SORGHUM, MILLET AND GROUNDNUT SEED PRODUCTION TECHNIQUES: ICRISAT CONTRIBUTION TO THE NATIONAL SEED SYSTEMS

By

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1.0 Introduction

Lack of functional seed production and distribution programs have been a major constraint limiting progress and impact of crop improvement research programs in many developing countries. Good Seeds, like fertilizer, water and pesticides are an important component of improving agricultural production.

Nigerian and industries are beginning to produce the seed of open-pollinated varieties of Sorghum and Pearl Millet.

However, the problems of hybrid seed production are a major constraint to the use of hybrids, frustrating and discouraging those involved. Four sorghum hybrids have been released in Nigeria, and the pearl millet hybrids will be available soon. Several early maturing improved varieties of Sorghum and Pearl Millet are available for seed increase and distribution.

Improved cultivars (pure-line varieties, compostites, and hybrids) are products of research conducted at experiment stations. Many countries have developed procedures for an orderly increase, distribution, and maintenance of improve cultivars. These procedures involve three broad areas of responsibility; breeding, commercial seed production, and certification. Usually, an experiment station develop and releases (upon approval from variety release committee) a cultivar for production by farmers,

after considering the worthiness of the new cultivar proposed by the breeder in comparison with the cultivars already under use in a specific agro-ecological zone. Experiment stations have the 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. Commercial production and distribution of hybrid seed requires a high level of competence and a coordinated, well organized sequence of activities. Seed certification is carried out by an independent agency that monitors and certifies the genetic purity and quality of the seed of the cultivar during production and distribution, or marketing to the farmer, according to well established standards. Certification standards vary slightly depending upon the stage or class of seed under production, which include breeder seed, foundation seed, and certified seed.

Procedures for the breeder seed production of open-pollinated varieties differ from those of hybrids.

There are some differences in the seed production between Sorghum and Pearl Millet because of the difference in floral biology. However, the procedures for hybrid seed production in two crops are more or less the same.

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

2.0 Seed Production of Open-Pollinated Varieties

2.1 Pearl Millet Variety:

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

In comparison with maize, however, a field of pearl millet is 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 1st or 2nd day of flowering, a field of pearl millet is vulnerable to any external wind-borne pollen because little is being produced within the field. In maize, however, tassels normally shed pollen before the silks emerge.

While the need for good isolation during 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 of off-type effects (a natural consequence of their variety population structure), and (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 alied genes or mutations.

Multiplication rates in pearl millet are high, particularly with varieties. Five kilograms (5 kg.) of seed are more than sufficient to sow 1 ha. This should produce at least 1,000 kg. of clean seed even at a moderate level of soil fertility.

Pearl Millet varieties vary slightly with the stage of multiplication reflecting the principle that extra care is needed to maintain genetic purity at the early stages, and that there should always be an onward flow from stage to stage. Only Nucleus Seed, which is used for planting breeder seed plots, should regenerate itself, and then only under rigorously controlled conditions.

2.2 Nucleus Seed:

Nucleus Seed maintained by the breeder is the fundamental stock from which all else derives and should be the only stock that regenerates itself. It should be produced only once in 4 years, when between 50 and 100 kg. of seed should be produced. The produce of the nucleus seed plot should be thoroughly dried, treated against insect pests, and divided into six lots of 5 10 kg. each, to be kept in sealed containers in a cool store. Lots 1, 2, 3, and 4 are used to plant the breeder seed plot for the next 3 years; lot 5 is used to plant the next nucleus see dplot 4 years hence, and lot 6 is a backup or insurance lot that should be kept in a different building from the other lots.

Nucleus seed plots should be grown in extremely good isolation at least 1 km from any other plot of pearl millet, wild pearl millet, or elephant/napier grass preferably in the off-season, when crop growth and seed quality will be good. The plot should be thinned at an early stage to evenly spaced single plant per hill. Several inspections prior to flowering are recommended, to remove by uprooting (rouging) and off-type plants. During flowering, daily inspections are needed to identify and remove all plants suspected of being not true to type before they shed pollen. However, a final rouging should be conducted in the standing crop before harvest to eliminate remaining off-types, if any. To ensure that variety norms do not change because too few plants have been grown, nucleus seeds plots should not be less than about 0.1 ha. containing at least 3,000 plants, and not more than about 0.2 ha. because, in plots of large size, it is difficult to scritinize all plants when daily inspections are required. Early flowering plants (around 50) should be tagged, and harvest separately for grain. These plants are more susceptible to foreign pollen.

2.3 Breeder Seed:

Breeder Seed is produced from nucleus seed, and the seed production technique is similar to nucleus seed production. The isolation distance should be around 1 Km. Good rouging at flowering will reduce the need to do further rouging in later stages. Not more than 1% of genetic off-types should be permitted at final inspection. The plot size can be 0.5 to 1.5 ha. according to how much seed is required at the certified seed production stage, assuming a multiplication factor of x 200. For example:

Breeder		Foundation		Certified		Grain
0.1 Ha.	=	24 Ha.	=	6,000 Ha.	=	1.4 m. Ha.
120 Kg.		30 Tons		7,200 Tons		

2.4 Foundation Seed:

Use only Certified Breeder Seed to plant these plots. These should be sown early on good uniform land at least 500 m away from the nearest pearly millet and preferably more from any pearl millet in the direction of the prevailing wind. With the same seed first plant a belt 5 m wide around the perimeter of the plot 4 - 7 days before planting the centre. 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 being to flower. This provides protection, based on dilution, against incoming wind-borne alien pollen. Before flowering, search for an destroy any volunteer pearl millet plants on field borders and ditches, and in nearby crop land. Rogue obvious off-types before flowering, to meet foundation seed standards. Varietal off-types should be less than 2% at final inspection.

2.5 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 400 m from other millet plants. Ensure that pearl millet farmers in the vicinity of the certified seed production plots are all given and agree to grow the same variety as that being multiplied. Rogue if possible, and make sure that varietal off-types do not exceed 5% at the final inspection.

3.0 Sorghum Variety

Sorghum varieties are generally pure lines or highly inbred lines, and only sometimes composites. They are uniform, and 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, possibly because, according to the order for flowering, the stigmas emerging in this region have relatively less access to pollen from the same panicle, the time at which florets open varies among regions and climates. Under tropical conditions, it is usually between 0200 to 0800 hours. As glumes open, the stigmas and anthers emerge outwards. 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 to 9 days depending upon cultivar, panicle size, temperature, and humidity. In cooler climates, 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 hours anthers dehiscence when they are dry and the pollen is liberated.

Sorghum is considered to be a wind-pollinated crop. Pollen is normally viable for 3 to 6 hours, so long as it is contained in the anther, even after dehiscence. Pollen is shed rapidly when the weather is warm and a mild breeze is prevailing. Pollen is usually available for a period of 4 to 10 days, since all the panicles in the field do not 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 are more than sufficient to sow 1 ha. This should produce at least 2,000 kg. of clean seed even at a moderate level of soil fertility.

3.1 Nucleus and Breeder Seed

The nucleus seed production technique in sorghum is similar to pearl millet, except the following:

Nucleus seed can be produced by selfing good heads in breeder seed production plot, or by planting in 0.1 ha plot isolated about a Km. from other sorghums, and related species. The good quality seed could be produced preferably in off-season. The plot should be thinned at an early stage to evenly spaced single plant per hill with a plant population of about 50,000 plants per ha.

Breeder seeds is produced from nucleus seed. The isolation distance should be around 400 m. Good rouging at flowering will reduce the need to do further rouging in later stages. Not more than 1% of genetic off-types should be permitted at final inspection. The plot size can be 0.5 to 1.5 ha according to how much seed is required at the certified seed production stage. Assuming a multiplication factor of x 200. For example:

Breeder		**Foundation**		**Certified**		**Grain**
0.1 Ha.	=	20 Ha.	=	4,000 Ha.	=	0.8 m. Ha.
200 Kg.		40 Tons		8,000 Tons		

3.2 Hybrid Seed Production:

The procedures for hybrid seed production both in sorghum and pearl millet are similar. In both crops, cytoplasmic-genetic male sterility system is used in hybrid seed production. This system is caused by an interaction of sterility-inducing factors in the cytoplasm with genetic factors in the nucleus.

4.0 Identification of Potential Hybrid Parents (A-, B-, And R-Lines)

Potential male and female parents for hybrids seed production are identified by crossing inbred (homozygous and pure) lines from a pollen parent collection (which could consist of the world collection of germplasm, cultivars, 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 a paper bag before enthuses, 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 exhibiting absolutely not seed set, i.e., male sterility was maintained in these hybrids. The corresponding pollen parent is classified as a non-restorer-maintainer or B-line and could serve as a source of a new potential 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 parent are rejected from 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 for various agronomic characters such as days to maturity, plant height, grain colour and quality, panicle size, hybrid vigor, grain yield, and threshability. Selected hybrids are advanced for further studies and their corresponding male parents included in the R-line collection.

5.0 Seed Multiplication Of Parental Line (R-, And A-Lines) - Nucleus, Breeder And Foundation Seeds

Nucleus seed is produced in small quantities or experiment stations by the sponsoring breeder under his direct supervision and is the basis for further rounds of 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 characters for the cultivars. In the case of hybrids, the A-line, B-line, R-line and the hybrid all require individual accurate descriptions because the certification process depends upon these description. The breeder provides small quantities of seed of the A-line, B-line and R-line to foundation seed producers. 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 is subject to seed certification.

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

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

5.1 R-Line: The 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. The seed multiplication plot of an R-line is sown in an area isolated by a ratios of > 300 m distance from other sorghum cultivars. If Johnson grass (*Sorghum Halepense*) or any other garage or grassy sorghum types are growing in the vicinity, an isolation distance of 400 m is recommended for the multiplication of R-lines. Any plant in the R-line plot appearing different from the true R-type (as described by the crop is 3 to 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 stem should be 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 such nitrogenous fertilizers as urea and ammonium sulfate. Alternatively, selective irrigation of one parent and delayed irrigation of the other parent will also help in synchronizing the flowering date of the parents. Careful manipulation of nitrogenous fertilizers and irrigation can greatly improve the synchrony of flowering of parents which differ by up to a week. Uniform and good crop management practices throughout the field help in synchronous flowering and good seed yields. ood nick of the male and female parents should be the main objective. Differential susceptibility of the parents to insect attack, nutritional factors, and diseases frequently result in asynchronour flowering, and thus timely plant protection measures plan an important role in seed production.

5.2 **Rouging:** Rouging, should be carried out in the hybrid seed production field regularly as soon as the crop commences flowering. A part from off-types, pollen 'shedders' can be a problem in A-lines. Shedders are plants that lack 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 under high temperatures (> 38°C). Delay in identifying shedders will result in out crossing to male sterile plants and subsequent contamination of the hybrid with female parent plants. Therefore, it is recommended that rouging be carried out in the early morning hours before pllen shedding takes place. The R-line should also be rouged periodically.

5.3 **Good Seed Set:** Hybrid seed harvested from the male-sterile parent (A-line) is the main interest to producers and this maximum percentage seed set on the male-sterile line is most important objective. To achieved good seed set pollen should be batted out of heads in the morning with sticks and a motorized back pack duster (without dust) to blow pollen into seed parents heads. It is beneficial for seed setting if the R-lines is taller than the A-line as pollen is predominantly disperse downwards, and this should borne in mind when making experimental hybrid combination. 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 experimental station when synchrony of flowering is poor, bulk pollination by hand (using paper bags) might be adopted.

5.4 **Avoiding Seed Contamination:** All possible precaution against seed contamination should be taken during harvesting of hybrid seeds production plots and threshing of panicle 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 caretully 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 to 2 ton/ha^{-1}

5.5 **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.

5.6 **Planning Commercial Hybrid Seed Production:** Commercial seed production must be carried out in a well-organised manner. Hybrid seed production agencies have to identify suitable areas for efficient seed production through preliminary experimentation. Areas endemic to serious diseases, pest, and obnoxious weeds like *S. halepense (in case of sorghum), P. purpureum* and *P. galucum spp monodii* (in case of pearl millet) and Striga, and areas prone to such natural disasters as floods, excessive birtl damage, or hail storms should be avoided. Excessive rains or high humidity during the grain-filling stages of sorghum could cause grain molds, discoloration, weathering, and parents, productivity vs. cost, and climatic conditions, particularly during the grain-filling stages, should be important considerations when selecting areas for seed production. If seed productuion 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 agfencies. 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 seeds certification should be enacted and rigorously enforced. Adequately laboratory facilities for seed testing and certification should be provided. The main objective of hybrid seed production is to make available to the farmers adequate quantities of good quality (true to type) seed of prescribed germinability and other standards. In this context, timely rouging 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-l;ines involved in the hybrid seed production and become familiar with themn through field demonstrations and orientation courses. Seed processing, treatment, and certification facilities should be made accessible in seed production areas.

5.7 **Purification of Varieties/Hybrid Parents:**

5.7.1 ***Sorghum Varieties:*** About 1,000 plants of true type should selfed, harvested and thresh them Separately. These should be evaluated in the next season for uniformity and the seed of true types should be mixed to produce pure seed.

5.7.2 ***Millet Varieties:*** About 2,000 plants of true types 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 to 3 cycles to obtain purified seed.

5.7.3 ***Hybrids:*** The seed parent (A-line) can be improved only by making several hundred A x B plant to plant crosses and evaluating thenm for pollen shedder, 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 seed. R-lines can be purified as sorghum varieties.