Groundnut Seed Production Manual

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Introduction

Seed is the basic input in agriculture. The quality of seed used by farmers determines the status of agriculture they practice. However, for maximum gain in productivity the use of both improved varieties and improved integrated crop management practices are required. Not only do they contribute to increasing productivity individually, but they also act synergistically.

Seed of improved varieties is a costly input; more so in the case of groundnut, where the non-availability of improved variety seed is a major constraint in most of the groundnut growing countries. The private sector has little interest in the groundnut seed enterprise – there is the low seed multiplication ratio, bulky nature of the produce, quick loss of seed viability, high cost of transportation, low profit margin and the self pollinated nature of the crop – therefore the task of making the seed of improved groundnut varieties available to farmers in required quantities and at the right price lies with the public sector seed services. Unfortunately, services have not been able to meet the demand of good quality seed of improved varieties of groundnut in many countries. There remains a large gap between the seed demand and seed supply resulting in low area coverage by improved varieties. This manual aims to provide information on groundnut seed production practices and attendant crop management practices. It targets both technicians and producers to ensure high quality seed production. It also briefly describes the current seed systems in West Africa.

The groundnut crop

Groundnut is the sixth most important oilseed crop in the world. It contains 48-50% oil and 26-28% protein, and is a rich source of dietary fiber, minerals, and vitamins. Groundnut is grown on 26.4 million ha worldwide with a total production of 37.1 million metric t and an average productivity of 1.4 metric t/ha (FAO, 2003). Over 100 countries worldwide grow groundnut. Developing countries constitute 97% of the global area and 94% of the global production of this crop. The production of groundnut is concentrated in Asia and Africa (56% and 40% of the global area and 68% and 25% of the global production, respectively).

Cultivated groundnut (*Arachis hypogaea* L.) belongs to genus *Arachis* in subtribe *Stylosanthinae* of tribe *Aeschynomenea* of family *Leguminosae*. It is a self-pollinated, tropical annual legume. At locations where bee activity is high, some cross-pollination can occur (Nigam et al., 1983). Cultivated groundnut has two subspecies, *hypogaea* and *fastigiata*, which in turn have two botanical varieties (var, *hypogaea* and var. *aequatoriana*). Each of these botanical varieties has different plant, pod and seed characteristics (Krapovickas and Gregory, 1994). However, most of the commercially cultivated varieties belong to the *hypogaea* (common name/market type: Virginia or runner), *fastigiata* (valencia), and *vulgaris* (Spanish) botanical variety groups. The characteristics of these three botanical varieties are described below.

Variety *hypogaea*: no floral axes or branches on main stem; alternating pairs of vegetative and reproductive axes on branches (alternate branching); inflorescence simple; vegetative branches moderate to profuse; primary branches longer than main stem; growth habit spreading, intermediate, or erect; usually two seeds per pod; pod beak not very prominent; seed size medium (runner market type) to large (Virginia market type); testa color generally tan (red, white, purple, or variegated also exist); cured seed dormancy moderate; maturity medium to late.

Variety *fastigiata*: floral axes on main stem; irregular pattern of vegetative and productive branches with reproductive branches predominating on branches (sequential branching); inflorescence usually simple; vegetative branches sparse; primary branches shorter than main stem; growth habit upright; two to four seeds per pod; pod beak absent, slight, or prominent; seed size small to medium; testa color tan, red, white, yellow, purple, or variegated; cured seed dormancy little.

Variety *vulgaris*: floral axes on main stem; irregular pattern of vegetative and productive branches with reproductive branches predominating, primary branches shorter than main stem; growth habit upright; mostly two seeds per pod (three seeds are rare); beak may or may not be present; seed size small to medium; testa color tan, red, white, or purple; cured seed dormancy limited.

Classes of seed

After the harmonization by Comité Permanent Inter-États de Lutte Contre la Sécheresse dans le Sahel (CILSS), G0, G1, G2, G3, G4, R1 and R2 generations and categories were retained. These apply in the CILSS countries such as Mali, Niger and Senegal.

Nucleus seed (G0): the nucleus seed is produced from the basic seed stock. This is available with the originating breeder. True to type (representing diagnostic characteristics of a released variety selected for Nucleus seed production) plants are selected individually from the space planted seed stock. The number of selected plants will depend upon the quantity of nucleus seed to be produced taking the multiplication ratio into account. These selected plants are studied for plant characteristics during the growing period in the field and for pod and seed characteristics after harvest. Only those plants that fully conform to the diagnostic characteristics of the variety under multiplication are retained individually. In the following season, these plants are space-planted in progeny rows and each progeny is again studied carefully during pre- and post-harvest, for diagnostic characteristics of the variety under multiplication. Any progeny deviating from these diagnostic characteristics is discarded. The selected progenies are then bulked to form nucleus seed stocks.

Breeder seed (G1, G2 and G3): nucleus seed is used to produce the breeder seed, which is done under the direct supervision of the originating or a sponsored plant breeder. It is used to increase the foundation seed and is not available for general cultivation. Because of the low seed multiplication ratio in groundnut, three stages of breeder seed production are permissible. The nucleus seed is multiplied to obtain breeder seed G1 I, which in turn is multiplied to obtain G2 and G3. The breeder seed crop is sown at normal recommended plant density.

Foundation seed (G4): this is the offspring of Breeder seed. The breeder and originating institution help to maintain genetic purity and identity of the foundation seed conforming to the standards prescribed for this class of seed.

Certified seed (R1 and R2): this is the offspring of Foundation, registered or occasionally certified seed and is available to farmers for general cultivation. Certified seed produced from foundation seed is not subjected to further seed increase under certification.

Seed certification standards

A regulatory authority sets the seed certification standards for various classes of seed of different crops in each country. These standards could vary depending on the local situations. Nucleus seed represents the highest degree of purity and stringent standards, which relax as the seed category moves down to certified seed. Breeder seed does not have any prescribed certification standards, but should generally be so pure as to guarantee that in the subsequent generation seed conform to the prescribed standards.

Harmonized seed certification standards for groundnut in the CILSS countries are presented in Table 1.

Table 1. CILSS harmonized seed certification standards in Mali, Senegal and Niger

	Seed classes		
Criteria	Breeder	Foundation	Certified
Minimum isolation in meters	3	3	3
Off-type plants (maximum at final inspection stage)	0.10%	0.1%	0.5%
Number of diseased plants/500 m^2	0/500 m^2	3/500 m^2	3/500 m^2
Pure seed (minimum %)	99.9	99.5	98 / 95
Specific purity (minimum %)	96	96	96
Inert matter (maximum %)	4	4	4
Other crop seed (maximum kg)	Nil	Nil	Nil
Weed seeds (maximum)	Nil	Nil	Nil
Germination (minimum %)	70	70	70
Moisture content (maximum %)	9	9	9
Bruchid infestation (maximum %)	2	2	2
Aspergillus contamination (maximum %)	5	5	5
Fusarium contamination (minimum %)	5	5	5

Source: INSAH (2002)

In West African countries, where limited availability of seed continues to remain a major constraint to promoting improved groundnut varieties among the farmers, it may be advisable to relax some of these standards to stimulate a seed production chain in the formal seed sector.

Monitoring and inspection

The nucleus and breeder seed do not come under the purview of a seed certification scheme. As such, there is no prescribed monitoring/inspection procedure for them. However, the breeder responsible should ensure full conformity to diagnostic characteristics of the variety under nucleus seed production and the highest purity standards of the seed. The breeder should carry out a thorough inspection of the crop before and after flowering and at harvest to eliminate any unhealthy, abnormal and off-type plants. This will ensure genetic purity, which in the next generation would conform to the standards of foundation seed.

Monitoring/inspection are mandatory for certification of other classes of seed (foundation, certified). A duly authorized seed certification agency organizes the field and post-harvest inspections by a team of technically qualified personnel. A seed analysis report and results of a grow-out test, wherever prescribed, are taken into account before issuance of a certificate.

Technical aspects of groundnut seed production

Introduction

One of the most efficient means for the farmer to improve the productivity is to use high quality groundnut seeds. Organizing high quality seed production and distribution is critical to the implementation of any seed program. This precondition also applies to other factors that affect productivity. Pod and grain size of a specific variety are important parameters for determining seed value. The crop should be grown under appropriate climatic and soil conditions to ensure good pod formation, filling, and seed maturity. Cultural techniques must be perfectly mastered in order for the plant to attain its full potential and ensure quality production. These standards are fundamental for producers who want to sign up for a national multiplication program. The farmer must also accept controls and conform to certification standards.

Soil selection

Groundnuts require well-drained sandy loamy soils that facilitate penetration of the pegs after pollination, and easy digging without pod loss. Groundnut plants are sensitive to salinity, and high soil acidity ($pH<5$) could induce magnesium or aluminum toxicity. In this type of soil, calcium should be added to maintain the pH above 6.

Climatic conditions

The optimum temperatures for growing groundnuts range from 25°C to 35°C. Cooler temperatures, especially at night, prolong the growing cycle. Groundnuts are slightly sensitive to photoperiod. Although groundnut is drought tolerant, good performance is strongly linked to adequate soil water content at sowing time, followed by well-distributed rainfall. Early maturing small-seeded varieties require 300-500 mm while the medium to late maturing large-seeded varieties need 1000-1200 mm rainfall.

Field isolation

Groundnuts are self-pollinating and therefore do not require isolation. A distance of 5-10 m between varieties is recommended to avoid mixing during harvesting and stripping.

Crop rotation

The groundnut fits into a wide range of farming systems. It can follow both cereals (maize, sorghum, pearl millet and sorghum) and root crops (cassava and sweet potatoes). Groundnut does well on virgin land or immediately following a grass fallow or a well fertilized crop such as maize. Avoid groundnut-groundnut rotation to discourage the build-up of pest and diseases.

Land preparation

Removal of crop residues that spread diseases and harbor pests is important. For light soils, this type of cleaning should be followed by a shallow raking after the first light rains. This eliminates early weeds and breaks up the soil surface. In wetter areas or with heavier soils, fields must be ploughed at the beginning of the season to suppress weeds and break up the soil, which must then be refined by harrowing. With this soil type, raised-beds are often made to limit run-off or water logging. If groundnut is to be grown on ridges, the ridges should be made at or just before sowing, and should be flat-topped. If the soil is dry when the ridges are being made, a light rolling after ridging will help make the seedbed firm.

Fertilizer application

A reasonable level of organic matter must be maintained in the light, weakly structured, tropical soils where groundnuts are grown. The groundnut plant has an extensive root system that allows it to explore a large volume of soil and therefore benefit from organic manure residues from the preceding crop (cereal). Groundnuts can be cultivated with a balanced fertilizer N-P-K. Calcium must be added to slightly acidic soils to correct the pH and improve the quality of the seeds. Calcium deficiency leads to a high percentage of aborted seeds (empty pods or "pops") and improperly filled pods. Calcium is barely translocated across the leaves, and should therefore be applied near to the fruiting zone (as a side dressing) at the onset of pod formation. The recommended fertilizer rate depends on soil type and varies between 200 to 600 kg/ha of gypsum for large-seeded varieties.

Sowing

Seed selection and treatment: before sowing, seeds should be carefully prepared. Groundnut pods intended for sowing should be hand-shelled and sorted in order to eliminate skinned, immature, moldy, and small seeds. Seeds are then treated with an insecticide/fungicide mixture to control seedling blights caused by soil bacteria and fungi. The fungicide will control soil pests that damage seedlings. The most common are: carbofuran[1], heptachlor[1], captafol[2], thiram[2], benomyl[2], captan[2], carbendazim[2], etc. depending on the regulations of the country where they are used.

Sowing: planting date is linked to rainfall distribution in the area and length of the crop season. Soil moisture must be sufficient to guarantee good germination. Seeds must not be sown immediately after heavy rains since they imbibe too much water, which causes rotting. This also results in excessive soil compaction, which may hinder germination. In general early sowing improves yields (significant delay in sowing can reduce yield by 50%) and seed quality.

Plant spacing and seed rate: spacing depends on the growth habit and the variety. Small seeded Spanish types are spaced at 60 cm between rows and 10 cm between stations. This gives an optimum plant population of 167,000 per hectare. The large-seeded Virginia types are spaced at 75 cm between rows and 15 cm between stations, giving an optimum plant population of 89,000 per hectare. Under irrigation, plant population can be as high as 250,000 plants/ha. The weight of seeds in shell required to sow one hectare is called the seeding rate (SR). This depends on variety characteristics, seed quality and planting density. The SR is calculated as follows:

$$\text{SR} = \frac{\text{Density (plants/ha)} \times \text{Weight of 100 seeds (g)}}{10 \times \text{seed viability (\%)} \times \text{shelling yield (\%)}}$$

With manual sowing, individual seeds are sown 3-5 cm deep. Mechanized sowing is widely practiced in Senegal. This is done using a single row planter, generally drawn by a horse or donkey. In this way, one hectare can be sown

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[1] Insecticide

[2] Fungicide

in 8 hours. A disk adapted to the seed size, turns on the inside of a hopper and regularly dispenses the seeds into a furrow opened by the planter blade. A weighted rear wheel then closes the furrow.

Crop maintenance

Weed control

Groundnut cannot compete effectively with weeds, particularly at the early stages of development (3-6 weeks after sowing). Early removal of weeds reduces this competition. Crop rotation may reduce certain species of weeds. Pre- and post-emergence herbicides may be used to eradicate weeds but they are too expensive for most small-scale farmers. The crop should be thoroughly weeded within the first 45 days. Once pegging begins, soil disturbance should be avoided or kept to a minimum, so as not to interfere with the developing pods. Instead weeds at this stage can be controlled by hand-pulling.

Rouging out off-type plants

This consists of manual removal of plants of other varieties present in the field. Depending on the degree of contamination a field can be retained or rejected for seed production. Fields of mother seeds should have less than one off-type in 1000 and those of certified seeds, one in 200. Regular field checks allow elimination of off-types based on phenotypic characteristics of the cultivated variety. Field rouging maintains the genetic purity and can only be effective if checks are rigorously continued throughout all operations.

Irrigation

Although groundnut is a rustic plant, high yield can be guaranteed using irrigation, especially for first generations. Irrigation also allows off-season groundnut production, which accelerates seed multiplication. Quality production is ensured using an irrigation program adapted to crop demand at each developmental stage. Different irrigation methods can be used including overhead (sprinkler), drip and furrow irrigation. The latter is the most commonly used in West Africa but does not always ensure homogenous water distribution, especially in large fields.

Plant protection

Groundnut is susceptible to a number of pests and diseases that can cause considerable yield losses. Recommended protection measures against diseases and insect pests should be regularly followed during the cropping season.

Harvesting

It is important to harvest groundnut at the right time, ie, when the crop is mature. Flowering is indeterminate in the groundnut; therefore there is a variable proportion of mature and immature pods at the end of the crop cycle. Groundnuts are mature when 70-80% of the inside of the pods shells have dark markings and the kernels are plump, with color characteristic of that variety. If harvested prematurely, the kernels shrink upon drying, resulting in decreased shelling percentage, poor seed quality and lower oil content. If harvested late, non-dormant varieties will sprout in the field, resulting in yield losses.

Post harvest handling

Seed quality mainly depends on appropriate handling and storage techniques for the harvested crop. Handling facilitates the selection of the best seeds while storage conditions ensure the conservation of high seed quality. Groundnut seeds are protected by a shell, which acts as an excellent natural barrier against pests and diseases. However, this shell should be intact. Removal of damaged pods is therefore necessary. Crop residues mixed with the pods are often sources of contamination.

Drying

The primary objective of curing or drying, is to achieve a rapid but steady drying of pods in order to avoid aflatoxin contamination. Harvested plants should be staked in the field for a few days to allow them to dry in the sun and air, before stripping the pods. Then drying should be continued until the moisture content is reduced to 6-8%. This can normally be achieved by drying the pods in the sun for 6-7 days, taking care to cover them if it rains. If pods are exposed to the sun too long, both kernel quality and seed germination will be affected.

Under mechanized farming systems, combine harvesters collect windrows, strip and clean pods in one single operation. The pods are then artificially cured in drying trailers. Airflow temperature should be 5-6°C above ambient temperature but should not exceed 35°C. Optimal depth varies from 0.6 to 3 meters according to pod water content and the type of curing equipment used.

Stripping–winnowing

Pods are stripped at about 2 to 6 weeks after harvesting, when the pod water content stabilizes at around 10%. This operation consists of separating the pods from the vegetative parts of the plants (vines). In traditional farming systems, manual stripping is the rule. Pods are individually detached from the vines and therefore dry very quickly stabilizing at 6-8% moisture content. The process results in a perfect quality product. This technique is used for the production of edible or confectionery groundnuts in order to minimize pod damage and contamination by *Aspergillus flavus*. However, stripping is most often done using sticks. These reduce the heap of groundnut plants into a mixture of chopped vines and partially broken pods that are then separated by winnowing.

Several types of mechanical combines can be used to strip groundnut windrows with less than 10% moisture content. This consists of manually feeding pods into the combine. Stripping is achieved by friction between the stripper bars against the base of the plant and the pegs. The stripped product is evacuated across a counter stripper made up of a cylindrical grid. Large pods retained by the grid are carried along by the rotation of the combine. Pods are then stripped a second time. A built-in blower separates the trash from the finished product. The intake speed, selection of the grid, combine rotation speed and airflow speed must be regulated (by adjusting the opening of the air intake shutters).

Sieving: this operation is generally done on the farm or at the collecting point. The classic sieve consists of a hexagonal or cylindrical cage made from bars. It allows part of the trash including sand, straw and broken pods to be eliminated. However, it cannot eliminate pods of other varieties, empty pods (pops), partially filled or immature pods. This is the most basic cleaning operation.

Density separator: groundnuts that have been stripped and winnowed using traditional methods are still highly contaminated by trash. A density separator can be used to get good quality seeds with a high level of variety purity, good maturity and absence of foreign bodies and empty pods (pops).

This process allows improvement of seed quality during drought years and it consists of two elements:

– a shaker, equipped with sieves adapted to the treated variety that eliminates trash (sand, straw, stems) and undersized pods;

– a blower with adjustable airflow that runs along a sloping surface. Pods are separated, while falling through the air stream, according to density. Pops and partially filled pods are ejected outside whereas full pods fall into a collecting bin.

The shaker and the blower are motorized (electric or gas engine). Gas engines must be equipped with an oil bath filter since the machine operates under rather dusty conditions. Adjustments can be made using a yield valve on the feeding tray. Adjusting the slope of the shaker sieves, the airflow valves or the lower plate of the sloping surface permits regulation of the reception opening for good pods (the smaller the opening, the greater the segregation based on pod weight).

Density separation considerably improves the quality of seeds in hulls, especially after a year of drought. For Virginia type groundnuts, seed yield is increased by an average of 9%. This translates into a mean decrease of 10 kg of seeds in shell per hectare.

Packaging: pods can easily be stored in bulk. Storage in clean jute or woven polyethylene fibre bags ensures the best protection of groundnuts and facilitates manipulation of stocks (manual or palletized). Groundnut seeds should only be stored in bags or drums. Each bag or drum must be properly labeled. Labels must show batch origin, year, level of multiplication, seed weight and eventual chemical treatments.

Seed storage and conservation: groundnut can either be shelled or stored in unshelled form. Groundnut is best stored unshelled in cool, dry conditions, protected from rain and vermin (particularly rats and mice). Bagged groundnuts—whether shelled or unshelled—should not be placed directly on a concrete floor due to the risk of dampness that may cause moulds to develop. Before bagging, pods should be dusted with Actellic Super to protect them from storage pests.

Shelled groundnuts are fragile and are exposed to various agents that cause physical, chemical and biological deterioration. They rapidly lose their seed viability when stored under natural conditions.

On-farm storage of pods: farmers only keep limited quantities of groundnuts because of financial and logistical reasons. They rarely distinguish between seed and grain. Protective chemicals are rarely used since farmers consume some of the groundnuts themselves. In humid tropical areas with two rainy seasons, farmers store their seeds in a ventilated area where they fumigate them. This storage method is inappropriate and generally leads to considerable losses caused by insects and fungi. Farmers can equally use collective facilities for storing large quantities. However, co-management is often problematic: contamination of the entire stock by poor quality batches, lack of confidentiality and restrictions on seed withdrawals to satisfy the farmer's financial needs. Groundnut storage is often conducted by salespersons who are not concerned about quality.

Collective or industrial storage: pods should be stored in order to provide a quality product and to ensure profitability. Groundnuts should be stored under the following conditions:

- collect quality raw material (well filled mature pods), clean, free from visible insect damage, well cured (6-8% moisture content);
- clean storage facilities;
- treat storage facilities and seeds;
- check seeds regularly during storage (every 15 days or once a month according to storage period).

Refrigerated storage: this system is simple, tried and tested and results in excellent long-term storage (over 3 years). However, there are certain technical and financial constraints:

- the stock is physically blocked in the store during the entire storage period;
- seeds must all be unpacked at one time and certain precautions must be taken. For example, the temperature must be increased gradually, especially during the rainy season and seeds must be rapidly used (within a few weeks) before they lose their viability;
- the cost increases sharply with storage time because energy consumption is high.

Industrial preparation of ready-to-use groundnut seeds

An experiment was conducted in Senegal on the use of ready-to-use coated groundnut seeds to reduce transaction costs associated with storing unshelled groundnuts.

Mechanical shelling

Mechanical shelling is relatively rough and can cause severe damage to the seeds (splitting, cracking). This requires experienced operators.

Operating principle: a mechanical sheller is equipped with a head made from perforated or barred semi-cylindrical grills, which form a cage. Pods are spread and broken by a rotor inside the cage. Pre-sorting is done by a cleaning system (sieving and blowing), designed to eliminate or collect by-products, broken or immature groundnuts. A grading shaker that allows unshelled groundnuts to be separated from whole and broken kernels completes the operation.

Importance of optimizing adjustments: for a batch of a given quality, the yield of whole kernels is significantly decreased if the grill size is smaller than the groundnuts, if the rotor speed is excessive and the feeding rate of the machine is too high. These requirements slow shelling speed and allow a judicious choice to be made between yield and quality. Since the pod size for each batch may be heterogeneous, pre-calibration of the groundnuts is recommended in order to optimize the yield of whole seeds.

Electronic color sorting: color sorters use color-based systems pre-set by the user. This principle gives an excellent reproducibility of the results, with a high yield for both visible and invisible wavelengths. The sorter consists of the following equipment:

- a vibrating electromagnetic hopper for precise feeding of the system;
- a steeply inclined descending chute aligning, directing and accelerating the seeds;
- an examination field composed of fluorescent lights, electronic optics opposite to reference screens;
- complex computerized equipment for data collection and analysis;
- an ejector that uses short blasts of compressed air to blow the offending kernel (darker or lighter than the variety standard) out of the stream of groundnuts.

Wavelengths reflected by each object arriving in the examination field are captured by the optical systems and transmitted to photoreceptors that transform them into electric signals. These are then analyzed by the computerized equipment. When a defective groundnut is detected it is eliminated by a blast of compressed air. The use of clean standard-sized groundnuts, stable power supply, availability of filtered and cooled compressed air and a clean area with air conditioning, are critical for successful color sorting.

Seed dressing

The typical dressing system consists of:

- a feeding tray regulating the flow of seeds to be treated;
- a treatment feeder to deliver the appropriate rate of chemical;
- a performing system that compiles the flow of seeds and chemical in order to ensure proper treatment rate (mechanic or electronic control);
- a mixing drum to homogenize the distribution of the treatment to all the seeds (this is equivalent to a draining or pre-drying system);
- a conveyor belt to transfer the seeds to the weighing-packaging area.

The principles for an optimized use of the system are:

- excellent quality seeds (seed value and integrity);
- regular seed feeding rate;
- precise chemical feeding (fungicide or fungicide + insecticide);
- reliable and rapid control system for seed feeding;
- chemical treatment adapted to the process (stable active ingredients, slow decanting, good dressing ability) and to the local soil micro flora.

Protection of stored seeds

The principle storage pests of groundnut are the seed bug (*Heteroptera sp*) and the groundnut seed beetle (C*aryedon cerratus*); these can cause significant damage. Other insects, particularly Khapra beetles (*Trogoderma granarium* E.), as well as flour beetles, (*Tribolium castaneum* H. and *T. confusum)* are also important, especially on shelled groundnuts. The groundnut seed beetle is the most important storage pest. The larva develops inside the pods and is therefore difficult to control.

Contact treatments: stacking sites should be treated with insecticide dust before windrows and stacks are formed for drying the groundnuts. A peripheral band should also be treated to protect the site. Groundnuts are thus protected against termites and seed bugs. Storage areas, containers, drums, bags and storage equipment (conveyors, etc.) should be treated before storing groundnuts. Cleaning of these areas can be followed by fumigation or spraying with insecticides. Pesticides are applied using a sandwich technique. Seeds are dusted during bagging, and then an insecticide dust is applied between each layer of bags. Organophosphates are contact insecticides currently used. Bromophos (500g of 2% dust/ton) or idofenphos (1000g of

2% dust/ton) are most commonly used products. Other available products with long residual activity include ethyl-pyrimiphos (Actellic®) methyl-chlorpyriphos (Reldan®). Their residual activity is low in the open air but is effective for more than 6 months on stored seeds protected from light.

Synthetic pyrethroids such as Deltamethrine (K. Othrine®) ensure good protection against insects if groundnuts were not previously infested. For this reason, preventive fumigation of seed groundnuts must be carried out.

Fumigation

Groundnut seeds (sorted pods or kernels) can be treated under airtight plastic tarpaulins, hermetically sealed silos or warehouses. Bags are arranged to form a pyramid that is slightly smaller than the tarpaulin. The base is sealed with a row of sandbags.

Hydrogen phosphide (PH_3) is the only authorized fumigant. It is available in tablet form and its use requires absolute adherence to manufacture's recommendations in order for it to be effective. Successful fumigation depends on ambient moisture, fumigant dose and duration. Fumigant dose can be reduced in airtight treatment areas with high temperature.

Stored groundnuts should be regularly checked and a seed sample taken every 3 weeks to ensure proper conservation.

Physical and mechanical methods

These methods are low cost, effective and readily available to farmers. Several techniques are used, depending on the area:

- groundnuts are mixed with powdered minerals (ashes, sand, etc.) that act as abrasives or physical barriers;
- hermetically sealed containers in which anoxic conditions limit insect development,
- Temperatures are below (<5°C) or above (>40°C) the optimum for insect development;
- solarisation of groundnuts under plastic or polyethylene mulching (thermosolar treatments), which greatly affects bruchids. Precautions must be taken to avoid decline in seed viability.

Seed physiology

Germination

Germination is defined as the appearance and development of the embryo, to form the essential organs of the seedling. The seed's ability to produce a normal seedling under favorable conditions can be determined by examining these organs.

The mature groundnut seed is made up of an embryo comprised of two cotyledons, a short hypocotyl, the plumule and the primary root. The plumule is formed by a central axis and the two cotyledon axes. It already contains nine embryonic leaves. These essential organs originate from tissue differentiation during the embryo's development inside the seed.

Viable seeds begin germinating when placed in a favorable environment (temperature, moisture, and oxygen). Germination takes place in several stages – imbibition, activation of enzymes, growth of the embryo, rupture of the testa, elongation and emergence of the radical and growth of the terminal bud and embryonic axis.

Imbibition is based on the seed's chemical composition, water availability in its environment and the permeability of the testa. Protein-rich seeds need to imbibe 2-5 times their dry weight in water to initiate germination. This is relatively high when compared to certain sugar rich cereal species. These need to absorb only one and a half to twice their dry weight in water. In order to germinate, legumes and cotton need a minimum water content of 50-55% whereas cereals need 30-35%, which is close to the observed water content at physiological maturity.

Water activates the enzymes responsible for hydrolysis of nutritional reserves (lipids, sugars and proteins). It is essential for transport and utilization of the simplest and most mobile components (glucose, amino acids, etc.) by the growing embryonic axis. Enzymes catalyze the reaction needed for the synthesis of new material required for tissue differentiation and growth of the embryo.

Germination in peanuts is epigeal. The cotyledons and the sprout are carried above the soil by the elongating hypocotyl. Seed viability can be determined by germination test. Four repetitions of 100 seeds or 8 repetitions of 50 seeds (a total of 400 seeds are used). Seeds are equally spaced on a moist substrate then placed in an incubator at 30°C and 90% RH. Seeds are evaluated after

5 days (germination vigor) or 10 days (germination ability). They are also classified as normal seedlings, abnormal seedlings and un-germinated seeds.

Seed dormancy

Dormancy is a natural phenomenon in the plant kingdom. It is defined as the inability of newly harvested seeds to continue their development under favorable environmental conditions (temperature and humidity). Dormancy allows plants to survive unfavorable environmental conditions.

Environmental factors can break the dormancy. It is absent in Spanish and Valencia groundnut or is naturally broken several weeks after seed maturity. Non-dormancy results in field sprouting especially if harvesting is delayed. This reduces seed yield and quality considerably. Virginia type groundnuts have a longer dormancy of 4 or more months.

Chemical products such as ethylene (3.5ppm) induce excellent germination. Ethephon® can also be used to break dormancy in groundnuts. Ethephon® or ethrel, originally a growth regulator, progressively decomposes into mainly ethylene as well as several other substances. It is available in liquid or powder form. The powder is added to the fungicide-insecticide mixture and the liquid is sprayed onto untreated seeds. Exposure to high temperatures (40-45°C for 15 days) can also break the dormancy.

Seed systems in West Africa

Formal seed systems

The formal seed system is a system where the principal activities are led by public institutions identified in accordance with the regulation in force. These activities include the organization of the seed-sector (planning production, training of the seed producers, selection of the seed producers and establishment of contracts for seed production, the identification of varieties to be cultivated according to the localities concerned, facilitating variety release process); production and maintenance of breeder seed (nuclear seed); production and maintenance of foundation seed; production of foundation and certified seed of first and second generations; legislation and quality controls (verifying that seed producers are respecting the set international rules and regulations); processing and storage; marketing (organized by public institutions).

In the majority of the countries in the sub-region, the formal seed systems do not meet the seed demand of the growers. The small quantities are produced at very high costs due to a decentralized system which does not render itself to the realities of the traditional groundnut crop; the non adaptation of seed legislation to the needs of the small-scale producers; the complex system of evaluation and certification of the varieties; and the high cost of improved seed compared to the farmers' seed.

Informal seed system

The yearly requirement of certified seed of groundnut in West Africa is about 600,000 metric t. The public sector and seed producing agencies meet only a small fraction of this requirement. Because of non-availability of seed of newly released varieties in required quantities, the old varieties such as 55-437, TS 32-1, 47-10, 28-206, RMP 12, and others continue to dominate the variety scene in groundnut farming in West Africa. Most of the farmers either save their own seed for the next season, or buy from the local markets, where the seed is often nondescript or mixed, resulting in low productivity of the crop. Unless farmers, NGOs and the private sector come forward in a big way, the demand for certified seed of groundnuts will remain unfulfilled. As a consequence, crop productivity will remain low due to non-realization of full returns on the investment made in groundnut improvement research.

Several schemes have been suggested to promote the informal seed sector to overcome the shortages of good quality seed and hasten the diffusion of improved varieties of groundnuts among the farming communities. These include the following.

Local village seed systems: suitable for groundnut that is bulky (involving large transport costs to serve large scattered farmers), with high seeding rates (requiring large amount of seed to plant), with low genetic deterioration (which can be grown for years without loss of purity) and with low seed viability (which cannot be stored for more than one year without losing germination power). Seed supply arrangements should emphasize schemes that entail low transaction costs. Therefore improving the capacity of village seed systems to maintain and distribute seed is essential to ensure sustainability. Efficient producers or a group of farmers in each community should be identified and encouraged to become entrepreneurs tasked with the multiplication and distribution of groundnut varieties. This scheme should be encouraged by a consistent supply of modern groundnut varieties that meet market requirements and are preferred by farmers.

The research institutes are responsible for the production of breeder and foundation seed. Foundation seeds are bulked into certified and commercial seed through out-growers, farmers associations, Community Based Organization (CBOs), and/or individual farmers. The informal seed sector supplies the majority of seed planted by farmers. At local village levels, most farmers consistently obtain seed from their own harvest. If they hold insufficient seed stocks, they obtain seed from family, friends or relatives, or purchase seed from the markets. Village seed systems offer a range of local and diverse varieties that are accessible and are of acceptable quality with flexible transactions costs. However, these systems are recycling seed of old varieties with low genetic purity and have difficulties dealing with emergency seed issues. These systems are also largely inefficient at generating new varieties that are critical to improve productivity.

Contract seed production: as the local seed sellers constitute the major source of groundnut seeds, they could promote quality seed production through contract farming of improved varieties. However, both farmers and traders need to be educated in the technical aspects of groundnut seed production, processing and storage. Contractual arrangements between processors and producers are necessary to motivate farmers to use other agricultural inputs such as fertilizers and pesticides.

Community based seed system (CBSS): local village seed systems are working relatively well but are inefficient in supplying new varieties to farmers. A better interface between small-scale seed producers or CBOs involved in seed production with the public sector suppliers of varieties and breeder seed, is likely to facilitate access and availability of seed of preferred varieties to farmers. Investment in organizing or reinforcing the CBOs or small-scale producers at producing subsequent seed classes (foundation and certified) and linking them to the markets is essential.

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