ICRISAT CORAF Peanut CRSP INRAB Benin

Summary Proceedings of the Seventh ICRISAT Regional Groundnut Meeting for Western and Central Africa

Sponsors

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

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Peanut Collaborative Research Support Program (Peanut CRSP)

Conference des responsables de la recherche agronomique africains (CORAF)

Sasakawa-Global 2000 (SG 2000)

Organizing Committee

ICRISAT. F Waliyar, B R Ntare, Bintou Keita, A Traore, and Boubakary Cisse

INRAB: J Detongnon, M Adomou, G Agbahunga, Henriette Hodonou Gotoechan, Calixte Houndonougbo, Antoine Affokpon, and Roger Degbessou

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We would like to thank IITA, particularly Dr Peter Neuenschwander for all the support provided during the Workshop. We would also like to thank all the members of the organizing committee of ICRISAT and INRAB.

About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the SAT ICRISAT's mission is to conduct research that can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is cosponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

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Opening Speech

M Cosme Akpodji[1]

Representative of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Director General of Programme d'Appui a la Recherche Collaborative sur l'Arachide, Director of the Groundnut Germplasm Project, Members of the Cabinet, distinguished guests, ladies and gentlemen!

It is a real pleasure for me today December 6, 2000 to open the Seventh Regional Workshop on Groundnut in West and Central Africa.

First of all, I would like to wish a warm welcome in Benin to all of you, scientists from US universities, CIRAD (France), India, CORAF, and national agricultural research system of our sub-region.

I would also like to thank you for choosing Benin to host this meeting that is of great scientific scope.

This is an opportunity for me to address my sincere thanks to the Director General of ICRISAT for the active cooperation that their institute maintains with Benin through various programs and research network. This cooperation through sorghum, millet, and groundnut networks and the groundnut genetic resources management project, all of which support the development of the main crops in our sub-region, is highly appreciated.

Ladies and gentlemen, the organization of the current workshop shows the interest that we have for agricultural research in general and groundnut research in particular.

In Benin, groundnut occupied and still occupies an important place both in food crops and cash crops. In fact, the average sown area under groundnut in 1999 was 145 ha and the average production was 121 t. Besides, *66%* of the area usable for agriculture is fit for this crop.

As for consumption, groundnut represents 4% of household expenditures in animal and vegetable products.

Groundnut is consumed grilled, boiled, or processed for oil and doughnuts. In terms of dietary constituents, the people of Benin obtain from groundnut 5% of their needs in calories, 8.5% in protein, and 20.5% in lipid.

Thus, ladies and gentlemen, despite the yield level that is still low, about 835 kg ha^{-1}, groundnut has an important place in the food in Benin.

1. Director of Cabinet of the Minister of Rural Development, BP 884 Cotonou, Benin.

Furthermore, as a legume that fixes atmospheric nitrogen, groundnut contributes to the restoration of soil fertility which plays a primordial role in human life. Hence, the Republic of Benin in the establishment of their rural development policy, has put an emphasis on the adoption of production systems associating groundnut in crop rotations which appreciably improve soil productivity.

The Beninese government is convinced that the most appropriate instrument to improve current yields is agricultural research. But to be effective and efficient, it should rely on a strong scientific cooperation at regional and international levels.

I appreciate holding the current workshop in Benin and also the workshop objectives to assess progress made in research accomplished over the last two years and to establish future collaboration between various partners involved in groundnut research. I remain convinced, in light of the high level and the scientific abilities of participants, that the work done in Cotonou (Benin) will lead to important recommendations that will contribute, with no doubt, to the development of groundnut channels in our sub-region. These results will influence, as far as we are concerned in Benin, the current redistribution of national research capacities in favor of this crop.

With these words of hope, I declare open today, Wednesday, 6 December 2000, the Seventh Regional Workshop on Groundnut in West and Central Africa.

Long live agricultural research in the service of development!

Long live regional and international scientific cooperation!

I wish full success to your workshop.

Thank you.

Opening Remarks

F Waliyar[1]

Director of the Cabinet of the Ministry of Rural Development, Director General of the Institut National des Recherches Agricoles du Benin (INRAB), representatives of regional and international centers, representatives of Peanut Collaborative Research Support Program (CRSP), representatives of national programs, participants, ladies and gentlemen!

Before starting, I would like to request to observe one minute silence in the memory of Dr K O Marfo, Director of SARI, Ghana, who died in a plane crash and Dr Olin Smith of the University of Texas A&M, USA, who passed away after a heart attack.

Thank you.

Allow me to welcome you at the Seventh Regional Groundnut Workshop for West and Central Africa.

The objectives of this meeting are:

- To assess progress made, particularly over the past two years.
- To develop collaboration between the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), national agricultural research systems (NARS), and other partners.
- To identify future needs for research on groundnut.
- To review the strategic plan for research on aflatoxin in West and Central Africa.

As you know, there are several constraints to groundnut production. Some technologies have been developed, particularly varietal improvement. But the real impact of research to date remains limited. It seems essential to me that the research community and the development actors make an effort so that results can reach farmers. There are several constraints for adoption of our technologies and we should try to understand them and come up with appropriate solutions. The lack of quality seed of improved varieties adapted to the needs of producers is one of the constraints that limit groundnut productivity in the sub-region.

Other research areas that are to be exploited include the improvement of groundnut quality as well as pod and haulm yields. For this we should have

1. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), BP 320 Bamako, Mali.

better planning strategy and give priority to different aspects of research. Hence we have planned to set up a working group in order to analyze priorities of future groundnut research and to propose to the assembly new research guidelines.

Regarding the aflatoxin issue that remains an important concern in the region, a strategic plan recommended by the last workshop was developed and sent to member countries of the aflatoxin working group. To date, this document was not finalized and we hope that this workshop will take the necessary time to review and amend it and adopt the recommendations.

At ICRISAT, we will continue our collaborative efforts with different NARSs since fruitful collaborations took place during the past two years through several collaborative projects. Among the most important changes regarding the research program in Africa, it is to be noted that ICRISAT put emphasis on natural resources management for which ICRISAT-Bamako is the center of excellence.

I would like to take this opportunity to thank CORAF, Peanut CRSP, and Sasakawa-Global 2000. I would also like to thank the Director, Natural Resource Management Program, ICRISAT for the financial support provided for the organization of this workshop.

I would like to sincerely thank our colleagues of INRAB for their best efforts to organize this workshop. I am sure the workshop will take place harmoniously and I would like to thank the entire group.

Mr President, let me wish a lot of success to the workshop and I hope that our results will be used and transferred by all means to needy farmers of these regions.

Thank you.

Peanut Collaborative Research Support Program (CRSP)

Having thanked Dr F Waliyar for his invitation to the 7th workshop, Dr J H Williams defined the areas of intervention of Peanut CRSP:

- Food security (aflatoxin control)
- Production efficiency
- Socioeconomic constraints and impact analysis
- Problems of postharvest technologies (and marketing)

Concerning the impact of Peanut CRSP in the West African sub-region, he stated that development is slow due to several constraints including lack of funds resulting in difficulties in attaining the goals set.

Dr Williams also defined the role of Peanut CRSP:

- Establish partnership among universities and other institutions
- Address common problems

He stated that Peanut CRSP is America's political support for establishing a sustainable collaborative program.

Welcome Address

J Detongnon[1]

Representative of the Minister of Rural Development, representative of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Mali; Director of Peanut Collaborative Research Support Program (CRSP), representatives of international and regional organizations, distinguished guests, ladies and gentlemen!

On behalf of the scientific community of the National Agricultural Research System of Benin, I am pleased and honored to welcome you in the INFO SEC conference room, wherein during the next three days we will participate in a workshop on groundnut research in West and Central Africa.

It is well known that groundnut is a very important food legume in our region. This workshop which is held every two years aims at measuring progress on research activities conducted on this crop over the last two years and to exchange views on issues of major interest.

We have unanimously decided during the last workshop held in Bamako, Mali in 1998 to hold the current workshop in Cotonou, Benin. Several communications will be presented during this workshop and several aspects of research in groundnut will be addressed: (1) Genetics and varietal improvement; (2) Agronomy; (3) Plant pathology; and (4) Food technology.

A special session on aflatoxin research will also be organized.

I would like to seize this opportunity to thank all those who have contributed to the effective organization of this workshop.

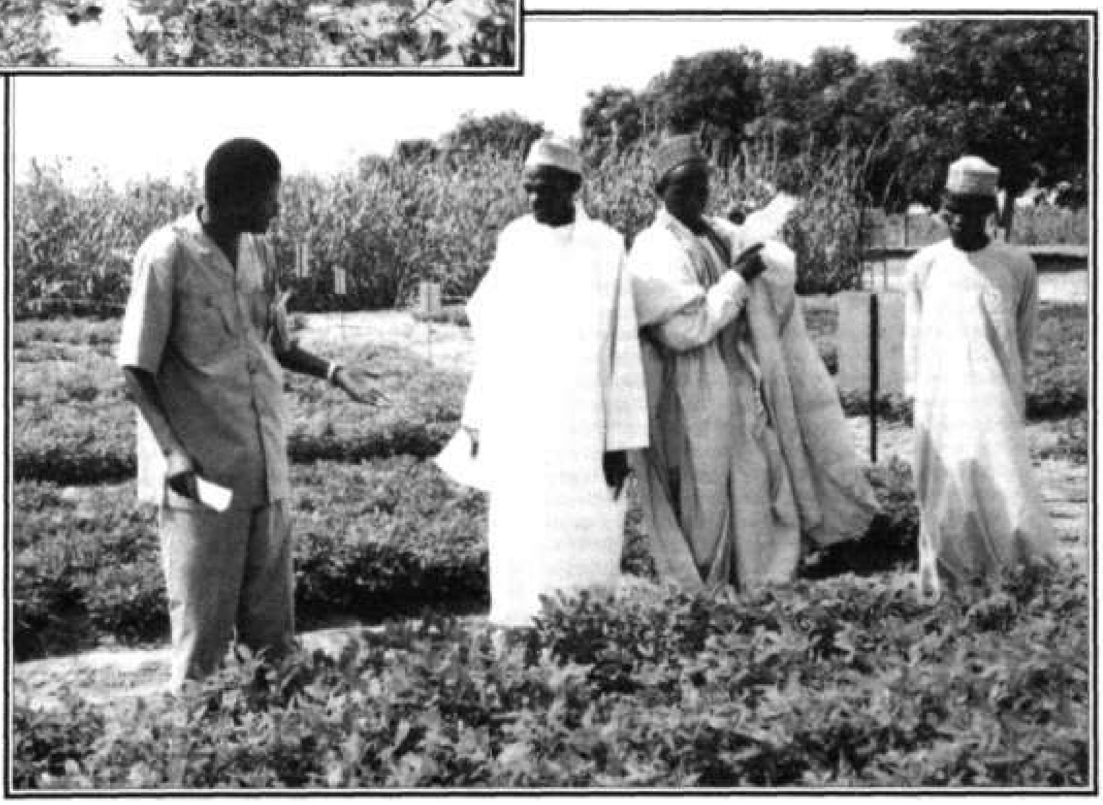
This is also a good venue to express my gratitude to the donors [United States Agency for International Development (USAID), European Union, and others], who do their best to bring substantial financial support to the accomplishment of our research activities in Benin.

The tasks we will have to go through over the three days are immense but I do not have any doubt on your capacity to overcome them. Before more authorized voices than my own express this, I wish all participants success in their work. Once again thank you and welcome to Benin.

Thank you.

1. Director General, Institut National des Recherches Agricoles du Benin (INRAB), BP 884 Cotonou, Benin.

Session 1: Agronomy



Performance of Groundnut Genotypes Introduced into Western Mali

Kodio Ondie[1]

Considered for a long time as the groundnut belt of Mali, the western part of Mali (Kayes) is presently the most important groundnut-producing zone. More than 90,000 ha of that zone is cultivated. Groundnut is the main crop cultivated after sorghum in the region and is one of the major staple foods of the people. Its importance as a cash crop in the economy of the region is justified by the establishment of a research center in the region. The varieties cultivated are those introduced long ago. They have suffered from genetic erosion and mixtures, and they no longer have the characteristics of a pure variety. Yields are generally low and hardly exceed 800 kg ha^{-1}, due mostly to several biotic and abiotic constraints (foliar diseases, drought, low plant density, etc.). An important on-station and on-farm research program has therefore been initiated for the past two years.

The objective of the program is to determine the agronomic performance of the new varieties of groundnut introduced in the region to transfer them on-farm for adoption by the farmers.

During the 1998/99 and 1999/2000 cropping seasons, joint regional trials were conducted in western Mali (Same et Kita) by the Institut d'Economie Rurale (IER)/International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)-Groundnut Germplasm Project (GGP). These trials involved, among others, resistance to foliar diseases, rosette, and drought. These trials were sown in the second half of July. Several agronomic parameters were measured (number of emerging seedlings, number of plants at harvest, days to 50% flowering, incidence of diseases such as leaf spots and rosette, pod and haulm yields, and shelling percentage).

Resistance to leaf spots

The statistical analysis of variance of parameters measured showed significant differences between treatments. In spite of the leaf spot diseases, the yields of test varieties exceeded that of the control GH119-20. The

1. Centre Regional de Recherche Agronomique de Kayes/Same\ BP 281 Kayes, Mali.

severity of leaf spot varied between 3 and 5 on a 1-9 rating scale. ICGV 92099 was more productive, with a pod yield of 2.4 t ha^{-1} and a haulm yield of about 5.0 t ha^{-1}.

Resistance to rosette

Poor emergence was observed in all the plots due partly to damping-off and collar rot. The analysis of variance made on the pod and haulm yield parameters, plant density, and rosette incidence showed a considerable difference between treatments. During the past years we have noticed a reduction in the prevalence rate of rosette at the national level, and the disease incidence varied between 1 and 4 on 1-9 rating scale. Pod and haulm yields obtained were acceptable with an average of 1.3 t ha^{-1} and 2.0 t ha^{-1} respectively. The variety ICGV-SM 88761 was most susceptible to rosette (observation on the 60^{th} day). Some varieties such as 249-8, ICGV 96894, and ICGV-IS 98814 performed better with haulm yields of 3.0, 3.1, and 3.0 t ha^{-1} respectively, which far exceed the two controls.

Resistance to drought

Favorable climatic conditions during 1999 did not make it possible to achieve the objective of the trial on drought tolerance. The pod yields obtained were very high. No drought period was observed during the vegetative phase. The average yield obtained was higher than 3 t ha^{-1}. The varieties ICGV 124, 55-21, and ICGV-MS 87003 with pod yields of 4.15, 3.99, and 3.95 t ha^{-1} respectively, proved to be the most productive in terms of pod production.

Influence of Pre-emergence Weeding and Depth of Sowing on the Emergence of Groundnut under Drought

M Sene[1]

In Sahel, the population density of groundnut is often affected by drought. Therefore, it is necessary to obstruct the harmful effects of drought during early stages of the crop to develop adapted cultural techniques. These techniques enable soil profile management to favor the conservation of soil surface humidity and efficient vaporization of soil water.

In Senegal, farmers practice pre-emergence weeding to suppress early competition for water use between groundnut seedlings and weeds. Pre-emergence weeding or hoeing are slightly modified techniques of flat weeding, utilized alone or in combination with burying of organic matter. This practice fits into the agricultural calendar and is adapted to the available equipment. In an off-season test which enabled to control the water supply, the minimal rainfall amount recommended to start groundnut sowing for each of the three types of rainy seasons were identified and used. In each case, we estimated the effect of pre-emergence weeding on early competition for water use between groundnut seedlings and weeds. Also, the effect of pre-emergence weeding or hoeing alone or associated with burying organic manure on the emergence of groundnut seedlings was studied.

The result of this test showed that pre-emergence suppresses early competition for water use between groundnut seedlings and weeds. Pre-emergence weeding or hoeing on the sowing line enables conservation of humidity of the broadbed more efficiently slowing down of the evaporation of the bare soil because of the mulch effect. Thus, there is a significant improvement of germination, emergence, and plant population. This positive effect on the emergence is even more conspicuous when there is limited rain during sowing.

1. Institut Senegalais des Recherches Agricoles (ISRA), Centre National des Recherches Agronomiques (CNRA), BP 53 Bambey, Senegal.

The sowing depth which could not have been rigorously controlled in this study revealed to be a determinant factor of emergence. To estimate the impact on the emergence, a test under raining condition was conducted to compare the emergence depths of 2, 4, and 6 cm. The results of this test confirmed that at depth of 2 cm, germination is low as evident by low plant density. The depth of 4 cm appears as optimal as seeds are exposed to sufficient water content for germination during the initial phase of soaking.

On-farm Agronomic Evaluation of CRSP Groundnut Varieties in Burkina Faso

Zagre Berlin[1] and Sankara Philippe[2]

The objective of groundnut varietal improvement in Burkina Faso is to search for oil, confectionery, and edible (pods and haulms) varieties, which are both productive and tolerant to various diseases and to drought.

The strategy used is based on the development of varieties and introduction of plant material from other research institutions. In this perspective and within the framework of the collaboration between Peanut Collaborative Research Support Program (CRSP) and Burkina Faso, some Peanut CRSP accessions were received and tested to identify varieties adapted to groundnut-growing conditions in Burkina Faso.

The test accessions included 12 varieties from an international trial. These varieties showed good performance in terms of yield. Such varieties were compared to a control, as part of on-farm test using a complete randomized block design with four replications during the 1999/2000 rainy seasons. The test was conducted at two sites: Niangoloko in the southwest (1000-1200 mm rainfall) and Gampela in the central region (700-900 mm rainfall) of Burkina Faso. The characters considered in this study were pod yields (g $plant^{-1}$ and kg ha^{-1}) and 100-seed mass:

- At Niangoloko the variety W16 performed better than the other lines and the control for all the three traits considered, with pod yields of 12.99 g $plant^{-1}$ and 1.1 t ha^{-1}, and 100-seed mass of 43.39 g.
- At Gampela, all the varieties tested behaved similarly for pod yield (g $plant^{-1}$ and kg ha^{-1}), which resulted in a level of significance equal to zero. The good seeds of the variety WI were much bigger than the others with 100-seed mass of 50 g followed by the variety W16 with 44.67 g.

The analysis of all the trials conducted in the two sites shows that all the varieties performed similarly for the traits studied. There is a significant correlation between the varieties and the sites.

1. INERA, 04 BP 8645 Ouagadougou, Burkina Faso.
2. Universite de Ouagadougou, 03 BP 7021 Ouagadougou, Burkina Faso.

Performance of the New ICRISAT Groundnut Lines in Togo

N Bltignime[1]

Groundnut occupies a very important place in the nutrition of the Togolese because of its high protein content (32%) and its diverse uses. Production is, however, constrained by degeneration of the varieties and lack of high-yielding varieties, which limits the choice of the farmers in relation to their needs. To address this problem Togo acceded to the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) network for groundnut varietal test in the sub-region. The trials included groundnut confectionery varieties and long-duration varieties resistant to rosette. In 1999, 24 new varieties of these two series of coordinated trials were tested.

The aim of the experiment was to test the performance of these lines and their resistance to rosette, and to select the lines that performed better. The trial was conducted on-station at Sotouboua, in the central region of Togo in a complete randomized block. Some promising lines were identified. The following confectionery lines produced the highest pod yield: ICGV 93053 and ICGV 88434 produced 1.07 t ha^{-1} each. Four of the rosette resistant varieties performed better compared to other varieties. These varieties are UGA-4 (1.92 t ha^{-1}), ICGV-IS-96812 (1.45 t ha^{-1}), ICGV-IS-96846 (1.45 t ha^{-1}), and ICGV-IS-96814 (1.31 t ha^{-1}). The experiment is being pursued to confirm the findings during the 2000 and 2001 cropping seasons. The best lines selected shall be tested on-farm to find out those that can be disseminated to farmers.

1. Institut Togolais des Recherches Agricoles (ITRA)/LRA-SH, BP 88 Soutoboua, Togo.

Groundnut Farming in Mauritania

Sidi-R'Chid[1]

Groundnut occupies an important place in the cropping systems practiced in Mauritania. However, the causes of low production are many and the most prominent include:

- Use of archaic means of production by farmers.
- Irregularity and poor distribution of rainfall which constitute a serious handicap engendering some drought-prone areas during the cropping season. Hence, there is a need to search for extra-early- and early-maturing varieties.
- Low productivity (local varieties with very small seed, composed of 60-80% single seeded, 10-20% 2-seeded, and 10-15% of empty pods, often with growing cycles that are not adapted, etc.).
- Low soil fertility (deficient in phosphorus and nitrogen) and soils that are not adapted to groundnut farming (often very heavy or very light).
- Incidence of diseases, insect pests, and weeds, mainly species of Cyperaceae.
- Socioeconomic constraints (inputs, policy, marketing, etc.).

Groundnut is grown under different cropping systems in rainfed, irrigated, or recess conditions on different types of soils (sandy, heavy, and light). The yields are very low (250-450 kg ha^{-1}). The resistance/tolerance of groundnut to drought as amply confirmed in rainfed farming by some institutes has led to neglect of the opportunities this legume can offer on hydro-agricultural schemes in Mauritania. At present, the main concern of farmers is to make maximum use of the agricultural development facilities. The desire to stabilize production encourages farmers to practice groundnut farming by cultivation of lands that are not suitable for rice farming.

In 1995/96 and 1999/2000 some on-station studies were carried out and some varieties such as TS 32-1, Fleur 11, CN 94-C, JL 24, ICG (FDRS) 10, ICGS (E) 104, and ICGV 86015 were identified and proposed for dissemination/extension. In 1999/2000 at R'Kiz, Mauritania some varieties have confirmed their on-farm performance. These include: JL 24, ICGS 11, TS 32-1, CN 94-C, and Fleur 1 1 with yields ranging from 0.84 to 1.4 t ha^{-1} pods and 3.1 to 4.6 t ha^{-1} haulms.

1. CNRADA, BP 22 Kaedi, Mauritania.

Evaluation of a Group of Confectionery Groundnuts for Yield and Adaptability in Northern Cameroon

Thomas Mekontchou, Timothe, and T Schilling[1]

Five advanced confectionery groundnut lines developed at the Institut de la Recherche Agricole pour le Developpement (IRAD) were evaluated on three sites during four cropping seasons. The American variety GH-119-20 was used as control. The pod yields produced by the lines CGS-310, CGS-531, and CGS-1406 were significantly higher than the control by about 42.6%, 37.6%, and 40% respectively. The 100-pod mass was similar in CGS-285, CGS-310, and CGS-162. The yields of all the lines (except CGS-285), when shelled was more than 60% and higher than that of the control, thus showing a good rate of pod filling.

The interaction between line x site x year is highly significant; it indicates that the lines are highly influenced by environment. It is therefore pertinent to recommend a yield stability study of such varieties in order to make available to farmers those which have proved their capacity and stability in some given ecologies.

Positive and significant correlations between pod and seed yields ($r = 0.97^{**}$), and also between grain yield and yield at shelling ($r = 0.42^{**}$) were observed.

Finally, in view of the demands of the confectionery groundnut market, the line CGS-310 appears to be better adapted to Northern Cameroon.

1. Institut de la Recherche Agricole pour le Developpement (IRAD), BP 163 Foumbot, Cameroon.

Groundnut Production in Sierra Leone: Problems and Research Needs

M T Moseray[1]

Groundnut is the most important grain legume in Sierra Leone. The area under groundnut cultivation was 36,000 ha in 1996; total production was 36,000 t and the average yield was 1.0 t ha^{-1}.

The fresh pods are boiled and the nuts are widely consumed while the dried nuts are either roasted and eaten directly, made into groundnut cake, or pounded into a paste which is used in preparing groundnut soup.

Groundnut yields in Sierra Leone have declined dramatically mainly due to the nine-year-old rebel war. Early leaf spot (*Cercospora arachidicola*) may become a major production constraint. Preliminary results in 1999 indicate that the disease severity was estimated at 80% and can cause up to 34% yield loss.

Results from other preliminary experiments showed the incidence of early leaf spot to be considerably lower at 5-7 sprays with the fungicide Kocide 101 while four different plant spacings had no significant effect on the disease at 60, 70, and 80 days after planting.

Lack of improved groundnut lines is one of the main constraints hindering improvement work not only at the Institute of Agricultural Research (IAR), but also in the entire country.

1. Institute of Agricultural Research (IAR), PMB 540, Freetown, Sierra Leone.

Session 2: Breeding

Genetics of Earliness as Measured by Days to First Flower in Groundnut

Zagre Berlin, Fanja Mondeil, and Didicr Balma[1]

Drought in Sudano Sahelian zone is manifested not only by a substantial reduction in the length of the rainy season but also by increased frequency of more or less dry spells during the cropping season. To cope with this situation, development of early-maturing varieties (75-80 days) is presently one of the major priorities of many groundnut-producing countries of the semi-arid zone.

Determination of maturity is essential for characterization of earliness. There are many techniques and characters for determining maturity (e.g., arginine dosage in seed, percentage of mature pods in relation to the total number of pods formed, 50% flowering, and scraping the outer part of the shell). There is little data available in literature on the origins of crosses, methods applied, and results obtained; most of this data lacks precision.

The problem often confronting breeders is the choice of parents for inclusion in a breeding program to select for early maturity in breeding populations. We are proposing the genetics of earliness by studying the inheritance of days to first flower in a 6 x 6 complete diallel cross F_1 progenies.

Six early-maturing varieties (75-90 days) with different genetic backgrounds and geographical origin were crossed in all possible combinations to produce 30 F_1 crosses. The 6 parents and 30 F_1 hybrids were grown in a randomized block design with 3 replications in 2 years at the Gampela research station located east of Ouagadougou (longitude 12°22' W and latitude 12°25' N). Each genotype was sown on two rows of 3 m, with a spacing of 40 x 15 cm. The days to first flower was recorded, and the data was analyzed using Griffing and Hayman methods of diallel analysis. The study showed that days to first flower in groundnut is favored by accumulation of dominant genes. A genitor with a majority of dominant genes will have a short cycle and therefore early in maturity. Inversely, a genitor with a majority of recessive genes will have a long cycle and therefore late in maturity. Heritabilities in narrow sense calculated by applying the Griffing and Hayman methods are 61% and 47% respectively.

1. INERA, 04 BP 8645 Ouagadougou 04, Burkina Faso.

Breeding Groundnut for Resistance to Preharvest Aflatoxin Contamination

C Corley Holbrook[1], David M Wilson[2], and Michael E Matheron[3]

There are two requirements for developing groundnut cultivars with resistance to preharvest aflatoxin contamination. First, there must be genetic variance for resistance. In other words, there must be a gene or genes for resistance. Second, reliable and efficient screening techniques must be available. These techniques are needed so that plants containing genes for resistance can be reliably and efficiently identified. When this project was initiated, techniques were not available for large-scale screening which is required for germplasm screening and/or plant breeding research. To be acceptable, the techniques must have a small number of escapes (uncontaminated susceptible samples) and a relatively low coefficient of variation (CV). A small number of escapes is needed to avoid selecting susceptible genotypes for additional study. A low CV is needed to accurately differentiate levels of resistance.

Aflatoxin contamination in groundnut is an extremely variable characteristic that primarily occurs under heat and drought stress. A study was conducted to develop a large-scale field system for screening groundnut germplasm for resistance to aflatoxin contamination. Yuma in Arizona, USA was chosen as a screening site since it consistently has hot and dry conditions. Before this study, it was unknown whether aflatoxin contamination would occur under the extreme soil temperatures that prevail in Yuma. This study demonstrated that aflatoxin contamination occurs in groundnut subjected to a late summer drought stress at Yuma. Through this study we also discovered that the use of subsurface irrigation during drought stress improved the screening system by resulting in higher and more consistent contamination. This system is being used to conduct large-scale field screening of groundnut germplasm for resistance to aflatoxin contamination.

A moveable greenhouse system was developed to provide a screening site at Tifton in Georgia, USA. Nine large rainout shelters were constructed. These structures can be moved in the field with tractors. They can be used three times each season. This system is being successfully used to screen groundnut for resistance to preharvest aflatoxin contamination at Tifton.

1. USDA-ARS, PO Box 748, Coastal Plain Experimental Station, Tifton, GA 31793, USA.
2. University of Georgia, Coastal Plain Experimental Station, Tifton, GA 31793, USA.
3. University of Arizona, Yuma, AZ, USA.

Artificial inoculation is frequently used when screening germplasm for resistance. It ensures uniform testing conditions and thus reduces the number of escapes and variation in the data which could mask genetic differences. The standard method for inoculation with *Aspergillus* has been a spore suspension in water applied at mid-bloom. This provided a high initial fungal pressure; however, soil populations of *Aspergillus* declined rapidly soon after inoculation. We developed a new method using cracked maize as a carrier for the fungus. The theory behind this new method was that maize would serve as a* food base for the fungus and result in more stable fungal inoculum on the developing pods. The use of maize as a carrier resulted in significantly greater soil populations of *Aspergillus* at harvest than the use of water as a carrier. This inoculation technique will help reduce the inherent variability of preharvest aflatoxin contamination and is being used for germplasm screening.

The above screening technique was used to examine groundnut germplasm for resistance to preharvest aflatoxin contamination. The first set of germplasm examined was the core collection of the US Peanut Germplasm Collection. All accessions in this core collection were first examined in a preliminary screening test using five replications in a single environment. Genotypes which had low contamination levels in the preliminary screening were then examined for a second year using 10 replications in two environments. Fourteen core accessions were observed to have an average of 70% reduction in preharvest aflatoxin contamination in multiple years of testing. Six of these accessions (Core Numbers 66, 99, 158, 215, 276, and 522) exhibited 90% reduction in preharvest aflatoxin contamination in multiple years of testing. These genotypes have been entered in a hybridization program to combine the resistance with acceptable agronomic performance.

Groundnut is often subjected to drought stress during some part of the growing season. A large root system may improve the plant's ability to continue growth during drought. We conducted research that identified groundnut genotypes which have larger root systems than standard groundnut cultivars. We also evaluated genotypes with larger root systems in the field under drought stress conditions. Many of these lines exhibited good drought tolerance and three had high pod yield relative to the standard groundnut cultivars.

The effect of drought tolerance on aflatoxin contamination is not known. We conducted research to evaluate preharvest aflatoxin contamination in genotypes known to have varying levels of drought tolerance. Two drought tolerant genotypes, PI 145681 and Tifton 8, and a susceptible genotype, PI 196754, were evaluated in two tests under rain protected shelters in Tifton. Drought and heat stress conditions were imposed for 40 days preceding harvest. The drought susceptible genotype had greater preharvest aflatoxin contamination than the check cultivar, Florunner. Both the drought tolerant genotypes had less preharvest aflatoxin contamination than Florunner in these tests.

Research is ongoing to identify indirect selection tools that may be used to select for resistance to preharvest aflatoxin contamination. An indirect selection tool could be very valuable in reducing the cost of selecting for low aflatoxin contamination. We have observed a moderate relationship between visual drought stress rating and aflatoxin contamination and between leaf temperature and aflatoxin contamination. It may be possible to use these measurements as indirect selection tools for resistance to preharvest aflatoxin contamination.

Selection Technique for Fresh Seed Dormancy in Short-duration Varieties of Groundnut

Ousmane Ndoye[1] and Charles E Simpson[2]

In groundnut (*Arachis hypogaea* L.), the early-maturing cultivars usually belong to the Spanish type (*A. hypogaea* L. subsp. *fastigiata* Waldron var. *vulgaris* Harz). Obtaining early-maturing cultivars with fresh seed dormancy is a major objective in some breeding programs, especially in the Sahel region of Africa where the rainy season is short and late rain may occur when the groundnut crop is physiologically mature. Germination of the seed prior to harvest alters both the quality and the quantity of groundnut yield.

A limited duration of fresh seed dormancy at harvest in the Spanish type is an important attribute as it can, at times of excessive and long-lasting rainfall at harvest, prevent serious pod yield loss and contamination by aflatoxins. However, little success has been achieved to introduce genetically controlled dormancy into the early-maturing subspecies *fastigiata,* although several breeders have attempted interspecific hybridization to obtain dormant Spanish type groundnuts.

The mode of inheritance of groundnut seed dormancy is not clearly understood. There are conflicting results in the few available studies on the subject. Most of these studies have used Virginia types (*A. hypogaea* L. subsp. *hypogaea* L.), which are long-duration (120-150 days) with dormant seeds, as their sources for dormancy.

The purpose of this study was to identify one or more selection criteria for effective screening for fresh seed dormancy in crosses between Spanish type cultivars. Crosses were made using the Spanish cultivar 73-30 that has fresh seed dormancy as a donor parent and Spanish cultivars (55-437 and Fleur 11) that lack dormancy.

Thirty lines from $F_{2:6}$ and $F_{2:7}$ progenies were evaluated in the field for two years (1999 and 2000) at two locations, Bambey and Nioro in Senegal. A split plot design with three replications was used; harvest dates were in the main plot and lines in subplots. The first harvesting date was at 90 days after planting; the second and third harvesting dates were scheduled later

1. Institut Senegalais de Recherches Agricoles (ISRA), Centre National de la Recherche Agronomique (CNRA), BP 53 Bambey, Senegal.

2. Texas Agricultural Experiment Station, Texas A&M University, PO Box 292, Stenphenville, TX 76041-0292, USA.

after 2 and 4 weeks respectively. Water was supplied as required. At harvest the number of sprouts for each plot was counted and 10 freshly harvested seeds were selected at random and incubated in petri dishes moistened with distilled water and placed at room temperature. The number of seeds that germinated at 24, 48, 72, and 96 h was counted. A seed was considered as germinated when the radicle was twice the diameter of the seed.

lines that exhibited transgressive segregation were observed. Hence, the ones that were more dormant or as dormant as the dormant parent were selected. Most of these lines (number 2, 4, 9, and 24) belong to the cross 55-437 x 73-30. Fewer lines were observed in the cross Fleur 11 x 73-30 perhaps due to the fact that Fleur 11 is less dormant than 55-437. Using this technique it was possible to make effective selection for fresh seed dormancy in short-duration groundnut.

Genetic Enhancement for Resistance to Aflatoxin Contamination in Groundnut

H D Upadhyaya, S N Nigam, and R P Thakur[1]

Groundnut is an important oilseed crop cultivated in 96 countries worldwide on 23.8 million ha with an annual production of 30.97 million t. It is an important cash crop in several countries of Asia, which accounts for 57.13% of world area and Africa, which accounts for 37.24% area.

Aflatoxin contamination of groundnut is a widespread serious problem in most groundnut-producing countries where the crop is grown under rainfed conditions. The aflatoxin contamination does not affect crop productivity but it makes produce unfit for consumption as toxins are injurious to health. The marketability of contaminated produce, particularly in international trade is diminished to nil due to stringent standards of permissible limits on aflatoxin contamination set by the importing countries. The aflatoxin-producing fungus, *Aspergillus flavus* and *A. parasiticus,* can invade groundnut seed in the field before harvest, during postharvest drying and curing, and in storage and transportation. The semi-arid tropical environment is conducive to preharvest contamination when the crop experiences drought before harvest, whereas in the wet and humid areas, postharvest contamination is more prevalent. Research on aflatoxin contamination is not regularly carried out by all the groundnut-producing countries because of the complex nature of the problem and lack of qualified personnel and appropriate infrastructure. Nevertheless, some countries have been regularly monitoring groundnut and its products for aflatoxin at different stages (farm, markets, and storage). Aflatoxin contamination can be minimized by adopting certain cultural, produce handling, and storage practices. However, these practices are not widely adopted particularly by the small farmers in the developing countries, which contribute about 60% to the world groundnut production.

One of the possible means of reducing aflatoxin contamination of groundnut is the use of cultivars resistant to seed invasion by aflatoxin-producing fungi or to aflatoxin production. These cultivars will be of great value to the farmers in both developed and developing countries as there

1. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India.

is no cost input. Therefore, breeding for resistance to *A. flavus* and *A. parasiticus* and/or aflatoxin production can play a significant role in preventing aflatoxin contamination in groundnut and consequently associated economic losses and health hazards.

The alleviation of aflatoxin contamination through genetic manipulation has been attempted since mid-1970s. We have achieved significant progress; however, these efforts have not resulted in complete eradication of aflatoxin contamination. In this paper we have briefly discussed the status of research on finding a genetic solution to this problem.

Types of resistance

In groundnut, based on the site at which it is tested or cultivated, resistance to aflatoxin-producing fungi may be of three types: resistance to pod infection (pod wall); resistance to seed invasion and colonization (seed coat); and resistance to aflatoxin production (cotyledons). The fungi have to penetrate the pod wall and the seed coat to reach the cotyledons from which they derive their sustenance. Resistance to pod infection is attributed to pod-shell structure, while resistance to seed invasion and colonization is mostly physical, and has been correlated with thickness, density of palisade cell layers, absence of fissures and cavities, and presence of wax layers. There are conflicting reports regarding the role of fungistatic phenolic compounds in imparting resistance to seed colonization.

Sources of all the three types of resistance have been reported (Mehan 1989). These include Shulamit and Darou IV for resistance to pod infection, PI 337394 F, PI 337409, GFA 1, GFA 2, UF 71513, Ah 7223, J 11, Var 27, U 4-47-7, Faizpur, and Monir 240-30 for resistance to in vitro seed colonization by *A. flavus* (IVSCAF); and U 4-7-5 and VRR 245 for resistance to aflatoxin production. The importance of preharvest aflatoxin contamination was realized only in the late 1980s, and some of the IVSCAF-resistant genotypes (PI 337394 F, PI 337409, GFA 1, GFA 2, J 11, UF 71513, and Ah 7223) were reported to have considerably lower natural seed infection by *A. flavus* than various IVSCAF-susceptible genotypes (Mehan 1989).

The value of a resistant source depends upon the level and stability of its resistance. Resistance to pod infection has been reported to be highly variable and of a low level. Similarly, IVSCAF-resistance is not absolute and even the best sources show up to 15% seed colonization; only a few lines

(J 11, PI 337394 F, and PI 337409) have shown stable resistance. For aflatoxin contamination, resistance levels are not very high (Anderson et al. 1995). Highly significant genotype x environment interaction effects have been observed for aflatoxin contamination.

Relationships between types of resistance

There are conflicting reports on the relationship between IVSCAF-resistance and resistance to natural seed infection, and aflatoxin contamination in the field. At the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India and in USA, though a significant reduction in the levels of seed infection by *A. flavus* under field conditions in the IVSCAF-resistant genotypes in comparison to the IVSCAF-susceptible genotypes was observed, the correlation was not perfect. In the breeding lines developed and evaluated, very low correlation (-0.07) was observed between IVSCAF and seed infection in the field, indicating two independent genetic mechanisms (Utomo et al. 1990, Upadhyaya et al. 1997). The high correlation observed in an earlier study (Mehan et al. 1987) might have been due to the inclusion of some selected germplasm lines; whereas the absence of correlation observed in breeding lines developed at ICRISAT Center (IC), Patancheru might have resulted from the recombination of genes controlling these mechanisms. Studies conducted, in the 1980s, in USA and at IC showed low levels of aflatoxin contamination in IVSCAF-resistant genotypes. However, the genotypes which were earlier reported to be resistant to IVSCAF or preharvest aflatoxin contamination contained high levels of aflatoxin, and when subjected to an extended period of heat and drought stress in USA, none of them was more resistant than the susceptible cultivar Florunner (Anderson et al. 1995). Highly significant genotype x environment interaction effects for aflatoxin contamination were observed in this study. The exact information on the relationship between different resistance mechanisms, their interactions, and possible contributions in reducing aflatoxin contamination have not been clearly established. Knowledge of these aspects is very crucial in developing strategies to reduce aflatoxin contamination.

Genetics of resistance

There are only few published reports on inheritance of resistance to seed infection, IVSCAF, and aflatoxin production, which give estimates of broad sense heritability and combining ability. The high estimate (79%) of broad sense heritability for seed colonization was reported from USA in a cross involving PI 337409 (resistant) and PI 331326 (susceptible). The heritability estimates in later studies in USA were 55% in the cross involving AR 4 (resistant) and NC 7 (susceptible), and 63% in a cross between GFA 2 (resistant) and NC 7 (susceptible). At IC, the values were 60% in a cross involving J 11 (resistant) and OG 43-4-1 (susceptible) and 59% in a cross between two resistant parents, J 11 and Ah 7223.

The heritability estimates for resistance to seed infection have been reported to be low in USA: 27% in AR 4 x NC 7 and 33% in GFA 2 x NC 7 (Utomo et al. 1990). However, in our study the estimates were moderate to high (56-87%) (Upadhyaya et al. 1997). For resistance to aflatoxin production, the heritability estimates were reported as 20% in AR 4 x NC 7 and 47% in GFA 2 x NC 7. A report from USA stated that there is no significant correlation among the three types of resistance, indicating that they are controlled by different genes (Utomo et al. 1990).

A study on combining ability of IVSCAF-resistance using lines x tester analysis at IC indicated UF 71513 to be a good general combiner and Var 27 to be a poor combiner for resistance to IVSCAF. J 11 had non-significant general combining ability effect. In a diallel study, significant reciprocal effects were noticed in some crosses indicating maternal influence on testa structure (Rao et al. 1989).

The genetics of resistance mechanisms has not been clearly established. The allelic relationship among various sources for each resistance trait needs to be elucidated to enable breeders to pyramid the non-allelic genes for each resistance mechanism.

Genetic enhancement for resistance

Breeding efforts for resistance to pod infection have not received any attention. Further, it was assumed that if shell thickness was related to resistance, then resistance breeding would result in low shelling percentages or difficulty in shelling groundnut. In the past, seed colonization resistance received maximum attention due to the ease of screening procedures. Of late, natural seed infection and aflatoxin production have received increasing attention, although screening for resistance to aflatoxin production is expensive. A much cheaper enzyme-linked immunosorbent assay (ELISA)-based methodology has been developed at ICRISAT (Reddy et al. 1988).

Research on breeding for resistance to aflatoxin contamination is in progress in India, Senegal, Thailand, and USA. The groups at Tifton (USA) and IC (India) have successfully transferred IVSCAF-resistance to different genetic backgrounds. The group at Tifton produced six breeding lines GFA 1, GFA 2, AR-1, AR-2, AR-3, and AR-4 (Mixon 1983a, 1983b). GFA 1 and GFA 2 (both runner market types), whose yields were equal to or better than that of Florunner, had equal or less than average seed colonization than the resistant control genotype (PI 337409). The yield potentials of AR-U-2, AR-U-3, and AR-U-4 are too low for their practical use as commercial cultivars.

In India, resistance breeding activities are mainly conducted at IC and the National Research Center for Groundnut (NRCG) at Junagadh. At IC, research on breeding for resistance to aflatoxin contamination started in 1976. Several hundred breeding lines have since been tested for yield and IVSCAF-resistance, and many lines with IVSCAF-resistance and high yield have been identified. Four hundred and seventy-two lines were evaluated for preharvest seed infection and yield. Some of these have seed infection and colonization equal to or less than the best resistant control cultivar J 11, and high-yield potential across seasons/years and locations. Of these, ICGV 88145 and ICGV 89104 have been released as improved germplasm lines (Rao et al. 1995). Recently, we have identified and released three more lines, ICGVs 91278, 91283, and 91284 as improved germplasm (Upadhyaya et al. 2001). These lines had seed infection and colonization equal to or less than J 11 and high yield across seasons and locations. These lines have also been evaluated for yield and other agronomic traits in national programs in Thailand and Vietnam, where they performed very well (Upadhyaya et al. 1997). Three lines (ICGVs 87084, 87094, and 87110), bred at IC for resistance to seed infection were also found to be resistant in Niger, Senegal, and Burkina Faso in West Africa (Waliyar et al. 1994).

In Thailand and Senegal, PI 337394 F, PI 337409, UP 71513, and J 11 are commonly used as resistant donors. The lines AR-1, AR-2, AR-3, and AR-4 are also being used in Thailand as sources of resistance; 55-437 has been used in Senegal.

In the breeding scheme at IC, the selection for resistance traits is delayed until later generations. However, it would be desirable to screen segregating generations and select only resistant plants/progenies. This would require modification of screening techniques currently being used to make them more suitable at the single plant level.

Future prospects of breeding for aflatoxin resistance

Although researchers have not been able to locate germplasm lines which show complete resistance to fungi at the pod-wall, seed-coat, and cotyledon levels, it was expected that the levels of resistance could be improved further by pyramiding resistance genes from different and diverse sources. It was also thought that by combining the three different kinds of resistance in one genetic background, the problem of aflatoxin contamination could be overcome to a large extent. Unfortunately, the progress made so far in conventional breeding has not been able to meet these expectations. The recourse to biotechnology, through modification of the aflatoxin biosynthesis pathway or the use of variants of hydrolytic enzymes (chitinases and glucanases) to provide transgenic protection to groundnut against infection by aflatoxin-producing fungi may help in obtaining groundnuts free from aflatoxin. Genetic resistance alone may not be enough to eliminate the problem of aflatoxin contamination in groundnut. It will have to be complimented with good crop husbandry and postharvest practices.

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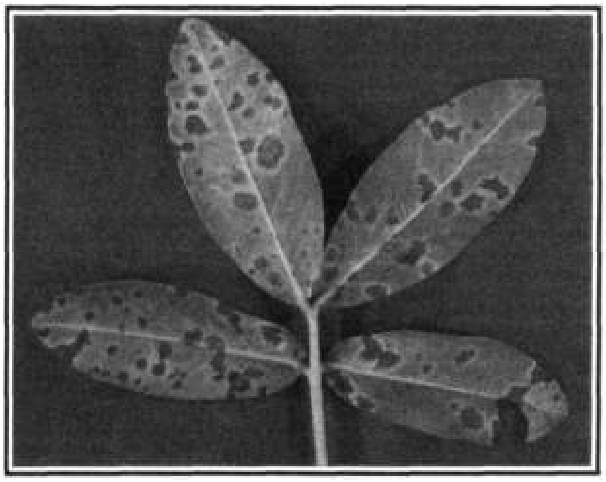
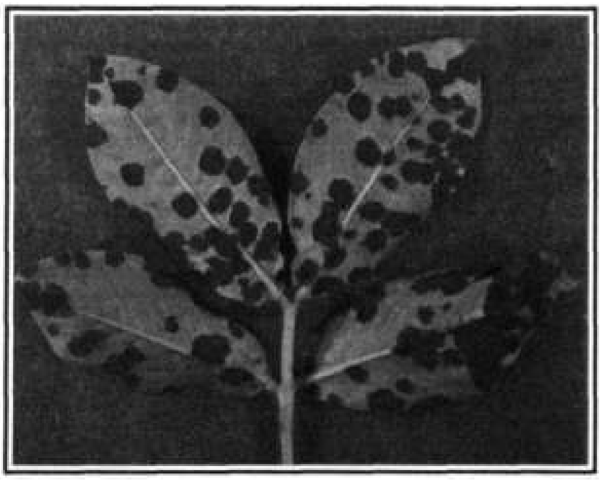




Progress in Combating Groundnut Rosette Disease in West and Central Africa: An Overview

B R Ntare[1], P E Olorunju[2], and F Waliyar[1]

Groundnut rosette is the most destructive disease of groundnut in West and Central Africa. Epidemics are sporadic and unpredictable but can cause substantial losses which are estimated at US$ 156 million per year across Africa. The disease is caused by a complex of three agents: groundnut rosette umbravirus (GRV) and its satellite RNAsat, and groundnut rosette assistor luteovirus (GRAV). All the three agents must be present together in the host plant for successful transmission of the disease by the aphid vector *Aphis craccivora.*

Disease management

Cultural practices

Earlier studies revealed that insecticide spraying to control aphids could be effective. They also showed that bringing forward sowing dates allowed the crop to establish before aphid populations reached their peak, and that using denser plant stands discouraged infestation, since aphids prefer light airy conditions. Small-scale farmers who grow groundnut, however, often face difficulties in adopting such practices. These adoption constraints coupled with dry years in the early 1980s led to rising aphid populations implying genetic resistance as potentially a more promising way forward.

Host-plant resistance

Pioneering research on the development of groundnut cultivars with resistance to rosette was initiated in early 1950s by the Institut de Recherche pour les Huiles et Oleagineux (IRHO). Sources of resistance to rosette were first discovered in 1952. These sources formed the basis for rosette resistance breeding programs throughout Africa. This resulted in the development of long-duration varieties such as 69-101 (120-125 days); RGI, RMP 12, and RMP 91 (140-150 days); and early-maturing

1. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), BP 320 Bamako, Mali.
2. Institute of Agricultural Research, Samaru, PMB 1044, Zaria, Nigeria.

types such as KH 149 A, KH 241 C, KH 241 D, and QH 243 C (90-100 days). Long-duration varieties are not adapted to the short-growing seasons of the dry savannah of West Africa, where the bulk of the crop is grown. The few short-duration rosette resistant varieties have poor agronomic characteristics and hence were not widely adopted by farmers. The challenge was to combine groundnut rosette resistance with early maturity (90-110 days), high-yielding Spanish types suitable for smallholder farmers in different ecosystems.

Germplasm screening

In 1990, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) began screening global germplasm for resistance in Malawi. Over 12,500 germplasm lines have been screened to date. More than 130 long-duration Virginia types and 20 short-duration Spanish types were identified as resistant sources. In West Africa, with financial support from the Groundnut Germplasm Project (GGP), 2301 germplasm lines have been screened at Samaru in Nigeria. Sixty-five new sources of resistance to rosette were identified and 10 accessions were of short-duration (100 days). These additional sources of resistance should be invaluable in breeding programs to broaden the genetic base of resistance and ensure stability of resistance. All available rosette resistant lines of cultivated groundnut are susceptible to GRAY Immunity to GRAV was identified in several wild *Arachis* species or accessions. This provides an opportunity to transfer immunity to GRAV into cultivated groundnut through conventional and/or biotechnological approaches.

Resistant varieties

Several high-yielding resistant breeding lines suitable for medium- and high-rainfall areas have been developed in Malawi and Nigeria. Excellent performance of these lines has been demonstrated in several countries including Mali, Burkina Faso, Ghana, and Nigeria. In partnership with the Institute of Agricultural Research (IAR) in Nigeria, short- (90-100 days) and medium-duration (115 days) rosette resistant cultivars combining high pod yield and other agronomic attributes have been developed. These yield 19-92% higher than the susceptible varieties under both natural and high rosette disease pressure. Promising lines have been made available to national programs in West and Central Africa. In Nigeria three early maturing rosette resistant lines (ICGV-IS 96894, ICGV-IS 96900, and ICIAR 18AT) have demonstrated excellent performance in farmer participatory on-farm trials.

Integrated disease mangement

Components of integrated disease management (resistant varieties + cultural practices) have been studied in Mali and are being verified in farmer participatory on-farm trials. Cultural practices can provide significant improvements in rosette control and yield. The use of insecticides was not an economically viable option during non-epidemic years. The ideal combination is high-yielding resistant varieties sown early at optimum density.

Perspectives

More concerted efforts are required to create a situation where available rosette resistance and management packages can be put into practice. Resistant material needs to be evaluated for performance against a range of variants of groundnut rosette disease agents in different environments. Immunity to GRAV has been identified in wild *Arachis* species and provides an opportunity to transfer this trait into cultivated groundnut through biotechnological approaches. Resistance to GRAV will reduce the disease considerably. Resistance to the aphid vector is a strategy being pursued in breeding for resistance. Plant resistance combined with cultural practices are key components for developing a successful management program against groundnut rosette. Understanding the epidemiological principles of the disease combined with resistance will lead to the development of sustainable integrated disease management strategies.

Simulating Yield of Groundnut as Affected by Leaf Spot Disease in Northern Benin

M Adomou[1], P V Vara Prasad[2], K J Boote[2], J Detongnon[1], and A O Sannl[1]

Groundnut crops in Benin often experience incidence of late leaf spot *(Cereosporidium personatum)* causing severe yield losses. The objective of this research was to use and test the ability of CROPGRO-groundnut model to simulate and quantify the effects of disease incidence on pod yield and dry matter production of early- and late-maturing groundnut cultivars grown under rainfed condition at different sowing dates in northern Benin. Two groundnut cultivars TS 32-1 and 69-101 were sown on three sowing dates between May and August during 1998 and 1999 at the Institut National des Recherches Agricoles du Benin (INRAB) research station farm at Ina (10° N latitude and 2.95° W longitude).

Incidence and severity of leaf spot were assessed based on the visual rating scale of 1-9 developed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Similarly, defoliation was assessed by counting the number of nodes with missing leaflets and the total number of nodes on the main stem. These assessments were done at 15-day intervals when the plants were sampled for growth analysis. It was observed that during both the years there was severe incidence of leaf spot in both cultivars; score 7 to 8 in TS 32-1 and 7 in 69-101. The defoliation on the main stem caused by leaf spot resulted in significantly more rapid loss in leaf area for late-sown cultivars. This clearly suggests that late-sown crops are greatly damaged by leaf spot and defoliation than the early-sown crops.

CROPGRO-groundnut model was able to predict and simulate the observed pod and dry matter yield over time when inputs on diseased leaf area (%) and observed defoliation (%) were provided. The best fit was obtained with inputs on observed main stem defoliation (%) values (estimated without considering the first four nodes from which the branches are formed) and diseased leaf area (%) (estimated from ICRISAT leaf spot scale).

1. Institut National des Recherches Agricoles du Benin (INRAB), BP 884 Cotonou, Benin.
2. Department of Agronomy, University of Florida, Gainesville, Florida 32611, USA.

The data clearly suggests that regardless of disease, the model was able to predict pod yields accurately until 50-60 days after sowing during both the years for both cultivars at all sowing date treatments. Thereafter, the model without the defoliation and disease function over-predicts the pod yields; this is because the model assumes that there is no incidence of diseases and it predicts the potential yields. Once the disease subroutine is turned on and the incidence of disease and the modified defoliation functions are used, then the model predictions of both pod yields and total dry matter significantly improved and were close to the observed values. Overall, across all the sowing dates the long-duration cultivar 69-101 produced significantly greater pod and total dry weight when compared to the short-duration cultivar TS 32-1.

To estimate and quantify the yield losses due to disease incidence during 1998 and 1999, the predicted pod yields at maturity from the simulations without disease effects (potential yield) and the observed pod yields in different treatments were compared. The results show that yield losses due to the disease ranged from 38% to 75% depending on the time of sowing. Yield loss due to the disease generally increased with later sowing. For the third sowing date (D3) in 1999 the potential pod yield was substantially reduced due to drought. The potential yield for no water deficit was 5498 kg ha^{-1} and therefore yield loss due to disease only would have been 75%. With severe disease pressure in D3 in 1999, the simulated leaf area index was lower and there was little water deficit.

Yield losses due to occurrence of disease could be overcome by adopting proper pest management strategies such as application of fungicide and planning soon after the arrival of sufficient rains. Two or three applications of systemic fungicides such as Corvet CM (Fenpropimorphe, 18.8%; Mancozeb, 40.0%; Carbendazim, 5.0%) have been successfully used to control leaf spot and improve crop yields in substantial monetary gains for farmers in West Africa (F Waliyar, ICRISAT, personal communication). Therefore farmers must be educated about the advantages of application of fungicides to control leaf spot diseases.

Susceptibility of Groundnut Genotypes to Termite Attack and Fungal Infections

V C Umeh[1], F Waliyar[2], and A Traore[2]

Surveys have shown that soil pests such as termites, white grubs, and millipedes constitute the most economically important pest problems in groundnut production in Western and Central Africa. Control measures are seldom applied by the small holding farmers that constitute majority of groundnut producers in the sub-region and thus yield losses are high. In recent times, efforts have been geared towards the amelioration of soil pest problems by conducting research on some control technologies that small holding farmers can afford and easily adopt.

ResistantAolerant groundnut varieties were assessed against termites (the most damaging soil pest of groundnut in Mali) in a field trial conducted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) station in Samanko in Mali to identify varieties that could be further evaluated and recommended to farmers for adoption. Twenty groundnut varieties, ICGV 87084, ICGV 87110, ICGV 89063, ICGV 89112, ICGV 91283, J 11, 55-437, PI 337394 F, UI-2-1, U4-47-7, VF 715131, ICGV 87094, ICGV 89092, ICGV 87095, ICGV 91289, ICGV 7333, ICGV 7330, Fleur 11, NC Ac 343, and NC Ac 243 were planted in plots of 8 m x 4 m in a randomized complete block design. The test genotypes included short- and long-duration varieties (90-120 days). Single super phosphate at 100 kg ha^{-1} was applied to the plots at planting. No pesticide was applied to the plots. External observations were made on stems and leaves for soil pest damage at 14-day intervals starting from 30 days after planting (DAP). Root damage was observed at 40 DAP and at plant maturity in samples of ten uprooted plants per plot. At harvest, pod damage by termites was also assessed in each plot. Samples of pods of each variety were shelled and used in a laboratory bioassay to determine fungal infection.

Leaf or stem damage by *Microtermes* spp was observed in some plots, but the damage was low. Various degrees of susceptibility to root attack was

1. National Horticultural Research Institute, PMB 5432, Idi-Ishin, Jericho Reservation Area, Ibadan, Nigeria.
2. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), BP 320 Bamako, Mali.

observed in the test varieties. At 40 DAP, termite attack on roots was so low that the variety NC Ac 343 had no plant attacked by termites. At harvest NC Ac 243 had significantly ($P < 0.05$) lower mean number of plants plot^{-1} with root attack than ICGV 91289, Fleur 11, and ICGV 89092. However, there was no significant difference between the number of plants with attacked roots in NC Ac 243 and that of ICGV 89112, ICGV 87110, ICGV 91283, NC Ac 343, and 55-437 which also had low termite attack at harvest. Termite attack on pods was significantly low in NC Ac 343, NC Ac 243, ICGV 87094, and 55-437 but was significantly high in all other varieties.

Aspergillus flavus, A. niger, and *Fusarium* spp were identified as the most important fungal species which infected seeds of the test varieties. In most cases these appeared as mixed infection. NC Ac 243 was less susceptible to termite attack and was significantly less attacked by *A. niger. Aspergillus niger* infection was relatively low in J 11 and ICGV 91289. These results suggest that varieties less attacked by termites did not facilitate infection by *A. niger.* No significant difference was observed between the varieties infected by *A. flavus;* however, the infection was high (minimum 25%). The percentage of seed infected by *Fusarium* spp was also observed to be significantly low in varieties such as NC Ac 243 and NC Ac 343, although the values were not significantly different than those of U4-47-7, PI 337394 F, J 11, and ICGV 89112. Correlation between the percentage of damaged pods and *Aspergillus* infection ($r = 0.32$) was not significant.

The study shows the prospect of incorporating varietal resistance/ tolerance in the development of integrated pest management for termites.

Managing Groundnut Leaf Diseases in Northern Ghana with Fungicides, Neem Seed Extract, and Local Soap

F K Tsigbey[1], J E Bailey[2], and S K Nutsugah[1]

Losses due to foliar diseases (Cercospora arachidicola, Cercosporidium personatum, Puccinia arachidis) in Northern Ghana are major constraints to groundnut pod and vine yields. Farmers do not practice disease control procedures and perceive dead leaves as signs of crop maturity. Field experiments conducted at Nyankpala in 1999 evaluated the following products; tebuconazole, Folicur 3.6F at 0.22 kg ai ha^{-1} mixed with azoxystrobin, Abound 2.08F at 0.45 kg ai ha^{-1}, Topsin-M® 50WP at 0.35 kg ai ha^{-1}), 20% neem seed extract and 1% local soap ("Alata Samina"). Plots were sprayed at about 14-day intervals.

Folicur/Abound treated plots gave the highest vine and pod yield (9.9 and 1.7 kg $plot^{-1}$ respectively) and recorded the least disease score (2.3, Florida scale) as well as defoliation (1.6%). Untreated and neem-sprayed plots had the highest disease scores (9.5 and 8.3 respectively), highest defoliation (90.7% and 89.2%), and lowest yields (0.7 and 0.8 kg $plot^{-1}$). Defoliation in Topsin-M® treated plots was 27.2% and was predominantly due to groundnut rust attack which resulted in pod yield loss of 22.9%. Local soap was comparable to Topsin-M®. In the absence of adopting any control measure an average pod loss of 60% was recorded between plots sprayed with Folicur/Abound and those receiving no fungicide treatment.

In another experiment, local soap at two concentrations (1.0 and 2.5%) was compared to Folicur/Abound and Topsin-M®. Soap at both levels gave higher pod yields than the untreated control. Treatment with 1% soap had lower defoliation (72.3%) than both 2.5% soap and the control without spray (86.0% and 89.8% respectively). Therefore soap at 1% has shown consistency in the control of groundnut leaf diseases by reducing defoliation as well as increasing pod yields.

1. Savanna Agritultural Research Institute (SARI), PO Box 52, Nyankpala-Tamale, Ghana.
2. Department of Plant Pathology, North Carolina State University, Raleigh, NC 27695-7616, USA.

Evaluation of Groundnut Rosette Resistant Varieties and Impact on Farmers' Livelihoods in the Teso System of Uganda

F M Kimmins[1], C Busolo-Bulafo, P van der Merwe[2], R A Naldu[3], and P Subrahmanyam[2]

The United Kingdom Department for International Development (DFID) recognizes that knowledge and technology underpin development but it has recently changed the emphasis from a sustainable agriculture research strategy to a framework which focuses on sustainable livelihoods. This approach considers the assets available to farmers and, in the case of agriculture, places it within the context of farmers' livelihoods, where health, education, markets, etc. play significant roles. The Crop Protection Programme (CPP) is one of the 12 research programs funded by DFID and its aim is to develop and promote pest management strategies through research that contributes to poverty alleviation. The sustainable livelihoods framework is helping the CPP to assess the impact of new crop protection technologies and their benefits to the poor and to identify the areas that need to be strengthened to facilitate uptake of sustainable pest management strategies.

The CPP groundnut evaluation project is using the framework to evaluate improved groundnut rosette resistant lines in the Teso system of Uganda and improve the adoption of successful varieties. It is important to note that the project builds upon almost four decades of research undertaken by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), in collaboration with African national programs and advanced institutions in USA, France, and UK. We now have the opportunity to demonstrate the impact of these efforts and investment by trying to improve uptake at the farmer level.

The Government of Uganda requested assistance in the regeneration of agriculture in the Teso system of a traditional pastoral community in the east of Uganda. In 1998 an extensive needs assessment exercise was led by the National Agricultural Research Organization (NARO) and, in the case of

1. MR International, Pembroke Chatham Maritime, Chatham, Kent, UK.
2. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), PO Box 1096, Lilongwe, Malawi.
3. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

groundnuts, improved rosette management was requested by both farmers and researchers. A previous CPP project had worked closely with ICRISAT-Malawi on rosette resistance mechanisms of the new improved short-duration rosette resistant lines and a new collaborative project was developed with the Serere Agricultural and Animal Production Research Institute (SAARI), CPP, and ICRISAT to evaluate these lines.

Stage 1 of the project involving a rapid rural appraisal of groundnut production in three districts of the Teso system has been completed and places the crop and disease in the context of farmers' livelihoods. The database provides information on farmers' varietal preferences, labor requirements, perceptions of rosette disease, and other production constraints, coping strategies, marketing strategies, and trusted information channels. The last category is being used to develop a communication strategy to promote new materials which perform well and are acceptable.

Stage 2 involves the survey of rosette incidence by researchers and over the last year we have estimated that rosette incidence on <40-day-old crops *is* 20-40% in the three target districts of Uganda. This confirms that rosette is a major constraint and the urgent need for improved disease resistant varieties to gain farmers' confidence in the crop.

Stage 3 concerns the evaluation of improved resistant material on-station and through farmer participatory seed selection and trials. This is in progress and involves training programs.

Stage 4 is concerned with developing linkages with implementing agencies in the local vicinity, i.e., extension offices and non-governmental organizations (NGOs) running farmer field schools. Outside the Teso system we are looking at marketing opportunities for groundnut and business opportunities for small entrepreneurs, i.e., quality seed producers, and groundnut processors.

The final stage will be the development of an action plan for SAARI and implementing agencies to attract direct bilateral funds from DFID and/or other donors to ensure the sustainability of the project once it has ended. It will identify acceptable varieties and effective dissemination routes to improve uptake. It should also identify potential markets for groundnut within Uganda, at least, and encourage farmers to increase production within and beyond the Teso system.

Soil Pests of Groundnut with Reference to Termites and their Role in Aflatoxin Contamination: A Review and Perspective for Future Research

O Youm[1], F Waliyar[1], V C Umeh[2], M Yacouba[2], and B R Ntare[1]

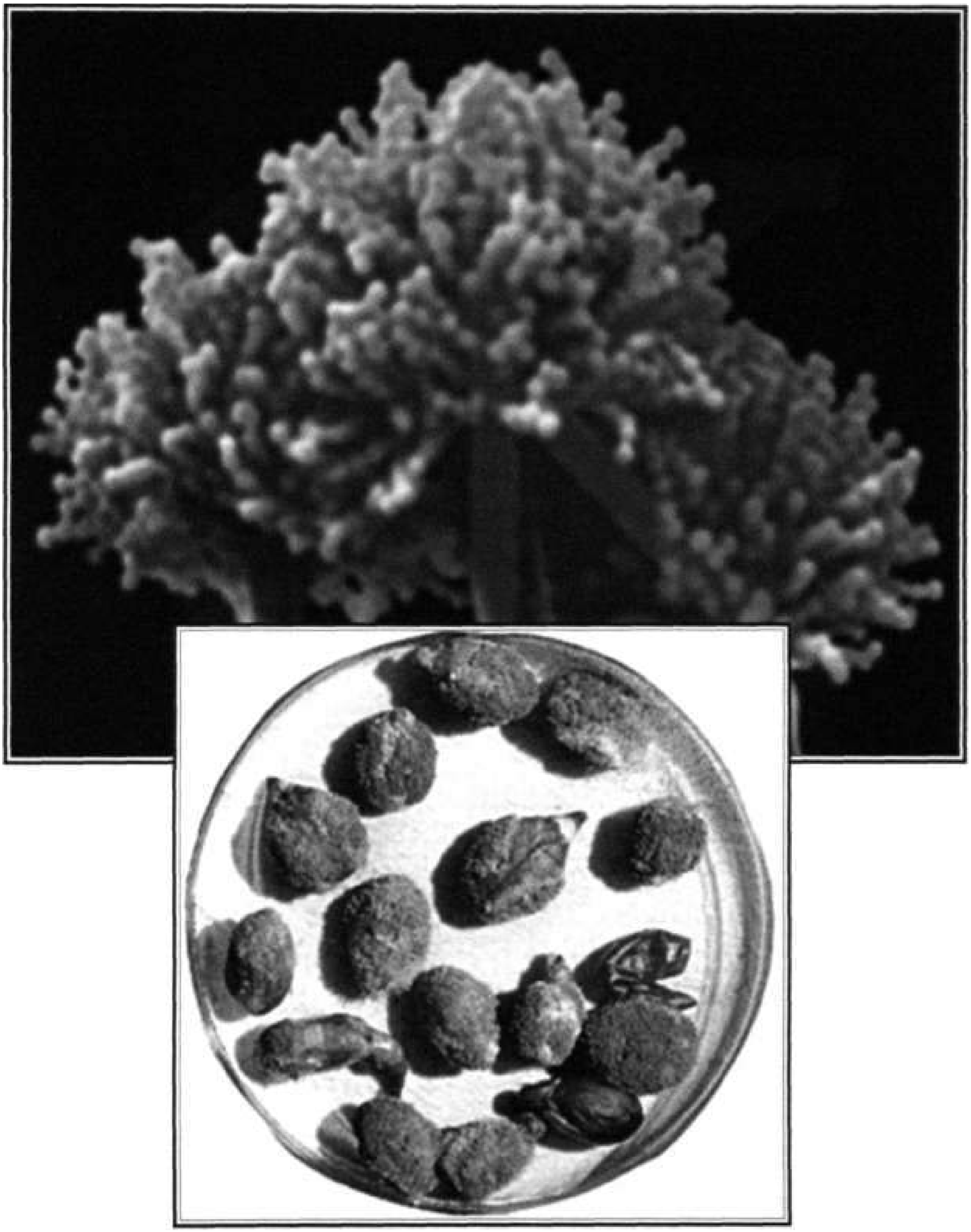
Many soil insect pests are reported to attack groundnut in West Africa, and extensive work in surveys and pest bio-ecology is described. Research findings in recent years have shown that termites (Isoptera: Termidae), white grubs (Coleoptera: Scarabaeidae), and millipedes (Myriapoda: Odontopygidae) are the major groups of soil pests that are widespread and of economic importance in groundnut production. Other identified Coleopteran pests such as wireworms (Alateridae) and false wireworms (Tenebrionidae) are of occasional importance. The biology, symptoms of damage, and crop losses due to soil insect pests in most groundnut-growing areas in Sub-Saharan Africa are generally well covered in the literature.

Studies by several authors have also attempted to shed some light on the relationship between soil pest damage, specially termites and aflatoxin contamination. In general, severe damage by termites through scarification and penetration of pods resulted in an increase in *Aspergillus flavus* contamination in pods and seeds. This is evident in areas where termite damage was severe.

This review is not intended to repeat past extensive reviews, but to take a critical look at the issue on soil pests, specifically termite incidence and damage to groundnut, and how it relates to the incidence of *A. flavus* and associated aflatoxin contamination. Implications on current knowledge as well as on future strategic research to understand the relationships and factors involved, and also to develop ways to reduce pest damage and aflatoxin incidence are discussed.

1. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), BP 320 Bamako, Mali.
2. National Horticultural Research Institute, PMB 5432, Idi-Ishin, Jericho Reservation Area, Ibadan, Nigeria.

Session 4: Aflatoxin



Management of Groundnut Contamination by Aflatoxin

F Waliyar, A Traore, and R Tabo[1]

Contamination of groundnut by aflatoxin is a major constraint to production in several countries. Such a phenomenon has an impact on exports and human and animal health. Infestation of groundnut by *Aspergillus flavus* occurs during the preharvest and postharvest periods. Preharvest infestation by *A. flavus,* which is responsible for production of aflatoxin, is very important in the semi-arid tropics when end-of-season drought occurs.

Management of aflatoxin contamination

Many national and international institutes, including the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), have focused on preharvest and postharvest management of aflatoxin. Studies on the climatic and edaphic factors and on control of their interactions in the fields have provided considerable information on the conditions for infestation by *A. flavus* before and after harvest. The findings of these studies have made it possible to make the following recommendations to farmers and major operators of the sector.

Postharvest practices

- Avoid damaging pods at the time of harvest.
- Avoid end-of-season drought effects by irrigating, if possible.
- Harvest only when crops are fully matured.
- Remove damaged pods.
- Dry pods up to relative humidity of 8%.
- Store pods away from insects and humidity.
- Avoid rehydrating the pods and seeds during storage.

Cultural practices

Several recommendations for aflatoxin control have been made involving adoption of certain cultural practices. For example, adjustment of sowing

1. International Crops Research Institute for the Semi-Arid Tropics, BP 320 Bamako, Mali.

and harvesting dates, and application of gypsum are effective in preventing aflatoxin contamination. There is a need to develop and demonstrate the effectiveness of such cultural practices on-farm. Furthermore, technologies for water conservation in the soil profile, especially at the end of the cropping season, help in reducing aflatoxin contamination. Studies have shown that there is correlation between drought, termite damage, and seed contamination by *A. flavus.*

Effect of application of lime and organic matter on aflatoxin

Trials on the effects of lime, organic manure, and crop residues on different varieties of groundnut have been conducted in Mali and Niger. The main findings are given below.

Seed contamination

Application of lime reduces seed contamination by *A. flavus* by 47%, manure by 33%, crop residues by 24%, and combination of manure and crop residues by 56%.

Aflatoxin content

Application of lime reduces aflatoxin content in seed by 48%, manure by 32%, crop residues by 27%, combination of manure and lime by 72%, combination of lime and crop residues by 71%, combination of manure and crop residues by 56%, and combination of manure, lime, and crop residues by 83%.

Pod yields

Application of lime and crop residues improved pod growth; lime increased pod yield by 18%, manure by 9%, crop residues by 7%, and combination of manure and lime by 27%. Manure increased the yield of groundnut variety 55-437 by 51% as against 12% in J 11. Certain interactions are not really visible during the first year of treatment.

Postharvest Control of Aflatoxin as Applied to African Confectionery Groundnut Sector

R Schilling[1]

Contamination of groundnut products by aflatoxin, under the conditions in which they are produced by African farmers, can be controlled at three major levels: prevention of farm infestation up to harvest (treated elsewhere); postharvest on-farm prevention; and elimination of contaminated seed from the farm up to the initial stages of the industrial process. Detoxification of finished products is obtained through a sophisticated industrial technology. We shall deal with the intermediary phase of production of confectionery groundnut particularly vulnerable to aflatoxin contamination, which poses risks to human health in the production zones (self-consumption); very strict health measures are imposed on the international market (export).

Confectionery (edible) groundnut meant for the international market should meet some stringent sanitary and technological criteria. The product should particularly have very low aflatoxin content. Before being processed, the analysis of bulk samples show a strong correlation between the percentage of pod or seed damaged and the aflatoxin content. Of the total harvest, an average of 25-30% of the harvest contains 80-100% of aflatoxin.

Screening of batches of pods/seeds delivered to the collection point, therefore, makes it possible to improve particularly the sanitary quality of the product, especially as it will have been previously dried and threshed carefully. Storage, even if temporary, should be effected only when the rate of humidity of the pods is stabilized at 6-8%. The threshing technique (uprooting, cleaning for 48 h, careful separation of pods followed by manual sorting of pods and drying in small layers) helps in obtaining pods, which are practically aflatoxin-free, provided they are harvested when fully matured. There is therefore a relationship between the improved farming techniques which lead to high productivity and good quality, on one hand, and techniques specific to prevention of aflatoxin on the other hand. In both cases, the objective is essentially to produce a healthy and marketable product in abundance.

1. CIRAD-CA, Agronome Programme Cultures Alimentaires, TA70/01 34398 Montpellier, France.

The problem, with regard to pricing and collection, will be to acknowledge the good quality of the product by working out and offering interesting prices. An experiment conducted in Senegal made it possible to establish a proper correlation between the specific weight of groundnut (by weighing double decaliter of shells from each batch) and its quality (maturity and filling). Thus three qualities and three corresponding purchasing prices were defined, as in the case of cotton. This system was abandoned for lack of an organization to handle separately the three qualities collected. But it is to be revived within the framework of the confectionery groundnut recovery project launched recently in view of achieving an integrated control of *Aspergillus flavus* at all stages of the production process from the plant materiel used (tolerant varieties) to delivery of healthy products.

The techniques applied at the initial stages of the industrial process involved essentially removing the seed susceptible to *A. flavus* and containing toxins. There will be quality controls (visual and densimetric) followed by a series of operations including cleaning, elimination of free seed shelling, removal of debris and broken seed, grading, and finally, colorimetric sorting making it possible to remove the seed with abnormal color. In Senegal all these techniques combined with a control-certification program should lead to defining an internationally recognized label which will help improve the market of confectionery groundnut and meet the sanitary standards imposed by importing countries. Improving the quality of the final product will help to propose in upstream to producers, a more profitable price than the one offered for the ordinary production meant for oil extraction. Rational organization of the sector will lead to the treatment of first grade groundnut of exportable quality and low quality groundnut will be sent for oil extraction.

Molecular Strategy for Groundnut Preharvest Aflatoxin Elimination: Recent Advances and Future Prospects

Daniele Clavel[1]

The traditional methods used for studying host-plant resistance to *A. flavus* are not conducive to identifying the specific components or metabolites that directly affect aflatoxin biosynthesis. Moreover, after twenty years of research in this area, no valuable sources of resistance have been found, particularly in the groundnut germplasm. Since conventional breeding methods for controlling aflatoxin are partially effective, novel biotechnology methods are needed to develop preharvest host-plant resistance to aflatoxin accumulation. This research concerns improving knowledge on: (1) the fundamental biological mechanisms that regulate aflatoxin biosynthesis by the fungus; and (2) the host-plant resistance factors to aflatoxin accumulation.

The state of knowledge on biotechnological strategies will be analyzed at the following three levels: fungal, host-plant resistance, and effects of environmental factors (drought stress).

Fungal level

Gene manipulations are used for monitoring the molecular regulation of aflatoxin within the fungus. The successful cloning of genes involved in aflatoxin biosynthesis will lead to their use as "molecular tools" for identifying agents and compounds that may naturally inhibit the aflatoxin biosynthetic pathway and genes. The main results concern the mapping of a single 75 kilobase gene cluster, upon which reside several genes governing the aflatoxin biosynthetic pathway, and promoter-reporter gene technologies used in maize. On this species, gene constructions linking the *Ver 1* gene, which is an aflatoxin biosynthesis gene, to the reporter gene GUS were used to measure aflatoxin related gene expression and A *flavus-GUS* transformants were successfully used for assessing fungal growth and the degree of fungal infection in maize kernels.

1. CIRAD, CERAAS-CORAF, BP 3320 Thies-Escale, Thies, Senegal.

Host-plant resistance

Molecular markers

Molecular marker assays have detected little variation at the nucleic acid level, even though cultivated groundnut varieties show considerable variation in agronomic and morphological traits. Preliminary attempts to associate seed storage protein markers showing different electrophoretic profiles, with recognized aflatoxin resistance, have been unsuccessful. Groundnut marker assisted selection appears, therefore, to be a limited method especially in case of breeding for resistance to aflatoxin where there are no clear differences between resistant and susceptible genotypes. Another approach based on a better knowledge of biochemical mechanisms developed in response to the fungal infection and environmental change is being developed. The first step consists in establishing the identity of plant mechanisms that inhibit aflatoxin formation in groundnut. This is followed by research on the enhanced host-plant resistance by incorporating specific antifungal genes into plant varieties through genetic engineering. The existence of various methods for the transformation and regeneration of fertile plants render this approach realistic for groundnut.

Candidate gene for antifungal enzymes in groundnut

Groundnut produces stilbene phytoalexin in response to fungal infection. The gene encoding the stilbene synthase, which is a key enzyme in stilbene biosynthesis, was successfully expressed in tobacco. It is postulated that enhancing the production of stilbenes in groundnut seeds by gene transfer makes them less prone to fungal infection.

The lipoxigenase enzymes (LOXs), recently characterized and cloned, are suspected of playing an important role in the *Aspergillus*/seed interaction. *Pn* LOXI *(Pn* for peanut) expression in groundnut cotyledon infected by *A. flavus* leads to a differential pattern of hydroperoxy linoleic acid, primary product of LOXs. Thus the study of LOXs expression might provide some support to screen genotypes.

Environmental factors: drought effects on maturation process and cell membrane stability

Drought has a strong effect on the biocompetitive (phytoalexins, antifungal protein) or protective compounds (phenols), which influence the growth of

A. flavus and aflatoxin synthesis. It also prevents proper maturation of groundnut seeds. Aflatoxin contamination decreases in seeds which are mature when harvested. As the moisture content in groundnut seed decreased during drought the capacity of the seed to produce phytoalexin decreased; resulting in fungal activity and aflatoxin contamination.

Due to their free-radical nature, fatty acid hydroperoxides and primary products of LOXs are capable of producing membrane damage and promoting cell death. PnLOXI gene being constitutively expressed in immature cotyledon, its activity is probably required for proper maturation of groundnut. Interestingly, some of the enzymes involved in the responses to fungal attacks such as chitinases, osmotins, peroxidases, and proteases are also involved in drought stress response through cell membrane-mediated mechanisms. Then, it is assumed that examining enzyme role and function, through cloning enzymes involved in cell membrane stability under infestation associated to drought controlled conditions, could lead to the detection of useful variations between genotypes, and provide molecular tools for selection of resistant lines.

Methods for Aflatoxin Detection in Research

David M Wilson[1]

The major constraint to successful research progress on reducing aflatoxin contamination in the field and marketplace worldwide on all crops is the cost and difficulty of aflatoxin measurement. There is a critical need for an easy and inexpensive screening method for aflatoxin content in research efforts. There has been relatively little effort put into simplified methods suitable for field work in the last 10 years. Since Charles Holiday retired from the United States Department of Agriculture (USDA) National Peanut Laboratory, Tifton, Georgia, USA and the advent of commercial aflatoxin products, there have been no concerted efforts to develop simple, inexpensive, and effective screening methods for aflatoxin determinations in groundnut. The method developed by Davis, Guy, and Deiner at Auburn University, USA led to the use of bromine or iodine in many HPLC and immunochemical methods that are currently used for quantitative analysis of aflatoxins, but no one has ever followed up their work to develop a screening method. There are also several other screening methods that show promise and need to be fully developed. The knowledge base for such methods exists. But the. problem is how to develop a simple, cost-effective screening method that can be used in field research programs in aflatoxin management.

The USDA, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), universities, and several commercial concerns have developed immunochemical methods such as enzyme-linked immunosorbent assay (ELISA) for aflatoxin measurement but this approach is limited by equipment and expertise in most cases. Other immunochemical methods are more labor intensive and not well suited for large numbers of samples because of cost factors. The University of Georgia, Tifton has made progress in developing a simplified HPLC method that requires no cleanup, but the HPLC needs to be maintained to keep operational. Binding the toxin on a matrix and shipping the material to a laboratory that can perform the analysis by TLC, HPLC, or immunochemical methods is another possible

1. Department of Plant Pathology, University of Georgia, Coastal Plain Experimental Staion, PO Box 748, Tifton, GA 31793, USA.

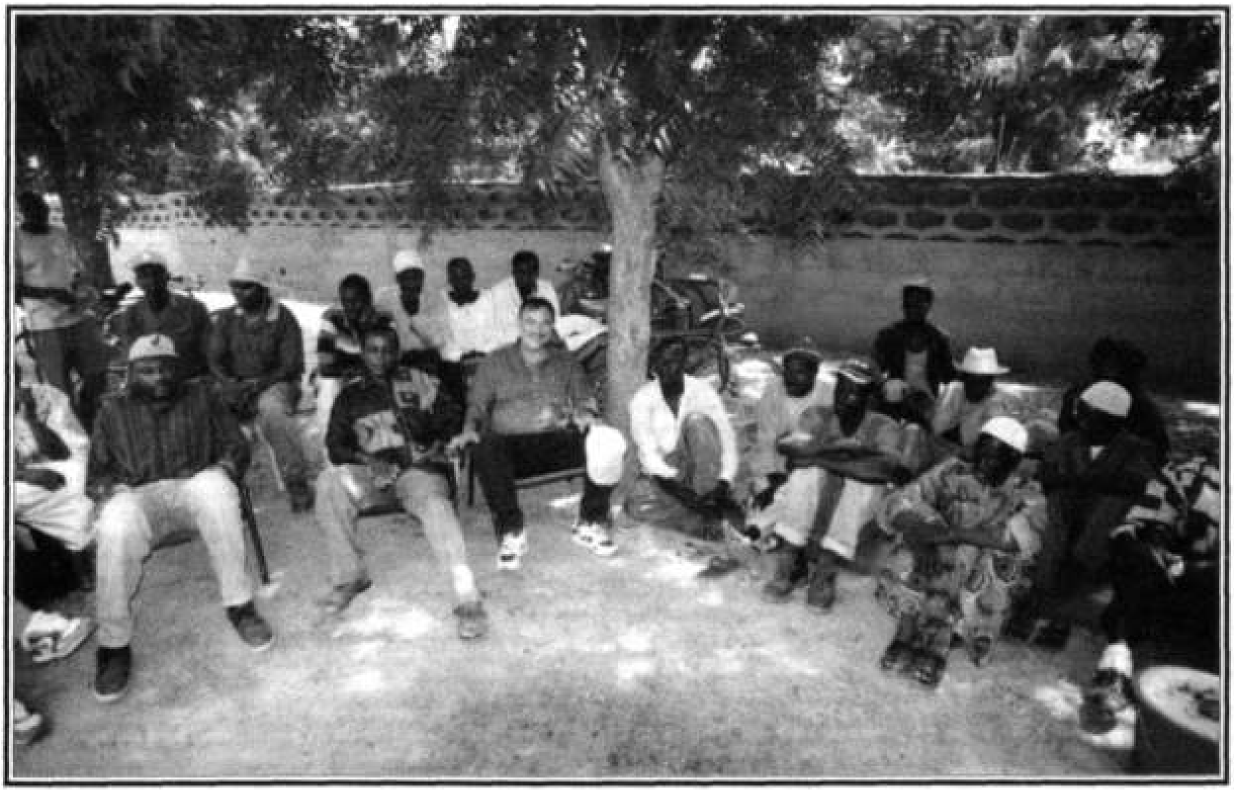
approach. The challenge is to optimize the methodology and to minimize the costs. Therefore, a major research thrust should be to develop such a screening method that can be used by any research scientist who will have confidence in the results.

In the last two years Dr Wellington Mubatanhema in our laboratory at Tifton has developed a simplified HPLC method for maize and groundnut, as part of his postdoctoral work supported by the USDA and the Peanut Collaborative Research Support Program (CRSP). We had the opportunity this year to test the method using groundnut samples from the genetic screening program of Dr Corley Holbrook, USDA-ARS, Tifton. Briefly, Dr Holbrook uses the Vicam column and a fluorometer to read the aflatoxin B_1 + B_2 content. Dr Holbrook uses Aflatest B columns that only recognize aflatoxin B_1 and B_2 and do not see the G aflatoxins because the antibody has no affinity for the G aflatoxins. The method uses an average of 1.7 Vicam columns per test giving a recurring cost of about US$ 8.47 per sample for Vicam columns alone. Dr Mubatanhema used the same extraction, filtration, and dilution procedures that are in the Vicam extraction but he collected the extracts rather than running them through the Vicam column. The extracts were injected directly into the HPLC using a pre-column to guard the analytical column and the aflatoxins were separated on a C18 column. There were linear results from about 7 ppb total aflatoxins to over 50,000 ppb in maize and groundnut; the detection limit with this HPLC method was about 5 ppb total aflatoxins. If a lower detection limit is needed then one has to use existing verified methods for these samples. There is presently no suitable screening method for research on aflatoxin contamination of groundnut that is not excessively expensive because of material and labor costs. This kind of research is not a high technology approach; it is an attempt to control costs and improve efficiency in data collection. The method needs to be accurate from zero to 50,000 ppb of aflatoxins, but it does not necessarily have to indicate the small differences between 2 and 10 or 20 ppb of aflatoxins as would be required in a regulatory method. The intent of a screening method is to give a field researcher the ability to tell the difference between the high risk components and the low risk components of the management, environmental, or genetic factors that are important to the project. Once the broad separations are made then other methods that are more sensitive will be appropriate. Right now we have very sensitive methods that were developed for regulatory purposes and are not well suited to field research.

Hence, we have to incur very high cost for aflatoxin analysis and the relevant data is often not collected because of the cost factors.

Developing inexpensive efficient chemical and fungal screening methods will not solve the aflatoxin problem, but useful methods that can be used by any investigator will give us the opportunity to generate the relevant data to understand the problem. Then we can use this information to recommend management approaches in groundnut production and utilization that will actually help minimize aflatoxin contamination.

Session 5: General



West Africa and Groundnuts in the Millennium: A Peanut CRSP Perspective

J H Williams[1]

Research is undertaken to achieve a defined goal. If our goal was scientific progress we can point to many achievements and accomplishments. However, if our goal was the establishment of a vibrant groundnut industry in the region we can be less comfortable with the achievements to date. Looking into the future we need to address the reasons for less than desired progress and make amendments in what we do.

With a wide array of technical progress on the problem of aflatoxin we still find that aflatoxin is a major constraint to large-scale development in the region. Despite knowing what determines and influence aflatoxin contamination we find that most of the population is exposed to aflatoxins. About 33% of the population is exposed to levels that affect their general health. It is an urgent requirement to integrate and deploy all the available information and technologies. We need to examine the economics of this problem because it seems clear that they are not fully understood by the governments. This should be a priority for the scientists of the region, but they need to associate with those interested in the medical and public health areas.

Productivity of groundnut is less than half of the potential yield, despite a wide and impressive array of technologies that the scientists of the region have developed. Despite scientific progress yields are generally declining and we need to ask and answer hard questions if investments in agricultural research are to continue. We will also address labor as an issue in production. This is important because HIV will change labor availability and technologies appropriate for the future may be critical. It seems that the problems of technology adoption lie in the areas of policy, demand, social issues, and scale of operation. If we have little prospect of impact then research investments should stop.

We believe that new production technologies will only be adopted if they are sufficiently profitable to the justifiably sceptical farmers. One way to increase profitability to the farmer is to increase the demand by the

1. Peanut Collaborative Research Support Program, 1109 Experiment Street, Griffin, GA 30223, USA.

processors. We need to work with anyone of any scale who can create that demand. This means focusing on groundnut as a food and ingredient for higher valued products.

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Development of High Protein Weaning Food by Extrusion Cooking Using Groundnut, Maize, and Soybean

W A Plahar[1], C K Gyato[1], and B Onuma Okezie[2]

A standardized extrusion cooking process was developed for the production of high protein weaning food based on groundnut, maize, and soybean. Major factors considered and evaluated in the product development process include the effects of blend formulation, extrusion temperature, and feed moisture content on ease of extrusion and product quality characteristics. The results showed that bulk density and hardness increased while expansion index decreased with increase in feed moisture content. At a fixed range of feed moisture content, however, product bulk density and firmness decreased while expansion index increased with increasing extrusion temperature. For ease of extrusion and best product quality in terms of sensory attributes and cooking properties, the following extrusion parameters were established for a blend formulation of 75% maize, 10% groundnut, and 15% soybean: feed particle size of 300-400 µm extruded using a screw speed of 500 rpm, with a feed rate of *4.6* kg min^{-1}, feed moisture content of 16-18%, and extrusion temperature of 100-105°C. Pair-wise comparison of the sensory attributes of porridges prepared from milled samples of the weaning foods showed detectable differences between the extruded products and the existing traditional counterparts, with very high scores for all the sensory attributes of the extruded products, especially the extruded raw (non-roasted) blend samples. In the Home-Use-Test, at least 92% respondents in two of the three major ecological zones of Ghana placed the overall sensory and functional characteristics of the extruded raw blend samples at 'highly acceptable'. The remaining 7% scored the sensory and functional quality attributes as 'acceptable'.

1. Food Research Institute, PO Box M20, Accra, Ghana.
2. Alabama A&M University, PO Box 1177, Normal, AL 35762, USA.

Nutritional Quality and Storage Stability of Extruded Weaning Food Based on Groundnut, Maize, and Soybean

W A Plahar[1], N T Annan[1], and B Onuma Okezie[2]

Samples of extruded high protein weaning foods were produced using a blend of groundnut, maize, and soybean to achieve the desired level of protein. Two sets of extruded products, based on a raw and a pre-roasted mix of ingredients were developed and characterized in terms of the hot paste viscosity characteristics, chemical and nutritional quality, amino acid composition, and storage stability. A comparative evaluation of the extruded products was undertaken in relation to two similar existing products: the traditional roasted maize flour weaning food, and the commercial product. In general, the extruded products had better nutritional quality than the traditional product as indicated by the high protein content and quality, and excellent rat growth response. For both types of extruded weaning foods developed, 60- to 100-fold increase in mean weight gain was recorded over the traditional sample. Correspondingly, the PER values of 2.3-2.5 were almost thrice the values obtained for the existing products. Significantly higher feed efficiency ratios were also obtained for the extruded products. Hematological data of test animals showed normal values of white blood cell (WBC) count, red blood cell (RBC) count, hemoglobin (Hb) levels, and packed cell volume (PCV) for all the weaning foods studied, except the existing traditional roasted maize flour. In terms of storage stability of the extruded products, predicted shelf life of 7.8-10.4 months was obtained for the extruded raw blend, and 5.6-7.1 months for the extruded pre-roasted blend when stored at the average ambient temperature of about 30°C in Ghana. In general, the pre-roasting treatment was found to reduce the quality characteristics of the eytruded product.

1. Food Research Institute, PO Box M20, Accra, Ghana.
2. Alabama A&M University, PO Box 1177, Normal, AL 35762, USA.

Elements for a Reinforcement Project of Groundnut Seed Production in West and Central Africa

R Schilling[1]

Seed production systems: enquiry

The FAO/CORAP enquiry led to the following report:

- Voluminous groundnut seed, large and small with a low multiplication rate
- Low financial income from the crop = low request for certified seed
- Technical reference is insufficient; not much effort to improve the seed quality at postharvest level by farmers
- Seed production policies are not applied much or/and disparate
- Seed local capital is insufficient, mainly given by informal sector
- Institutional system is not very efficient = lack of foundation seed and coordination of supply and demand

Assessment of the seed production situation: operating consequences

Analysis of past experiences:

- Short-term project without durable effect
- Durable project characterized by:
  - Precise genealogical multiplication diagram
  - Centralized management of first generation and control function
  - Steady follow-up of first level seed (10% of the capital)
  - Seed leasing by cash sale or credit with reimbursement in kind or cash with interest

Competent and viable trader insertion in this system is not yet defined in the countries that started this change.

1. CIRAD-CA, Agronome Programme Cultures Alimentaires, TA70/01 34398 Montpellier, France,

Guidance proposals for a regional seed organization

- Reinforce varietal improvement national program and creation of regional program for common interest
- Standardization and uniformity of policies, procedures, legislation, and seed terminology
- Conservation and characterization of germplasm regional assembly
- Temporary maintenance of a multiplication foundation seed device to contribute to national program
- Maintenance of training, information, and technical support programs initiated by the Groundnut Germplasm Project (GGP) extended to seed sector
- Institutional support for a study on private trading sector and socio-economic constraints

For the seed production option, GGP experience and knowledge constitute an essential basis but still weak for downstream work to reach the ultimate objective: to make the required quality and quantity of groundnut seeds available to the small producers in Africa. This objective was established when GGP was initiated. Now, it is a matter of specifying the technical basis of an operation to be able to achieve it.

Experience of acquisition and the enquiry teaching led to the following fundamental guidance proposals, from which any groundnut seed production reorganization action in West and Central Africa should be inspired:

- Perpetuate and strengthen GGP acquisition.
- Establish, within national structures, a seed cell responsible for the contact between authorities and local operators, first, and also with the regional level (GGP).
- Global seed objective: Need of seed (survey of 14 countries) is around 600,000 t per year. It is accepted that a renewal by third of this capital, 200,000 t (level 2), is necessary to maintain the sowing capacity and ensure an appreciable productivity improvement. The last generation, leading to 200,000 t from 20,000 t, will be created either directly by farmers themselves from "mini-doses" used for sowing individual fields, either by cooperative management of their own seed production or by following local modalities which have to be defined.
- Devote important measures to level one (20,000 t) and involve private

professionals. In all scenarios, institutional sector will be limited in its actions to the key fields of foundation seed and controls. Quality norms will be established in function of users' technical level and investment capacity; norms would not have the effect, with the intention to follow international quality level, of imposing leasing price that would place certified seed out of reach of the small producer.

- Give responsibilities and strength to farmers' sector, which is in charge of level 2. This sector, called "informal", will take on the essential groundnut seed production. Progress will thus be made through this action of giving responsibilities and strength to the farmers' organization.
- Genealogical multiplication diagram and strategic stock central control.

Groundnut Germplasm Project (GGP)

A Working Group (WG) was constituted by the Groundnut Germplasm Project (GGP) under the guidance of CORAF with the following objectives:

- To exploit the results from the survey of the regional groundnut seed systems (1999);
- To continue the research work;
- To identify a plan of action for consolidating the GGP achievements; and
- To identify solutions to the constraints of groundnut seed sector.

The mandate of the WG was confirmed by the GGP Steering Committee in July 2000 and was approved by the FAO.

After a brief presentation of the objectives of the GGP and the reasons for constitution of the WG, two documents were presented during the Workshop. They were addressed to NARS of the groundnut-growing countries from the sub-region and to the institution member of GGP. This constitutes the first contribution of the WG and the mission allocated to them.

- The first document presents the GGP achievements from the start of the project and make the proposition for the actions to be taken on a continuous basis and consolidate the achievements which could constitute the scientific base for the backstopping of the operation for the seed production.
- The second document makes an exhaustive analysis of the information assembled during the regional survey of seed system. It also presents a typology of different situations and elaborates the technical basis for seed multiplication and distribution to farmers.

Groundnut Germplasm Project for West Africa: A Framework for a Follow-up

B R Ntare, A Mayeux, and J Ndjeunga[1]

The groundnut germplasm project (GGP) was initiated in 1996 and will end in June 2002 after an extension of one year at no cost. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is the Project Executing Agency (PEA) in partnership with CIRAD and ISRA. The Common Fund for Commodities (CFC) through the Food and Agricultural Organization's Intergovernmental Group on Oilseeds, Oils and Fats (IGG/OOF) provided the grant. The goal is to enhance the productivity of groundnut and the sustainability of production systems in the West African region through provision of quality seed.

Accomplishments

The GGP has addressed groundnut production sustainability and biodiversity in the broad sense through project components consisting of germplasm assembly, maintenance and conservation, characterization of germplasm for traits of economic importance, germplasm distribution and exchange, foundation seed production, training and information dissemination. The project components addressed are of regional and/or global relevance.

Germplasm assembly and conservation

A short- and medium-term regional gene bank containing 6000 groundnut accessions has been established. A quarter of the accessions are from West African countries. Seed can be stored for up to 10 years without loss of viability, seedling vigor, or genetic integrity. In the short term, NARS can use this gene bank to duplicate their unique germplasm. There are opportunities for repatriation of groundnut germplasm to countries in the region on request.

1. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), BP 320 Bamako, Mali.

Germplasm *characterization*

The assembled germplasm has been characterized for the most important botanic and other agronomic traits. The data has been compiled in a catalog (Part I and II). In-country characterization and evaluation has been done in Nigeria, Mali, Burkina Faso, and Senegal and corresponding databases developed. Simplified groundnut descriptors have been compiled in a handbook and distributed to NARS in the region.

Germplasm evaluation

Germplasm has been screened for resistance to groundnut rosette disease. Seventy germplasm and over 100 breeding lines in various maturity groups with resistance to rosette were identified. Promising lines are being tested in regional adaptation nurseries and on-farm trials. The Institute of Agricultural Research (IAR), Nigeria has become a lead center for screening and breeding for resistance to groundnut rosette virus (GRV) in the region.

Peanut clump virus is soilborne as well as seedborne and is widespread in West Africa. The disease has implications in germplasm movement and exchange in the region. Germplasm and breeding lines are monitored for the occurrence of any seed transmitted viruses to ensure production and distribution of virus free seeds.

Among foliar diseases, early and late leaf spots and rust are the most important. Thirteen and 21 stable sources of resistance have been identified for early and late leaf spots, respectively. Over 80 sources of resistance to rust were identified. Agronomically acceptable lines are being evaluated in regional on-station and on-farm trials in several countries in the region.

Work on Aflatoxin contamination concentrated on screening varieties and germplasm. A number of lines resistant to *A. flavus* and aflatoxin contamination have been identified and promising lines evaluated in regional trials.

Drought is an important factor limiting groundnut production in the region. Work conducted by ICRISAT and CIRAD in association with ISRA/CERAAS has resulted in varieties, which produce reasonable yield at dry sites in the region.

Crop diversification in irrigated area offers an opportunity for irrigated edible groundnuts, which results in excellent quality harvest. A number of promising varieties developed by ICRISAT and ISRA are being tested in regional trials.

Distribution and exchange of germplasm

Seed requests have been met wherever seed quantities are permitted. Rejuvenation standards have been applied to ensure production of good quality seed for distribution and also help avoid genetic shifts that may be caused by selection pressure imposed during crop growth. Technical aspects of quarantine procedures have been documented in consultation with NARS partners. General principles and procedures in germplasm transfer and exchange have been established.

Foundation seed multiplication

A 4-ha farm was developed at ISRA, Bambey, Senegal with appropriate facilities (irrigation, seed processing, storage, etc). The most frequently requested elite breeding lines were also multiplied. The project has assisted NARS to improve production of breeder and foundation seed. An alternative conservation method under modified atmosphere was developed. A regional review of groundnut seed production systems in West Africa found that limited availability of good quality seed of appropriate varieties for planting remains a major constraint to groundnut productivity in the region.

Training

The project has endeavored, wherever possible, to strengthen the capability of national programs in their task of genetic resources conservation and groundnut production in general. A number of workshops and training courses have been held to foster interaction between NARS scientists and to upgrade skills in a number of aspects of groundnut research and development.

Information dissemination

Project results have been published in annual reports, newsletters, catalogs, training manuals and electronic media. Project staff shared their achievements with their colleagues at regional and international conferences.

What needs to continue

Germplasm maintenance and conservation

Most national programs in the region still lack basic germplasm conservation facilities and have limited communication and documentation systems. The distribution of germplasm remains to be of paramount importance and may be attributed to conservation of the collections. The objective is thus to further strengthen conservation and utilization of groundnut genetic resources. One of the activities that could impact on ex-situ conservation of groundnut in West Africa is the search for an alternative to cold storage. Cold storage is considered to be the best conservation method; but it requires high investment and operational costs. This has significant implications for development. The expected outputs are:

- Safe and cost-effective ex-situ conservation of groundnut diversity.
- Evaluation of the impact of adoption of new varieties on biodiversity.
- Development of alternative low cost effective conservation methods.

Germplasm distribution

A working collection has been established at the regional level to reinforce and secure groundnut biodiversity. An appropriate system must be developed and maintained to facilitate access and distribution of germplasm to all stakeholders. The expected outputs are:

- Easy access to regional collection.
- Distribution of pest-free germplasm.

Variety promotion and demand assessment

A number of varieties have been screened and proven tolerant or resistant to foliar diseases, groundnut rosette, aflatoxin contamination, and drought. Varieties suitable to the confectionery market have also been identified. However, a range of constraints still remains unresolved. The project will build on gained experiences and those of other projects already in the region to increase farmer income through uptake of improved groundnut varieties.

The expected outputs are:

- Promotion of identified groundnut varieties with traits acceptable to farmers and processors using participatory procedures.

- Assessment of the medium-term demand for confectionery versus oil extraction, dual-purpose groundnut, etc. in rural communities of West Africa.
- Assessment of acceptability of new groundnut varieties, evaluation of constraints to broader adoption, and identification of options for resolving the constraints.
- Reliable mechanisms for developing, on a regular basis, new superior varieties that are required for introduction into national seed multiplication systems at frequent intervals.

Seed multiplication, distribution, and storage

The supply of improved seed in most West African countries remains insufficient. Therefore there is a need to strengthen the national seed systems to ensure that different categories of stakeholders have access to good quality breeder and foundation seeds in adequate quantities, at the right time and places and at affordable prices.

The expected outputs are:

- Opportunities for improving the efficiency of breeder and foundation seed production and distribution.
- Examination of the structure - of incentives for the production and distribution of groundnut seed. Assessment of the relative roles of public and non-governmental organizations and private seed production and distribution channels.
- Diagnosis of groundnut-marketing problems and identification of options for resolution.
- Adoption of appropriate pricing policies for breeder, foundation, and certified seed aimed at sustainability of seed industry.
- Development of private sector enterprises into small-, medium-, and large-scale seed ventures.
- Dependable contract growers with entrepreneurial skills developed.
- Maintenance of high quality standards for all classes of seed through quality control and certification program.
- Improvement of various facets of seed production (processing and quality control).
- Institutional reforms leading to changes in the roles and responsibilities of the public sector, accelerating development of the seed programs, pricing of seeds, improving the effectiveness of seed certification, and quality control operations.
- Seed security stocks.

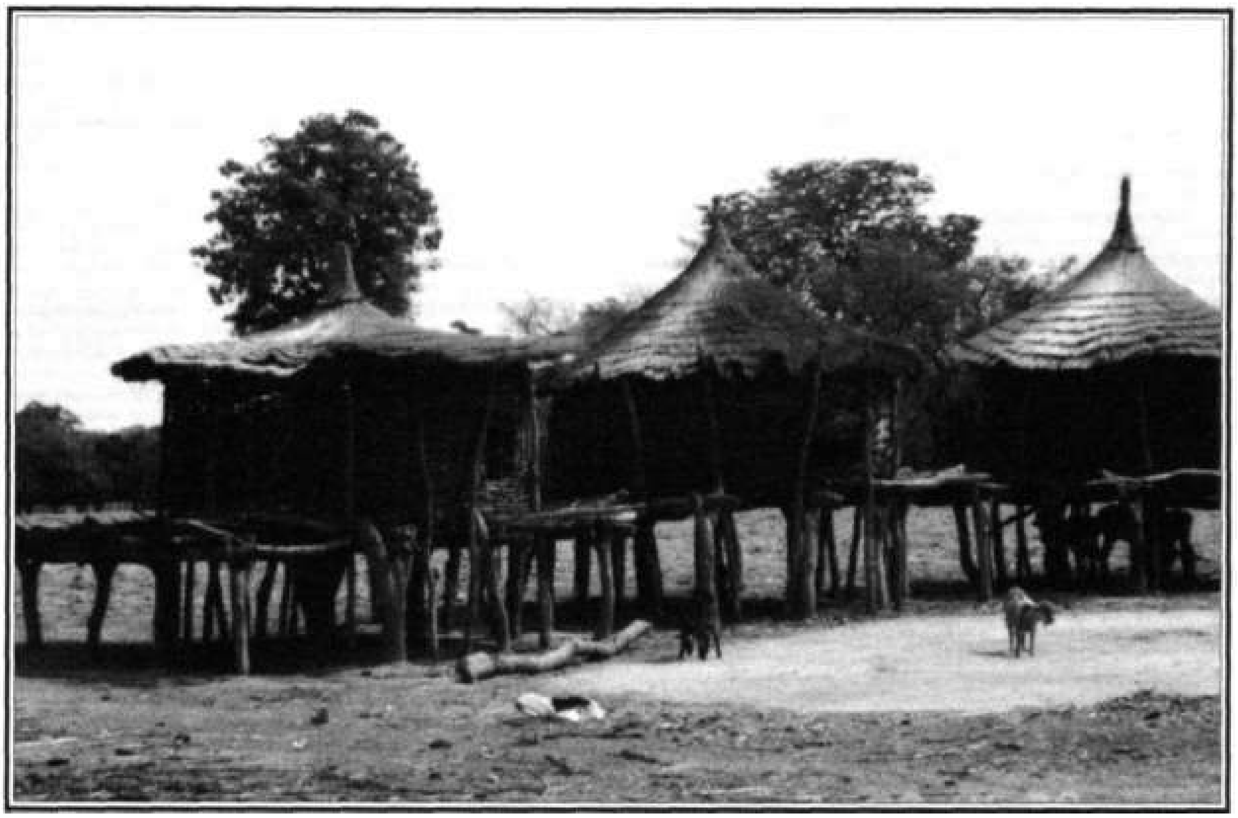
Documentation and information dissemination

Accessibility to information is still a major problem in NARS of West Africa. There is still a need to develop efficient documentation of information at NARS level in the form of databases such as prices, markets, seed laws, quarantine, intellectual property rights, input delivery systems, product quality, etc. These need to be disseminated widely.

The expected outputs are:

- Technical manuals and bulletins
- Newsletter
- Variety catalog and maps
- Targeted workshops
- Public awareness brochures

Clossing Session



Closing Remarks

G Agbahunga[1]

Dr Farid Waliyar, Representative of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); Dr Williams, Director of Peanut Collaborative Research Support Program (CRSP); scientists from other national agricultural research systems (NARS); ladies and gentlemen!

You have been examining for three consecutive days, the major constraints to groundnut production in West and Central Africa in the light of the research activities carried out. You have particularly been concerned with the problems of production of improved seed. The aflatoxin problems which represent a particular threat to production have been strongly highlighted.

Moreover, on opening the workshop on Wednesday, 6 December 2000, the Permanent Secretary of the Minister of Rural Development of Benin, who stood in for the latter, presented to you the actual situation of groundnut sector in Benin and in the sub-region. He highlighted the expectations of Benin and also those of the entire sub-region. As far as agronomic research is concerned, the need to focus on impacts was highlighted as absolute necessity for scientists to meet the requirements of partners and decisions makers.

I have listened attentively to your rapporteur as well as the recommendations made by your workshop.

I can assure you that our hopes are filled. It is therefore my duty to forward to the Benin authority the recommendations and proposals addressed to them. These proposals will inform decisions on capacity building of the NARS and the support for the regional program. I can but highlight, at this juncture, the atmosphere of frank collaboration which prevailed throughout the Cotonou meeting, thus displaying the spirit of harmonious complementarity among the NARSs and international agricultural research centers (IARCs), with particular reference to ICRISAT, as well as regional and bilateral cooperation between countries and cooperation with universities of the North.

I cannot conclude this intervention without thanking ICRISAT, Peanut CRSP, CORAF, Sasakawa-Global 2000 and all the other partners who contributed effectively to the organization of the Cotonou workshop, which has been quite successful.

1. Representative of the Director General of INRAB, BP 884 Cotonou, Benin.

I would also like to commend the joint effort by ICRISAT and INRAB in organizing this workshop - an effort that has proved to be a success and I congratulate all the members of this team.

My special thanks go to Dr Farid Waliyar of ICRISAT. We have been told that he is the architect of this regional workshop on groundnut.

I thank the International Institute of Tropical Agriculture (IITA) for providing this workshop with interpretation services.

My thanks also to all the participants who have come from far away places (Africa, Europe, and United States) as well as the local participants.

While wishing you safe journey back to your respective countries, I, on behalf of Benin, declare the Seventh Regional Workshop on Groundnut for West and Central Africa closed.

Thank you.

Recommendations

Recommendations

Special Session on Aflatoxin

The following recommendations were made during the session:

- In view of the complex nature of the subject it is henceforth necessary to adopt an integrated approach involving all the sectors engaged in ensuring food safety, with reference to aflatoxin (research, health, trade, economy).
- There are a lot of sectoral technical results; it is, however, necessary to group them together under a global model for management of contamination of groundnut by aflatoxin.
- Greater importance should be given to socioeconomic studies related to aflatoxin contamination, research on market development, economic cost of aflatoxin, etc.
- A strategic plan should be prepared taking into account all aspects of research, marketing, health extension work, etc. This plan is expected to serve as a basis for integration of research activities and search for new financing sources for the latter.

Recommendations

- All means available should be used to promote groundnut within the economies of countries in the region.
- Value adding opportunities need to be identified and developed to create better returns to farmers.
- Emphasis should be on groundnut as a food source rather than oil because of other competing vegetable oil sources (soybean, sunflower, and cotton).
- Groundnut is a source of essential nutrients and plays a significant role in reducing obesity problems.
- Market development is a fundamental requirement for promotion of groundnut.
- There is a need for a coordinated approach to groundnut research and development in the region.

Participants

Benin

J Detongnon
Director General
INRAB
BP 884 Cotonou
Tel: (229) 30 02 64
Fax: (229) 30 37 70
E-mail: inrabdg4@bow.intnet.bj

M Adomou
Responsable Programme Arachide
Direction Scientifique
INRAB
BP 884 Cotonou
Tel: (229) 30 02 64
Fax: (229) 30 37 70
E-mail: madomou@yahoo.com

Burkina Faso

Sankara Philippe
Universite de Ouagadougou
03 BP 7021 Ouagadougou
Tel: (226)36 48 60/21 15 97
Fax: (226) 30 72 42
E-mail: sankph@fast.univ-ouaga.bf

Cameroon

Thomas Mekontchou
Selectionneur
IRAD
BP 163 Foumbot
Tel: (237)44 58 14/44 22 27

France

R Schilling
CIRAD-CA
Agronome Programme Cultures Alimentaires
TA70/01 34398 Montpellier
Tel: 04 67 61 58 78
Fax: 04 67 61 56 93
E-mail: robert.schilling@cirad.fr

Ghana

P G Lokko
Senior Scientific Officer
Food Research Institute
PO Box M20
Accra
Tel: (233) 50 28 84
Fax: (233) 50 28 84
E-mail: plollo@libr.ug.edu.gh

W A Plahar
Director/Chief Research Scientist
Food Research Institute
PO Box M20
Accra
Tel: (233)21 777 330/761209
Fax: (233) 21 777 647
E-mail: fri@ghana.com

F K Tsigbey
Pathologist
SARI
PO Box 52
Nyankpala-Tamale
Tel: (233)7122 411
Fax: (233) 71 23 483

India

H D Upadhyaya
ICRISAT
Patancheru 502 324, Andhra Pradesh
Tel: 91 40 329 6161
E-mail: h.upadhyaya@cgiar.org

Mali

Bamory Diarra
Chef de Laboratoire Biochimie
IER
BP 262 Sotuba, Bamako
Tel: (223) 24 24 49

J Ndjeunga
Agricultural Economist
ICRISAT
BP 320 Bamako
Tel: (223) 22 33 75
Fax: (223) 22 86 83
E-mail: j.ndjeunga@icrisatml.org

B R Ntare
Selectionneur/Principal Scientist
ICRISAT
BP 320 Bamako
Tel: (223) 22 33 75
Fax: (223) 22 86 83
E-mail: b.ntare@icrisatml.org

Kodio Ondie
Chef Programme Arachide
CRRA
BP 281
Kayes
Tel: (223) 252 2005
Fax: (223) 252 2005
E-mail: CRRA.kayes@ier.ml

R Tabo
Groundnut Phytopathologist
ICRISAT
BP 320 Bamako

A Traore
Scientific Officer
ICRISAT
BP 320 Bamako
Tel: (223) 22 33 75
Fax: (223) 22 86 83
E-mail: a.traore@icrisatml.org

F Waliyar
Groundnut Phytopathologist
ICRISAT
BP 320 Bamako
Tel: (223) 22 33 75
Fax: (223) 22 86 83
E-mail: f.waliyar@icrisatml.org

Mauritania

Sidi-R'chid
Agronomist
CNRADA
BP 22 Kaedi
Tel: (222) 535 378
Fax: (222) 535 377
E-mail: cnrada@opt.mr

Nigeria

Cheick Dia
Interprete
IITA
OYO Road
Ibadan
Tel: (234) 2 241 2626
E-mail: c.dia@cgiar.org

V C Umeh
Entomologist
National Horticultural Research Institute
PMB 5432, Idi-Ishin
Jericho Reservation Area
Ibadan
Email: emnumea@skannet.com

Senegal

Arthur Dasylv
Production Semence
ISRA/CNRA
Chef Service Production Semences
BP 53 Bambey
Tel: (221) 973 63 36
Fax: (221) 973 63 37
E-mail: upse@telecomplus.sn

Daniele Clavel
Selection arachide
CIRAD
CERAAS-CORAF
BP 3320 Thies-Escale, Thies
Tel: (221) 951 49 93
Fax: (221) 951 49 95
E-mail: clavel@cirad.fr
ceraas@sentoo.sn

Hanne Lamine
Free-lance
Communication/Interprete
BP 6482 Dakar Etoile
Tel: (221)820 43 37/638 82 81
E-mail: hannelamine@hotmail.com
lhanne@telecomplus. sn

A Mayeux
Genetic Resources/Project Manager
CIRAD
GGP
BP 6478 Dakar Etoile
Tel: (221) 823 9265
Fax: (221)823 9265
Email: mayeux@sonatel.sn

Ousmane Ndoye
Selection/Chercheur
ISRA-CNRA
BP 53 Bambey
Tel: (221) 973 60 50
Fax: (221) 973 63 48
E-mail: ousndoye@syfed.refer.sn

M Sene
ISRA
BP 53 Bambey
Tel: (221 973 63 48
Fax: (221) 973 63 48
E-mail: modousen@refer.sn

Sierra Leone

M T Moseray
IAR
PMB 540, Freetown

Togo

N Bitignime
Agronome/Chef Programme
ITRA/CRA-SH
Legumineuses a Graines
BP 88 Sotouboua
Tel: (228) 53 00 32
Fax: (228) 53 00 32

UK

F M Kimmins
Entomologist/Deputy Manager
Crop Protection Programme
MR International
Pembroke Chatham Maritime
Chatham, Kent
Tel: 01634 883306
E-mail: F.M.KIMMINS@GRE.AC.UK

USA

C Corley Holbrook
Research Geneticist
USDA-ARS
PO Box 748
Costal Plain Experimental Station
Tifton, GA 31793
Tel: 912-386 3176
Fax: 912-386 3437
E-mail:
holbrook®tifton. cpes.peachnut. edu

Curtis Jolly
Agro-Economist, Professor/Researcher
Department of Agricultural Economics
Auburn University
AL 36830
Tel: 334 884 5613
Fax: 334 844 5639
E-mail: ejolly@acesag.auburn.edu

David M Wilson
Mycotoxin/Professor
Department of Plant Pathology
University of Georgia
Coastal Plain Experimental Station
PO Box 748
Tifton, GA 31793
Tel: 912 384 3368
Fax: 912 386 7285
E-mail:
Dwilson@tifton .cpes. peachnet. edu

Keith T Ingram
Agronomy/Associate Professor
Department of Crop and Soil Sciences
1109 Experiment Street
Griffin, GA 30223-1797
Tel: 1 720 412 4045
Fax: 1 720 229 3215
E-mail: kingram@griffin.peachnet.edu

Mike Bertelsen
Economist
OIRD Virginia Tech.
1060 Litton Reaves Hall Blacksburg,
VA 24061-0334
Tel: (540) 231 6338
Fax: (540) 231 6741
E-mail: bertl@vt.edu

Mohamed Ahmedna
Assistant Professor
Food Science and Nutrition
171 Carver Hall
North Carolina A&T State University
Greensboro, NC 27411
Tel: 336 334 7963
Fax: 336 334 7239
E-mail: ahmedna@ncat.edu

B Onuma Okezie
Professor, Food Science/Nutrition &
Director, International Programs
Alabama A&M University
Office of International Programs
PO Box 1177
Normal, AL 35762
Tel: (256) 851 54 18
Fax: (256) 851 51 96
E.mail: Ookezie@aamu.edu

Richard Mattes
Nutrition/Professor
Purdue University
212 Stone Hall
W Lafayette, IN 47907-1264
Tel: 765 494 0662
Fax: 765 494 0416
E-mail: MATTES@CFS.PURDUE.EDU

Terry Hardt
Government Officer
USAID
Suite A-52, 1730 W Lynn St
Arlington, VA 2209
Tel: 202 712 0434
E-mail: THARDT@USAID.GOV

J H Williams
Program Director, Peanut CRSP
University of Georgia
1109 Experiment Street
Griffin, GA 30223
Tel: 770 228 7312
Fax: 770 229 3337
E-mail: crspgrf@gaes.griffin.peachnet.edu
twillia@griffin.peachnet.edu