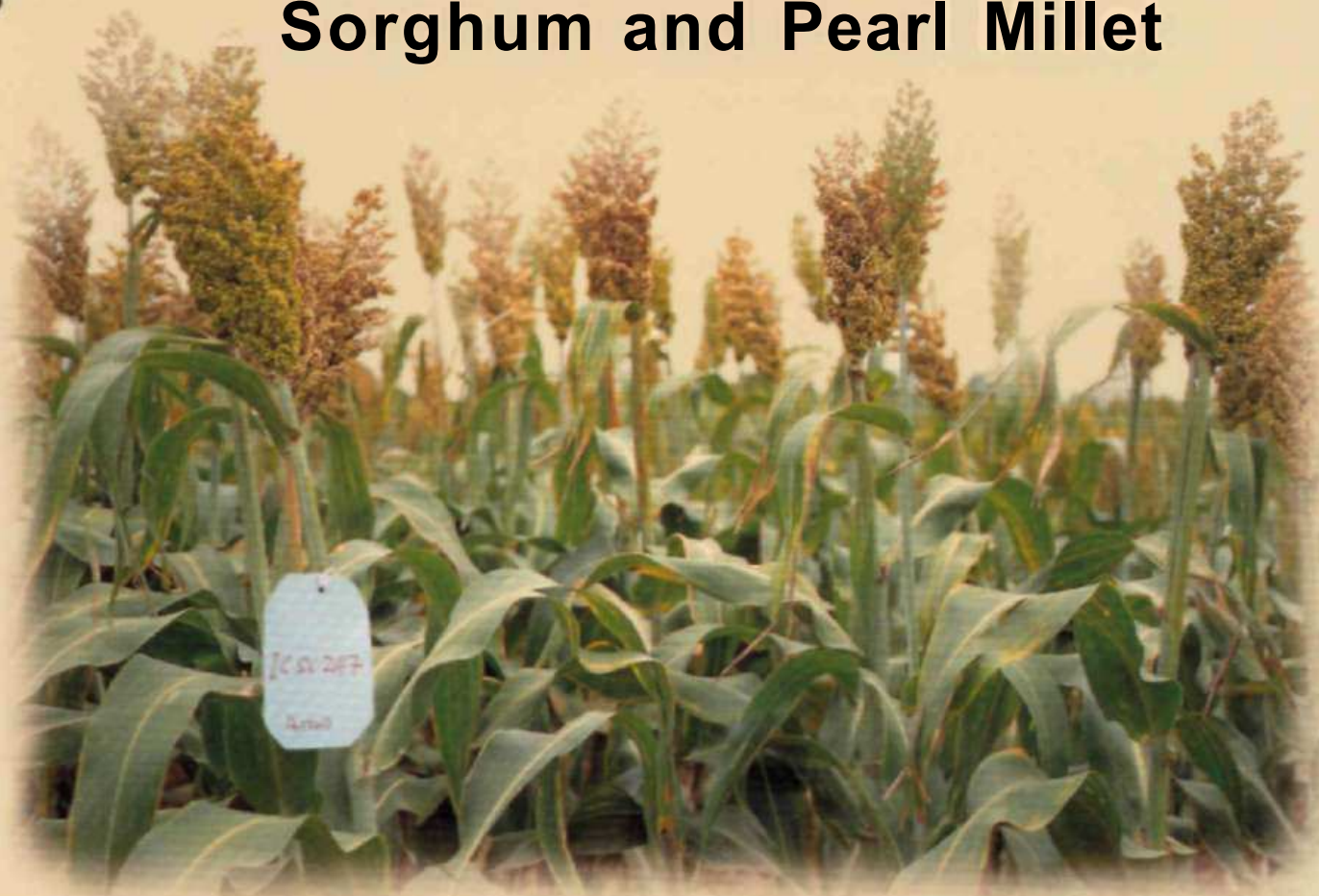




# Seed Production Procedures in Sorghum and Pearl Millet



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## **Abstract**

Functional and healthy seed is one of the important factors in improving agricultural production. Farmer-based seed production programs for pearl millet and sorghum have been introduced in some of the developing countries (Senegal and Namibia) and are proving to be successful. The areas of responsibility in terms of producing improved cultivars (pure-line varieties, composites, and hybrids) are breeding, commercial seed production, and certification. While breeding is carried out by a research station, commercial production and distribution require a well-organized operation. Certification is carried out by independent agencies that monitor the quality and purity of the cultivar during production.

The procedures for seed production of the open-pollinated varieties differ from those of hybrids. There are also differences in the seed production of both sorghum and pearl millet. Maintaining varietal purity of both the crops requires adequate precautions that need to be taken against physical admixtures during sowing, harvesting, threshing, and storage. Both pearl millet and sorghum have specific requirements for protection against contamination so that good quality seed can be produced.

## **Résumé**

***Procédures de production semencière du mil et du sorgho.*** Les bonnes semences sont parmi les plus importants facteurs dans l'amélioration de la production agricole. A cette fin, les programmes de semences paysans pour le mil et le sorgho ont été introduits dans quelques pays qui sont en voie de développement (comme le Sénégal et la Namibie) et, ces programmes sont en bonne voie. Les domaines de responsabilité en ce qui concerne la production de meilleurs cultivars (les variétés de lignée pure, les composites et les hybrides) sont la sélection, la production des semences commerciales, et la certification. Pendant que la sélection est faite par une station expérimentale, la production commerciale et la distribution ont besoin d'une opération bien organisée. La certification est faite par les succursales indépendantes qui contrôlent la qualité et la pureté du cultivar pendant la production.

Les processus pour la production des semences (variété-pollinisation libre) se diffèrent de ceux des hybrides. Il existe aussi des différences dans la production des semences du sorgho de même que du mil. Pour maintenir la pureté variétale des deux cultures, on doit prendre les précautions contre les mélanges physiques pendant le semis, la récolte, le battage et le stockage. Tous les deux, le sorgho et le mil, ont des besoins particuliers en ce qui concerne la protection contre les polluants pour qu'une bonne qualité de semences puisse être produite.

# **Seed Production Procedures in Sorghum and Pearl Millet**

**S C Gupta**

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## Introduction

Lack of functional seed production and distribution programs have been limiting progress and impact of crop improvement research programs in many developing countries. Good seeds, along with fertilizer, water, and pesticides are important components of improving agricultural production.

Improved cultivars (pure-line varieties, composites, and hybrids) are products of research conducted at experiment stations. Many countries have developed procedures for an orderly increase, distribution, and maintenance of improved cultivars. These procedures involve three broad areas of responsibility: breeding, commercial seed production, and certification.

Usually, an experiment station develops and releases (upon approval from a variety release committee) a cultivar to the farmers, after comparing the new cultivar proposed by the breeder with the cultivars already under use in a specific agroecological zone. Experiment stations have the added responsibility to provide and maintain pure seed of the variety or parents of the hybrid in small quantities. Multiplication and distribution of the seed is carried out by competent private or public agencies including experienced growers. Recently, farmer-based seed production programs have been started in some developing countries like Senegal and Namibia.

Commercial production and distribution of hybrid seed requires a high level of competence and a coordinated, well-organized operation. Seed certification is carried out by an independent agency that monitors and certifies the genetic purity and quality of the cultivar during production and distribution to the farmer, according to well-established standards. Certification standards vary according to the stage or class of seed under production, which include, nucleus seed, breeder seed, foundation seed, and certified seed.

Procedures for the seed production of open-pollinated varieties differ from those of hybrids. There are also some differences in the seed production methods between sorghum and pearl millet because of the difference in floral biology. However, the procedures for hybrid seed production in both the crops are more or less the same.

This information bulletin concentrates on certain aspects of varietal purity of sorghum and pearl millet when the variety/hybrid seed is being produced. It assumes that adequate precautions are taken against physical admixtures either during sowing (e.g., seed carry-over in machinery or volunteer seed in the soil) or during harvest, threshing, and storage (in machinery or containers).

# Seed Production of Open-pollinated Varieties

## Pearl Millet

The term variety, for a cross pollinated crop (such as pearl millet), indicates a self-reproducing population of plants that, although not genetically identical, exhibit unique, recognizable, and stable association of characteristics. The pearl millet varieties include: landrace varieties, synthetic varieties made from inbred parents, and varieties resulting from recurrent selection, including mass selection. A variety is a narrow-based breeding population exhibiting a range of variability that needs to be protected against contamination by pollen of external origin during seed multiplication.

A field of pearl millet, as compared to maize, is far more easily contaminated by outside pollen because of the species' protogyny (that is, the emerging heads become female-receptive before they become male-fertile). Therefore, during the first or second day of flowering, a field of pearl millet is vulnerable to any external wind-borne pollen. In maize, however, tassels normally shed pollen before the silks emerge.

While the need for isolation during seed multiplication is recognized, permissible levels of off-types in varieties of cross-pollinated crops such as pearl millet can be higher than in varieties of self-pollinated crops or in hybrid parent lines. This is because:

- a. Cross-pollinated crop varieties have a higher "buffering" capacity for off-type effects (a natural consequence of their variety population structure).
- b. If good isolation has been maintained, most of the observed "off-types" will have arisen through recombination of genes already present and not from the introduction of alien genes or mutations.

Multiplication rates in pearl millet are high, particularly with varieties. Five kg of seed is more than sufficient to sow one ha. This should produce at least 1500 kg of clean seed even at a moderate level of soil fertility.

Pearl millet varieties vary slightly with each stage of multiplication, indicating that extra care is needed to maintain genetic purity at the early stages, and also, there should always be an onward flow from one stage to the next. Seed production procedures of various classes are described below.

**Nucleus seed.** Nucleus seed, maintained by the breeder is the fundamental stock from which all else is derived and should be the only stock that regenerates itself. 50-100 kg of seed should be produced only once in 4 years. The nucleus seed produce should be thoroughly dried and treated against insects and pests. It is divided into six lots of 5-10 kg each that are stored in sealed containers in a cool place. Lots 1, 2, 3, and 4 are used to plant the breeder seed plots for the next 4 years. Lot 5 is used to plant the next nucleus



seed plot 4 years hence, and lot 6 is a backup or insurance lot that should be stored in a different building from the other lots.

Nucleus seed plots should be grown in extremely isolated conditions; at least 1 km from any other plot of pearl millet, wild pearl millets, and elephant/napier grass. The plot should be thinned at an early stage to evenly space a single plant per hill. Several inspections are recommended prior to flowering to remove (by uprooting or roguing) any off-type plants. Daily inspections during flowering are needed to identify and remove all plants that are not true to type before they shed pollen. However, a final roguing should be conducted in the standing crop before harvest to eliminate any remaining off-types. The recommended size for nucleus seed plots is from 0.1-0.2 ha containing about 3000 plants. This ensures that variety norms do not change because too few plants have been grown. In plots of larger size, it is difficult to scrutinize all plants when daily inspections are required. Early flowering plants (around 50) should be tagged, and harvested separately (as grain) because they are more susceptible to foreign pollen.

**Breeder seed.** Breeder seed is produced from the nucleus seed and the seed production technique is similar to nucleus seed production. The isolation distance should be at least 1 km and a good roguing at the flowering stage will reduce the need for further roguing. Normally, no more than 1% of genetic off-types are permitted at final inspection. However, this depends on the seed certification standards of the country. The plot size can be 0.5-1.0 ha according to how much seed is required at the certified seed production stage. Assuming a multiplication factor of x300, for example:

	Breeder	Foundation	Certified	Grain production
Area (ha)	0.5 ha =	150 ha =	45000 ha =	13.5 m ha
Quantity (t)	0.75 t	225 t	67500 t	

Breeder seed can be produced once and used for foundation seed production for 2-4 years.

**Foundation seed.** Only breeder seed is used to plant these plots and is sown early in uniform land, at least 400 m away from the nearest pearl millet, napier grass, and wild pearl millet fields. The plot should preferably be further away from any pearl millet, according to the direction of the prevailing wind. As a precautionary measure, first plant a belt of 5-10 m wide around the perimeter of the plot with the same seed, at least 7-10 days before planting in the center. The perimeter can be planted dry while the center can be planted, just after the rains. The purpose of the perimeter planting (from which the seed will be harvested separately and sold as grain) is to provide pollen by the time the

plants in the center begin to flower. This provides protection, based on dilution, against incoming wind-borne alien pollen. Before flowering, search for and destroy any volunteer pearl millet plants on the field borders and ditches, and in nearby cropland. Rogue obvious off-types before flowering, to meet foundation seed standards. Normally varietal off-types should be less than 2% at the final inspection.

**Certified seed.** Use only approved foundation seed and sow large contiguous blocks, if possible in areas where other pearl millet plots will not be planted; but there should be a gap of at least 300 m from other pearl millet plants. Ensure that pearl millet farmers near the certified seed production plots are all provided with and agree to grow the same variety as that being produced. Rogue if possible, and make sure that varietal off-types do not exceed 5% at the final inspection.

## **Sorghum**

Sorghum varieties are generally pure or highly inbred lines, and are rarely composites. They are uniform, and it is easy to identify off-types unlike in pearl millet varieties.

Sorghum is classified predominantly as a self-pollinated crop. The amount of cross-pollination is usually 2-10%, and is normally higher in the top quarter of the panicle. This is possibly because, according to the order of flowering, the stigmas emerging in this region have relatively less access to pollen from the same panicle. Florets opening time varies among regions and climates. Under tropical conditions, it is usually between 0200-0800 hrs. As glumes open, the stigmas and anthers emerge outwards and usually the stigmas and anthers protrude just before the glumes open and frequently anthers protrude first. Flowering of a panicle may be spread over a period of 4-9 days depending upon the cultivar, the panicle size, temperature, and humidity. In cooler climates, the panicle blooming period may be extended. The time of dehiscence is very much dependent upon weather conditions. In the tropics, on clear days, dehiscence occurs around sunrise. If damp or cool weather prevails early in the morning, dehiscence could be delayed up to 1000 hrs. Anthers dehisce when they are dry and the pollen is liberated.

Sorghum is a wind-pollinated crop. Pollen is normally viable for 3-6 hrs, so long as it is contained in the anther, even after dehiscence and it is shed rapidly when the weather is warm and a mild breeze is prevailing. Pollen is usually available for a period of 4-10 days, since not all the panicles in the field flower simultaneously. The stigmas remain receptive up to a week or more after blooming depending upon the weather. However, they are most receptive during the first 3 days after their emergence.

Multiplication rates in sorghum are high, particularly with varieties. Ten kg of seed is more than sufficient to sow 1 ha. This should produce at least 2000 kg of clean seed even at a moderate level of soil fertility.

**Nucleus seed.** The nucleus seed maintained by the breeder is the fundamental stock from which all else is derived and should be the only stock that regenerates itself. Once in 4 years, 30-50 kg of seed should be produced. The nucleus seed produce should be thoroughly dried and treated against insects and pests, and divided into six lots of 5-10 kg each, and kept in sealed containers in a cool store. Lots 1, 2, 3, and 4 are used to plant the breeder seed plots for the next 4 years; lot 5 is used to plant the next nucleus seed plot 4 years hence. Lot 6 is a backup or insurance lot that should be kept in a different building from the other lots.

Nucleus seed can be produced by selfing 1000 to 2000 good panicles in breeder seed production plots by an experienced breeder. Otherwise, a head-to-row procedure is usually followed to confirm the uniformity of plants. Individual self-pollinated true to type panicles (100-200) of the cultivar are selected, harvested, and threshed individually. The seed of each panicle is used to establish a single row in the subsequent season, all the plants are selfed by bagging. The plants in rows are scrutinized thoroughly to determine their authenticity to type. Any rows, which show variation and deviation from the description, are discarded. The rows in which all the plants are uniform and true to type are harvested and bulked to form the basis for nucleus/breeder seed multiplication.

**Breeder seed.** The nucleus seed is planted to produce the breeder seed. These plots should be extremely isolated and at least 400 m away from any other plot of sorghum, Johnson grass, and other forage or grassy sorghum types. These plots should be grown preferably in the off-season, when crop growth and seed quality is good. The plot should be thinned at an early stage to an evenly spaced single plant per hill. Several inspections prior to flowering are recommended, to remove any off-type plants. During flowering daily inspections are needed to identify and remove all plants that are not true to type before they shed pollen. However, a final roguing should be conducted in the standing crop before harvest to eliminate any remaining off-types. Roguing at the flowering stage will reduce the need for any further roguing. Genetic off-types permitted at the final inspection depends on the seed certification standards of the country; normally it should not exceed 0.01%. The plot size can be 0.5-1.0 ha according to how much seed is required at the certified seed production stage, assuming a multiplication factor of x200. For example:

	Breeder	Foundation	Certified	Grain
Area (ha)	0.5 ha =	100 ha =	20,000 ha =	4 m ha
Quantity (t)	1 t	200 t	40,000 t	

**Foundation seed.** Use only breeder seed to plant the foundation seed plots and should be sown on good uniform land at least 300 m away from the nearest grain and forage sorghum plots. Before flowering, search for and destroy any volunteer sorghum plants on field

borders and ditches, and in nearby cropland. Rogue obvious off-types before flowering, to meet foundation seed standards. The genetic off-types permitted at the final inspection depends on the seed certification standards of the country; normally it should not exceed 0.05%.

**Certified seed.** Use only approved foundation seed and sow large contiguous blocks, if possible in areas where other sorghum plots will not be planted; but there should be a gap of at least 200 m from other sorghum plants. Ensure that the sorghum farmers near the certified seed production plots are all provided with and agree to grow the same variety as the one being multiplied. Rogue, if possible to reduce the varietal off-types. Genetic off-types permitted at the final inspection depends on the seed certification standards of the country; normally it should not exceed 0.1%.

### **Hybrid Seed Production (Sorghum and Pearl Millet)**

The procedures for hybrid seed production in both sorghum and pearl millet are similar. Both crops use cytoplasmic-genetic male sterility system in hybrid seed production that is caused by an interaction of the sterility-inducing factors in the cytoplasm with the genetic factors in the nucleus. The procedures described earlier for the production of different varieties of seed (pure line, and composites) is largely applicable to the seed production of hybrids too. Additional information is given below:

### **Identification of Potential Hybrid Parents (A-, B-, and R-lines)**

Potential male and female parents for hybrid seed production are identified by crossing male-fertile plants (inbreeds, varieties, germplasm, breeding stocks in advanced generations, etc.) to a male-sterile line (A-line) and observing their corresponding hybrids in small plots of an observation nursery. A few plants of each cross are subjected to a bagging test, i.e., covering a few panicles with paper bags before anthesis, and observing seed-set under the bag after a few weeks. A normal bisexual fertile panicle would exhibit nearly 100% seed set whereas in crosses with A-lines, the following three types of hybrids are encountered.

1. Hybrids have no seed-set, i.e., male-sterility is maintained in these hybrids. The corresponding pollen parent is classified as a non-restorer/maintainer or B-line and as a potential new A-line.
2. Hybrids exhibiting complete seed-set under the bag, i.e., male fertility has been completely restored in these hybrids. The corresponding pollen parent is classified as a potential male-parent /restorer line or R-line and could be useful in producing hybrids.
3. Hybrids exhibiting partial seed set under the bag. Such hybrids and their male

parents are rejected for further studies because experience shows that it is difficult to extract stable R-lines or B-lines from such parents.

Type 2 hybrids, in which fertility was found to be normal, are evaluated visually in comparison to local control genotypes. Various agronomic traits such as days to maturity, plant height, fodder yield quality, grain color quality, panicle size, hybrid vigor, grain yield, threshability, and resistance to diseases and insects are considered. Selected hybrids are advanced for further studies and their corresponding male parents included in the R-line collection.

### **Seed Multiplication of Parental Lines (R-line, B-line, and A-lines): Nucleus, Breeder, and Foundation Seed**

Nucleus seed is produced in small quantities on experiment stations by the sponsoring breeder under his direct supervision and is the basis for further seed multiplication. The organization sponsoring cultivar release has the responsibility for the supply and safe storage of nucleus and breeder seed. The breeder provides a complete description of all distinguishing morphological traits of the cultivars. In the case of hybrids, the A-line, B-line, R-line and the hybrid all require individual and accurate descriptions because the certification process depends upon it. The breeder provides small quantities of seed of the A-line, B-line, and R-line to the foundation seed producers. While the experiment station sponsoring the release of the hybrid, trains the technical staff involved in the production and certification of hybrid seed and familiarizes them in the identification of distinguishing characters of the parents and the hybrid. Breeder seed is the source of basic or foundation seed and is subject to seed certification.

In case of hybrids, foundation seed is produced to increase the seed quantity (certified seed) of parental lines from breeder seed. This is done under close supervision of the breeder and certified seed production agencies, as it requires specific and high standards during production and processing. These A-line and R-line seeds require grow-out tests in small plots before being supplied to certified seed growers.

The details of production of R-line, B-line, and A-lines are given below:

**R-line.** The sorghum restorer (R) line has self-fertile bisexual florets and is a pure line. Therefore, it can be multiplied with ease in a manner similar to that of pure line varieties (described earlier). The pearl millet R-line could be either an inbred line or open-pollinated variety; can be multiplied as variety (describe earlier). However, in the seed multiplication of an inbred line, at the final inspection, genetic off-type should not be permitted more than 0.05%. Any plant in the R-line plot appearing different from the true R-type (as described by the breeder) in any way (major or minor) should be uprooted, or rogued, before anthesis. Although the process of roguing starts soon after the seedling stage, the boot leaf and panicle emergence stages are critical, as detection of off-types is

easier during these stages. Off-types that escape detection during the flowering stage should be removed before harvest to minimize contamination. It is recommended that plants of doubtful status should also be removed. Purity of the parental seed is very important because it affects the quality of hybrid seed that is generated.

**B-line.** The maintainer or B-line is self-fertile and can be multiplied in an isolated plot in the same manner described for the R-line. However, it can also be harvested from the A-line/B-line seed production plots that are explained below.

**A-lines.** Large scale production of male sterile (A) lines is carried out by growing the A-line and its corresponding maintainer, B-line together in an isolated plot. The isolation distance required for A x B production fields is at least 1 km. A ratio of 4A: 2B or 6A: 2B rows is maintained and the borders of the field are sown with B-line, The male-sterile line (A) and its maintainer (B) flower at about the same time and thus there are no problems of asynchronous flowering. Pollen produced by the B-line fertilizes the male-sterile plants (A) and the seed produced thus, gives rise to the A-line again. Roguing in A-line seed production plots should be more stringent because A and B plants cannot be easily distinguished after flowering. The pollen shedders in the A-line rows must be identified and uprooted each morning during the flowering period. Utmost caution must be exercised in labeling and harvesting A-line and B-line rows and the B-line rows are harvested first, followed by the A-line rows. Purity of the A-line is very important and any lapses can lead to huge losses of both time and money spent in roguing the hybrid seed (A x R) production plots in the next generation. Normally, no more than 0.05% genetic off-type are permitted at final inspection in foundation seed. Since both A-lines and B-lines exhibit synchronous flowering, seed yields on the A-line in A/B seed production plots are relatively better than in the A and R (hybrid) production plots. Seed of the B-line harvested from the A/B production plots might be reused for the next generation, depending on the seed laws of the country.

### **Hybrid (A x R) Seed Production (Certified Seed)**

The hybrid seed is produced only as a certified seed under the vigilance of seed certification agencies on a very large scale by private agencies, seed farms, experienced growers, and other extension organizations using foundation seed. Millet and sorghum hybrids involve A x R seed production and are carried out according to the prescribed standards of production and processing in terms of isolation distance, genetic purity, and seed quality. Seed certification and seed law enforcement agencies have an important role to play in certified hybrid seed production and distribution, because the farmers' crop performance is directly dependent upon the quality of the certified seed used. Although production of hybrid seed can be carried out by small individual growers, it is convenient to grow it in large areas of 100-150 ha. The quantities of certified seed produced depends upon the projected demand for the seed of the respective cultivar; normally an excess of 20% over the demand is produced. The requirements of isolation distance must be

satisfied by a negotiated contract between a group of farmers living in a community (the seed village) and the seed firm. The seed companies train supervisory staff who will in turn advise and assist the seed growers in hybrid seed production during various stages of the crop. Foundation seed is supplied to the seed growers by the company or firm. The company staff should train the growers in identification of the correct plant types, male-steriles, and roguing of shedders and other off-types. Close communication between seed growers and the company supervisory staff during the entire hybrid seed production season is necessary.

Male-sterile (A) and restorer (R) lines are sown in alternate strips of rows, normally in a ratio of 4 A : 2 R or 6 A : 2 R, depending on the local experience of success and the ability of the R-line to disperse pollen. The borders on all four sides of the hybrid seed production field are sown with the restorer (R) lines to ensure an adequate supply of pollen and guard against incoming stray pollen.

An isolation distance of at least 300 m is generally recommended for hybrid seed production. In case of sorghum, a distance of at least 400 m is necessary if Johnson grass and other forage or grassy sorghum types are growing in the vicinity. Similarly, isolation distance should be increased for pearl millet hybrids if napier grass and wild millet are in the vicinity. Time isolation seed production (i.e., sowing a seed production plot so that there is no overlap in the flowering period of the production plot and the adjacent crop) is possible only on experiment stations under the supervision of breeders. Row spacing can vary from 45-90 cm.

It is essential that the parental lines chosen for hybrid seed production, flower at the same time i.e., the viable pollen is available when stigmas are receptive. Therefore, a prior knowledge of the flowering patterns of both the parents in hybrid seed production is important. Sowing dates of the respective parents should be synchronized with the flowering of the male and female parents. Hybrids whose parents 'nick' in their flowering when sown simultaneously are ideal, because a difference of 4-5 days in flowering between the two parents could seriously affect seed set on the male-sterile line. If parents differ in their days to 50% flowering by more than 3 days, staggering of sowing dates is recommended. For example, if the male parent is known to take 65 days to 50% flowering and the female parent (A-line), 75 days to 50% flowering, then the male parent has to be sown 10 days after sowing the female parent. Under rain-fed production conditions, this might be difficult. When the difference in days to 50% flowering is narrow, i.e., less than 5 days, then the male parent can be sown simultaneously with the female rows, while the border rows may be sown 4-5 days later. The flowering behavior of the two parents may change with different day lengths and temperatures at various locations or seasons. Therefore, some preliminary data on flowering behavior of the male and female parents, and pollen producing capability of the male parent from the seed production locations during the appropriate season, is necessary before undertaking commercial hybrid seed production.

The relative growth stages of the male and female parents should be critically examined when the crop is 3-4 weeks old, or even later depending upon the length of their vegetative growth period. Plants from the male and female rows could be randomly sampled, the stems stripped of leaves and the floral primordia and the apex carefully examined. Differences in the time of initiation and size of the panicle bud would indicate the differences in their time to 50% flowering. The late flowering of a parent can be hastened by selective application of nitrogenous fertilizers like urea and ammonium sulfate. Alternatively, selective irrigation of one parent and delayed irrigation of the other will also help in synchronizing the flowering date of the parents. Careful manipulation of nitrogenous fertilizers and irrigation can synchronize flowering of parents that differ by up to a week. Uniform and good crop management practices throughout the field help in synchronous flowering and good seed yields. Good nick (flowering at the same time) of the male and female parents should be considered while selecting the hybrids. Differential susceptibility of the parents to insect attack, nutritional factors, and diseases frequently result in asynchronous flowering, therefore, timely plant protection measures have an important role in seed production.

Roguing should be carried out in the hybrid seed production fields regularly as soon as the crop commences flowering. Apart from off-types, pollen 'shedders' can also be a problem in A-lines. Shedders are plants that look similar to the B-type and exhibit fertile anthers and shed pollen. Such plants can only be identified at anthesis and should be uprooted immediately. Shedders can also arise from partial breakdown of sterility in the A-lines due to high temperatures ( $>38^{\circ}\text{C}$ ). Delay in identifying shedders will result in out crossing to male-sterile plants and subsequent contamination of the hybrid with female parent type plants. Therefore, it is recommended that roguing be carried out in the early morning hours before pollen shedding takes place. The R-line should also be rogued periodically.

Producers are interested in hybrid seed harvested from the male-sterile parent (A-line) and thus the objective is to achieve maximum percentage seed-set on the male-sterile line. To achieve good seed-set, pollen should be batted out of heads in the morning with sticks and a motorized back pack duster (without dust). It is beneficial for seed setting if the R-line is taller than the A-line as pollen predominantly disperses downwards, and this should be borne in mind when making experimental hybrid combinations. If the common trend in wind direction during the production season is known, seed production plot rows should be sown perpendicular to the wind direction. On experiment stations, when synchrony of flowering is poor, bulk pollination by hand (using paper bags) might be adopted.

All possible precautions against seed contamination should be taken during harvesting of hybrid seed production plots and threshing of panicles from the A-line rows. Usually, the R-line is harvested first and the harvest removed from the field. Later the A-line rows are carefully inspected for off-types and other chance admixtures and then harvested. Hybrid seed yield (on the A-line) depends upon the yield potential of the A-line, percent seed set,



and environmental conditions. Under good conditions, seed yields could range from 1-2 t ha<sup>-1</sup>.

**Harvest of R-line seed from A x R plots.** Seed of the R-line harvest is generally not permitted to be reused as 'seed' for hybrid (A x R) seed production again in the next season but instead sold as grain. However, if there are no pollen shedders, and no chance of seed contamination, R-line seed from selected A x R plots can be reused for hybrid seed production.

## **Planning Commercial Hybrid Seed Production**

Commercial seed production must be carried out in a well-organized manner. Hybrid seed production agencies have to identify suitable areas for efficient seed production through preliminary experimentation. Areas endemic to serious diseases, pests, and obnoxious weeds like *S. halepense* (in case of sorghum), *P. purpureum*, and *P. glaucum sp monodii* (in case of pearl millet) and *Striga* are not suitable. Areas that are prone to such natural disasters as floods, excessive bird damage, or hailstorms should be avoided. Excessive rains or high humidity during the grain-filling stages of sorghum could cause grain molds, discoloration, weathering, and preharvest sprouting, all of which affect germinability. Days to 50% flowering of the hybrid parents, productivity vs. cost, and climatic conditions, particularly during grain-filling stages, should be important considerations when selecting areas for seed production. If seed production is planned for the off-season, access to irrigation facilities is important.

The quantities of each class of seed required should be roughly estimated on an annual basis in advance, depending upon the projected demand for the commercial hybrid under cultivation. It is desirable to maintain significant quantities of carry-over seed as an insurance against unforeseen seed crop losses. The progress of seed production and status of seed stocks should be reviewed annually in joint meetings among representatives of seed growers, foundation seed agencies, and national seed agencies. The various activities of the multiplication chain of breeder seed, foundation seed, and certified seed should be coordinated.

Quality control, either voluntary or compulsory, has an important role in hybrid seed production. Suitable laws that provide for minimum standards of seed certification should be enacted and rigorously enforced. Adequate laboratory facilities for seed testing and certification should be provided. The main objective of hybrid seed production is to keep the farmer adequately supplied with large quantities of good quality (true to type) seed of prescribed germinability and other standards. In this context, timely roguing practice by the seed growers, supervisors, and certification agents is of critical importance. Proper training of all technical staff involved in the hybrid seed production and certification processes is essential. They must be supplied with a list of all morphological distinguishing characters of the A-, B-, and R-lines involved in the hybrid seed production and become

familiar with them through field demonstrations and orientation courses. Seed processing, treatment, and certification facilities should be made accessible in seed production areas.

### **Purification of Varieties/Hybrid Parents**

**Sorghum varieties.** About 1000 plants of true type should be selfed, harvested, and threshed separately to be evaluated in the next season for uniformity. The seed of true types should be mixed to produce pure seed.

**Millet varieties.** About 2000 plants of true type should be selfed. Harvest only 400-500 self plants based on visual performance, and thresh them together. The selected selfed bulk should be grown in isolation for random mating. This procedure should be repeated for 2-3 cycles to obtain purified seed.

**Hybrids.** The seed parent (A-line) can be improved by making several hundred A x B plant to plant crosses and evaluating them for pollen shedding, and other traits. The remnant seed of selected A-lines can be mixed to produce pure A-line. Similarly, the seed of corresponding B-line can be mixed to produce pure B-line. R-lines can be purified as described in the nucleus seed production.

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**ICRISAT**

International Crops Research Institute for the Semi-Arid Tropics  
Patancheru 502 324, Andhra Pradesh, India