and diseases and appropriate agronomic practices can minimize problems. Select sites with low incidence of diseases and pests. Where resistant lines are not yet available, chemical control may be necessary (Table 3).

Some chemicals are systemic; that is, they are taken up by the plant and are effective in most plant parts. Apply such chemicals as a seed dressing or at the seedling stage. Examples are Apron Plus and Furadan.

Take precautions when treating seeds and handling chemicals for seed treatment. Always use a coloring agent with seed treatments and indicate toxicity on sacks and labels.

Seed multiplication fields should be weed-free to reduce the risk of contamination with weed seeds and the spread of weeds to other fields. Weeds reduce seed yield. Control weeds by hand, chemicals or both.

Mechanical cultivation 30–35 days after planting may improve weed control and reduce N losses by incorporating the side-dressed fertilizer into the soil.

If you weed by hand, weed 2–3 weeks and 5–6 weeks after planting. Supplementary weeding may be necessary at a later stage.

Select chemical weed control methods according to cost effectiveness and target weeds. An excellent preemergence herbicide for maize is atrazine (5 liters per hectare). Most commercially available products combine atrazine with other ingredients to control a broad range of weeds.

Spray preemergence herbicides within two days of planting. Ensure that maize seeds are well covered with soil. You can use a higher herbicide dose on heavier clay soils or dark soils with considerable organic matter. Use lower dosages on sandy soils. All preemergence herbicides need a moist soil.

You can also spray postemergence herbicides such as paraquat (4 liters per hectare) between maize rows about 6 weeks after planting. Never spray paraquat onto the plants. Use shield-guards to protect maize plants from herbicide droplets.

Several herbicides such as atrazine, persist in the soil for over 10 months, and have a residual effect on the subsequent crop. Soybean, cowpea, and some other legumes are especially sensitive to herbicide residues in the soil.

Table 3. Symptoms and control measures of diseases and pests in hybrid maize seed production sites.

Diseases and pests	Symptoms	Control
Maize streak virus (MSV)	Continuous whitish stripes on the leaves.	Plant only resistant lines.
Striga (*Striga* spp.)	Stunting, leaf scorching and barren plants; *Striga* emerging at base of plant.	Do not use a *Striga*-infested field for seed multiplication. Plant tolerant and resistant lines. Rotate maize with soybean, cotton or groundnut. Apply well-balanced fertilizer of N,P,K, and minor elements. Use a specific preemergence herbicide. Weed by hand; do not allow *Striga* to flower.
Blight *Bipolaris maydis* (lowland) *Exserohilum turcicum*; (highland/savanna)	Longitudinal necrosis and/or roundish or rectangular spots on the leaves.	Plant only resistant lines.
Rust *Puccinia polysora* (lowland) *Puccinia sorghi* (highland/ savanna)	Powdery and brownish pustules on the leaves.	Plant only resistant lines.

Downy mildew *(Peronosclerospora sorghi)*	Whitish-yellow discoloration starting from leaf base, whitish spore powder on lower leaf surface, plant resembles elephant grass.	Do not produce seeds in infested areas, plant resistant lines, treat seeds with Apron Plus™ if the line is susceptible.
Stem, ear and kernel rots (*Diplodia* spp., *Fusarium* spp., *Gibberella* spp., *Botryodiplodia* spp., *Macrophomina* spp., *Pythium* spp., *Penicillium* spp.)	Green, brown, or black discoloration of the infected plant part; abundant fruiting bodies of fungus; rotteness.	Plant resistant varieties. Plant at the right time to permit proper drying. Do not delay harvest, especially in the forest zone early season. Use crop rotation and seed treatment.
Birds	Damage of seedlings, tassel and ears.	For early stage: treat seed with bird repellent such as methiocarb. Before harvest, use bird scarers.
Soil insects (termites of different genera; millipedes; white grubs and others)	Early attacks reduce plant emergence and cause stand loss; later attacks cause stunting and wilting through root damage; late attacks cause lodging.	Analyze soil before planting for insect presence; treat seeds with carbosulfane (2–3 grams active ingredient/kg of seeds) if necessary.
Stem borers *(Sesamia calamistis, Eldana saccharina, Busseola fusca)*	Early attacks (mostly *Sesamia* in the forest and *Busseola* in the savanna and midaltitude) cause dead heart, plant loss, and distortions; later attacks, mostly *Eldana,* cause stem lodging, ear infestation.	Late plantings, second season or off-season plantings may require seed treatment with carbosulfane or other systemic insecticide; late attacks controllable through carbofuran granules in whorl. Plant resistant lines, if available.

4 Detasseling

Detasseling is most important in hybrid maize seed production. Start detasseling female rows when tassels appear in 5% of the plants. Continue to detassel all the female plants over the next 10–14 days. Detassel fields at least once daily, preferably early in the morning. Never allow any plant in the female rows to produce pollen. Detassel any tillers that may grow within the female rows.

Also, to produce pure hybrid seeds, remove all off-type plants in male rows before pollen shed. It is also a good idea to rogue the female rows.

Mismanagement of detasseling affects hybrid seed quality. Effective detasseling is essential to obtaining pure hybrid seed, and only pollen from male plants (pollen parent) should be available for female plants in each hybrid seed production field. Any foreign pollen contaminates the hybrid. Contamination shows up as off-types in hybrid maize fields.

We recommend removal of male (pollen parent) rows after pollen shed is completed, usually about 3 weeks after the start of pollen shed. Delayed removal of male rows may reduce hybrid seed yield. However, if the male parent is an inbred line, male rows may be harvested for seed increase of the male parent. In this case, harvest male rows several days before harvesting F1 hybrid seeds from female rows.

Detasseling may be avoided if the female parent is male sterile. However, suitable male sterile genes have not been found. The most common gene, Texas male sterility (Tms), has been associated with susceptibility to race T of blight caused by *Bipolaris maydis*.

At present, in West and Central Africa, detasseling is the most feasible technique for producing hybrid maize seeds.

Even if female and male inbred lines are planted according to instructions, weather and other factors may affect synchronization of silking and pollen shed.

Other emergency situations that may occur in the field are late silking and insufficient pollen production.

In emergency situations, try the following:

- cut off the tip of the ear to accelerate silk emergence (1–2 days)
- collect pollen from male plants and pollinate by hand (pollen movement)
- shake male lines to enhance pollen movement in case there is no wind

These exercises can increase hybrid seed yield 2–3 times. Minimize the need for emergency treatments by:

- obtaining reliable data on flowering dates (tasseling and silking)
- understanding seed production ecology and problems
- spreading the planting of male rows over a 3–5 days period to increase duration of pollen production
- planting extra rows of the male parent around the border of the field
- managing the field to minimize stress to the maize plants (low N fertility and drought stress delay silk emergence)

5 Harvesting, processing, storage

Harvesting. First, harvest or discard all male plants. Then harvest female plants (F1 hybrid seed) manually or mechanically.

Label each bag of ears twice, both inside and outside the sack, with the name of the contract seed grower and the code number of the variety. Record the date of harvest separately.

In the savannas, dry maize as much as possible in the field (if crop maturity coincides with the end of the rainy season). The ideal moisture content of the seed is 12–15%. Late harvest causes deterioration of seed quality due to damage by insect and rodent pests. Late harvest may also cause severe damage of seed by ear rots, depending on ecology.

Early harvest, even at physiological maturity of grain (black layer formation at the base of the kernels) can increase seed quality if a good drying facility is available.

The forest zone of West and Central Africa is not as ideal for hybrid seed production as the savanna. If seed is produced during the first rainy season in the forest zone:

- harvest as early as possible after physiological maturity
- remove all diseased (especially rotted) ears before drying and shelling
- treat remaining ears with insecticide to reduce field-to-store pests
- dry seeds artificially at temperatures of 35–45 °C
- monitor the entire drying process carefully to avoid high temperatures

Temperatures above 45 °C may injure the seed embryo. Therefore, dry moist seed for 1–2 days at 35–40 °C, then gradually increase temperatures to 45 °C.

Exposure of maturing maize to high rainfall and slow, inappropriate drying increases fungal infection of seed in storage. *Penicillium* spp., *Aspergillus* spp., *Rhizopus* spp., and *Fusarium* spp. are examples of fungi frequently associated with poorly dried seed. Fungi quickly reduce seed viability with detrimental effects on the subsequent year's crop.

In the forest of West and Central Africa, seed production is not as problematic in the second season as in the first season; that is:

- seed quality is better
- natural drying in the field is possible

However, seed yield is lower than in the savanna zone, due to several factors including higher incidences of certain diseases and stem borer species.

Processing. Seed processing includes:

- ear selection and shelling
- testing seed viability
- grading and packing
- seed treatment

Ear selection and shelling. Select ears carefully before shelling because it is difficult and time-consuming to pick out individual off-types or bad kernels after shelling.

Use the following criteria for ear selection:

- discard ears with kernels of off-type color, texture, and size; harvested ears must have the appearance of the original female parent
- discard ears affected by diseases and insects; if damage is restricted to the tip of the ear, remove only the tip
- discard ears exceptionally light in weight, as they may be associated with stalk rot and lodging

Ear selection is not feasible for most large-scale growers. This objective is achieved by careful roguing of female rows in the field during the growing season, and by proper adjustment of seed shelling, cleaning, and sizing equipment.

The ideal moisture content for ear shelling is 13–18%. Adjust the speed of the machine according to ear moisture and the threshing gap according to the size of the ears. Shell mechanically with care. Kernels should not be damaged. Seeds that are too dry (< 12% moisture) or too wet (> 20% moisture) are easily damaged during mechanical shelling. After shelling, remove all chaff with a wind blower.

Testing seed viability. Keep good records on seed stocks, seeds for germination % and discard any seed stock with less than 95% germination. Pay contract growers on the basis of germination percentage and seed yield.

Since fewer problems occur with field drying in the savanna, the viability of seed from the savanna is often higher than the viability of seed from the forest areas. The marketing company has the responsibility to ensure

adequate seed processing for seed viability and germination at marketing time.

Grading and packing. Grade well-dried and shelled seeds for shape and size. Two major grades are:

- seeds for machine planting: regular in size and shape, consistently flat, moderately large size
- seeds for hand-planting: seeds can be irregular or even roundish in shape

Seeds are packed in 50- or 100- kg bags but could also be repacked according to market demand in smaller-size bags of 2, 5, 10, and 20 kg. Although packaging costs are greater for small sizes (for example, 2 or 5 kg), most small-scale growers prefer them.

Seed treatment. Use fungicides and insecticides to control seed or soil-borne diseases, and early insect attacks, respectively. Weigh additional costs and risks of seed viability damage and human toxicity against possible benefits. Preferably, use fungicides with low toxicity, low cost and low risk. Insecticides such as aldrin and carbofuran are highly toxic and may affect seed viability. Use insecticides only where necessary and at the farmers' request. Hybrid seed marketed in downy mildew-infected areas must either be resistant or chemically treated (for example, with Apron Plus).

Storage. A maize seed store should be:

- dry
- cool or even cold
- free of storage insects and rodents
- well-ventilated if the storage is under natural conditions in the savanna

Before storage, most seeds can be dried down to 10% moisture content. Without an artificially cooled seed store, you can store hybrid seed in the savanna for one year with only 10–15% reduction in viability. Seed stored without chemical treatment maintain viability better than treated seed.

In the forest area, without a well equipped cold room, seed remains viable for only about 6 months. Large-scale seed production in this zone, particularly during the first season, needs careful planning and a high investment in drying facilities and cold room storage.

The relative humidity of the storage room is important. At a temperature of 10 °C and a relative humidity of 45%, seed remains viable for 4 years or more. If the relative humidity is high, seed loses viability quickly.

6 Foundation (parental) seed multiplication

The progeny resulting from breeders' seed is foundation seed. Different types of foundation seed exist depending on the type of hybrid to be produced. For example, inbred lines are foundation seed for Sx, whereas Sx hybrids serve as foundation seed for Dx hybrids.

Seed production agencies must produce foundation seed of parental lines (such as inbred lines, single crosses as parents for double crosses, or open-pollinated varieties for top crosses and varietal crosses) in separate fields to ensure purity of parental seed.

For seed increase of inbred parents, the minimum isolation distance recommended is 400 m from any other maize field. There are no female and male rows. Plant a single line or variety in one isolated field. Removal of off-type plants and field management are similar to hybrid seed production, but there is no detasseling of female rows or removal of male rows. Inbred lines are sensitive to environmental conditions and poor management. Only good management enables maximum seed yield of parents.

Foundation seed of single-cross parents for three-way crosses and double crosses are produced in the same way as single-cross hybrids.

Foundation seed can be multiplied by seed companies as well as national seed programs. Breeders' seeds (a base of the parental lines) are often stored and multiplied by the breeder that developed the line.

Inspection and certification. After the development of a hybrid, large-scale production of high quality seed is needed so that farmers can benefit from the improved seed. The following procedure is recommended for field

inspection and certification based on common legal requirements for F1 hybrid and foundation seed production fields.

Seed companies have the responsibility of preparing all legal documents specifying details of seed production (areas of seed production, names of hybrids and parental lines, and so on). All documents must be submitted to the seed certification agency.

Staff of the seed company pay regular visits to the fields to ensure that contract growers carry out proper procedures. Official inspectors from the governmental seed certification agency also pay routine visits to the fields.

During field inspections, the contract seed grower must accompany inspection staff to the field to answer any questions.

Five field visits are recommended for the inspection of F1 hybrid seed production and foundation seed multiplication:

1st inspection (before planting)	• Check isolation and cropping history of the field. • Isolate the maize field at a specific distance from other maize fields to minimize the risk of contaminating the seed parent by foreign pollen. For foundation seed: 400 m; for hybrid seed production: 200 m. Where buffer crops (*that is, crops other than maize*) are planted on the borders, isolation distance may be reduced to 300 and 150 m, respectively.

2nd inspection (3–5 weeks after planting)	• Check field layout for proper female-to-male ratio.
	• Check if female and male lines are exactly as they were characterized morphologically.
	• Remove off-type plants from both male and female rows.
	• Remove diseased plants.
	• Check all management practices such as weeding and side dressing with fertilizer.
3rd inspection (flowering to after flowering)	• Check that all female plants are properly detasseled. Detassel female plants before pollen shed of male plants.
	• Check characteristics of female and male plants (plant type, leaf size, direction and angle), tassel of pollen parent, and so on and compare with expected characteristics of each parent. Any off-type plants should not be present in the male rows.
4th inspection (at harvest)	• Check that no male plant is present during harvesting, unless special seed increase of the male line is required.
	• Check moisture content of seeds (%).

	• Check for disease on the ears and remove diseased cobs.
	• Check that harvested cobs are properly labeled.
5th inspection	• Examine ears (before shelling) and see that they are all true-to-type.
	• Remove off-type ears.
	• Maintain absolute cleanliness in the processing plant before shelling and during other operations.

After shelling, the seed company must send seed samples to the seed certification agency to test seed viability and purity. If seeds have over 95% viability and over 95% purity, the seed certification agency issues a certificate to the seed company for seed marketing. Certification is a legally authorized system for maintaining quality control in seed multiplication, production, and processing. Certification protects farmers from buying and planting seeds of doubtful quality and also protects seed companies.

7 Bibliography

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8 Suggestions for trainers

If you use this Research Guide in training

Generally

- Distribute handouts (including this Research Guide) to trainees one or several days before your presentation, or distribute them at the end of the presentation.

- Do not distribute handouts at the beginning of a presentation, otherwise trainees will read instead of listening to you.

- Ask trainees not to take notes, but to pay full attention to the training activity. Assure them that your handouts (and this Research Guide) contain all relevant information.

- Keep your training activities practical. Reduce theory to the minimum that is necessary to understand the practical exercises.

- Use the questions on page 4 (or a selection of questions) for examinations (quizzes, periodical tests, and so on). Allow consultation of handouts and books during examinations.

- Promote interaction of trainees. Allow questions, but do not deviate from the subject.

- Respect the time allotted.

Specifically

- Discuss with trainees about their experiences with hybrid seed (10 minutes).

- Present and discuss the content of this Research Guide, using as many of the study materials listed on page 3 as possible: maize plants, equipment, materials, and so on.

  Illustrate your presentation with slides of seed fields, machinery, equipment, drying and storing facilities, and so on.

  Do not describe the seed production procedures too extensively in theory; practice them.

- Practice the production procedures suggested on page 3 in groups; 3–4 trainees per group (½ day). Make sure that each trainee has the opportunity to practice. Have resource persons available for each group and practical.

- Visit farmers, seed companies and contract seed growers (½ day). You may assign different locations to different groups. Ask groups to prepare, present, and discuss their findings.

- During the visits, follow the recommendations of IITA Research Guide 36: "The art of the informal survey", by RE Rhoades (see Bibliography).



International Institute of Tropical Agriculture (IITA)
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