Assessment of groundnut research achievements in the savannah regions of West Africa(1)

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Abstract — Groundnut (*Arachis hypogaea*) research in West Africa was initiated in the 1920s and conducted on three major locations. Samaru, Nigeria; Bambey, Senegal; and Niangoloko, Burkina Faso. Breeding led to selection of a number of productive varieties as regards drought tolerance, disease resistance, earliness, dormancy, and adaptation to the edible market demand. Long-term agronomy trials indicate that applying only mineral fertilizer will not prevent soil acidification by cation reduction, resulting in reduced yields. Maintaining the organic matter content of the soil is essential if the reproducibility of a cropping system based on alternating groundnut and cereals is to be ensured in the Sudan-Sahelian Zone. The phytosanitary problems in West Africa are becoming more acute as crop rotations become shorter and continuous cropping is expanded. Research work is based on five major topics emergence disease and pest protection - inexpensive and highly effective seed-dressing treatments are applied: leaf disease control - rosette-resistant varieties are available and integrated pest managements of rust (*Puccinia arachidis*) and leaf spot (*Phaeoisariopsis personata*) diseases are being investigated, millipede (class: *Diplopoda*) control - emergence protection and the use of baits have been developed; aflatoxin control - preventive methods at the field level and corrective control at the industrial level have been developed, and nematode control -a control method was developed and applied full-scale in northern Senegal For post-harvest technology, current research is helping to develop processes for more effective improvement of groundnut products. Disinfection of stocks, refrigerated seed storage, and vacuum storage of seed have been developed. Industrial production of ready-to-use seed will be undertaken in the near future in Senegal. Mixed research and development operations are under way in different fields, notably seed and edible nut production and processing. They enable researchers to follow closely the requirements of the producer and consumer, and ensure the coherence and effectiveness of the program as a whole.

Key words. — Groundnut, breeding, agronomy, technology, research/development, technical approach

Groundnut (*Arachis hypogaea*) research in the West African savannah regions was initiated as early as the 1920s at the Institute for Agricultural Research, Samaru, in Nigeria and in 1930 at the Bambey Research Station in Senegal. Research on groundnuts became important from 1950 with the establishment of the Institut de recherches pour les huiles et oléagineux (IRHO) in Senegal and Burkina Faso. Research activities also gained impetus thereafter in other countries, notably Gambia, Ghana, Sierra Leone, and Côte-d'Ivoire. With the debut of the United States Agency for International Development (USAID)-Peanut Collaborative Research Support Program (CRSP) in the early 1980s, research on specific but common problem areas in selected countries in the region resulted in an increase in groundnut research. The creation of the Conférence des responsables de recherche agronomique africains (CORAF) Groundnut Network in 1987, which coincided with the inauguration of the ICRISAT Sahelian Center (ISC) at Sadoré, Niger, provided a significant back-up and complementarity as well as new perspectives on national research efforts on groundnuts in the region.

The need for research cannot be overemphasized in view of the reduced production of groundnuts particularly during the 1978-1989 period in most groundnut-producing West African countries. Reduced production was most marked in Niger and Nigeria. Despite declining production, research has contributed substantially to crop intensification. This paper describes major groundnut research achievements in the savannah regions of West Africa.

VARIETAL IMPROVEMENT AND PHYSIOLOGY

Fundamental research (on breeding and developing assessment and screening tests) is mostly carried out in Nigeria (Samaru), Senegal (Bambey), and Burkina Faso (Niangoloko). The last two of these stations cover problems in the Sudan-Sahelian Zone (where the major constraint is drought) and the Sudan-Guinean Zone (where the major constraint is disease). Samaru covers both problems. The programs have changed considerably in terms of goals and the methods used to achieve them. These changes were reflected in the complete renewal of the seed on offer to growers in West Africa, shifting from low-yielding local, creeping varieties with small seeds and a 120-day cycle, to a range of high-yielding erect varieties, better adapted to drought, tolerant of certain diseases, or with characteristics making it possible to sell the seeds to more lucrative markets as edible groundnut. Varieties distributed in Senegal vary depending on the evolution of climatic conditions. The effective production and distribution of seeds each year is determined by the results of research and by government policy

Two major subprograms can be distinguished and are discussed below.

(1) Paper presented at an ICRISAT international workshop, 25-29 Nov 1991, ICRISAT Center, Patancheru, Andhra Pradesh (India).

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Drought tolerance subprogram

The drought tolerance subprogram launched in Senegal now covers central and northern Burkina Faso and involves a wide range of partners in geographical areas affected by drought (e.g., northeastern Brazil, Botswana). After the general drought in the early 1970s, breeding for drought resistance and short maturity cycle have been given research priority in Nigeria, Ghana, Mali and Niger.

Physiologists and breeders have been working together in these countries for several years, and have identified a few varieties that may be drought tolerant.

Various drought tolerance techniques have been used and a set of tests have been developed. The tests were applied to the collection of groundnut varieties available in Senegal. Varietal trials were carried out in the field under natural or artificial drought conditions, which led to the distribution of variety 55-437, offered for extension in the northern part of the groundnut basin, the most severely drought-affected area (400-650 mm rainfall). This variety, which is currently released for commercial production in Niger and the drier zones of Nigeria, Chad, Gambia, and Cameroon (Table I), is being used as a parent in the program underway at Samaru, Nigeria, and at the ICRISAT Sahelian Center (ISC), Niamey. The variety SAMNUT-18 (RRB) released in Nigeria has 55-437 as one of the parent sources. The lack of seed dormancy typical of Spanish and valencia types means that there is a risk of immediate germination if the soil is still damp at the time of maturity: breeding was therefore geared towards obtaining drought resistant and dormant types destined to minimize this draw-back in areas that are subject to late rainfall (600-900 mm). Hence, variety 73-30, with a 95-day cycle, and 73-33, with a 105-day cycle, were obtained from Spanish × Virginia crosses. This material is unique, and was introduced by ICRISAT into collections and varietal trials in most producer countries in the semi-arid zone. It has been very widely distributed in Senegal and Gambia (Table I). The varieties are currently under intensive evaluation in Guinea.

Drought in the Sahel and Sudan-Sahelian Zone can take two forms:

- short rainy season and low rainfall, typical of higher latitude region; and
- long rainy season, but often of irregular distribution and often inadequate total rainfall: this occurs frequently in the central and southern zones.

In the northern region, the goal is to develop breeding programs geared primarily towards producing early-maturing varieties from parents with a 75-90 day cycle. In the central and southern regions, the aim is to develop varieties with physiological characteristics that will enable them to withstand periods of drought without suffering irreversible damage: the late-maturing varieties have a higher production potential and their ability to recover after drought at the start or in the middle of their cycle means that they are often chosen in preference to early varieties. A drought adaptation ideotype was defined, on the basis of three main physiological characters:

- root growth,
- protoplasmic resistance, and
- optimum stomatal transpiration.

For a given type of drought, the results enable a definition of the adaptation characteristics required of the preferred ideotype. Four tests were developed to enable screening of around 800 individuals in each breeding cycle, based on protoplasmic resistance to heat and drying, by measuring electrolyte escape, on water loss regulation measured using detached leaves, and on rooting characteristics, studied in a rhizotron.

Productivity improvement subprogram

The productivity improvement subprogram covers and combines the other topics. It takes into account the main yield components and the quality of the products obtained, depending on local production conditions. The following traits are important to breeders: yield (pods, haulms, emergence, and shelling), ecological adaptation (cycle length, dormancy, drought tolerance, and disease resistance), response to cropping techniques (soil preparation, fertilization, and mechanization), and product quality (oil and amino-acid composition, and commercial and organoleptic characteristics).

Nearly 50 varieties are currently being commercially multiplied in various West African countries (Table I). Most of them were obtained at the breeding centers at Bambey, Niangoloko, and Samaru, and then very widely distributed throughout the region, in Cameroon, and in zones of southern Africa with a similar climate. They were all chosen because of their desirable traits (productivity, erect habit, oil content, and simultaneous maturity). Important traits of some of these varieties are given in Table II.

AGRONOMY AND CROPPING SYSTEMS

The apparent decline in groundnut production in West Africa had been partly due to nonadoption of improved agronomic practices for obtaining high yields. Unfavorable climatic conditions, characterized by frequent droughts, high temperatures, and a decline in soil productivity following continuous cultivation are exogenous factors that have resulted in low yields. Results from research institutes in the region have shown, however, that recommended production practices for obtaining high yields include selection of good quality seed for sowing, a weed-free seedbed, timely sowing maintaining a high plant population, application of fertilizers, weed and disease control, and timely harvesting.

Despite these recommendations, crop husbandry practices for groundnuts in large areas of West Africa have remained unimproved and the crop is still a subsistence crop. Farmers grow the crop with minimum inputs, which normally entails sowing poor-quality seed of traditional varieties as a component of mixed cropping systems with inadequate weeding and no chemical fertilizers or pest management practices.

Increased groundnut productivity is sought both from improved varieties and by developing cropping systems likely to make the best possible use of the seed, taking account of:

- environmental factors (the need to maintain and improve soil fertility on a long-term basis), and
- socioeconomic constraints affecting the rural environment (land availability, equipment and input costs and installation, grant and credit policies, etc.).

Intervention strategy: restrictions on intensification

Groundnut research has included studies of the socioeconomic environment of production, which is a basic constraint on the application of research results. Prices and price fluctuations are a determining factor: purchase price, harvest prices, price paid for inputs, and expected relative income govern the farmer's technical decisions and market opportunities. Groundnut, which is a 'driving' crop in the Sudan Sahelian Zone, proves the suggestion that pricing policies are not usually in accordance with official declarations of intention and do not make the most of the technical and financial resources that are available for development. There is no other way of explaining the erratic use of fertilizers in West Africa and the dramatic decline in their use over the past decade; the oft-proclaimed intensification

TABLE I. — **Some improved groundnut varieties under commercial production in West African countries**

Variety	Burkina Faso	Benin	Cameroon	Ghana	Gambia	Guinea	Mali	Niger	Nigeria	Chad	Togo	Senegal
47-16								x[1]				
55-437			x		x			x	x	x		x
73-27												x
73-30												x
73-33					x							x
40-16								x				
57-422								x				x
48-115A			x		x							
48-115B									xN[2]			
48-37		x						x				
RRB									xN			
28-204								x				
28-206			x		x		x	x				x
IB 66			x									
57-313												x
47-10							x					
69-101	x	x							x		x	x
RMP 12	x	x						x	x		x	
RMP 91	x	x	x						x			
KH 149A	x							x				
KH 241D	x											
59-426	x										x	
TE 3	x											
TS 32-1	x	x										
GH-119-20			x							x		
K 1332-781			x									x
M513-771			x									
90 Saria	x											
CN 14	x											
554.761												
Spanish 205									x			
Spanish 207-3				x					x			
M25.68									x			
MK 146				x					x			
MK 374												
MK 383				x					x			
Mani Pintar				x								
Florispan Runner				x								
Natal Common				x								
Shitaochi				x								
Tirik				x								
Philippine Red				x								
Kumawa				x								
FMIX				x								
Samaru 38									x			
Samaru 61									x			
Georgia											x	
Deli Rose										x		
756-17						x						
ICGVs 86053, 86551, and 87119						?[3]						

1. x = Most widely grown varieties 2. N = Newly released 3. ? = Promising varieties, grown elsewhere but still under local adaptation trials

TABLE II. — **Characteristics of the main groundnut varieties distributed in West Africa**

Variety	Early (<100 days)	Dormancy	Drought tolerance	Rosette resistance	Shelling rate >70%	100-seed mass >50g	Suitable edible/confectionery
55-437	x		x		x		x
73-30		x	x		x		
47-10	x				x		x
Te3	x		x				
Ts32-1	x		x				
KH-149 A	x			x			
KH-241 D	x			x			
55-422		x			x		x
73-33		x	x		x	x	
28-206		x			x	x	
69-101		x		x	x		
57-313		x			x		
RMP 12		x		x	x	x	
GH119-20		x				x	x
756 A		x				x	x
73-27		x			x	x	x
73-28		x			x	x	x

policies sometimes saw the denial of credit and a tripling of fertilizer prices, which resulted in the almost total removal of fertilizers from groundnut and other rotation crops.

This situation makes it logical to recommend the methodical and widespread use of so-called light techniques in the small-holder environment, in preference to inevitably sporadic and expensive heavy practices, limited to a few farmers who can afford them e.g., the ploughing/deep phosphate applications/high annual fertilizer rate combination, which is no longer being applied in Senegal. This realistic move should be continued.

Farming systems

• Groundnut intercropping

Groundnuts play a significant role in the farming systems of West Africa. Although it is grown as a sole crop to a certain extent, the widespread traditional practice throughout the region involves intercropping with cereal crops, particularly sorghum (*Sorghum bicolor*) and millet (*Pennisetum glaucum*). The production of groundnut as a sole crop was first dictated by the colonial emphasis on groundnut as a cash crop. Therefore, sole cropping research results were not applicable, and therefore not adopted by farmers for the traditional mixed cropping systems. It is only relatively recently that research on mixed/intercropping systems has been initiated.

Several advantages of intercropping include: insurance against complete crop failure due to pests/diseases and/or weather conditions, greater total productivity per unit of land for intercrops than for sole crops, supply of a better balanced diet for the farm family on a limited farm land area; better control of weeds and soil erosion; and avoidance of expensive labor costs during the cropping period. In spite of these advantages, the level of groundnut productivity is still very low.

One of the controversial issues requiring study is the effect on groundnuts of the N applied to cereals, and the transfer of N from groundnut to the associated cereal in situations where the farmer applies no or insufficient N fertilizer, particularly when his soil is low in organic matter content. Furthermore, the reduced nodulation and N-fixing activities of groundnut in intercropping systems would lead to a greater demand on native soil N by both the groundnut and the cereal component of the crop mixture. Because of the scarcity and high cost of N fertilizers to the small farmers, however, the productivity and fertility levels of their farms have continued to deteriorate. This is particularly aggravated by the fact that the crop residue is removed for livestock feed, fuel, and binding instead of incorporating it back into the soil.

There is a need for research on biological N-fixation, similarly, studies are required on the choice of crop combinations and varieties, optimum sowing dates, plant arrangement/geometry in intercrops, optimum fertilizer application levels, choice of herbicides, rotation schedules, pest and disease management, and the economics of production in intercropping systems.

• Sole cropping

The groundnut/cereal rotation is a common practice wherever the crop has evolved from self-sufficiency to market economy, particularly in Senegal and other northern regions of the West African cropping area. Advantages of the system are to be found in better disease and pest control, as well as in the introduction of animal-drawn tillage and specific crop husbandry, including fertilization. These factors will result in a significant increase of total land and labor productivity, in areas where fallow (a compulsory component of the traditional cropping systems) is becoming scarce. The effect of natural fallow or ploughed fallow on groundnut and cereal yields was compared with yields for the same crops grown continuously in rotation trials over several decades in Senegal, Burkina Faso, and Nigeria.

Grass fallow, essentially comprising wild grasses, can help to preserve the soil profile and slightly increase the organic matter in the soil. It limits, although it does not entirely eliminate, degradation and yield reductions in extensive cropping systems and in regions with particularly unfavorable soils and climate. However, with good soil and climatic conditions, the length of the fallow period can be reduced in accordance with the fertilizers applied, or abandoned altogether.

Of the cropping systems tested, those which prove the most profitable for the farmers, while maintaining soil fertility, are the most 'highly developed' systems, combining organic and mineral fertilizer as well as using harvest residues.

In high-risk areas (with low rainfall, very sandy soils, susceptible to erosion, and where repeated ploughing is not advisable), groundnut/cereal/fallow rotation is to be recommended; in more propitious areas, continuous groundnut-cereal growing can be considered.

In both cases, it is essential to maintain the organic matter content of the soil: in continuous cropping, applying only mineral fertilizer will not prevent soil acidification by cation reduction, even if is satisfies the major element requirements, and the subsequent reduction in fertility leads to reduced yields. Despite the problems posed by availability of organic matter, this factor is essential if the reproducibility of a cropping system based on alternating groundnut and cereals is to be ensured in the Sudan-Sahelian Zone.

• Fertilizer studies

In West Africa, the main fertilizers applied to groundnut contain phosphorus, calcium, and sulfur.

Fertilizer studies were based on research on physiology and mineral nutrition, backed up by factorial fertilizer trials. The critical levels for N, P, K, Ca, Mg, and S were determined by leaf analysis. The contents of these elements, measured by leaf-sample analysis, provide useful information on plant nutrition and on the deficiency thresholds; in fact, this involves N × dry mass, P × N and S × N critical curves. In addition to soil analyses and field experiments, this technique made it possible to define the most cost-effective formulas for each zone, based on response and cost curves. A fertilizer map has thus been produced for Nigeria and Senegal. This has governed fertilizer application for several decades and sticks closely to local soil and climatic conditions. There is a dominant P deficiency except in the Thies region (Senegal), where phosphates are naturally abundant. Some of the fertilizer recommendations in the region are: application of soluble forms of P in the northern region; gradual incorporation of less soluble tricalcic phosphates in the central and southern regions; and correction of Mo deficiency in certain areas by mixing molybdate (30 g ha^{-1}) directly with the seed fungicide treatment or in the form of Nutramine.

In other producing countries, particularly Nigeria, the fertilizers applied on groundnut consist of combined manure (2.5 to 7.5 t ha^{-1}) and single super-phosphate (60 to 100 kg ha^{-1}) applications, with a view to maintaining sufficient levels of organic matter in the soil and to correcting the major deficiencies (S and P). The current recommendation using mineral fertilizers alone requires the application of 300 kg ha^{-1} of single superphosphate and 54 kg ha^{-1} of muriate of potash before sowing.

There is a general Ca deficiency throughout much of the West African semi-arid savannah soils where empty pods or poor pod filling is a problem. Although single superphosphate and gypsum have been found to remedy the situation, it has been advocated that genetic variation can be exploited,

particularly in the light sandy soils of the Sahel. Since pod size has been established as a factor influencing the Ca nutrition of pods, which is dependent on surface. volume ratio, small pods are less likely to experience Ca deficiency than large pods. Research efforts have therefore been directed at identifying varieties with desirable agronomic characters, optimum pod size, and efficient exploitation of available Ca.

- **Weed control**

Weeds growing at the beginning of the season can have an extremely adverse effect on young groundnut plants, and adequate weeding at the right time is necessary for crop success. Early manual or mechanical weeding also makes it possible to loosen the soil and dig in the fertilizer, thus maximizing its effectiveness. This cropping technique is a significant step forward in increasing the growers' technical skills, and mechanical weeding is now widespread in major production areas (particularly in the Senegal groundnut basin and northern Nigeria).

Herbicide formulas have also been tested successfully: Lasso® + diuron, and Cotodon®, in Burkina Faso; Cotodon® + Gramoxone®, and Gesaten® in Senegal; and I-gram Combi® and Dual® in Nigeria. However, the use of herbicides by farmers is limited due to lack of resources and application difficulties. This is particularly difficult in intercropping systems.

Recommended technical practices

Research organizations have made precise recommendations on the techniques developed to improve the main rainfed crops (groundnut and millet-sorghum) in Nigeria, Senegal, and other countries. Some of these recommendations are:

- use of selected varieties;
- seed fungicide treatments;
- sowing in rows, at the right time, right density and right depth,
- light mechanization using animal traction (sowing, hoeing, lifting);
- light mineral fertilizer application, spread and dug in at the right time;
- weeding at the right time; and
- harvesting at the right stage of maturity.

The interaction of these techniques and the estimates of profits obtained in terms of yields (in agronomy trials) are given in figure 1.

The wide-scale application of these techniques in Senegal during the 1960s led to a general shift from manual to mechanized agriculture, both for groundnut (which funded the shift) and for cereals grown in rotation with it. Although some of these recommendations have been adopted in other West African countries, albeit poorly, mechanization is not as wide-spread as in Senegal where animal traction practices have been developed.

The strategy that was adopted needed to take the minimum number of risks in a drought-prone area. It required:

- rustic varieties, capable of withstanding difficult soils and climatic conditions;

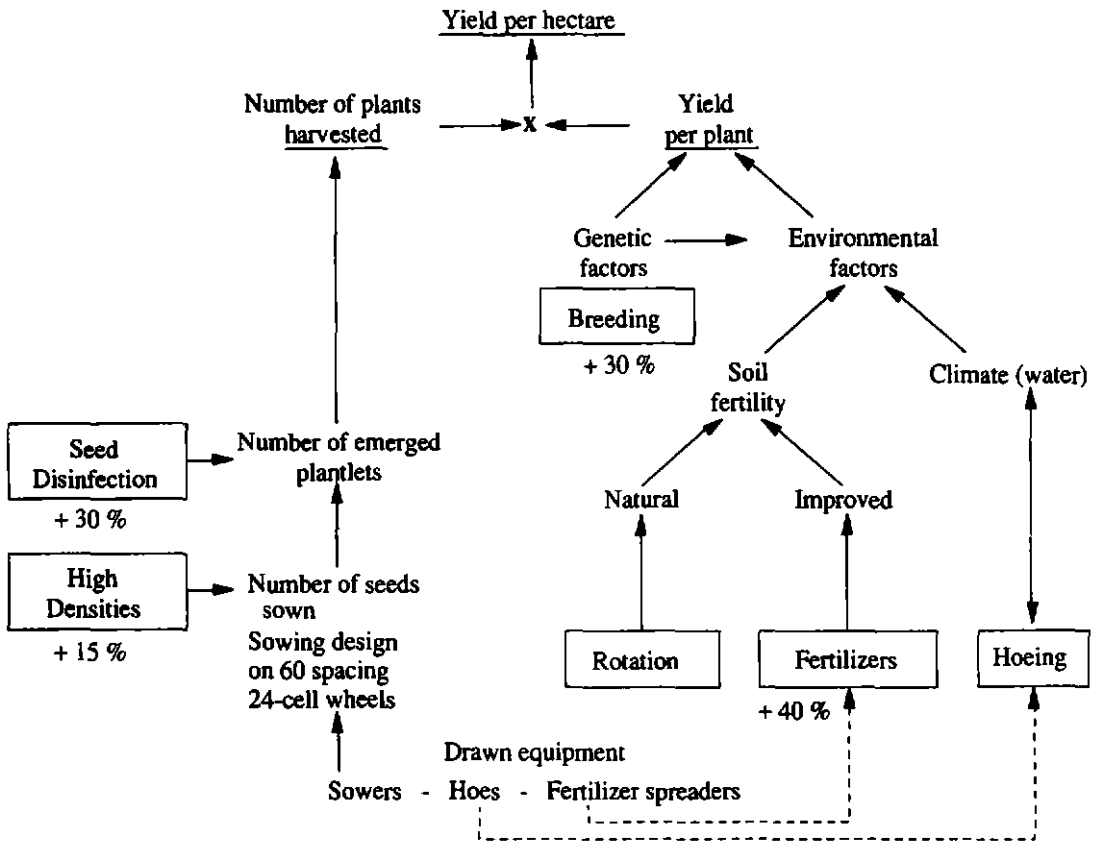

FIG. 1. — Principal groundnut yield factors. (*Source : propositions pour l'augmentation rapide des rendements de l'arachide au Sénégal - Institut de recherches pour les huiles et oléagineux/Institut de recherches agronomiques tropicales et des cultures vivrières (IRHO IRAT), 1963*)

- low-cost, multipurpose equipment and hitched tools;
- light fertilizer rates, based on short-term cost effectiveness; and
- effective integration of traditional cropping practices and farming calendar.

CROP PROTECTION

Groundnut is attacked by numerous predators, and the damage caused is reflected in a significant fall in productivity and poorer product quality. Attacks by arthropods (insects and myriapods), worms (nematodes), and pathogens (fungi and viruses) are seen, in addition to weed competition. The phytosanitary problems in Africa are becoming more acute as crop rotation periods become shorter, the system of cropping twice a year becomes more widespread, and international seed exchanges develop. Researchers have studied these problems in terms of cropping practices, varietal improvement, and chemical and technological treatments: we shall discuss five main topics.

Emergence disease and pest protection

Numerous fungi and insects (termites, coleoptera) and myriapods (julids) attack seeds and seedlings during germination and lead to emergence losses of up to 50%. Treating seeds with fungicides + insecticides is essential, and has been studied widely. A dry coating technique has been developed and several formulas have proved their effectiveness (benomyl + captafol, captan + carbosulfan, etc.). Granox® (10% benomyl, 10% captafol, 20% carbofuran) gives excellent results in Senegal (average effect + 33% at the densities generally practiced). Until recently when they were phased out, Aldrex T® (thiram 25% + aldrin 25%) and fernasan D® (thiram 25% + lindane 20%) were the major routine seed dressing chemicals used in Nigeria and Ghana. Apron Plus® (metalaxyl + captan + furathiocarb) and Marshall ST® (carbosulfan + thiram) are being tested under Nigerian conditions. These inexpensive but highly effective treatments are applied on a very wide scale, and products are distributed to farmers in all the areas where a specialized service provides seed supplies. The fungicide component of the treatment is by far the more important, and the hypothesis that fungi become established in wounds that already exist has been proved. Industrial coating and the distribution of ready-to-use shelled, fungicide-treated seeds is currently at the preextension stage in Senegal.

Leaf disease control

Four diseases (rosette, early and late leaf spot, and rust) have an economic impact on groundnut productivity in Africa. Disease incidence is higher the further one is to the south of the savannah area.

- **Virus disease**

Rosette is a virus disease transmitted by an aphid, *Aphis craccivora*. Resistant varieties have been bred in Burkina Faso, Senegal, and Nigeria. Although the transmission mechanism and the epidemiology of the disease in fairly well understood, the way the virus acts is not yet entirely clear. Rosette can devastate harvests over vast areas if climatic conditions in a given year are propitious for early infestation; although traditional small-holders do not have access to chemical treatments, the use of resistant varieties makes disease prevention possible irrespective of the circumstances. Varieties that have been extended in areas where rosette is endemic and have proved highly successful are 69-101 in Nigeria, Casamance, Guinea-Bissau, and Chad; RMP 12 and RMP 91 in Burkina Faso, Chad, and Mozambique; and SAMNUT-16 (M554.76 I) and SAMNUT-3 (M25.68) in Nigeria. ICRISAT has included them in its varietal development and international varietal trial program.

- **Leaf spot diseases**

Leaf spot diseases (early and late) are seen in varying degrees wherever groundnut is grown. They lead to premature defoliation and yield reductions of up to 50%. Many products and formulas have been tested, but chemical control in the small-holder environment is always difficult, particularly since it is often necessary to treat against rust and leaf spot diseases at the same time. Only mancozeb (Dithane® M-45) is effective against all three diseases, but high cost and the necessary weekly application frequency rules it out for small farmers. Preventive cropping techniques limit disease incidence: alternating groundnut/cereals, early sowing, applying mineral fertilizers (particularly sulfur applications), removing haulms, and eliminating harvest residues (burying or burning).

- **Rust**

Rust first appeared in West Africa some time after 1970, and is spreading quickly. Studies are currently concentrated on breeding resistant varieties, pathogen biology and epidemiology, and chemical treatments. Information has been obtained on how rust survives on site from one year to another, on epidemiology in relation to climatological parameters, on the host-pathogen relationship (critical infection periods in terms of yield), on methods for assessing resistance (as a back-up to breeding), on preventive agronomic methods, and on chemical control. It has been established that rust, as well as leaf spots (early and late), can be controlled with fungicides other than mancozeb. The chemicals carbendazim, tridemorph + maneb or tridemorph + MBC + maneb, which are systemic in action, require only 4-5 applications per season as opposed to 8-10 with mancozeb. Spraying of Calixin-M®, commencing at first appearance of symptoms and applied fortnightly, was also found to be effective for the control of foliar diseases in Nigeria.

- **Multiple disease resistance**

Multiple disease resistance, which is the ultimate answer to the foliar disease problem on groundnut, is being investigated in Nigeria and Burkina Faso with some promising results. The varieties RMP 12 and RMP 91 from Burkina Faso and SAMNUT-6 from Nigeria were found to be resistant to both chlorotic and green rosette, have high yield potentials, and are resistant and moderately resistant, respectively, to early and late leaf spot diseases. The varieties MDR 8-15 and MDR 8-19 were resistant to rosette virus in addition to rust and leaf spots.

Julid control

Studies have identified the five most harmful millipede species that cause most of the damage seen on emergence in rainfed crops and on young, not yet fully formed, groundnut pods. Three types of treatment have been developed: emergence protection, by mixing an insecticide with the product used to dust the seeds; julid poison baits spread at the time of fruiting; and soil treatment using synthetic chemicals and neem products. Only the first two have been used in some countries on edible groundnut, which is particularly susceptible and therefore makes expensive treatments a more cost-effective undertaking. The third treatment has been tried in Senegal, Niger, and Nigeria with varying degrees of success. Research is continuing on both bio-ecological data and new products. The possibility of a long-term biological control is also being considered.

Aflatoxin control

Aflatoxin, which is found in many foodstuffs, including groundnut, is thought to cause hepatic lesions, to which young stock animals are particularly susceptible. There are also strong suspicions that these substances (secreted by the fungus *Aspergillus flavus*) play a role in liver cancer etiology in man. As the toxin is eliminated when the oil is refined, only two factors pose a problem

- seed and seed byproducts used directly as foodstuffs, and
- cake used as animal feed.

The conditions for groundnut contamination are known, and control methods, tried and tested in agronomic terms, have been proposed:

- using varieties having a cycle that fits in with the rainy season;
- using optimum sowing and harvesting dates;
- applying recommended agronomic techniques: crop rotations, sowing densities, fertilizers, weeding, to ensure optimum physiological development;
- harvesting and processing the most heavily contaminated pods separately (prematurely withered plants, plant snapping when pulled up);
- applying effective insecticides and julicides; and
- shortening the critical drying period as much as possible, and implementing early mechanical threshing as soon as it is practicable.

It goes without saying that these measures must be part of an overall plan. It would be pointless to obtain an innocuous intermediate product and then not protect it at later stages of the chain (cake, edible groundnut and byproduct manufacturing, storage, packing, and transport).

- **Corrective control**

Corrective control is part of the industrial processing and treatment (detoxification) of products, edible groundnut, and cake to ensure that they comply with the increasingly stringent constraints imposed by the international market. Techniques have been developed for eliminating contaminated pods and seed by electronic sorting; removing the seed coat with hydrogen peroxide enables early segregation of contaminated seeds and makes sorting easier; detoxifying cake with ammonia makes is possible to obtain a safe, nitrogen-enriched product. Senegalese oil mills have applied this industrial procedure on a large scale, and detoxified Senegalese cake is now available on world markets again.

- **Artificial inoculation tests**

Artificial inoculation tests have been developed and are used to sort varieties and hybrid progenies (programs to breed tolerant varieties).

Nematode control

Of the 47 or more nematode species that attack groundnuts in West Africa, *Helicotylenchus* sp, *Scutellonema* spp, *Tylenchorhynchus sp*, *Pratylenchus* sp, *Trichodorus* sp, and *Criconemoides* sp are the most widespread while about 13% of them have been responsible for disease situations in fields.

Nematodes that affect groundnut cause heavy pod and haulm yield losses, particularly in Gambia and the northern half of the Senegalese groundnut basin, where the problem was first detected, and probably also in most production areas. The most harmful species in Senegal was identified as *Scutellonema cavenessi* and other *Scutellonema* spp in Benin, Burkina Faso, Mali, Niger, and Nigeria. The seed testa nematode *Aphelenchoides arachidis* Bos is restricted to Nigeria. A control method was developed and applied full scale in central-northern Senegal (DBCP, 12 kg ai ha^{-1} applied as a soil treatment on 4000 ha in 1988). Pod yields increased by 500 kg ha^{-1} and haulm yields by 1000 kg ha^{-1} on average, the after-effect on the subsequent cereal crop was also positive (350 kg ha^{-1}), and the treatment has a 5-year carryover period. In Nigeria, application of Furadan® 3G at 2.5-3.0 kg ai ha^{-1} and Mocap® 10G at 6 kg ai ha^{-1} proved effective in reducing nematode populations. Research in many countries is currently concentrating on product trials (dose and application methods and residues, if any), on complementary agronomic measures (densities, ploughing, fertilization) and on implementation methods in the small-holder environment (organizing producers, credit, and socioeconomics).

POSTHARVEST TECHNOLOGY

The initial aim of the groundnut postharvest technology program was to assess the industrial processing performance of new groundnut varieties developed or introduced (definition of varietal ideotypes and technological tests) to back up breeding programs. Certain aspects of groundnut quality problems quickly became research objectives, conducted in close collaboration with upstream programs, development organizations, and industrialists; current research programs are helping to develop processes to enable more effective improvement of groundnut products.

Improving groundnut technological and seed qualities

Edible groundnut has to satisfy very strict standards, some of which are specific, whereas other lead to an overall improvement of groundnut production, particularly in terms of health (aflatoxin control) and seed technology. Edible groundnut is a driving force and a test bench for the entire product range. Market and producer demands are concerned with the following:

- shelling percentage,
- germination capacity,
- prevention of aflatoxin,
- seed and pod size and shape,
- skinning and splitting performance, and
- organoleptic qualities after roasting.

Reliable and reproducible tests have been developed to measure the above parameters. These methods are used for varietal screening and batch quality assessment. Around 10 varieties, including 73-27 and 73-28, have been adopted as possible replacements for the edible variety GH 119-20, which is currently grown in central-southern Senegal, or to extend the crop into new areas. A few varieties were adopted for their dual oil-confectionery role (e.g., 55-437 and 73-33) and their shorter cycle which is more suitable for dry regions.

The effect of various agronomic treatments on groundnut seed qualities has been measured; calcium spread around the plant (top-dressing) improves pod density and size, shelling yields, seed size, exportable seed yields, and germination capacity. Application of about 25 kg ha^{-1} of boron significantly improves seed germination in many situations, particularly in the event of drought. Applying a growth regulator (daminozide) increases pod yields and the number of seeds, but also leads to a marked reduction in pod and seed size (10 to 15%). Hence, it is extremely beneficial for seed multiplication, but not for first generation exports.

Study of shelled groundnut preservation and storage methods

The bulk storage method traditionally used is not suitable for high quality products such as seed and edible groundnut. These products have to be disinfected either before or after shelling, by fumigation with methyl bromide, following well-defined instructions (dosages, number of treatments, seed moisture content, etc) and done by an expert, then adequately packed and stored following the procedure of the edible groundnut project in Senegal Large-scale storage in bags stacked in pyramidal shaped heaps as practiced in Nigeria requires constant fumigation and protection against rats and adverse weather conditions.

- **Refrigerated seed storage**

Refrigerated seed storage was developed between 1970 and 1975. It enables storage over long periods (up to 2 years) with no appreciable reduction in seed germination capacity, providing that the seeds are returned gradually to ambient temperature when taken out of storage. The main aim of this method is to preserve 'emergency stocks' for dry areas. Senegal, which practices this method, currently has a capacity for 2000 t of seed. This technology is not popular in most West African countries.

- **Nitrogen-compensated vacuum storage**

Nitrogen-compensated vacuum storage in 25 kg airtight bags, has been studied closely. Once packed, the seed can be distributed, and stored by the user, with no need for any specific precautions: the residual vacuum prevents the seeds being shaken, hence avoiding the risk of breakage and skinning due to rubbing during transport and handling. The technique, which has been tried in Nigeria and Senegal, has now gone beyond the experimental stage in Senegal.

Improving the industrial seed processing technique

Studies have been carried out at all the critical stages of the industrial process used to produce high quality seeds suitable for use as seed or for export on the edible groundnut market.

- **Shelling**

Improvements in shelling techniques have made it possible to obtain much higher whole seed/shell yields than had previously been achieved (between 50 and 60%), by modifying standard oil mill equipment. Machine prototypes developed at Samaru, Nigeria, can shell groundnut with a whole kernel output of over 90%.

- **Electronic sorting**

Electronic sorting specifically adapted to groundnut enables the elimination of almost all aflatoxin-contaminated seeds and imperfect seeds that are of a different color. It was adopted in Senegal for seed production and the manufacture of blanched seeds destined for roasting. This high technology is found mainly with industrial establishments

- **Ready-to-use groundnut seed**

Industrial production of ready-to-use groundnut seed was developed in Senegal; the shelling, sorting, coating, and packing procedures can now be totally mechanized, although there are obstacles to be surmounted before the technique can be transferred to the industrial pilot stage. All these procedures are of prime importance, since the limited state-managed seed capital in most West African countries means that efforts will have to be made to maintain quality. At the same time, greater attention should be paid to the problems encountered by the farmer (on-farm seed production and storage).

APPLYING RESEARCH AND SUPPORTING DEVELOPMENT

Researchers have often set up and managed pilot operations to confirm and apply groundnut research results. These operations have frequently expanded in the form of development projects or even national state-sector organizations, to which research is continuing to provide technical support. Highlights are given below of some major activities in West Africa.

Seed multiplication and seed plans

Research provides technical support for programming, technological production monitoring and seed storage and packing. This support often takes the form of mixed basic seed production/adaptive research/development support operations, and has played a major role in extending new varieties and in consolidating national seed structures, particularly in Nigeria, Senegal, Niger, and Chad. In Nigeria, all agencies (government, parastatals, or private) concerned with the groundnut industry are encouraged to demonstrate active involvement in seed multiplication schemes with the National Seed Service as the starting point after the Institute of Agricultural Research at Samaru has released a variety. In ensuring availability of improved seeds, the state agricultural development agencies in each area aim at multiplying and maintaining the adopted cultivars.

In Senegal, where the varietal map has changed entirely over the past two decades, the seed production structure has made it possible to maintain the areas sown with groundnut, despite the impact of drought. The new policy in Senegal, implemented in 1985, eventually foresees seed renewal only every three years. This will mean directing research and development programs more towards helping farmers to produce and store their own seeds and towards centralized management of emergency stocks corresponding to one-third of annual requirements (around 35 000 t unshelled).

Edible groundnut operation

Under the New Agricultural Policy in Senegal, edible groundnut production management was entrusted to a specialized organization with technical support from research. An integrated structure ensures input supplies and utilization, campaign credit systems, choice of producers, producer training and crop monitoring, harvest purchases, credit recovery, organization of transport and delivery to processing mills, seed production, and packaging, and storage. The project does not benefit from any state funding or subsidies, and funds all supervisory expenditure from its own pocket. About 28 000 t were marketed in the regions of Kaolack and Fatick in 1991, and IRHO was asked to carry out a study for the setting up of a mill to process the seeds produced, with a capacity of 25 000 t, expandable to 50 000 t, including facilities for roasted-salted groundnut packing and peanut butter production.

Similar studies were carried out in Mali (confectionery groundnut packing unit at San) and Burkina Faso (engineering advisor on an industrial edible groundnut and seed equipment in Ouagadougou).

In other countries, particularly Nigeria, groundnut rehabilitation efforts are underway to involve oil millers, in support of government moves, to strengthen research and extension.

Pest control

Pests (insects, nematodes, and millipedes) have an adverse effect on groundnut and crops grown in rotation with it [millet, sorghum, and cowpea (*Vigna unguiculata*)]. Spec-

tacular results have been obtained, in terms of pods, haulms, and seeds, using chemical treatments. A pest control project was launched in 1984, in Senegal, aimed at eradicating nematodes in the areas around Thies and Diourbel. The operation is being conducted jointly by the Research, Extension, and Crop Protection Services. Similar pest control projects have been reported in Nigeria, Niger, and Burkina Faso

The constant interaction between mixed research and development operations and specific research programs in an integral part of the way groundnut research operates and one of the reasons for its success. It enables researchers to adapt themselves very closely to the requirements and difficulties of the rural environment, and ensures the coherence and effectiveness of the program as a whole, at all the various stages of the chain, from variety selection to industrial packaging and exports of products.

CONCLUSION

Although this paper has highlighted impressive research and development achievements in the groundnut industry in West Africa, there are still serious constraints to increased production that vary with the countries Priority areas that need short and medium term attention include:

- breeding for short-season, drought, pest, and disease resistance along with the need to strengthen and expand the existing seeds multiplication schemes so as to ensure availability of improved seed to the farmer;
- integrated pest management strategies that are adoptable by resource-poor farmers should be developed;
- development of appropriate technological labor-saving devices to make farmers less dependent on hired labor for sowing, weeding, and harvesting is urgently needed;
- there is the need to diagnose and study the farming systems currently used by farmers as a basis for research and development of new technologies for the farmers' use;
- extension training needs to be boosted, and
- international cooperation and collaborative research and information exchange need to be strengthened to avoid duplication of efforts and waste of scarce resources, particularly in areas with similar ecological conditions.

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RESUME

Evaluation des résultats de la recherche arachidière dans les régions de savane d'Afrique occidentale

R. SCHILLING et S.M. MISARI. *Oléagineux*, 1993, **48**, N°7, p. 323-332

La recherche sur l'arachide (*Arachis hypogaea*) a été lancée au cours des années 1920 en Afrique de l'Ouest en trois lieux principaux : Samaru (Nigéria), Bambey (Sénégal) et Niangoloko (Burkina Faso). La sélection génétique a permis la mise au point d'un certain nombre de variétés productives en ce qui concerne la tolérance à la sécheresse, la résistance aux maladies, la précocité, la dormance et l adaptation au marché de l'arachide de bouche. Les essais agronomiques à long terme indiquent que l'épandage d'engrais minéral ne suffit pas à empêcher l'acidification du sol par la réduction des cations provoquant une réduction des rendements. Il est essentiel de maintenir la teneur en matière organique du sol afin d'obtenir une production soutenue d'un système de culture basé sur une rotation de l'arachide et des céréales dans la zone soudano-sahélienne. Les problèmes phytosanitaires en Afrique occidentale deviennent de plus en plus aigus à mesure que les rotations deviennent plus brèves et que la culture continue se répand Les travaux de recherche portent sur cinq thèmes majeurs : les maladies de la levée et la protection contre les insectes ravageurs - des traitements peu coûteux et extrêmement efficaces par enrobage des semences sont appliqués; la lutte contre les maladies foliaires - des variétés résistantes à la rosette sont disponibles et les chercheurs travaillent en ce moment sur une lutte intégrée contre la rouille (*Puccinia arachidis*) et la cercosporiose (*Phaeoisariopsis personata* ; la lutte contre les iules (Diplopodes) - la protection au moment de la levée et l'usage d'appâts ont également été développés, la lutte contre l'aflatoxine - des méthodes de prévention au niveau du terrain et la lutte corrective au niveau industriel ont été développées; et la lutte contre les nématodes - une méthode de lutte a été développée et appliquée à grande échelle dans le nord du Sénégal.Au niveau de la technologie post-récolte, les recherches actuelles aident à mettre au point des processus pour améliorer plus efficacement les produits arachidiers. La désinfection des stocks, le stockage réfrigéré des semences et l'emballage sous vide des semences ont été mis au point. La production industrielle de semences prêtes à être utilisées sera entreprise sans tarder au Sénégal. Des opérations mixtes de recherche et de développement sont déjà entreprises dans différents domaines, notamment pour la production de semences et de graines de bouche et leur traitement. Ceci permet aux chercheurs de suivre de près les demandes des producteurs et des consommateurs et d'assurer la cohésion et l'efficacité du programme dans son ensemble.

Mots clés. — Arachide, sélection, agronomie, technologie, recherche/développement, itinéraires techniques.

RESUMEN

Evaluación de los resultados de la transcurso de maní en las regiones de sabana de Africa occidental

R. SCHILLING y S.M. MISARI. *Oléagineux*, 1993, **48**, N°7, p. 323-332

En el transcurso de los años 1920 se lanzó la investigación sobre el maní (*Arachis hypogaea*) en Africa del Oeste en tres principales lugares: Samaru (Nigeria), Bambey (Senegal) y Niangoloko (Burkina Faso). La selección genética permitió que se consiguiera cierto número de variedades productivas referente a la resistencia, a la sequía, a las enfermedades, a la precocidad, al estado de dormición y adaptación al mercado del maní comestible. Los ensayos agronómicos a largo plazo indican que la fertilización mineral no basta para impedir la acidificación del suelo al reducir los cationes que provocan una reducción de los rendimientos. Es esencial mantener el contenido de materia orgánica del suelo para conseguir en la zona Sudano-Sahela una producción sostenida de un sistema de cultivo basada en una rotación de maní y cereales. Los problemas fitosanitarios en Africa Occidental se vuelven cada vez más agudos conforme las rotaciones se van volviendo más cortas y el cutlivo permanente extendiéndose. Los trabajos de investigación versan sobre cinco temas mayores: las enfermedades de emergencia y la protección contra las plagas - se aplican tratamientos de costo reducido y extremadamente eficaces mediante semillas polvoreadas, control de las enfermedades foliares - se dispone de variedades resistentes a la roseta y los investigadores trabajan actualmente sobre el control integrado contra la roya (*Puccinia arachidis*) y la cercosporiosis (*Phaeoisariopsis personata*), control de los ciempiés (Diplopodes) - también se han desarrollado la protección cuando la emergencia y el empleo de cebos, control de la atlatoxina - se han desarrollado métodos de prevención en el campo y control correctivo al nivel industrial, y control de nematodos - se ha desarrollado y puesto en aplicación un método de control a gran escala en el Norte de Senegal. Al nivel de la tecnología post-cosecha, las investigaciones actuales ayudan a realizar procesos para mejorar más eficientemente los productos del maní. Se efectuaron la desinfección de las existencias, el almacenamiento refrigerado y el embalaje en vacío de semillas. Dentro de poco tiempo se emprenderá en Senegal la producción industrial de semillas listas para sembrar. Se emprenden ya operaciones mixtas de investigación y de desarrollo en varios sectores, especialmente para producir semillas y semillas y realizar su tratamiento. Esto permite a los investigadores vigilar estrechamente los pedidos de productores y de consumidores y asegurar la cohesión y la eficiencia del programa en su totalidad.

Palabras claves. — Maní, selección, agronomía, tecnología, investigación/desarrollo, itinerarios técnicos.