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Technical Manual

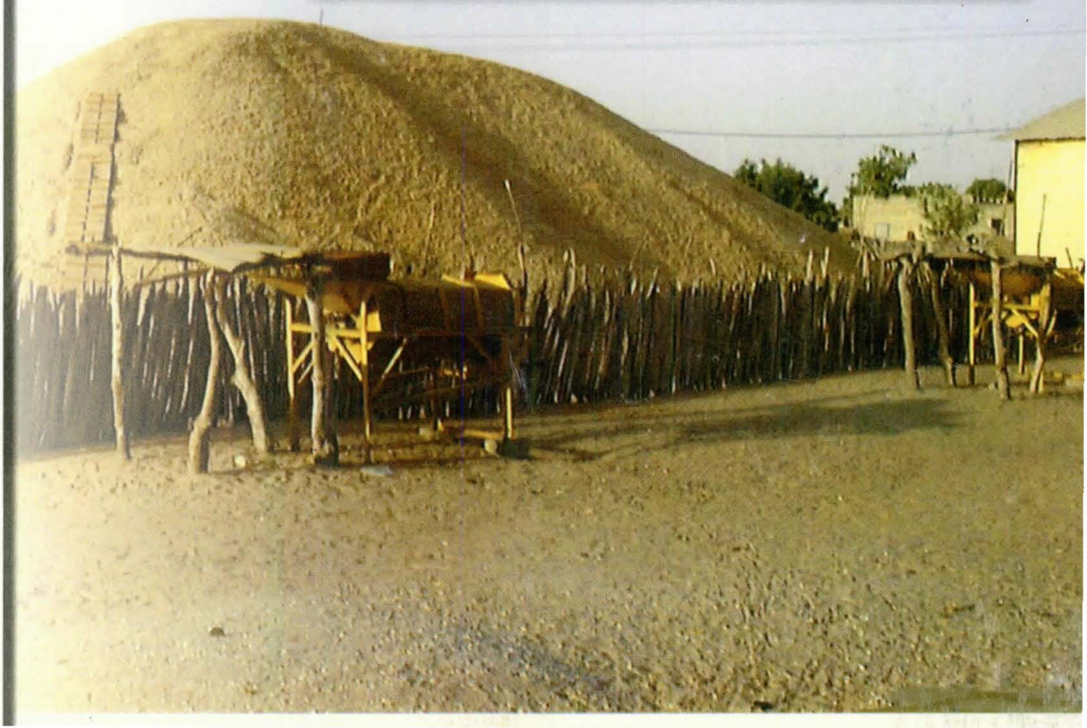
Guidelines for groundnut seed production, storage and distribution for traditional farming systems

PROJET GERMPLASM ARACHIDE
GGP
Groundnut
Germplasm
Project

ICRISAT
International Crops
Research Institute
for the Semi-Arid
Tropics

CIRAD
Centre de Coopération
Internationale
en Recherche Agronomique
pour le Développement

ISRA
Institut Sénégalais
de Recherches Agricoles



Session 1

The variety, a starting point in seed production

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Introduction

In the process of making available an improved variety, seed production is the last technical step before distribution-commercialization to producers. Seed production itself follows a series of steps aimed at offering minimal quantities necessary to regularly reconstitute the seed capital. This is the minimum quantity, which has to be renewed each year for the benefit of producers. Seed production does not generally depend on agricultural research but is largely determined by the quality of the initial product provided by research in the upstream process. It equally depends on the number and characteristics the varieties constituting the target regional variety map, which are equally established by national agricultural research services. The principal discipline responsible for development of an improved variety is plant breeding. Breeding is a multidisciplinary activity based on set objectives, integrating other disciplines is achieved through a series of agronomic trials under target climatic conditions for each variety. The objective of this chapter is to furnish the basic principles of variety improvement for which seed constitutes the starting point of the seed sector.

Breeding principles

Due to the autogamy of groundnut, it is envisaged that simple multiplication methods will reduce costs. Experience shows that seed multiplication and diffusion of improved seed requires special organization whose efficiency depends on the primary performance of the variety and the quality of the first level of seed production. The major principles and steps in creating a new variety vary very little or not at all based on the species. Only methods used and breeding objectives can vary according to the mode of reproduction.

Creation of a variety

Terminology

At the start of a breeding program, there has to be genetic resources of the plant material. This generally consists of a collection of varieties, called at this stage genotypes to distinguish them from improved released varieties. These are used by producers and are often called cultivars (cultivated varieties) or commercial varieties. Experimental varieties are those, which have not gone through the whole process of evaluation and have not yet been released. In the case of groundnut and other self-pollinated crops, the term lines is frequently used and is synonymous with genotype and is applicable to all categories. In practice, however, the term is rarely used when referring to released or commercial varieties. When this term is used alone, it often refers to those, which are still in the development stage. In the context of the breeding program we distinguish between fixed lines and segregating lines. Fixed lines are those whose genetic make up (DNA) no longer varies. These fixed or pure lines or homozygous lines represent the last step of breeding: stabilization of lines. Inbreeding several generations is necessary to obtain homozygous lines.

Steps in creation of a variety

The process leading to the creation of a new variety is often long whatever the species and breeding objectives. Breeding is an operation in the chain of events leading to provision of the basic material for use in seed production. The length of the program varies according to the

collection of genetic resources, or if we choose to introduce or create varieties. Under normal circumstances, a successful introduction requires 6 to 7 years before a new variety is recommended. If, based on the objective, all steps have to be followed from assembling a working collection to adaptation techniques for variety adaptation, this will require 12 to 15 years.

The different phases constituting breeding programs up to seed multiplication are as follows:

Definition of breeding objectives

The duration of a breeding program is around 10 years, thus it is important to fix objectives, which determine the scheme of the first stages of breeding. While defining objectives it is important to analyze all information from the target environment and scientific information available. Information from producers themselves or development agencies, results from agronomic studies and diagnosis of constraints to production must be taken into consideration. Literature review will determine the scientific feasibility of the program to be embarked on.

If we want to introduce resistance to a biotic factor, the type of resistance to a particular disease or insect pest or adjusting the growing cycle, we begin by making crosses among two or several parents and screen their offspring (see paragraph on screening below) generally consisting of dozens of segregating populations. If a source of resistance and/or early maturing parent is available and screening conditions are selective, transfer of this type of characteristic does not pose a problem. If the source of resistance is partial to a stress which is not available in nature, the parent for length of the growing season needed, selection will be impossible..

Concerning abiotic stresses such as resistance to drought, or soil acidity, search for resistance is particularly difficult. The nature of the character being selected for is complex. These characters are controlled by many genes compared to simple characters described above. Breeding schemes for such characters are often longer and more complex.

Constitute a working collection

This consists of a series of several hundreds of pure lines of different origins. These lines could have been introduced from other breeding programs or international centers. National breeding programs often conserve national collections. They are enriched, described and characterized for morphological and phenotypic traits. If the species has been in the region for a very long time or from another region, often one finds local landraces within the country. This situation is, however rare for groundnut which originates in South America and was only introduced into Africa in the 18th century.

Variety Screening

Variety screening is applied to selection among a large number of lines based on particular criteria and the breeding objective. The objective at this stage is to reduce the number of lines and concentrate on those that are promising as potential parental lines to be used in a breeding program. The lines are compared with checks. This often involves non-replicated trials. The quality of screening depends on the value of the variety created. A good screen requires a high pressure of the stress whose resistance is being looked for. Checks are often two or three varieties representing high susceptibility and resistance or tolerance of the character to be improved. The last step of screening uses a currently grown variety to be replaced.

Application of appropriate breeding scheme

The breeding scheme will depend on the breeding objective and the complexity of the character to be improved. All breeding schemes are based on clearly defined breeding methods and begin with making simple or multiple crosses to obtain stable lines. Following a cross, the lines are heterozygous meaning that their genetic composition, their genotype, varies from one line to the other. It is this variability, which permits selection. We also talk of segregating lines to differentiate

them from stable lines. The process of producing stable lines is long, requiring at least five generations of selfing. Inbreeding reduces heterozygocity leading to a pure variety in seed production terms. It is important to respect the process of variety purification as off types can contaminate levels of the selection scheme.

Variety Introductions

The creation of a new variety through planed crosses is not always necessary for a breeder. It is through the definition of objective and literature review that a selection strategy can be established. On the other hand, variety creation and introduction are not exclusive of each other. If for example, one is looking for a confectionery groundnut variety with large kernels, this can be achieved by introducing confectionery types and evaluating them directly. In parallel, the breeder can make crosses among available confectionery groundnuts to create supplementary quality. In all cases the breeder who evaluates them makes new introductions. If they prove promising, time and money will be saved by avoiding making unnecessary crosses and following the various selection schemes. If it is not the case, promising material can be used in a breeding program as parents. Unless it is poorly adapted such material is added to the working collection.

Introduction of new varieties has nothing to do with importation of commercial varieties. This work remains a perogative of the national research programs. Precautions are necessary while introducing a new variety to producers considering the phytosanitary risks involved. Some viral, bacterial and fungal diseases are often seed borne. Appearance of a new disease in a particular region is always due to lack of precautions undertaken while introducing a new variety and to illicit importation. A phytosanitary certificate only guarantees absence of seed borne diseases. Crop protection is often dependent on quarantine services to make observations on the first generation of plants from introductions. Such services are effective if there is good liaison with research. In the absence of phytosanitary problems, there are other inconveniences from uncontrolled importation, which can result in disruption at the level of seed production, if introduction of a new cultivar was not anticipated.

Comparative evaluation of new or introduced varieties.

The step following stabilization or introduction of a new variety, is variety evaluation. This is done in two phases. In the first instance evaluations are done on the principal research station and secondly outside. On the station, varieties are compared with a check, which is normally the most widely grown and is to be replaced. All necessary agronomic observations are made and these are statistically analyzed to compare performance of the varieties. The initial number of varieties is reduced to a few dozens including experimental as well as introductions. In the past such evaluations were done at sub-stations of a principal research center in the target regions. This type of multilocation testing allows stability analysis that facilitates choice of the most promising variety proposed for diffusion and release. Nowadays, this type of multilocation trial is limited by lack of qualified personnel and appropriate infrastructure at the sub-stations. The last resort to partially fill the gap are the NGOs that specialize in agronomic trials.

Comparison of lines.
Photo D. Clavel

On-farm testing

The last stage of making available a new variety is done in the farmers' fields with farmer participation. This can take several years depending on the variety and technical level of potential users. However, in the second year a small quantity of seed can be made available to seed services to avoid the first stage of seed production. At this stage and if not already envisaged, involvement of an agronomist is indispensable and the breeder is no longer at center stage. Participation of a mechanization specialist and an economist is also required. The success of this stage will depend on good collaboration between research, extension services and specialized NGOs because it is through these on-farm tests that the adoption of the new variety is guaranteed. Such tests should be done with a few promising varieties in larger plots because the aim is to demonstrate the potential of such varieties in the real world following an appropriate technical guide. The technical guide optimizes factors that influence production. These are essentially, date of sowing and harvest, plant density, fertilization, use of pesticides (herbicides, fungicides and insecticides) and adapted mechanization systems. A variety description (annex 1) summarizing necessary information must be established by research to serve as a reference to all seed producers and extension agencies.

Production of breeder seed of a variety

Breeder seed or basic seed or nucleus seed comes from a minimum of 100 plants, sometimes 1000 depending on need. Strict control of conformity to variety characteristics helps to eliminate doubtful elements. Varietal purity is carefully controlled as this determines the homogeneity of the following stages of seed multiplication. In practice a variety is sown in single plant progenies. The seed of each progeny is carefully examined and sown the following year. This technique helps to determine the stability of the lines. Groundnut is not 100 % self-pollinated and 0.2 to 6% out crossing can occur depending on the variety. This necessitates proper separation of different varieties in multiplication plots and can be achieved through staggered planting or surrounding each variety with border rows. Agronomic conditions should, as much as possible be near those under which the crop will be grown to avoid undesirable selection pressure. At harvest and after selecting lines to constitute seed for the following year the remaining seed should be handed over to a seed producing organization (usually a research station) to assure the beginning of a seed multiplication program.

Breeding methods

Most commonly used breeding methods of self-pollinated plants apply to groundnut. A breeding method is chosen on the basis of breeding objectives and the selection method. There are four principal breeding methods:

Pedigree method

This is the most commonly used method in self-pollinated crops. It involves advancement and selection among progenies of a cross from generation to generation. The first generation (F1) consists of identical genotypes. Genetic segregation or heterozygocity is maximum in F2. This is the generation in which plant selection starts as it represents maximum variability. Each plant from F2 is sown as single progeny row. This permits to follow up on single plant progenies tracing back from a single F2 plant. Heterozygocity and consequently variability is reduced by half each generation until it becomes negligible after 6 or 7 generations. It is at this time that the lines become fixed. Selection for resistance to foliar disease of groundnut has been done following this method.

Backcross breeding

This method is used to transfer desirable traits such as erect plant type, earliness and rosette resistance into adapted genotypes. The adopted genotype is the recurrent parent that is the object of improvement. Five to six backcrosses are needed. In each backcross, genotypes representing desired traits are selected. These genotypes are then used in the following backcross with the recurrent parent.

Single Seed Descent (SSD)

This consists of sowing a single seed from each plant starting from the F2 generation. This continues until homozygocity is attained, resulting in recombinant lines. The main advantage of this method over pedigree is that it preserves genetic variability. However, the main weakness is that one ends up with a large number of lines to evaluate.

Recurrent selection

This is a method, which must be used in breeding for characters controlled by many genes such as resistance to drought. If gene action of a character is additive, i.e. stable and heritable, the method is efficient. It starts with a population arising from multiple crossed between complementary lines. This is followed by a series of selection cycles. Each cycle is achieved through a large number of crosses between chosen genotypes. The resulting population is advanced to F2 from which selections are made. These are then intercrossed. The process can go on for as long is deemed satisfactory as variability never reduces. Recurrent selection method is rarely used in groundnut because of difficulties in making the necessary crosses to reconstitute the initial variability after each cycle of selection. A recurrent selection program for physiological drought resistance was attempted in Senegal from 1985 to 1999.

Definition of a variety map

The choice of a groundnut variety is a function of final production and performance in a given environment. Certain grains due to their seed size and form are consumed directly e.g. edible or confectionery groundnut based on large seed size. Varieties that do not meet these criteria (small grains) are used for oil extraction.

Repeated agronomic evaluations in time and space and in different tests in the farmers' environment allow the choice of the best varieties adapted to different uses. The results of variety tests determine variety distribution in a particular region of a country. This is often based on agro-ecological and cultural conditions. A variety map is not fixed. It evolves as a function of changes in the environment of market and nutritional demand.

A variety map is thus a tool produced by research to enable choice of varieties according to target regions. This map represents a summary of information updated according to changes in climate and research results. A variety map proposed by Senegalese research done in 1996 is presented in Annex 2. The country is divided into two major agro-ecological zones: drought-prone north and well-watered areas. This translates into two production domains: farmer practices relative to the maturity cycle of existing varieties and a research domain of new varieties adapted to new rainfall regimes.

This tool is of great importance in seed production because the map can help in estimating the area to be covered and thus seed requirements. It also shows distribution of varieties and their zone of adaptation.

The presence of a variety map helps in determining variety characteristics and can also facilitate identification of appropriate varieties in case of natural disasters.

Conclusion

Diffusion of a new variety is an operation, which takes several years especially groundnut which has a low seed multiplication rate (average 8). However, if the cultivar meets farmers' needs, demand is guaranteed because seed is the most critical renewable input for production. Users can renew a good variety of self-pollinated crop without much difficulty; They can then easily become producers in the seed production chain.

If the time taken to diffuse a variety is long, added value from its use is high and investment in research and development is rapidly repaid to the benefit of the producer. This can be illustrated as follows:

Gain projections to producers by replacing variety 55-437 by Fleur 11 and GC 8-35 in Senegal

– Production of 55-437 in Louga, Thies and Diourbel: 180,000 tones
– Estimated pod yield from distribution of the two varieties: 15% or + 27,000 tons
– Price of produce: 130 CFA /kg of pods (average for the last five years)
– Profit to producer: 3.5 billion CFA per year
– Cost of research (personnel (2) technical training (4) plus overhead over 15 years: 60 million CFA /year or 900 million CFA over 15 years.
– The yield increase expected would be able to repay investment in research for 15 years just in one crop season, even when the distribution of the two varieties only covers a quarter of the area.

Discussion

The major points raised in this session were:

National breeding programs

There are groundnut improvement programs in most countries. However, based on human, and financial resources available, three categories of programs can be identified:
– Classical breeding programs: These exist only in a few countries and involves international research programs (mainly ICRISAT)
– Programs characterized by introduction of segregation population from International center such as ICRISAT, CIRAD) : this is the case of Burkina Faso, Senegal, Nigeria, and Ghana
– Programs limited to introduction of fixed lines: these are the most common in the region.

National Collections

All countries with a breeding program have a national working collection. However the importance of these collections varies from a few dozen (e, g Mauritania) to a few hundred samples (Nigeria, Senegal). Certain varieties are registered in national variety catalogues.

Regional collections
It was unanimously agreed that a regional working collection must be maintained in order to guarantee quality and make material available to other countries when needed. GGP can promote this activity.

Production constraints
Even though there are production constraints such as the well-known foliar diseases, insect pests, drought etc. selections should be made for extreme conditions, for example resistance to salinity.

Variety introduction/evaluation
Most often varieties are introduced by national agricultural research systems in collaboration with international centers (ICRISAT) or regional structures (GGP). However due to lack of resources the majority of the varieties remain on station. Efforts are needed to ensure that these varieties are registered and rapidly diffused.

Relationship between research and extension
In Senegal, Ghana and Nigeria, collaboration between research services and extension assures the diffusion of new varieties. However, it appears that the weakness in the extension services of most countries is the primary cause of lack of promotion of improved varieties.

Production of breeder seed
In Niger (for 3 years) and Mauritania there are intermediate structures or parallel programs, which produce breeder seeds outside of the national programs

Variety maps
In most countries such as Mali, Burkina Faso and Togo, variety zones exist but not a variety map like the one presented for Senegal. Participants showed enthusiasm in making such a tool available to farmers and seed producers.

In conclusion, breeding programs are destined to respond to demand. Nevertheless institutional, financial and human resource constraints in most countries hinder execution of important upstream activities, which are important in the seed production chain. Adaptation in Niger and Mauritania and creation of autonomous seed units working directly with seed production organization is a welcome development.
Maintenance of a regional working collection will enrich and support a wide range of germplasm for the future. It is equally important to recognize the importance of seed quality of first generations in the seed multiplication chain, which determine the success of subsequent stages of seed production.