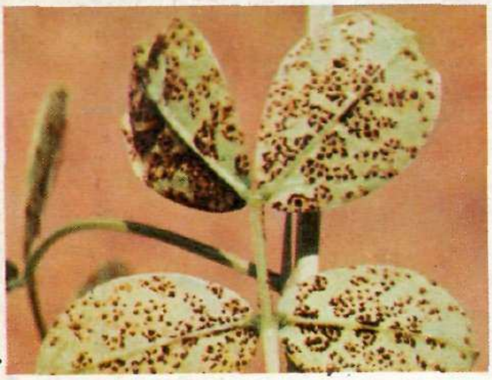
Proceedings

International Workshop on Groundnuts



International Crops Research Institute for the Semi-Arid Tropics

Proceedings of the

International Workshop on Groundnuts

ICRISAT Center
Patancheru, India
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ICRISAT Patancheru P.O.
Andhra Pradesh 502 324, India

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Workshop Coordinator
and
Scientific Editor

R. W. Gibbons

Publication Editor

J. V. Mertin

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Foreword

One of the important functions of an international research institute is the holding of workshops, conferences, and symposia where delegates from many parts of the world can meet together to discuss research problems and progress. ICRISAT has hosted many such workshops, but this is the first one that has been held solely for groundnuts.

It was an appropriate time to hold such a meeting, as our program at ICRISAT Center is almost fully staffed and we are preparing to place staff at research stations in Africa.

The research program of ICRISAT presented at the Groundnut Workshop and the deliberations and discussions thereon clearly indicate that the Institute's main lines of research, aimed at overcoming major yield-reducing constraints, are appropriate and welcome.

One area that undoubtedly needs early and more concentrated attention is drought resistance. It is alarming to hear of the devastation that has affected groundnut production and reduced the cultivated area, particularly in the drier zones of West Africa.

We are pleased that the groundnut physiology program is now under way, and we look forward to fruitful cooperation with our colleagues in national programs.

It is also pleasing to find that the Indian groundnut research program is being strengthened and that a new national center is being formed in the high production area of Gujarat State. This is very appropriate because of the large deficit of vegetable oils in India, which in turn means that precious foreign exchange has to be spent on imports despite India being the largest groundnut producer in the world.

There is undoubtedly also a pressing need in many other parts of the world to increase groundnut production and initiate more research. We believe that ICRISAT can help.

On behalf of ICRISAT I would like to thank all the delegates, many of whom travelled far to Hyderabad, for making this workshop a success.

L D. Swindale
Director General

Opening Session

Chairman: R. W. Gibbons

Welcome and Overview of ICRISAT

L. D. Swindale*

It is with very considerable pleasure that I welcome you to ICRISAT and to our first International Workshop on Groundnuts. This morning I want to give you an overview of ICRISAT and its activities. I will not deal very much with groundnuts because you are going to discuss this subject in depth over the next few days.

ICRISAT is the International Crops Research Institute for the Semi-Arid Tropics. Our logo shows that we work on cereals, and on legumes, and because we are working in the semi-arid tropics, our logo also reminds us of the importance of every drop of water, the scarcest natural resource in the region.

There are four objectives in the mandate statement of ICRISAT — (1) to serve as a world center for the improvement of the genetic potential for grain yield and quality of groundnuts, sorghum, pearl millet, pigeonpea, and chickpea; (2) todevelopfarmingsystemsto help increase and stabilize agricultural production through more effective use of natural and human resources in the semi-arid tropics; (3) to identify socioeconomic and other constraints to agricultural development in the semi-arid tropics, and to evaluate alternative means of alleviating them through technical and institutional changes; and (4), to do what we are doing today — assisting national and regional research programs through cooperation and by sponsoring conferences, operating international training programs, and assisting extension activities. These are the four objectives of the mandate statement of ICRISAT.

We generally define the semi-arid tropics (SAT) in terms of the distribution of rainfall and the potential evapotranspiration (PET) throughout the year. The rainfall tends to occur mostly in a few months of the year while the evapotranspiration exceeds rainfall for most of the year. But for a short period, long enough for cropping, the reverse is true, and rainfall exceeds PET giving us normally enough water to grow crops, and a little extra. One of the things that we are doing in ICRISAT is trying to determine if we can make good use of that little extra. The semi-arid tropics cover a very large area of the world including a large part of the African continent, most of the South Asian subcontinent, appreciable and significant areas in the Americas, other parts of Asia, and Australasia.

Much of the world production of the five ICRISAT crops is consumed as human food in the SAT. The crops are low in cash value and with one exception (groundnuts), do not enter world trade to any extent. There has been very little research in the developed countries on most of these crops, mainly because they are tropical and subtropical crops, and inadequate research in the developing countries. Fertilizer-responsive genes are yet to be discovered, particularly for the legumes. The crops are grown mostly under rainfed conditions, the yields are low and unstable, and high input technology has not yet been feasible. Very important to us is the fact that they are grown by subsistence farmers in the poorest countries of the world.

We are not discouraged by all these things because we believe that the potential for production is very high. Here at ICRISAT, under rainfed conditions, we have already obtained several times the average yields of these crops under low-input conditions, and as you know, much higher yields again are possible in more intensive agriculture. We believe the potential is there — we know the potential is there. It is our job to unlock the potential and bring it to the use of the small farmers. They have limited means and limited inputs and are without the benefits of regular regional irrigation. They constitute a particular target group for which ICRISAT has been charged to work by the Consultative Group on International Agricultural Research, which is the donor group behind us. It is our responsibility to concentrate our efforts for the benefits of this target group, but naturally we

* Director General, ICRISAT.

also work for the other producers of our crops. This is particularly true of the crop that interests you — groundnuts. The small farmer of limited means is a common sight here in India, and also in the African countries, Central America, and the other countries covered bythe ICRISAT mandate.

Although the small farmer is ourtarget group, we also have a client group, which consists of the scientists, and workers in the national research institutions, extension, and action agencies. We are an international institute, and it is not our responsibility to undertake the work of national programs of scientific research or extension. We work for and help our client group with our results so that they in turn, will help the small farmer. We fashion our products so that they will help scientists help the small farmer. That is the way in which we work.

At ICRISAT Center, our crop improvement work is conducted on two major soil types of the SAT. One is the black deep Vertisol (the black cotton soils), and the other is the red soil with a sandy top and a clay subsoil. This latter type we know as Alfisol. In Africa, however, we tend to work much more upon very sandy soils like the soils on the outskirts of Niamey in Niger where there is a little concentration of clay in the lower parts of the horizon but, for the most part, the soil is very sandy, and has a very low exchange capacity and very low nutrient status.

Regarding our programs in West Africa, we have scientists working together with national programs in Senegal, Mali, Upper Volta, Niger, Nigeria, and also in Sudan, and in East Africa. Our major effort at the present time is in Ouagadougou in Upper Volta, and we are also trying to establish a center at Niamey in Niger. At the present time, we do not have a program working on groundnuts in Africa but our donor group, the CGIAR, has agreed that we should. In the near future, this year and next year, we hope to establish an ICRISAT groundnut program in Africa, possibly in two different locations or localities, with the first one probably being in Malawi.

In carrying out our mandate for the small farmer and our client scientists, we concentrate firstly upon collecting germplasm from all over the world. We have many lines now. This has been done with the considerable help of the Indian Government quarantine services and particularly the Central Plant Protection Training Institute (CPPTI) which has undertaken the responsibility of quarantine services for material coming into India for ICRISAT and its release to us. We are interested in the highly responsive and stable high yielding varieties. We test for stability in an international network at Hissar in northern India, at ICRISAT Center, at Bhavanisagar in southern India, at Kamboinse in Upper Volta, and in the other countries that I have mentioned in West Africa.

We carry out research on diseases of our five crops and we also work upon insects including the pod borer, which is probably the worst insect pest in the tropical world. We also work upon weeds, including resistance to parasitic weeds such *as Striga* which occurs in the cereal crops both in India and Africa. This is a very serious pest of the cereal crops and there are similar parasitic pests upon groundnut and other legumes.

In addition to our work on crop improvement, we have a farming systems program and a program in socioeconomics. Trying to overcome the constraints that small farmers face is very difficult and you cannot do it if you do not know what they are. So we are undertaking a considerable program, probably the largest program in social sciences in any of the international agricultural research centers, in order to understand, quantitatively if possible, the exact reasons for the lack of development amongst this group of people in the SAT. For example, we are trying to understand at first hand why areas of Vertisols, the deep black soils, are being left fallow when there is plenty of water in the rainy season. What are the reasons that cause the farmers to do this and are they solvable by scientific research?

We have done a great deal of work in this particular field and recently we released a document summarizing our results to date on farming systems components for selected areas in India. This evidence was gained over about 8 years of work here and in conjunction with the All India Coordinated Research Projects. We can now say how to overcome many of the constraints to development in these areas, particularly in the areas with deep black soils and where the monsoon rainfall is reliable. Under these conditions we think we now have the elements, indeed most of the components, of a new farming systems technology. We are now discussing with the Indian national program the way in which this can be tested on a larger scale than we, as an international institute, are able to handle. Our new technology is based upon a watershed concept in which we try to deal with the whole watershed as a unit. It incorporates improvements in cropping systems, in land and water management, in implements, in institutions, and in human activities. All these changes are necessary in order to implement the improved technology. Fortunately, although the package is complex it is possible to implement it step by step. We have a good idea of what are the lead practices that can be relied upon to start the farmers in this process of development and then allow them to pick up other practices at later stages. Dr. Kanwar will probably discuss this with you in his paper.

I have noticed that the Groundnuts Workshop program does not include the training aspects of ICRISAT or the possibilities for training here at ICRISAT Center, so I thought I would mention this myself. There are people here, particularly from the developing countries, who might wish to see that their younger colleagues have opportunities for training here. There are also people from developed countries who might like to know that we have training programs for graduate students and postdoctoral candidates.

ICRISAT Center provides five major types of training — international internships, research fellowships, research scholarships, in-service training programs, and apprenticeships.

The international internships are for postdoctoral fellows from our donor countries to give them an opportunity to work for a while at ICRISAT in a developing country. Research fellows are M.Sc. and Ph.D. degree holders from SAT countries who work with ICRISAT scientists on specific problems for one or more years. We also have research scholars who are students of overseas universities and of universities here in India. These scholars undertake certain aspects of their research program here at ICRISAT under the guidance of an ICRISAT scientist with the cooperation of their thesis or dissertation supervisor from their own university.

Our largest training program is the in-service program. We bring in young scientists and extension workers for a very concentrated program of training, usually for one cropping season, on all aspects of how to grow a particular crop and how to conduct good field research with it. Our training philosophy is problem-area and skill-development centered; practical experience out in the field is the heart of our training program. We try to teach our trainees the importance of socioeconomic relationships associated with new technology. We insist that they undertake individual experiments and demonstrations and learn something about managerial, communication, and leadership skills. We have training programs in crop improvement, crop production, and in farming systems. We teach people to learn by getting them to do things for themselves, such as getting behind a couple of bullocks for the first time in their life or planning their own experiments, organizing them, laying them out in the field, and then living with the results even if the results are not successful.

The students learn from both their successes and failures. When they receive their certificate here at the completion of their training program, they can go back home with the feeling that they have learned something. They will have the confidence to go out in the field and work either in research or extension and not find that they have only a great deal of academic knowledge with very little practical skill in the growing of crops.

Thank you very much. You are indeed welcome here and I hope that you have an enjoyable and profitable conference.

Research at ICRISAT — An Overview

J. S. Kanwar*

It is my great pleasure indeed to welcome you to the ICRISAT Center and to participate in this workshop.

Dr. Swindale in his address has given you the spectrum of all the activities of ICRISAT — its goals, mandate, problems, approaches, targets, achievements and how we function. Because our statistician tells us that replication is essential in scientific agriculture, I am going to replicate Dr. Swindale's address just to improve the reliability of the results and make them better interpreted and better understood.

I wilt give you a brief idea about the activities of our fifteen programs. Six of them are called research programs, seven are the research support programs and the other two, that is Information and Administration, are our support programs.

ICRISAT has to work for two groups of people. There is the target group consisting of resource poor farmers. The other group, the so called client group, is composed of scientists, extension workers and technicians.

In the semi-arid tropics, SAT, the farmer target group has to produce under very difficult climatic conditions. There is a short rainy season followed by a long dry period. The rainfall received is also very variable and no two years are the same. Sometimes the rainfall is very light and sometimes it is so heavy that the farmers experience flooding and drainage problems.

In the SAT, there are Alfisol and Vertisol soil types. The former are red soils, low in fertility and moisture-holding capacity, and they are used for the cultivation of groundnuts and other crops. The Vertisols are black soils with a high moisture-holding capacity, but with low fertility They are very difficult to manage particularly during the kharif season, i.e., the monsoon or rainy season, when they should be cropped but many of them are left fallow.

* Director of Research, ICRISAT.

Regarding our strategies for research, the first emphasis is on assembling, evaluating and utilizing the germplasm resources. This is followed by striving to build higher yield potential and yield stability in the hybrids, composites and experimental varieties. We are also interested in incorporating disease and pest resistance, and better nutritional qualities into our mandate crops.

Not only do we attempt to improve grain acceptability but we also try to improve the lysine content of sorghum and millet grains, and the sulphur-bearing amino acid content of the pulse seeds.

We are developing a computerized system of records for our 50 000 germplasm lines which have been accumulated over the last 6-7 years. Not only do we receive germplasm from many countries, but we also distribute thousands of samples to a great many national programs in the world.

The field experiments of ICRISAT scientists have shown that all of the mandate crops have good potential for increased yields under rainfed conditions as indicated in the following table:

Crop	Average SAT yield (kg/ha)	Experimental yield at ICRISAT (kg/ha)	
		High fertility and good management	Low fertility and average management
Sorghum	842	4900	2627
Pearl Millet	509	3482	1636
Chickpea	745	3000	1400
Pigeonpea	600	2000	1000
Groundnut	794	2573	1712

The problem is that unless the farmers are able to get those types of yields, we cannot get a big improvement in national production.

Regarding disease research at ICRISAT, we disseminate resistant material developed here to the national programs for screening in their countries, particularly at the hot spots in the international nursery system. Diseases on which ICRISAT is working include downy mildew on sorghum and pearl millet; ergot on pearl millet; grain molds and charcoal rot of sorghum; sterility mosaic in pigeonpea; wilt of chickpea; and leaf spots and rust of groundnut.

In entomology, we have evolved a screening technique for shoot fly and we are also developing one to screen for pod borers.

Using a technique developed by ICRISAT, we can screen plants for drought tolerance, in which different moisture level regimes are applied to the plants being tested.

ICRISAT scientists are also studying the parasitic weed *Striga.* Apart from being a serious problem in Africa, it is now causing considerable concern in India too and it is being screened here.

Recognizing that the ultimate reality of whatever improved material we produce is its suitability and acceptance, we test newly developed material with a tasting panel. What is suitable for India may not be suitable for Africa and what is suitable for the Sudan may not be suitable for Nigeria and so on.

Our Economics Program has two major subprograms — production economics and marketing economics. They are examining marketing problems and how to improve the possibilities of farmers making more profits.

We are concerned with the poor fertility of soils, and the drainage problems associated with the black soils, i.e., the Vertisols. Phosphate, zinc and sulphur deficiences have been noted.

ICRISAT has developed a watershed concept in its Farming Systems program so that water movement from the higher levels is conserved by various techniques instead of all moving to the lower levels. I would like to emphasize the point that the availability of water acts as a catalyst for a new agriculture. When farmers find that they have some water available, they are prepared to take risks.

In the farming system developed here, broad beds and furrows are used and appropriate machinery is necessary to make them. Also, a suitable cropping system must be incorporated into the overall production scheme.

Materials are tested here at ICRISAT under a range of environmental situations such as under pesticide protection; without pesticide protection; irrigated and nonirrigated conditions; and in low and high fertility areas.

With new developments, we are very conscious of thefactthat unless a farmer sees a two or three-fold benefit, he will not be very enthusiastic about adopting a new technique or new variety. In particular, under dryland farming conditions, a farmer is not prepared to take too many risks because of climatic conditions. So naturally, we must find a technology which gives him good stability in production and also more benefits.

In order to get new developments in technology and new varieties to farmers, we are involved in a linkage system for the transfer of technology. We have cooperative linkages with various international institutes, with national institutes, and with various other organizations.

Fundamentally, the ICRISAT program acts through two bases — the seed base and the resource base. ICRISAT reaches the national programs and they in turn work with the farmers. When a farmer adopts a new variety and can say at harvest time that he has just obtained the largest yield in all his farming life, then we know that we have achieved one of our objectives — increased agricultural production.

ICRISAT's International Cooperative Program

J. C. Davies*

The basic objectives of ICRISAT and the thrusts of the research effort have been explained by my colleagues, Drs. Swindale and Kanwar. I do not propose to reiterate these, but I would like to re-emphasize that an important premise, when the Institute was established, was that it would serve to strengthen and support established agricultural research programs and effort, both in the host country and other nations in the SAT. Clearly, the establishment of a Cooperative Program was vital in achieving this goal. About 50 countries on four continents have some SAT areas within their boundaries (20 million sq miles), and the majority of these are less developed or are developing countries. There was a necessity to determine priority countries, crops, and research areas for maximizing the returns from resource input — both by way of staff and funding in cooperative ventures.

Vital Statistics Influencing Location of the Cooperative Program

Some 66% of the SAT area is in Africa — 24% in W. Africa, 22% in E. Africa, and 20% in southern Africa. The population of the SAT is around 600 million — 56% of which, i.e., about 350 million, live in India (which occupies only 10% of the SAT land surface). About 90 million live in SAT W. Africa. The second largest SAT country is in Africa, the Sudan, which has only a minute 3% of the SAT population in 8% of the land area. These figures highlight the wide differences in land to population ratios which exist in the SAT countries.

Populations in Africa are growing at an extremely high rate. A further factor which affected program siting was that in the 1970's, a drought situation existed in much of Africa, but particularly in sub-Sahalian Africa, causing untold suffering and misery to millions of people.

A study of the statistics for three of ICRISAT's mandate crops — millet, sorghum, and groundnuts — indicate their importance in the SAT, both in hectarage and production terms (Table 1). However, average yields are low. Cereals are very important in the SAT and two of ICRISAT's mandate crops, millet and sorghum, are vitally important, especially in view of their comparative drought tolerance. Millet is important in almost all the West African countries and India, and sorghum in several countries (Table 2). In Eastern Africa, millet is of great importance in Sudan and Tanzania. Sorghum is of prime importance in the Sudan and of considerable and possibly increasing importance in Tanzania, and to an extent in the other countries (Table 3).

These facts together with the predictions of a number of agencies that food deficits will be a feature of the 1980's in Africa, greatly influenced the development, crop choice and siting of our initial cooperative research efforts in the West African region.

Program Development and Structure in West Africa and East Africa

In early 1975, UNDP and ICRISAT entered into a 3-year contract that had as its prime objective strengthening of existing West African programs and development of higher yielding and stress resistant sorghums and millets. The project covered 12 countries in W. Africa stretching from Senegal to Nigeria; subsequently Sudan was included. The strategy in the first phase was to post ICRISAT scientists to existing research stations at Bambey, Senegal; Kamboinse (initially Farako Ba), Upper Volta; Maradi in Niger; Samaru in Nigeria; and Wad Medani in the Sudan — thus ensuring close day to day and effective collaboration with national program scientists. The ICRISAT scientists posted

* Director for International Cooperation, ICRISAT.

overseas would also effectively collaborate with the ICRISAT Center at Hyderabad.

The first scientist was posted in 1976 and the 1977 season was the first full crop year. The pattern of staffing in the second phase currently includes — a project manager based at Dakar (partly funded by IRAT); a millet breeder and cereal entomologist at Bambey, Senegal; a sorghum breeder (initially UNDP, now on core); a millet breeder, a cereal pathologist and agronomist at Kamboinse. The Dutch Government assisted with an agricultural engineer. Elsewhere we have a millet breeder at Maradi, a millet breeder and cereal pathologist at Samaru, and millet and sorghum breeders at Wad Medani.

To this network there have been added in the past few years an agronomist and a sorghum/millet breeder in Mali under a USAID contract, and under a subcontract to IITA/USAID, a sorghum breeder in Tanzania. In the sorghum and millet crops therefore, a strong interconnecting series of teams has been formed. This wide spread of teams, to a considerable extent, covers the range of agroclimatological, broad edaphic and food preparation situations exist-

Table 1. SAT and world production of sorghum, millet, chickpea, pigeonpea, and groundnut Data represent averages for the years 1973, 1974, and 1975. (Source: FAO, various issues).

	Area			Production			Yield		
Crop	SAT ('000 ha)	World ('000 ha)	SAT/World %	SAT ('000 mt)	World ('000 mt)	SAT/World %	SAT ('000 kg/ha)	World ('000 kg/ha)	SAT/World %
Sorghum	34 553	43 269	80	20 082	52 800	55	842	1220	69
Millets	35 595	70 352	51	18 109	46 959	39	509	667	76
Chickpea	9 150	9 974	92	5 406	6 008	90	591	602	98
Pigeonpea	2 669	2 792	96	1 777	1858	96	666	665	100
Groundnut	14 604	19 084	77	11 594	17 868	65	794	936	85

Table 2. Total area under cereal crops in the SAT countries in West Africa and India. (Units expressed as '000 ha).

Country	Maize	Sorghum	Millet	Rice	Wheat
India	5900.00	16 015.00	18 351.67	39 504.00	20 859.67
Mali	91.67		1214.67	204.33	2.00
Niger	10.67	715.67	2 651.67	224.00	2.00
Nigeria	1612.67	5 980.00	4 906.67	311.00	13.67
Senegal	48.33		934.67	74.33	
Upper Volta	110.00	1 079.34	907.00	42.33	

Table 3. Total area of cereal crops in Eastern Africa. (Units expressed as '000 ha).

Country	Maize	Sorghum	Millet	Rice	Wheat
Botswana	71.67	100	10		
Malawi	1033.33	120		45	
Zambia	1050.00	80	134.67	2.33	1.67
Kenya	1550.00	209	80.67	7.00	120.67
Sudan	85.00	2705.67	1170.33	8.33	294.00
Tanzania	1300.00	338.33	213.33	180.00	50.00

ing in the sorghum and millet areas of West and East Africa.

As the program developed it became clear that further strengthening of the research effort was required. In the early part of Phase II of the UNDP program, it was decided to strengthen the team at Kamboinse and to assist with the improvement of physical facilities and the farm lay-out. This helped in forging links with the OAU/SAFGRAD program. Currently ICRISAT has four scientists on its staff in W. Africa funded from this program — one soil scientist posted at Kamboinse, and three shortly to be posted to Nigeria, including a sorghum breeder, an agronomist and an entomologist, all with an essentially regional program of work.

At Kamboinse, the staff has also been augmented by a *Striga* scientist under a restricted core IDRC grant and by the posting of a core program economist to initiate village level studies and studies on adoption of improved technology. A core funded entomology post has also been created. The station will mainly be concerned with the development of improved sorghum cuitivars and farming systems for the 800 mm rainfall areas of W. Africa. The location of core staff indicates the commitment of ICRISAT to a long-term research effort in Africa.

In view of the importance of millet in the Sahelian area, weare negotiating an agreement with the Government of Niger to site a center near Niamey. This will deal with pearl millet improvement and farming systems, which are essentially concerned with millet/groundnuts in the 600 mm sandy soil situations, which are so common in W. Africa. Recruitment of some staff for this situation is under way.

Cooperative Programs in Other Areas

In addition to these programs, ICRISAT currently conducts a sorghum program in Central America, based at CIMMYT in Mexico, which follows up on a previous program that was aimed mainly at production of cold tolerant sorghums for higher elevation areas. This program is currently being diversified and is producing good quality white sorghums, which are proving to be very useful in several countries in the region where sorghum is used as a human food. Several lines are already being multiplied by national programs, and these are useful for admixture with maize for making tortillas.

Two years ago it was recognized that ICRISAT should have a research effort on chickpea outside the host country, as this would be valuable in breeding the kabuli type. This program was based in the Middle East. A team of one breeder and one geneticist is currently based in ICARDA, at Aleppo, Syria. The emphasis in breeding will shift slightly in the future towards breeding for disease resistance.

Role of ICRISAT Scientists in the Cooperative Program

All ICRISAT scientists posted to the Cooperative Program have a tripartite role to play:

1. They make a direct contribution to the national program of the country in which they serve. This may be large or small, depending on the strength of the national research program. They form an effective link through which genetic material and information flows to national scientists from other ICRISAT scientists in the Cooperative Program and from ICRISAT Center, Hyderabad.
2. They make an increasing contribution to regional programs by assisting with exchange of genetic material, particularly through organization of or assistance with the assembly of regional trials, but also through personal contact and information exchange through visits.
3. They have an important role in carrying out experimentation, including conduct'ingnurseries, whichfeed back information to ICRISAT Center and other ICRISAT scientists in the Cooperative Program, on the performance of material under a range of climatic, disease, pest and edaphic conditions. Such information is crucial to building up a good data base and developing long-term fully integrated strategies for crop improvement and farming systems work. The exchange is not all one way, e.g., Africa has already provided the Center program with useful genetic material for development of downy mildew resistant lines of pearl millet for the Indian subcontinent.

Results flowing from the program to date are most encouraging in all three roles. The performance of improved cultivars vis-a-vis local land race materials is being assessed and lines have been developed which are superior to cultivars currently being grown.

Many lines having stress resistance have been identified and this resistance has been tested across a range of environments. The increasing amount of information obtained on the quality characteristics of improved sorghum and millet strains for preparation of local foods has been particularly useful. This is crucially important in ensuring acceptance of improved cultivars by small farmers.

Training

This topic was dealt with earlier in the symposium by Dr. Swindale; however I would like to emphasize that this is a very important area of activity. Cooperative program scientists, in collaboration with national scientists, have a very useful role in identifying technicians and scientists for training at ICRISAT Center. Additionally, they have initiated training and lecture courses locally in several countries to assist in staff development. The training effort is recognized as being of great importance in strengthening national research efforts and is an activity on which we place very great store.

Future Developments in the Cooperative Program

In spite of the fact that groundnut figures prominently in Table 1 with a hectarage of over 14 million in the SAT, our program to date overseas has been negligible. This is largely because groundnut was added to our mandate only relatively recently and much effort has been expended to date in building up our germplasm base and activities at the Hyderabad Center. We are currently investigating the possibility of initiating a program on groundnuts in central Africa and have plans to start work in West Africa, as soon as the center in Niger is established. Both breeding and pathology will be covered in the first phase, together hopefully with microbiological studies, when funding is identified.

In the immediate future we intend to concentrate on the establishment of the Niger Center, which will cater for both groundnut and millet, expanding our program on farming systems in Upper Volta, and developing a program in this field of endeavor for the sandy soil, low rainfall areas of W. Africa, basing the program in Niger. We are collaborating with the Government of Mali in establishing a research center at Cinzana for work on crop improvement and farming systems in that country.

ICRISAT has been requested by the Heads of State of Southern African States to develop a regional center and we are actively pursuing this. A fact-finding mission will leave for the area within 3 weeks, and it is hoped that working agreements may evolve from this.

We look forward to cooperating fully with national programs in the great task ahead of helping the small farmer of limited means in the SAT. These farmers have been neglected in the past, but they form a major component of the populations in mostSAT areas. Thetask of helping them should not be minimized, the road ahead is difficult and tortuous, and given the difficult conditions underwhichthefarmerstoil, progress is unlikely to be punctuated by big breakthroughs. The task will take persistence, continuity and patience. I know that we at ICRISAT can assist you in your endeavors with the groundnut crop, and I hope that from this conference will come firm plans of action and guidelines on tackling the many problems we all face in assisting the farmers in the various countries represented here.

May I wish the Workshop every success in its deliberations.

The ICRISAT Groundnut Program

R. W. Gibbons*

Groundnuts in World Agriculture

The cultivated groundnut, *Arachis hypogaea* L, is a native of South America and the crop is now grown throughout the tropical and warm temperate regions of the world. Although groundnuts are predominantly a crop of the tropics the approximate limits of present commercial production are between latitudes 40°N and 40°S.

In 1978, it was estimated that just over 18.92 million hectares were planted and 18.87 million tonnes were harvested at an average yield of 998 kg/ha (FAO Trade Statistics). Asia is the largest producer (.10.9 million tonnes), followed by Africa (5.2 million tonnes). North and Central America (1.98 million tonnes) and South America (0.8 million tonnes).

Of the individual countries, India is the largest producer in the world (6.2 million tonnes), followed by China (2.8 million tonnes), USA (1.8 million tonnes) Senegal (1.0 million tonnes), Sudan (0.8 million tonnes) and Nigeria (0.7 million tonnes). Approximately 80% of world production comes from the developing countries and 67% of the total is produced in the seasonally dry rainfed areas of the semi-arid tropics (SAT).

Production Constraints in the SAT

Yields in the SAT are low, around 800-900 kg/ha, compared to yields of approximately 2500 kg/ha in the developed world (Gibbons 1977). The major constraints are pests, diseases, and the unreliable rainfall patterns of the SAT. Apart from the natural hazards which restrict production, there are relatively small numbers of well trained, specialist groundnut researchers available.

Although groundnuts are often regarded as a cash crop, the necessary inputs are often not available to small-scale farmers to control pests and diseases, for example, even when appropriate research recommendations have been made. Very often these recommendations have been based solely on trials conducted on experimental stations, and not under conditions where the farmer actually grows groundnuts.

Few research programs in the SAT have concentrated on breeding for resistance to the main factors which presently limit production. Some exceptions are the production and release of cultivars resistant to rosette virus in Africa and cultivars resistant to drought in Senegal (Gillier 1978).

The ICRISAT Groundnut Improvement Program

Background

In 1974 a team of four consultants was invited to Hyderabad to review world research needs of groundnuts, to consider whether ICRISAT ought to help meet these needs and, if so, to suggest a possible program of international research. It was concluded that the crop did require international research, would be an appropriate subject within the mandates of the international research system, and that ICRISAT was the appropriate Center as groundnuts are primarily a crop of the SAT (Bunting et al. 1974).

The consultants considered that the crop needed international research because (1) groundnut research at national stations in most countries would benefit from international cooperation, exchange of information, training, and in particular by the formation of a world germplasm base, and (2) groundnuts are an important food crop in many developing nations and the fact that it is also a cash crop

* Program Leader, Groundnut Improvement Program, ICRISAT.

should be no bar, as by selling crops, farmers help to feed the nations as a whole.

In 1976 a program of research was presented to the Governing Board of ICRISAT. The report was accepted, and the recruitment of staff commenced (Gibbons 1976).

Research Organization

Within the program, at the research center in Hyderabad, there are a number of subprograms which include breeding, pathology, cytogenetics, microbiology, entomology and physiology. The germplasm subprogram was originally in the Groundnut Improvement Program but is now part of the Genetic Resources Unit, which has assumed responsibility for all the mandate crops of the Institute.

The consultants also decided that general agronomic studies should not form a major part of the program because such problems were locale-specific and were the responsibility of national programs. The consultants also recommended that although ICRISAT should be fully informed about the insect pests of groundnuts, no special program should be formulated (Bunting etal. 1974). However, since this report it has become apparent that insect pests are a serious worldwide problem, both directly and as vectors of virus diseases, and a decision has been taken to increase entomological research at ICRISAT from 1981.

Staffing of the center program is now almost complete, except for the physiology program which has only very recently commenced.

Objectives

The main objective is to produce high yielding breeding lines with resistance to the main factors presently limiting production. It is not the intention to produce finished cultivars, but rather to supply germplasm and breeding lines on which further selection can be practiced in cooperating countries. For this, there is a need to know the exact requirements of cooperating countries. These requirements vary greatly, even within a country. For example in the Sudan, large-seeded, long season groundnuts are grown under irrigation in Wad Medani for export; but under rainfed conditions farmers cultivate short season cultivars that are more adapted to those conditions (Osman 1978). In Malawi, long season groundnuts, primarily for the confectionary export trade, are grown in the plateau areas; cultivars for oil crushing are grown in the lake shore areas; and short season cultivars are adapted to the low elevation, drier and hotter areas in the southern part of the country (Gibbons 1972).

Specific Research Goals

The program has emphasized the following specific research goals:

Breeding for Resistance to Major Diseases and Pests

The most important foliar diseases causing severe yield losses on a worldwide basis are the leaf spots (*Cercospora arachidicola* and *Cercosporidium personatum*) and rust (*Puccinia arachidis*). Bunting et al. (1974) conservatively estimated that the leaf spot fungi alone cause the loss of about 3 million tonnes of kernels per year. Losses in kernel yields of around 10% have been estimated in the USA, even when fungicides are routinely applied (Jackson and Bell 1969). In the SAT where chemical control is often not used, losses in excess of 50% are commonplace (Garren and Jackson 1973). Rust of groundnuts has become a worldwide problem since 1969 (Subrahmanyam et al. 1979).

Intensive programs have been started to search for resistance to these diseases, both in the cultivated and wild species of the genus, and to incorporate this resistance into high yielding and commercially accepted cultivars (Nigam et al., Subrahmanyam et al., Nevill — this conference).

Programs are also being developed to breed for resistance to *Aspergillus flavus,* which produces a toxic metabolite that affects human health. Breeding lines possessing dry seed resistant to penetration by this fungus have been identified in the USA (Mixon and Rogers 1973) and are being utilized in the breeding program.

The germplasm collection is also being screened for sources of resistance to such commonly occurring fungi as *Aspergillus niger, Fusarium* sp, *Pythium* sp, and *Rhizoctonia* sp.

Virus diseases of groundnuts are common and serious in the SAT. The major virus diseases being investigated presently at ICRISAT are bud necrosis, caused by tomato spotted wilt virus (TSWV), and peanut mottle virus (PMV). The germpiasm collection is being screened for sources of resistance, and other methods of control are also being investigated (Ghanekar; Amin and Mohammad — this conference).

Although insect pests are often limited in their distribution, some are of worldwide distribution and importance. Among the latter are species of aphids, jassids, thrips and termites. Some of these species occur at the ICRISAT research center and germpiasm is being screened for sources of resistance in special pesticide-free areas located on the research farm at Hyderabad.

Breeding for Earliness, High Yield and for the Farming Systems

There is a need to generate high yielding lines which are adapted to the harsh conditions of the SAT. As already stated, it would be important to incorporate into these lines resistance to the major constraints and stability of yield over years. However, not every environment has severe disease or erratic rainfall constraints, so high yield per se is also important.

Earliness is also an important objective, as groundnuts fit into relay or sequential cropping systems where residual moisture is available from the preceding crop. With the advent of short duration rice cultivars, large areas of Southeast Asia are now able to grow more than one crop per year. Rice, followed by rice, or an upland crop is now a common practice and groundnuts would fit well in this system. Sources of earliness are being utilized in the breeding program (Nigam et al. —this conference).

Groundnuts are also commonly intercropped, particularly in India and Africa. In the Guinea Savanna zone of Nigeria, only 16% of the total area is planted as sole crop groundnuts (Kassam 1976). The Groundnut Improvement Program is cooperating with the ICRISAT Farming Systems Research Program in identifying superior groundnut cultivars for the intercropping situation (Reddy et al. — this conference).

Increasing Biological Nitrogen Fixation

The groundnut is an efficient fixer of nitrogen and attempts are being made to manipulate both the *Rhizobium* and the host plant component of symbiosis to increase nitrogen fixation, and hence groundnut yields. There is also a beneficial effect on the subsequent crop from a well nodulated groundnut crop (Nambiar and Dart — this conference).

Exploiting the Wild Species of *Arachis*

A major component of the program is the utilization of genes from the wild *Arachis* species to improve the commercial groundnut crop. Resistance to fungal diseases, pests, viruses and drought occur in these species but genetic manipulation is required to incorporate these characters into the cultivated groundnut because of differences in ploidy levels and other barriers to interspecific hybridization (Moss 1980).

Exploiting Physiological Characters for Groundnut Improvement

This is the last of the programs to be staffed. The research program will be formulated in the very near futu re and a major part will be to study and exploit characters associated with drought resistance.

Linkages

International Cooperation

The ICRISAT program has been, and stilt is, developing linkages with other institutions conducting research on an international or regional basis. Cooperative programs have been formed with North Carolina State University on the transfer of groundnut germpiasm, biological nitrogen fixation research and the utilization of wild *Arachis* species in the improvement of the cultivated groundnut. A joint program has been formed between ICRISAT and the USDA in screening all known sources of resistance to rust at the ICRISAT research center. The Government of Japan has provided visiting scientists and facilities for research on viruses. The International Board for Plant Genetic Resources (IBPGR), the germpiasm center in Brazil (CENARGEN), ICRISAT, and national scientists from the USA and other countries are cooperating on groundnut germplasm collections in South America. Research on the utilization of wild species of *Arachis,* carried out at the University of Reading and financed by the British Government, has been of immense help in the ICRISAT program.

Other linkages are being investigated and there is particular interest in cooperating with non-groundnut growing countries in the investigation of viruses and whether races of important fungi occur. These investigations cannot be carried out in India because of quarantine regulations and the risks of introducing new diseases into groundnut growing countries.

Cooperation with National Programs

The program has developed very close links with the Directorate of Oilseeds Research in India. The entire Indian germplasm collection was placed at the disposal of ICRISAT and cooperative links have been formed with Indian universities and research stations. A new national center for groundnut research has recently been created and located in the state of Gujarat, the largest groundnut producing area of India. It is envisaged that close cooperation will develop between ICRISAT and this center.

In the relatively short time that the international program has been operating, links with national programs interested in groundnut research have developed satisfactorily. There is now a need though to intensify and expand these links as breeding material is now becoming available for widespread distribution.

The training facilities in groundnut research at ICRISAT are also becoming available and already personnel from several countries have attended courses in such subjects as hybridization techniques, disease scoring methodology and virological techniques. It is intended that these facilities should be expanded in the future.

The Future

There is still a long way to go before marked success can be achieved for the underprivileged farmer of the SAT. It is felt however that the major research emphasis on stable disease resistance and high yield will begin to be achieved in the not too distant future. The Center program needs to be intensified, particularly in the fields of entomological and physiological research, and more cooperation with national programs is required. In 1981 a regional program is planned for Eastern and Central Africa, and also in 1981 a second regional program will be set up in West Africa. These regional programs will initially be staffed by a breeder and a pathologist and be funded from the core budget. If noncore funding becomes available, then a microbiologist will be added to each team.

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Session 2

Research Organization and Development

Chairman: C. Harkness

Rapporteurs: J. P. Moss
D. C. Sastri

Indian Coordinated Research Project on Oilseeds with Special Reference to Groundnut

Vikram Singh*

The evolution of agricultural research in India commenced as early as 1870. Its development to the present coordinated research approach has been expedited by two almost simultaneous developments: first, the acceptance of the Uppal Committee report (1954-56) to regionalize research on cotton, oilseeds, and millets; and the second, the successful experience of the coordinated approach applied for the first time in maize in the late 1950's. It has been refined since then and extended to all the crops, including oilseeds.

The cardinal philosophy and the special features of the coordinated research as developed over the years (Singh 1980 a), and common to all projects, are:

1. A multidisciplinary approach to problem solutions.
2. Free exchange and flow of material, information, and ideas among research workers.
3. Compulsory analysis, report, and discussion of research results prior to the future planning of the next season/year program.
4. Planning the technical program and research methods by common discussion and consultation among research workers during annual workshop/meetings.

The following six special features also apply:

1. The project/program operates on a national scale under the direct supervision of the Indian Council of Agricultural Research (ICAR).
2. All participating institutions/organizations in the country work as a team to impart a national character to it.
3. The project/program has a full-time Project Coordinator/Principal Investigator to coordinate, supervise, and watch the progress for reporting to Council/Government.
4. The state provides the required land and laboratory facilities for the cooperating center(s) located within its bounds.
5. The research investment is shared between the Council and state on a 3:1 basis.
6. All major disciplines are represented on the project work on the basis of equivalence and mutualism.

The Oilseeds Project

The All India Coordinated Research Project on Oilseeds, which was established in 1967, was raised to the status of Directorate of Oilseeds Research (DOR) on August 1, 1977 in order to enlarge its scope and activities (Vikram Singh 1978). The main objective of the Oilseeds Research Project is to coordinate, encourage, initiate and plan research activites with a view to providing a research base which would result in an increase in the productivity and stabilized production of oilseeds in India.

The Groundnut Program

The specific objectives of the Directorate's groundnut program are:

1. Development of high yielding varieties possessing resistance/field tolerance to diseases and pests of economic importance for the different groundnut growing agroecological zones.
2. Development of production technology for maximum yield exploitation under irrigated and unirrigated conditions in different groundnut growing zones.
3. Development of simple and cheaper crop protection technology with an emphasis on integrated control of the disease-pest complex.

* Project Director, Directorate of Oilseeds Research, ICAR, Rajendranagar, Hyderabad 500 030, Andhra Pradesh, India.

4. Demonstration of the proven research results through onfarm trials for the benefit of farmers as well as extension workers.
5. Identification of the stable sources of resistance to diseases and pests, and other desirable agronomic traits in the germplasm, and their use in future breeding programs.
6. Production and maintenance of a continuous supply of breeder's seed for multiplication into further categories of seeds for ultimate supply to the farmers.
7. Resolving any other problems.

The number of main and sub-centers for all oilseed crops is now 62. Of these, 17 are deployed for research on the groundnut crop. In addition, support from other centers has been enlisted. Active cooperation of scientists in the Groundnut Program of the International Crops Research Insitute for the Semi-Arid Tropics (ICRISAT) since the beginning of the program in 1976 has been noteworthy. Additionally, the Directorate of Oilseeds Research derives advantage from the experiences of other Coordinated Projects (such as the Model Agronomic Scheme, Dryland Farming Project, Cropping Pattern and Land Use Project, and Crop Projects such *as* pulses, sorghum, millets, and sugarcane wherein oilseed crops form a part of cropping pattern) and the Institute like the Central Arid Zone Research Institute, Jodhpur, and Central Soil Salinity Research Institute, Karnal.

The scientific strength at a main center in the National Oilseeds Research Project normally consists of a breeder, agronomist, plant pathologist, entomologist, biochemist, and a statistician, while that of subcenter is limited to a breeder, or a maximum of assistant agronomist in addition.

In 1979, the National Research Centre for Groundnut (NRCG) was established at Junagadh, with a mandate to generate and distribute breeding material at early stages and to engage in basic research with a view to break yield barriers in the groundnut crop.

Thetwoproceduresdevelopedforgroundnut research for various disciplines are:

Four-Tier System of Testing

For rapid multilocation testing of promising breeding material and to assess the material's suitability for different agroecological zones or adaptability at national level, each of the promising lines enter the Initial Yield Evaluation Trials (Stage I). Depending upon performance, an entry can rise up to the National Evaluation Trial after which it is identified by the research group as a potential variety. The period of testing and promotion from one stage to the next higher are given in Table 1.

After an entry has been identified as promising, a V stage (Minikit/District Level Trial) as the final stage between the identification and final release of the variety, has been introduced since 1979.

Development of Agro-Protection Technology

In thedisciplines of agronomy, plant pathology, and entomology, simple to complex coordinated experiments are formulated and implemented uniformly at all the stations.

Table 1. Four-tier system of testing groundnuts.

Stage No.	Stage Name	Seasons of trial: Maximum	Seasons of trial: Minimum	Remarks
I	Initial Yield Evaluation Trial (IYET)	2	1	An entry from IYET/PVT can be promoted to the next stage after a one-season trial, if its average yield exceeds the check variety by 25%. (applies to I, II, III)
II	Preliminary Varietal Trial (PVT)	2	1	
III	Coordinated Varietal Trial (CVT)	2	2	
IV	National Evaluation Trial (NET)	1	1	

Location-specific trials under the category of station trials are also discussed and finalized for different stations.

Groundnut Research Achievements

The dependence of groundnut cultivation on highly erratic rainfall, susceptibility to devastating pests and diseases, and the limited capacity of the groundnut grower make groundnut research rather more challenging.

Particular achievements in the groundnut program are:

Germplasm

The groundnut program of DOR has shared its entire collection (4968 entries) with ICRISAT (Anon. 1979), which was designated as the world center for collection, preservation and documentation of the genus *Arachis* by the International Board for Plant Genetic Resources (IBPGR). The groundnut program currently has access to more than 9000 accessions of the ICRISAT Center.

The National Research Centre for Groundnut is being developed as the second important center for maintenance and evaluation of groundnut germplasm in the country.

The program in its multilocation testing of germplasm/breeding material has identified a large number of lines resistant to one or more pests/diseases. These are being evaluated further in the multilocation uniform disease nurseries (Vikram Singh 1979). The most notable findings are listed in Table 2.

Table 2. Some results of multilocation tasting of germplasm/breeding material.

Source/line	Resistant/tolerant to
G 201	Leaf spot
Ah 7724, Ah 7747, *EC76446	Leaf spot, rust
Ah 7795	Aphid, Jassids
Ah 7799	Aphid, Leaf miner
Ah 7983	White grub

* Also reported by R. W. Gibbons (1979).

Varieties Released for Cultivation

Since 1967, some 28 varieties belonging to the three broad growth habit groups (16 in bunch, 5 in semi-spreading, and 7 in spreading type) have been released for different adaptability zones. Of these, M-13 and TG-1 (Vikram) are the only two varieties that have been released by the Central Variety Release Committee at national level. These two varieties when evaluated on farmers' fields across 3 to 5 groundnut growing States, on average yielded 74 and 51% more than local varieties (VMA 1978).

Agro-Protection Technology

The optimum agro-protection technology for the different agroclimatic zones in respect of available varieties has been worked out by different cooperating centers. Agronomic and plant protection research findings have been recently discussed by Singh (1979). Salient research findings with recent additions are:

Agronomic Practices

a. Plant stand. The use of optimum seed rates and control of seedling diseases is the easiest and surest way to higher yields.
b. Field preparation. An increase in depth of plowing from 10 cm to 30 cm has given significant yield increases in the red soils of Andhra Pradesh, primarily due to increased water intake and increased root penetration activity (Table 3).
c. Groundnut nutrition. Except for some areas like the Saurashtra region of Gujarat and the Kurnool district of Andhra Pradesh, where fertilizeris being applied by farmers (in some cases much more than the recommended levels), the level of nutrients applied ranges from low to nil. Results obtained in the groundnut program suggest higher levels of nutrition in respect of N, P, and some minor elements (Singh 1980b). Gypsum applied at 250 kg/ha has given significantly higher yields.
d. Package of practices. During the past 2 to 3 years, the relevance and effectiveness of the research results when applied to a large scale area has been engaging the attention of oilseed research workers. Results from multilocation trials conducted to compare

the recommended package of practices with the farmer's method (local) have shown that groundnut yields can be doubled by adoption of the package of practices (Table 4).

The significant yield increase obtained from following the recommended package of practices is further confirmed by the results from the demonstration trials conducted on farmers' fields by the State Departments of Agriculture (Singh 1979), and by the results of a survey undertaken on the causes of low yields. The survey clearly showed that wherever farmers adopted recommended practices (not in full), the district average groundnut yields have been 4100 kg/ha as against the average yield of 1000 to 1100 kg/ha where farmers did not adopt the recommended practices (Reddy and Reddi 1979).

Protection-Technology

Large reductions in yield due to attacks by diseases and pests rank second only to the reductions due to unfavorable weather.

Due to the unavailability of resistant/tolerant varieties to major diseases and pests and keeping in mind the limited investment capacity of the farmer, the Project from the very beginning has emphasized the development of relatively simple and cheaper control measures. Control measures for all the important diseases and pests i.e., leaf spots (both early and late), groundnut rust, various rots, and aphid, leaf miner and white grub have been determined.

At current prices, most of the control measures (operational cost included) cost less than Rs.150/ha and have resulted in significant yield

Table 3. Effect of depth of plowing on groundnut yields in the rod soils of Andhra Pradesh.[a] Yield in quintals/ha (1q = 100 kg).

Plowing	Treat. year	Residual effects		
	1972	1973	1974	1975
Shallow (10 cm)	4.2	8.6	5.7	13.3
Deep (30 cm)	5.4	11.7	8.2	14.2
CD	2.1	2.2	2.1	NS

a. Data from Dryland Farming Project.

Table 4. Average yield response of two groundnut varieties under different management practices at Ludhlana (Directorate of Oilseeds Research 1980).

Treatment	Pod yield (kg/ha)[b]			
	M-13	% Increase over (A)	PG-1	% Increase over (A)
(A) Local practices	1058.33		974.67	
(B) Recommended package of practices	2468.33	133.23	2313.00	137.31
(C) B minus seed treatment and termite control	2130.00	101.26	2057.00	111.05
(D) B at 75% seed rate	2302.00	117.51	2132.00	118.74
(E) B minus fertilizers	1964.33	85.61	1872.33	92.10
(F) B minus weed control	1667.00	57.51	1815.33	86.25
(G) B minus protective irrigation	1645.67	55.50	1770.67	81.67
(H) B minus plant protection	2074.67	96.03	1699.33	74.35
(I) B but less duration[b]	1838.67	73.73	1939.67	99.01

a. Average of three kharif season trials (1977-79).
b. The crop was harvested 15 and 20 days earlier than the normal harvest time for M-13 and PG-1, respectively, in order to vacate the field for next crop.

increases and a net return of more than Rs. 400/ha. Controlling white grub costs Rs. 280/ha, but the yield increase is more than 100%. Net returns in the case of rust control have ranged from Rs. 200 to 370/ha.

Other Notable Aspects

Attempts at hybridization in groundnut in the past have had a very low success rate (about 10%). This has now largely been overcome and the success rate has increased to more than 50%, and sometimes it has been over 80%. Some success towards identification of the successful one from the accidentally selfed one, on the basis of pod morphology, has been made (Raman 1980). However, successful fertilization of both the proximal and distal ovules has not been accomplished in all cases.

The higher success rate of hybridization has helped to achieve a long overdue project mandate, i.e., free exchange and flow of groundnut breeding material. The large scale exchange of breeding material for the first time was accomplished in the 1979 groundnut season, wherein the contribution from the ICRISAT Groundnut Program was largest.

The Future Strategy

The research goal is stabilized groundnut production in the country. Fortunately, the national research infrastructure already developed for the groundnut program, reinforced by the two developments in the recent past — i.e., the establishment of the Groundnut Program at ICRISAT, Hyderabad, in 1976 and the establishment of the National Research Centre for Groundnut at Junagadh (Gujarat) in 1979 — has the capacity to meet the future challenges. What is required now is reorganization and reallocation of priorities, and the strengthening of weak links in the program.

It is believed that these could be achieved by:

1. Identification of regional/national problems of a short and long-term nature; the fixing of priorities and assignment thereof to specific worker(s)/center(s) as against the present practice of everyone working on each and every problem.
2. Identification of centers and strengthening thereof, for the generation and early sharing of breeding material having desirable traits like disease and pest resistance, drought tolerance, early or late maturity groups, and interspecific hybridization.
3. Strengthening and development of programs in plant pathology and entomology with emphasis on identification of sources of stable resistance to various pests, immuno-genetic studies, eco-biology of the pest, integrated pest/disease management and prognosis of diseases and pests of economic importance.
4. Establishment of a center for intensification of research in all disciplines for irrigated groundnuts — an aspect hitherto not covered in the national groundnut program.
5. Strengthening and development of research in plant physiology and microbiology. NRCG (Junagadh) and ICRISAT have been identified as the main centers for these two programs.
6. Identification of centers for intensive studies on groundnut yield-weather relationships; detailed and in-depth studies on micronutrient-nutrition of the groundnut crop; and nitrogen nutrition of groundnut in relation to rhizobial inoculation and varieties.
7. Introduction of compulsory on-the-farm trial programs at each center.
8. Standards and measures to improve the quality of experiments and therefore the validity of results.

Many of the basic studies are being carried out and will be carried out in the future at ICRISAT, from which the national program has derived/will derive advantage. The existing relationship between the national groundnut program and the ICRISAT groundnut program is very close and cooperative. It is hoped that both will benefit from each other and the results that flow from such joint efforts will benefit the ultimate consumer — the groundnut grower.

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Role and Function of the IRHO in Groundnut Research and Development

P. Gillier*

Structures

The IRHO is a private nonprofit organization sponsored by the French Government and incorporated into the GARDAT (Study and Research Group for the Development of Tropical Agronomy).

Its head office is in Paris, where the General Directorate, Research Department, and the Plant and Technology Departments (oil palm, coconut and annual oil crops) are also located.

The scientific departments and laboratories are at Montpellier. They coordinate the outside activities which are carried out in various forms in the tropical zone.

This structure is assisted by a Documentation and Publication Department, which distributes in 75 countries in French, English, and Spanish a monthly review called OLEAGINEUX which specializes in oil crops.

Objectives and Action

The IRHO is devoted to the development of tropical oil plants. It deals with the oil palm, coconut, and annual oil crops in the framework of international cooperation. Its activities range from scientific research to the practical application of its results. It contributes to technical and economic promotions in the countries concerned.

The technical aid and assistance made available by IRHO is solidly based on experience acquired in the tropical zone in numerous research stations, plantations and oil mills in more than thirty countries for over thirty years.

Means of Intervention and Resources

The IRHO can call on 85 technical executives (scientists and research workers) covering a very wide range of disciplines: pedology, ecology, genetics, cytology, physiology, chemistry and biochemistry, agronomy, phytopathology, virology, entomology, statistics and software technology and economics; this does not include the administrative executives, Plantation and Project Directors, and extension workers.

The IRHO can intervene in many areas, including agronomic research in the strict sense (conception, control and interpretation of experiments); specialized studies in pedology, climatology, mineral nutrition, phytosanitary treatments; creation of new varieties and supply of selected seeds; contributing to designing development plans; technical control of plantations; advice and control in building and operating oil mills; specialization of scientists; and pre-extension work on techniques developed in the stations, in rural areas.

These interventions occur in the framework of general cooperation agreements existing between the French Government and other countries (in general, Francophone African countries) in the framework of a private agreement between the IRHO and the government concerned, or in the framework of private contracts between the IRHO and various research or development bodies, or international organizations.

In 1980, for a budget of US$ 16.5 million, a breakdown of the origin of the credits is: from French governmental organizations, 25%; from foreign beneficiary states, other states and international organizations, 12%; and the IRHO's own resources and private credits, 63%.

Created immediately after the war, the IRHO only began to work on annual oil crops, and on the groundnut in particular, in 1948. The Insti-

* Director, Annual Oil Crops Department, IRHO, (Institut de Recherche pur les Huiles et Oleagineux — Research Institute for Oil and Oilseeds). 11 Square Petrarque, 7501L, Paris, France.

tute has thus been working for exactly 32 years on these plants in the Mediterranean area. Certain basic techniques were created there in the laboratory (leaf diagnosis, growth measurements etc) and then in West and Central Africa. We are now moving into Southern Africa and other countries that have demonstrated an interest.

Groundnut and annual oil crops represent only 20% of the IRHO's activities. The basic framework of our interventions in this area, and where they now stand are described below:

Conditions for intervention and Localization

The Annual Oil Crops Department is working on the groundnut almost exclusively in Francophone Africa. Before these states became independent, the Department had its own research stations, or specialised sections, in various countries and took part in the general agronomic research effort in this area. At that time, this was coordinated on the level of the AOF and AEF federations.

After independence, revision of the arrangements lent the various interventions a more national character; coordination of the various arrangements was lessened. Fortunately, present relations between states, and privileged links between the research workers themselves, have to a great extent prevented the same work being done twice over.

The IRHO has pursued its activities in the areas of applied agronomic research, pre-extension work and seed multiplication. The latter two activities are essentially linked to applying research results. To date, we operate in six countries: Senegal, Mali, Guinea Bissau, Upper Volta, Niger, Tchad.

Depending on the situations, the work to be carried out, and the type of contract signed, the research workers or technical advisors are assigned to precise programs or projects. There arethus many methods of work. For example, in some cases only the research workers' salaries and transport expenses to the work site are covered by the IRHO; the host government ensures the whole operation. In other cases, the salary and operation are entirely at the expense of the IRHO which manages the program or the operation.

For a company or government, the advantage in working with our Institute stems mainly from the support and logistical backup which the isolated agent on a station or the technical advisor assigned to a specific operation can receive, as well as the rather considerable range of oil crop scientists or technicians available to help solve their problems.

Although the staff of the Annual Oil Crops Department numbers only about 20 scientists and technicians, the IRHO tries to satisfy all requests in function of the states' requirements. It answers calls for tenders for the supply of services in its area, and ensures a certain number of study, technical advice or consultant missions throughout the world.

Range of Activities

Some of the past or present activities pursued by our agents in the framework of contracts or agreements are described below. In most cases, they are not exclusive to the IRHO, as they are part of ateam undertaking, butourparticipation is often essential, and justifies our claiming them as part of our knowledge, and a result of our experience.

Research

Physiology

From 1956, systematic work has been pursued on groundnut drought resistance, its precise measurement, evaluation of sensitivity stages, and development of rapid tests enabling precise evaluation of the plants' reactions to water stress. This aspect of research conducted in Benin and Senegal was mainly designed to enable practical sorting and selection to be done on progenies, bulks or populations, and to better evaluate the intrinsic value of choices.

At present, we have in-depth knowledge of the plant in this particular field,.authorizing judicious manipulations. This can eventually serve other species with similar characteristics.

Mineral Nutrition

From 1948, the first work done by the IRHO on groundnut dealt with the plant's mineral nutrition. The groundnut was then considered to be capricious in response and often unprofitable for mineral manuring.

Precise and methodical analysis of absorption conditions forthe various mineral elements during growth, linked to plant productivity, enabled nutrition standards to be specified (critical level and response curve).

Numerous fertilizer trials carried out in more than 10 producing countries, followed up by the leaf diagnosis technique, confirmed the validity of these standards. We now have a valuable basic element for evaluating manuring needs and mineral correctives to be applied to the crops. This technique is used to control the evolution of the plant's nutrition during rotation and in development projects where application of an economical fertilizer fulfilling the plant's strict needs is the foremost requirement.

Almost unknown and unused before 1948, mineral manuring is now widely used in West Africa, where both simple and complex formulae have proved their profitability with constant results.

Agricultural Techniques and Packaging

Depending on the country, the crop types, and the varieties used, simple growing techniques have been tested and proposed for wider application.

The IRHO has made a significant contribution to the study of fallow land (duration, treatment), rotation, sowing density, fertilizer application, harvesting etc. Prototypes of small-scale equipment like fertilizer-spreaders, thresher, shellers, and groundnut washers have been produced and distributed. Simple themes applicable by the growers under the extension workers' control have been developed and proposed to the development projects for wider use. Specific production and packaging techniques for edible groundnut have been developed and processing units installed and adapted to local production conditions.

Selection

Previously, one or two great selection centers dealt with problems of varietal improvement for all the countries in the zone. Each country now wants its own varietal creation unit. Many states are pursuing work whose character is unfortunately sporadic: their means do not remain constant, so research cannot be carried on normally. This is most problematic where selection work is concerned.

The IRHO has tackled the major problems, depending on the situation, and thanks to its varied arrangements, has tried to ensure they are followed through.

DROUGHT RESISTANCE. This program was started in Senegal, but due to the multilocal tests carried out in Mali, Niger, Upper Volta etc. it took on a multinational character. The first resistant variety, called 55-437, first distributed in the Louga area in 1962, now covers more than 400 000 ha in the Sahel area.

Since then, great progress has been made and the contribution to this problem has gone very much beyond the Senegalese framework. At present, there are at least 10 usable resistant varieties. Obviously, many other countries could benefit from the advantage of this characteristic. A new mixed variety (edible and oil, known as 73-33) is thus being distributed in the centre of Senegal, and will very likely cover vast areas in the future.

RESISTANCE TO ROSETTE. This was studied more specifically in Upper Volta, but the use of varieties created from resistance genes isolated in the Northern Ivory Coast has enabled the improvement of very diverse groundnut types, including long cycle ones suitable for high rainfall areas, and short cycle ones suitable for dry zones or zones with two rainy seasons (Gabon, Congo, etc).

RESISTANCE TO *ASPERGILLUS FLAVUS*. This is one of the themes studied by technologists, pathologists and breeders. Strains only slightly susceptible have already been isolated, and in the future, there will be truly resistant groundnuts. Similar work has just begun on rust resistance.

PRODUCTIVITY, SEED QUALITY, OIL CHEMICAL COMPOSITION, ETC. These characteristics have been or are the subject of special selection on various stations where IRHO breeders work.

Crop Protection

Several methods are being examined, with special attention to the major pests likely to limit groundnut yield. There is a systematic study of fungal diseases attacking seedlings using new formulae proposed by the phytosanitary products' manufacturers. Control techniques against millipedes are gradually being developed and perfected.

Aflatoxin

It is by itself a vast program, insofar as prevention and detection are concerned. Developing tests enabling seeds' resistance to penetration by the fungus, the use of sampling and sorting techniques are the result of a first series of studies, from which numerous developments are expected in the near future.

Other diseases and parasites are being studied (rust, aphids, bugs, bruchids) but represent only a small part of the IRHO's research activities.

Development and Extension Studies

One of our Institute's main concerns is applying research results. Research workers are only too often satisfied with publishing their work, citing the results of fantastic experiments, without it being possible to know whether they are applicable to traditional agriculture.

Thus, wherever possible, we have tried to get beyond experimenting, and to make full size tests of research results with the peasants.

In Senegal, on a network of several hundred ha representing typical farms with groundnut, grain and fallow land rotation, we proved the profitability of weak mineral manuring chosen judiciously as a result of leaf diagnosis over a 15-year period.

On an extension sector in Upper Volta, we were able to demonstrate the value of Rosette-resistant varieties associated with simple growing techniques (sowing density, fertilizer, etc.), thus reintroducing groundnut growing in an area where it had practically ceased.

In Niger, Guinea Bissau, Mali, etc, we set up propagation units to develop new varieties and supply growers with a solid basis for applying modern production techniques with guaranteed profitability.

The IRHO is also present in integrated development projects to which it contributes aid and specialized knowledge of the groundnut. Its intervention occurs either at the level of direct participation (as in Senegal for the edible groundnut operation, etc) or at the level of occasional technical advice (as in Mali to define technical themes and the evolution of their application) or even by building industrial units for product processing (SAN confectionery groundnuts).

The IRHO also participates in complete studies for restructuring the industry and production, as was the case in Gambia for the whole groundnut sector, and in Senegal for the whole edible and confectionery groundnut sector.

Conclusion

Created as a national body, the IRHO has become over the years an international association, giving developing countries specialized aid so that they can define, set up, and operate research programs, development projects or processing installations for tropical oil crops.

Appendix

List of countries where IRHO has been operating for the last 15 years on a long-term basis (**), on a short-term basis at present (o), or as a consultant (*).

West Africa

(o) Benin:
Castor research; consultancy for a development project (SONACO); yearly support for directing agricultural research (groundnut, castor).

(**) Chad:
Study of the participation in the integrated development project of southern Chad (groundnut, cotton); groundnut seed multiplication and experiments.

(*) Gambia:
Study for restructuring the groundnut sector including production and industrialization.

(**) Guinea Bissau:
Participation in scientific research and development activities for the Mancara Project; experiments; seed multiplication and other studies.

(»*) Mali:
Scientific research on groundnut, sesame, and soybean; technical advice to OACV; technical assistance for groundnut seed multiplication and storage; technical assistance and services offered for the construction and operation of a confectionery groundnut processing unit.

(**) Niger:
Participation in scientific research on groundnut and sesame; technical assistance for organizing seed multiplication operations in Zinder, Maradi, and Dosso; periodic consultation for improving groundnut production.

(*) Nigeria:
Study of the possibilities of a cash crop (groundnut) rehabilitation project in the north; study of a groundnut seed multiplication unit in the State of Kano.

(**) Senegal:
Participation in ISRA's research work on groundnut; technical assistance for confectionery groundnut production; technical assistance for the establishment and operation of a national seed service; study of the agroindustrial channels for confectionery groundnut.

(*) Sierra Leone:
Study of the possibilities of the groundnut section in the northern development project (IBRD).

(*) Togo:
Study of the groundnut section of the development project in the maritime zone (IBRD).

(**) Upper Volta:
Scientific research on groundnut, sesame, soybean, and shea butter trees; research station marragement; seed multiplication; extension sector management.

Central Africa

(*) Cameroon:
General oilseed crops study.

(o) People's Republic of the Congo-:
Agricultural research on groundnut; seed multiplication; consultancy forthe development of annual oilseed crops.

(o) Central African Republic:
Agricultural research on annual oilseed crops and study of a development project.

(o) Gabon:
Agricultural research on groundnut; study of a development project in the plateau region.

East Africa

(*) Mozambique:
Consultancy for the plantation societies and the government.

Southern Africa

(*) Botswana:

Changes in the research and development requirements of groundnut.

(*) Zambia:
Technical support for planning a groundnut processing unit.

Indian Ocean

(*) Madagascar:
Mission for assessing oilseed requirements and the development plan; assistance to a castor project for genetic studies.

Far East

(*) Indonesia:
Consultancy for improving castor production.

Central and South America

(*) Dominican Republic:
Consultancy for groundnut development.

(*) Haiti:
Consultancy for the development of annual oilseed crops.

(*) Mexico:
Mission for identifying and studying the possibilities of groundnut and soybean projects on the east coast of Mexico for the Plan Nacional Hydraulico, and IBRD.

Oceania

(**) New Hebrides:
Groundnut research and experiments.

Peanut Collaborative Research Support Program Planning

C. R. Jackson and D. G. Cummins*

Our purpose at this Workshop is to inform you of the Peanut Collaborative Research Support Program Planning (CRSPP) effort. The collaborative concept is a new USAID research program in addition to other existing research, and is designed to aid research on a global basis. The planning is supported through a grant from USAID to the University of Georgia, made under provisions of the Title XII program of the U.S. Board for International Food and Agricultural Development (BIFAD). The planning office is located at the Georgia Experiment Station, Experiment, Georgia, which is very fitting since much of the modern peanut research originated at this station.

The planning grant was awarded on August 12, effective August 1,1980 and will extend over an 18 month period. Curtis R. Jackson, Planning Director, and David G. Cummins, Associate Planning Director, will be responsible for activities under the grant. Robert Jackson, DS/AGR, is the AID Project Manager.

The Collaborative Research Support Program (CRSP) concept is new to many of us. It is an arrangement which facilitates long-term collaborative research among U.S. universities, the U.S. Department of Agriculture, U.S. Department of Commerce, International Agricultural Research Centers, other research institutions, and developing country research institutions. Collaborative research embodies the idea of working jointly in a research endeavor. Funds and benefits flow primarily to the developing countries, and the research is done in the developing countries themselves, to the maximum extent practicable.

The primary goal of the CRSP is to develop a structure through which scientific talent and resources of the USA, not available in developing countries, can cometo bear on food production, distribution, storage, marketing, and consumption problems in developing countries. The CRSP approach will link institutions (and individuals) having common interests in organized research programs on selected problems. The CRSP is built upon existing research programs in developing countries. Developing country institutions would participate out of a sense *of* priority research needs and their capability to contribute to a solution of the priority research problems.

The CRSP is unique in providing the linkage between the U.S. and developing country institutions, and in that the program must maintain a university identity.

We, as the planning group, are interested in contact with interested individuals from the peanut-producing countries around the world. Our primary goals relative to developing countries will be to determine constraints to peanut production and utilization, assess interest in participation in a CRSP, evaluate research capability and resources, and to improve our knowledge of peanut research and production, and utilization.

Duringthefall and winter of 1980-81, we will be involved in site visits and other activities to determine country interests, develop the state of the art information, and identify constraints to peanut production and utilization. In the early summer of 1981, preproposals will *be* solicited from U.S. universities and other research institutions to determine interest in collaborative research programs to relieve these constraints. A selection process with the aid of a Technical Panel will later result in full research proposals, establishment of U.S. and developing country institutional linkages, and final project development. The planning process is scheduled for 18 months, concluding January 31, 1982.

* Planning Director, and Associate Planning Director, respectively, Peanut CRSP, University of Georgia, Georgia Experiment Station, Experiment, Georgia 30212, USA.

A newsletter highlighting planning activities will be published periodically during the course of the project. Any inquiries of interest in the newsletter or anything else concerning the project should be directed to Dr. Curtis R. Jackson, Planning Director, or Dr. David G Cummins, Associate Planning Director, University of Georgia, Georgia Experiment Station, Experiment, Georgia 30212, USA, Telephone 404-228-7312.

Research and Extension Inputs Resulting in High Yields of Groundnuts in the USA

Ray O. Hammons*

The groundnut, *Arachis hypogaea* L., is an important economic farm crop in the United States. Ninety eight percent of the commercial production is in seven states — two on the mid-Atlantic coast, three in the Southeast, and two in the Southwest. Most of this area is a relatively humid zone although some of the Southwest crop is grown under semi-arid farming.

Groundnuts rank ninth in area among the USA row crops and second in dollar value per hectare. In 1979 the harvested crop area was 617 400 ha, with a production of 1805 000 metric tons (MT), averaging 2925 kg/ha.

Since the major thrust of this paper focuses on production inputs in Georgia, the leading groundnut state, the following production statistics show the current level of technology achieved there. In 1979, Georgia farmers produced 763 000 MT on 213 450 ha, for an average of 3576 kg/ha. The crop value at the farm level was S360 000 000. In Georgia, groundnuts were the No. 1 crop enterprise accounting for 12.1% of the state's cash farm receipts.

This efficiency level can be attributed to technology developed by research and transferred to the farmer by an effective agricultural extension service. Since these major developments occurred during the past 25-30 years, let me describe the situation then as a framework against which the production advances will gain perspective.

Thirty years ago, the land was prepared with the mold board plow and a spike tooth harrow, and seed was planted in a slight furrow using a single row walking planter. The plants were cultivated and hoed 3 or 4 times. Plant protection consisted primarily of an application of copper-sulphate dust for leaf spot. A long-season cultivar was grown and harvesting was usually begun when the leaves shed. Land preparation, cultural practices, and the lifting operation were done with animal-drawn equipment. When the plants were lifted they were stacked around a pole to field cure. After 6 weeks or more, the stacks were moved to a stationary mechanical picker where the groundnuts were removed from the vines. This system of production was labor intensive, requiring about 185 hr/ha. Yields averaged under 900 kg/ha (McGill 1979).

Little research and extension effort was applied to the crop. Some cultivar improvement, row and drill spacing studies, and the copper-sulfur leaf spot fungicide work formed the technology information bank. Nevertheless farmers from six Southwestern Georgia counties, meeting in January 1950, attracted the attention of the state's leading newspaper by setting a goal of a "half ton per acre", or 1120 kg/ha. As marginal land went out of production and growers began to try the new technology, the Georgia goal was reached in the 1956 season.

Cultural practices in the middle 1950's were poor by modern standards but were the best then known. Weeds were controlled by plowing as close as possible to the drill, hoeing, and dirting to smother other weeds.

Many farmers grew established landrace cultivars, with relatively low yielding potential, and kept their own seed or purchased it from a neighbor or a sheller-seedsman. In the latter instance, Thiram® (Arasan®) was usually applied as a protective fungicide.

Adaptive cultivars were developed mainly by line selection from farmers' stocks or by screening the limited stocks of exotic introductions, although the first series of cultivars developed by selection following hybridization were also becoming available. By 1960, farmers in the

* Supervisory Research Geneticist and Research Leader — Crops, the United States Department of Agriculture, Science and Education Administration, Agricultural Research, Southeast Area, at the University of Georgia Coastal Plain Station, Tifton, Georgia 31793, USA.

Southeast had the choice of a number of cultivars developed by public breeders in State Agricultural Experiment Stations and the U.S Department of Agriculture.

Since there were consumer products utilizing the major morphological groups of peanuts, growers had the option of growing one or more of the three USA market types and more than one cultivar of each type:

SPANISH. Small Spanish, Dixie Spanish, GFA Spanish, Argentine, Spantex, and Spanette.

RUNNER. Dixie Runner, Early Runner, Florispan Runner, Southeastern Runner 56-15, and Virginia Bunch 67.

VIRGINIA. Georgia 119-20, Virginia Bunch G2, Virginia Runner G26, NC 2, and Virginia 56R.

Results of uniform variety tests, reorganized after 1955 to provide comparative performances among cultivars and advanced breeding lines within market types, were widely publicized. These data gave the farmer a rational choice of cultivars to use in his farming system.

The framework of cultivars adapted to the soil and climatic features of the area provided a suitable backdrop for a number of breakthroughs in groundnuts research and development. It is not my purpose hereto provide a full chronology of these events since many of the achievements were interwoven together into the production package.

The highlights of research technology and extension inputs which have led to high yield levels in the Southeastern United States may be outlined as follows:

Shaker-windrower and Combine

The first major advance was in equipment technology. Groundnuts had emerged as a commercially valuable crop with the development of the stationary picker in 1905 but although horses, stationary engines, and eventually tractors were used to power these machines, very little improvement in picking efficiency had occurred in 40 odd years.

Two pieces of equipment developed in the late 1940's revolutionized harvesting practices. One was a shaker-windrower, which picked up the groundnuts after they were dug, shook out the soil, and formed two adjacent rows into a random windrow for curing. This eliminated the stacking practice (Mills and Samples 1973). Then in 1948-50, J. L. Shepherd and *W.* D. Kinney developed a once-over mobile peanut combine in research at Tifton. These two innovations, quickly adopted, cut the harvest labor requirement by about 85%. They also led to the development of artificial drying principles used initially at buying stations, but soon adopted as an on-the-farm practice.

Tillage Methods for Disease Control

The second major advance was the development of tillage methods for nonchemical disease control. The practice of deep plowing, followed by shallow, nondirting cultivation, formed the basis of the suppression of the white mold caused by *Sclerotium rolfsii.* L. W. Boyle and CO-workers (Boyle, 1958; Boyle and Hammons, 1956) developed concepts, confirmed by a large body of experimental evidence, on the benefits of deep turning to bury surface organic matter.

Selective Herbicides

The third major breakthrough came with the discovery of selective herbicides for weed control. L. W. Boyle, E. W. Hauser and associates at the Georgia Agricultural Experiment Station developed a new scheme of culture through research to lay the foundation for gains in yield and crop quality and allowed farmers to use the genetic improvements bred into the newer cultivars.

About 1959, Hauser led the pioneering studies showing that herbicide mixtures, applied at the ground cracking stage of seedling emergence, were more effective than the components of such mixtures. These results today still form an essential component of weed control systems for groundnuts (and other crops).

Precision Land Preparation

The fourth step was provided by J. L Shepherd i.e., engineering innovations in precision land preparation tactics to maximize the pathologic-agronomic practices and precision planting to optimize plant populations.

Organization of Peanut Extension Program

The University of Georgia established the position of Extension Agronomist — Groundnuts, in the Cooperative Extension Service in 1959 when J. Frank McGill undertook this work. The pathological, agronomic, and engineering principles described above were unified into a package approach for use. This package of technology, carried through the County Agricultural Agents, was quickly adopted.

Since 1959 the Extension Specialists team, located in the heart of the peanut belt at Tifton, has increased to six: two in agronomy and one each in engineering, entomology, plant pathology, and weed control. The significance of this team lies not only in their skills in transmitting useful and timely research information directly to farmers and/or through the County Agricultural Agents, but also in their function to relay the farmers' needs and problems back to the researchers.

Research/Education Planning Conferences

In the late 1950's the University of Georgia and cooperating USDA scientists organized a conference of workers engaged in groundnut research and education. This group has met annually with administrators in planning sessions which systematically identified problem areas, discussed recent progress, and recommended new approaches and personnel requirements. This conference provided an updating of key production constraints, a cross-fertilization of ideas, and an' opportunity for shifting research responsibilities and resources toward solving new or difficult problems.

Growers Support Research and Extension

A different kind of activity that has stimulated groundnut production in Georgia followed the organization in 1961 of the Georgia Agricultural Commodity Commission for Peanuts (the PeanutCommission). This grower group, using a self assessment of $1 per ton since 1961 (and $2 more recently), has generously supported groundnut research at Georgia's three agricultural research facilities, has strengthened the extension specialist program and has sponsored graduate research fellowship grants. This support equalled $2.5 million from its initiation until June 1980 and is continuing. The Commission regularly publishes a groundnut magazine, which is.circulated to all growers in Georgia, Florida, and Alabama (where more than 60% of the crop is grown). It provides a readily available medium for the rapid transfer of new technology to small scale farmers as well as their more favored neighbors.

Effective Seed Dressings

Other significant research achievements came during the 1960's. The development by C. R. Jackson and D. K. Bell of seed dressings using organomercurials significantly improved stands by virtually eliminating *Aspergillus* Crown Rot, the No. 1 seedling disease. After the removal of the mercurials by the Environmental Protection Agency, effective organic fungicide combinations developed by Bell have served as a reliable replacement.

Subsurface Herbicide Incorporation

In the early to mid-1960's Hauser developed devices and methods for the subsurface incorporation of the herbicide vernolate ®. The new subsurface treatments enabled fanners to control annual weeds and nutsedge more effectively (and with better crop tolerance) than with the previous methods of application.

Irrigation

The next major step came with the documentation by Engineers L. E. Samples and J. L. Stansell in 1965-68 of the magnitude of yield and quality responses due to groundnut irrigation in the Southeast. In this area the sandy soils, rolling topography, fluctuating rainfall, and high cash value of the crop have led to the use of sprinkler systems for growing irrigated groundnuts. Research and on-farm test data showing a 10-18% increased average yield, and frequent drought stress, led to a widespread adoption of the new technology. From 7.5% of the Georgia groundnut crop area irrigated in 1970, the practice escalated to 23% by 1975, and to 48% in 1979. For 1980, a year of severe drought and heat stress, the estimate is 54%.

Variety Shifts

Although a dozen groundnut cultivars were grown in Georgia in the late 1950's, two were predominant. The Runner market type accounted for 55% of ail production area and Dixie Runner alone for 34%. Spanish type occupied 41% of the area, with Dixie Spanish on 24%. Virginia type accounted for less than 4%.

The widespread availability of newer cultivars which responded well to the improved technology influenced a marked shift by growers. As the Argentine and Starr cultivars replaced Dixie Spanish, Spanish-type production moved to more than one-half the Georgia area. Even though the Early Runner cultivar replaced Dixie Runner, the total area in Runner type declined to about 40% by 1969.

The startling change was the rapid rise in production of Virginia type groundnuts, which moved from 3% in 1959 to 14% in 1969. This change was influenced by a newly available cultivar, Florigiant, and by a price structure favoring the larger seeded Virginia type.

The decade of the 1970's was a time for the integration of many research and extension inputs resulting in high yields of groundnuts in the United States.

Insect Scouts

In Georgia, entomological research by L. W. Morgan and associates about 1970 showed that the systematic use of insecticides eliminated beneficial insects, thereby increasing the total pest problem and population costs. As a direct result of this research, an insect pest management program was initiated in 1972 and the service now includes almost one-fifth of Georgia's crop area. This program is based upon the principle that insects must be at economic levels before control measures are justified. That is, the loss in yield or quality attributable to insect damage must exceed the cost of control. The program is voluntary by the growers and requires trained insect scouts who regularly check fields to monitor insect levels. Growers adopting the program have greatly reduced the number of insecticide applications (Information courtesy of L Morgan, H. Womack & R. Lynch).

Broadleaf Weed Control

Weed scientists in Georgia and Alabama cooperated in showing that the groundnut plant effectively suppresses certain broadleaf weed species when the crop is maintained weedfree for 5-6 weeks after they emerge. These results, combined with subsequent row spacing studies, increased the understanding of the competitive capacity of the peanut plant and enabled farmers to better plan their weed control strategies for more efficient and more economic production. More recent and current research indicates that weed weights may be reduced by up to 50% and the yield of groundnuts increased by 10% or more simply by manipulating row spacing (Information courtesy of E. W. Hauser and G. Buchanan).

The Florunner Cultivar

The most significant input of production research technology to high yield performance in the USA was the release of the Florunner groundnut cultivar in 1969 and its acceptance by growers and the industry. Research and development of Florunner was conducted at the Florida Agricultural Experiment Station and the breeding methodology in use there will be discussed by A. J. Norden (this conference). My concern here is to describe some of the impact as other research inputs were meshed with the Florunner cultivar in the production package.

At the time of its release, Florunner had been evaluated in cultivar performance trials in Florida, Georgia, and Alabama, where it performed well across a wide range of soil and climatic conditions, excluding prolonged drought.

Florunner is a product of a broadbased, open-ended breeding program that produces multiline groundnut cultivars with greater genetic diversity than the pure line cultivars they replaced (Norden 1980; Hammons 1976). At the time of its release, Florunner outyielded its predecessor Early Runner by about 20%. By 1979 it was grown on 98% of the peanut crop area in the Southeast and occupied some 64% of the total crop area in the nation (Hammons, unpublished survey data).

Organic Fungicides

Prior to 1970 almost ail of the groundnut farmers used copper-sulfur dusts for controlling leaf spots. With the discovery of the systemic fungicide benomyl (Benlate ®), and a protective fungicide chlorothalonil (Bravo ®), control of leaf spot was significantly improved and yield losses from early defoliation were sharply reduced. These organic fungicides came on the heels of the introduction of Florunner and their use lengthened the fruiting period by up to 2 weeks (Information courtesy of R. H. Littrell). The increasing use of irrigation systems provided additional water to support the extra production when natural rainfall was sparse.

Fungicide-tolerant Strains

The widespread and extensive use of benomyl resulted in sel ection of strains of the *Cercospora* and *Cercosporidium* leaf spotting fungi that was unparalleled in the use of fungicides for disease control. Research pathologists in Alabama and Georgia almost simultaneously discovered strains of these fungi tolerant (resistant) to this otherwise highly effective fungicide. Tolerant strains were found in 1973 using laboratory techniques before economic losses occurred under field conditions.

In Georgia, R. H. Littrell, using laboratory and greenhouse experiments, proved that benomyl-tolerant strains survived and were capable of causing disease. Based upon these results, the fungicide was removed from the list recommended for 1974. Research data in 1974 indicated benomyl was completely ineffective, and yield in benomyl-treated plots did not differ from that in the untreated controls. Should benomyl have been used in 1974, dramatic losses from foliar diseases would have occurred (Littrell 1974 and personal communication 1980; Smith and Littrell 1980).

A Package Approach

By the middle of the 1970's the original package of production technology (McGill and Samples 1969) had been modified (McGill et al. 1973) to incorporate new discoveries. Further fine-tuning of the principles provides the framework for farmers in Georgia in the 1980's (Henning et al. 1979).

Cultivar/Insecticide Interaction

An additional input in the area of herbicide application is an example of further research to optimize the yield potential of the crop. E. W. Hauser led a three-state team that evaluated the genetic vulnerability of groundnuts to intensified pesticide treatments. They found that the yield of Florunner was significantly increased most of the time by the insecticide disulfotan (a finding which surprised entomologists). An understanding of these cultivar/insecticide interactions will enable groundnut farmers to more logically devise pesticide sequences for effective pest control (personal communication, E. W. Hauser 1980).

Fungicide/Nematocide Combination

In a similar manner, Pathologist S. S. Thompson led a team in demonstrating the benefits of the soil fungicide PCNB in combination with a nematocide (Mocap ® or Oasinit ®) in suppressing the white mold fungus S. *rolfsii.*

Other major and minor advances in agronomy, engineering, pathology, entomology, and other disciplines have contributed substantively to the production package. Time will not permit my discussing many of these. Among those which may be listed are:

1. Improved agronomic practices, including balanced fertility of major and minor nutrients applied following soil test recommendations, precision liming, and the ex-

tensive use of gypsum (CaSC4) on Runner and Virginia type peanuts.

2. Windrow inverters to shorten exposure of the dug crop to potentially adverse weather and thus reduce losses in combining.
3. Availability and general use of effective pesticides which reduce mechanical contact with plants, provide season-long control of insects and foliar diseases, and give moderate control of soil-borne diseases and nematodes.
4. Increasing use of some form of solid-set irrigation system to provide adequate soil moisture upon demand.
5. Finally, and perhaps of greatest importance, is the improved educational level of farmers with their greater awareness of the value and impact of agricultural research.

Farmers, now more than ever because of sharply escalated costs, *are* willing to incorporate effective and timely research results into commercial production practices. This evolving grower attitude has had a very positive effect on the entire crop management program, particularly in the southeastern peanut belt.

Actually, with recent emphasis by the public research sector on applied as contrasted with basic research, and the rapid assimilation of results by growers, the stockpile of unused technology is less extensive than it formerly was.

The examples of cooperative interactions between researchers and their linkages with a multidiscipline extension team as described in this paper have shown that this approach is better than that of an individual alone trying to solve a myriad of problems.

Acknowledgments

The author is indebted especially to J. Frank McGill for discussions on this subject since 1959 and for sharing his unpublished notes. D. K. Bell, E. W. Hauser, R. H. Littrell, and D. H. Smith made detailed responses, with examples, to a request for information and gave permission for me to use their views. Appreciation is also expressed to R. W. Gibbons who encouraged me to attempt this overview of technology integrated with rapid application by growers.

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Session 2 — Research Organization and Development

Discussion

T. P. Yadava

In *Haryana,* white grub has become an important insect pest and a check on groundnut development and spread. Do we have some measures to control this insect?

Vikram Singh

D. R. C. Bakhetia has been looking for effective low cost insecticides, and the use of these as seed dressings.

D. R. C. Bakhetia

For white grub control in groundnut, seed treatment with insecticides has given very encouraging results. Out of seven insecticides tested, seed treatment with chlorpyriphos 20 EC, isofenphos 40 SD and carbofuran 50 WP at 2.5 g a.i/kg seed gave an excellent control of the pest. The insecticides were also tested in combination with thiram (5 g/kg seed) to check collar rot incidence. Thus the control of white grub, collar rot and both together helped in obtaining 80 to 144, 104, and 130 to 196% increase in yield over control, respectively These were tried at two locations over 2 years.

Chairman

The costs of these seed treatments is low relative to total production cost

Vikram Singh

These treatments are not yet an official recommendation, as they have not been tested by AICORPO.

R. W. Gibbons

Please, could P. Gillier give details of seed multiplication and certification schemes in francophone West Africa?

P. Gillier

The schemes are different in each country. In Senegal, there is a government seed service. Seed is grown by farmers under contract Foundation seed is grown by these farmers under strictly controlled conditions, with specified seed dressings etc. It is then multiplied by cooperatives and then bought by the seed service for distribution. The seed service is a large organization, with good control over the seed and its purity and germination.

In Upper Volta, each farmer receives 10 to 20 kg of seed and increases it himself for his subsequent crops.

In Niger, seed is multiplied by farmers under contract.

R. W. Gibbons

What are the problems of seed multiplication and distribution in India?

Vikram Singh

The initiation of an efficient multiplication system for breeders' seed is one of the short-term objectives of AICORPO, so we hope there will be no further problems. Production of foundation and certified seed is beyond our reach at present.

C. Harkness

In Nigeria, there are difficulties in getting large quantities of new seed. Will the farmers grow the seed for multiplication of the new varieties?

Vikram Singh

We plan that the breeder will multiply breeders' seed in the early generations, but are debating what to do next with regard to foundation seed. However, certified seed wilt have to be grown on farmers' fields.

R. W. Gibbons

I have been impressed in the USA by the number of extension workers who are groundnut specialists. Which other countries have appointed groundnut specialists to their extension service?

K. S. Labana

In the Punjab, India, we have extension workers who are oilseed specialists, based in the Universities at Ludhiana and Kapurthaia. The State Agricultural Department has extension officers too, not only in groundnut but for other crops also. Most of these people are breeders.

Vikram Singh

Extension officers must be specialists in a particular discipline. We need workers with a thorough training especially in entomology, pathology, or agronomy.

G. D. Patil

What are the causes of variation in areas under different groundnut types in Georgia in different years?

R. O. Hammons

The reasons are not related to soil type nor farmer preference. One is that there are slightly different price structures for different types of groundnut, but the industry is also able to interchange end uses between different types, and grow those types which give the grower the maximum profit. Florunner gives high yield and greatest shelling out-turn, and so favors the grower, who is paid on shelling out-turn. We grow for edible use, not for oil extraction.

H. M. Ishag

Is shelling percentage solely controlled by genes, or is it controlled also by agronomic practices? In Sudan, we noted that in badly managed crops, we have high shelling percentage (it goes up to 70 to 72%) while in well-managed crops shelling percentage drops to 62 to 65%.

R. 0. Hammons

Shelling percentage is an inherent trait, but it does vary depending on the time in the growing season at which pod set occurs, and on otherfactors. In general, Florunner usually has 75 to 77%, Florigiant 69 to 72%, and Spanish types in between.

H. M. Ishag

What is the reproductive efficiency of Florunner?

R. 0. Hammons

We do not know what the reproductive potential of these varieties is.

U. R. Murty

Does the overproduction of flowers in groundnut represent an evolutionary mechanism related to survival or does it also represent a potential for increasing the productivity?

R. 0. Hammons

We have recovered 1400 seeds, plus 700 pegs which had not matured at harvest, from a single plant. In the same trials we had more than 1000 seeds on over 20 plants. Can we transplant cuttings, say of F_1 hybrids, and achieve improved yields?

H. T. Stalker

Cuttings of Fi hybrids will not produce as many seeds as plants grown from seedlings. The reproductive efficiency of most cuttings is much lower than seedlings; much of this is due to fewer branches being produced on most cuttings. Also the cotyledonary lateral branches usually produce most of the plant's seeds, but cuttings do not have these highly productive branch structures. The conclusion is that a field of F_1 cuttings probably will not produce as much per hectare as seedlings of a good variety.

J. S. Chohan

With the use of Benlate, was there an increase in the incidence of rust in the course of time? If so, how did you face this problem?

R. O. Hammons

Rust is not a problem in USA except in Texas.

D. H. Smith

Benlate is not effective against rust. Rust is sometimes more severe when *Cercospora* leaf spots are controlled by Benlate, because the competition with the leaf spots is eliminated.

Vikram Singh

The yield levels of 3500 kg/ha in Georgia are impressive; much of this is due to growing Florunner. Has the full yield potential of Florunner been exploited, or is there still a gap between existing yields and potential yield?

R. O. Hammons
Some groundnuts are grown on poor land not ideally suited to them. Some of the yields obtained by the better farmers on good land (up to 7300 kg/ha) compare well with the best yields on our experimental plots (which are not on the best land!).

S. H. Patil
According to Dr. Vikram Singh of ICAR in India, about 8 years are required for a variety of groundnut before recommending it for general cultivation. How many years of evaluation are required in the USA for similar recommendation?

R. 0. Hammons
Normally 3 years of trials are needed before the state can recommend a new variety, but if already recommended in another state, only 2 years are necessary. We also test our breeding lines, so we have 3 to 5 years of test data. Two organizations are involved in release and production of seed. The Georgia Foundation Seed Development Corporation takes the seed from public breeders and multiplies it on state-owned farms in the foundation generation; that seed is then sold to farmers in the Georgia Crop Improvement Association who multiply the seed under supervision, and the Agency certifies the seed.

S. M. Misari
I was impressed with the ever-increasing yields in groundnuts in the USA. In Nigeria at the moment we have one extension worker to 2000 to 3000 farmers. May I know how you have gone aboutyour extension methodology and what is the present ratio of extension workers to farmers in the USA?

R. O. Hammons
The basis of the service is the six-man extension team, and a County Agricultural Agent in each county. There are about 75 extension officers for 16 000 farmers, or about 1 to every 200 farmers.

K. S. Labana
Is there any micronutrient problem in USA? In Punjab we are facing micronutrient problems like deficiency of Zn, Fe, Mn, and Ca in groundnut soils.

R. O. Hammons
I can't provide details now, but write to me and I will send you the information.

J. A. Thompson
What is the place of inoculation with root nodule bacteria in the package deal for growing groundnut in USA?

R. O. Hammons
We use a complete fertilizer, 400 lb/acre of 5:10:15 or 4:12:12. Groundnuts usually follow previous groundnut crops, so less than 0.1% of farmers use inoculum; usually this is on land cropped to groundnut for the first time.

B. S. Gill
Dr. Hammons, you indicated that the area under Florunner increased rapidly in the 70s, and during the same period the area of irrigated crop also increased. I would like to know the relative contribution of the improved variety and the irrigation.

R. O. Hammons
There is a 10 to 16% yield increase with irrigation; there are variety responses to irrigation and to excess irrigation; some varieties give a 20% yield increase when irrigated.

N. D. Desai
Do you have areas under rainfed conditions (without irrigation)? Is there any production technology developed for such areas or is any variety available?

R. O. Hammons
I am sorry, we cannot offer you technology or released varieties. We have noted in variety trials that one of our lines, Tifton 8', grows better and wilts later than other varieties under drought conditions, and we will make seed available if you request it. It does not respond well under ample moisture, however.

P. S. Reddy
Now that more than 50% of groundnut in Georgia is irrigated I presume that a lot of information might have been accumulated on irrigation studies. Can Dr. Hammons kindly

enlighten us on the following?

a. The critical stages of moisture stress for different habit groups?
b. Quantum of irrigation water required per irrigation?

R. 0. Hammons

There is not an easy answer, as we get "irrigation" from frequent showers in addition to the irrigation water applied. The results from rain-out shelter studies are available and can be referred to for details.

M. A. Ali

Dr. Hammons mentioned that deep plowing has helped to control *Sclerotium rolfsii.* Was the control permanent or did the fungus become more serious when that particular piece of land was deep plowed again after 1 or 2 years?

M. K. Beute

Deep plowing is a short-term control measure. Its effectiveness depends on when the debris is brought back to the surface.

D. J. Nevill

How will Title XII interact with ICRISAT Projects, and how will ICRISAT feature in the planning stage?

C. R. Jackson

ICRISAT will be written into projects where applicable. Also Title XII will not duplicate on-going, well-funded projects.

J. S. Saini

There is a strong observation that groundnut sown for the first time in a field gives good yield under Punjab conditions. But the same field after 3 to 4 years of continuous groundnut cultivation shows a considerable decline in yield, even with the adoption of the same production technology. Have you observed this phenomenon in USA also, and what can be the possible reasons for this decline under such a situation?

R. O. Hammons

Our package includes intensive crop protection, so we do not have such problems.

Chairman

Any comments on monocropping?

N. D. Desai

In Gujarat, groundnut is grown year after year and from generation to generation in the same field. Not only that, but in the same furrow — yet, there are no observations about decline in yield.

S. V. Jaiswal

Groundnut, when cultivated for the first time in the Punjab in a sandy field, will yield as high as 3 tonnes/ha. The farmers felt very much encouraged and during the second year, with the application of the same inputs, the yield came down to 1 Vi to 2 tonnes/ha. This sudden decline in yield during the second year of groundnut cultivation needs to be explained. This occurs especially in sandy soils.

J. S. Chohan

The explanation for the difference between the sandy soils of the Punjab and the heavier soils elsewhere is probably that in the sandy soils there are fewer microorganisms which are antagonistic to the survival of the pathogen in the soil between crops, so the second and subsequent crops are exposed to higher levels of inoculum than a crop in a field sown to groundnuts for the first time.

Session 3

Genetics and Breeding

Chairman: R. O. Hammons

Rapporteurs: S. L. Dwivedi
R. W. Gibbons
D. McDonald
S. N. Nigam

Groundnut Genetic Resources at ICRISAT

V. R. Rao*

It is well known that the success of modern crop cultivars, the population explosion and the disturbance of the ecosystem have together tended to reduce the genetic variability in plant resources available to man. The grower, processor, distributor and consumer have demanded uniformity in crop varieties and food products. The plant breeder, to meet these demands, has reduced the genetic diversity in our major crop species and this has often resulted in their increased genetic vulnerability. In a way, plant breeders have become victims of their own success. With diversity existing in landraces being replaced by homogeneous improved cultivars, the danger of genetic erosion has become serious (USDA 1979). In groundnut, this process started as far back as 1875 when Holle introduced into Java the Waspada cultivar, maturing in 4-5 months, that completely replaced native cultivars maturing in 8-9 months (Hammons 1973).

With modernization and urbanization, the natural environs of wild and weedy species have been disturbed and some may become extinct. Natural habitat destruction, which occurs only slowly, can be seen happening today in South America as far as *Arachis* species are concerned. It is imperative that whatever genetic diversity remains should be assembled and *conserved.* This may be for immediate utilization in crop improvement, or for future utilization when the situation is expected to be even more alarming.

Arachis Genetic Resources

Groundnut ranks 13th in importance among the world food crops and is the most important food legume (Vamell and McCloud 1975). Compared to other oilseed crops and grain legumes, it is relatively daylength insensitive and has a high oil and protein content. As a crop it is well adapted and is readily accepted as a food. Groundnut is grown on about 20 million hectares, extending from tropical to temperate zones, in about 80 countries. The major production zones are in the semi-arid tropics. Average yields in the developed world are about 2000 kg/ha, but the world average is less than 900 kg/ha.

Arachis genetic resources include all the wild species and the cultivars under production. The genetic diversity in cultivated groundnut has been continuously eroded in the groundnut-growing countries since crop improvement work started in this crop. This process is very clear in India and in some African countries, where improved cultivars have been introduced, and the older landraces have almost completely disappeared. In some regions of many groundnut-growing countries, the process is slow and timely collection now would result in conservation of such landraces. In South America, where *Arachis* originated, much valuable material exists. The developmental activities in many of the countries in this region would soon result in the loss of this valuable germplasm (W. C. Gregory, personal communication). Hence there is an urgent need to collect and conserve *Arachis* germplasm from these countries.

Some efforts to collect and conserve germplasm have been done in a few places around the world in a fragmented manner. Some of the major known *Arachis* collections are listed in Table 1. There is, undoubtedly, a certain amount of duplication in these collections. Table 2 lists the catalogs known from various centers of conservation. From the list, one may take the vastness of the resources for granted. Gregory et al. (1973) have warned about such a possible misconception. These reserves are finite and exhaustible. Harlan (1976) has indicated the limitations of our potential genetic resources in the light of the possible genetic wipe out of the center of

* Groundnut Germplasm Botanist, Genetic Resources Unit, ICRISAT.

Table 1. Known sources of groundnut germplasm collections.

Country	Institute/organization
USA	a. Southern Regional Plant Introduction Station (SRPIS), Experiment, Georgia b. North Carolina State University, Raleigh c. University of Georgia, Tifton d. University of Florida, Gainesville e. Texas A&M University, Stephenville f. Oklahoma State University, Stillwater g. Tidewater Research Center, Suffolk
Argentina	a. University of the North-East, Corrientes b. National Institute for Agriculture and Technology (INTA), Cordoba
Brazil	a. Agronomy Institute, Campinas b. CENARGEN/EMBRAPA, Brasilia
Venezuela	CENIAP, Maracay
Senegal, Upper Volta Ivory Coast, Niger etc.	a. Oils and Oilseed Research Institute (IRHO), Paris, France b. Senegalese Institute of Agricultural Research (ISRA), Bambey, Senegal
Nigeria	Institute of Agricultural Research, Ahmadu Bello University (Samaru and Kano)
Malawi	Ministry of Agriculture and Natural Resources (Chitedze Research Station)
S. Africa	Department of Agricultural Technical Services, Potchefstroom.
Zimbabwe	Crop Breeding Institute, Salisbury
Sudan	Gezira Research Station, Wad Medani
Israel	a. Ministry of Agriculture, The Volcani Center, Bet-Dagon b. The Hebrew University of Jerusalem, Rehovot
Japan	Kochi University, Kochi-ken
China	National Academy of Agricultural Sciences, Beijing
Indonesia	Central Research Institute for Agriculture, Bogor

Continued

Table 1. *Continued*

Country	Institute/Organization
Australia	Department of Primary Industries, Kingaroy, Queensland
Malaysia	Malaysian Agricultural Research and Development Institute
India	a. Oilseeds Research Directorate, Hyderabad b. All India Coordinated Research Project on Oilseeds (AICORPO)

Table 2. Groundnut catalogs available at ICRISAT.

Index Seminum Varieties d'arachide (*Arachis hypogaea*)	ISRA, CNRA, Bambey, Senegal
List of Groundnut Germplasm, Potchefstroom	DATS, Republic of S. Africa
Catalog of Seed Available at the SRPIS, Georgia, USA	ARS-USDA, USA (1974 & 76)
Cultivated Germplasm Catalog-Peanuts	NCSU, Raleigh, USA
Germplasm Screened at Delhi, Ontario, Canada	University of Guelph, Guelph, Canada
Groundnut Germplasm Bank in India	AICORPO (ICAR), India
Catalogo Analitico de Poblaciones de Mani	INTA, Argentina
Groundnut Seed Stored at NSSL	NSSL, Fort Collins, USA
Partial List of Groundnut Available at CBI, Zimbabwe	CBI, Salisbury, Zimbabwe
Peanut Accessions	NPGRL, Laguna, Philippines
List of Introductions from 01/61 to 08/76	The Hebrew University of Jerusalem, Rehovot, Israel
List of *Arachis* Germplasm	EMBRAPA-CENARGEN, Brazil

diversity and Hawkes (1979) clearly described the ways in which such a wipe out may occur. It is clear to everyone concerned that there is an urgent need to collect and conserve *Arachis* genetic resources if we are, indeed, to cope with the present and future groundnut improvement problems. Realizing this urgency, ICRISAT has been designated by the Consultative Group on International Agricultural Research (CGIAR) as a major repository *for Arachis* germplasm and has been charged with the responsibilities of genetic resources activities.

Arachis Genetic Resources at ICRISAT

The work in the groundnut improvement program was initiated at ICRISAT in 1976. Simultaneously the genetic resource activities also commenced. The objectives are collection, maintenance and evaluation *of Arachis* genetic resources and documentation and distribution of seed material and information. During 1979, the genetic resources work was reorganized with the creation of the new Genetic Resources Unit which took over the germplasm work in all five ICRISAT mandate crops. This did not change the basic scope and objectives of groundnut germplasm work. Figure 1 shows the basic activities of the Genetic Resources Unit.

Collection and Assembly

Present Status

Initially the major available resources were identified. Top priority was given to acquiring collections available at various known centers for ICRISAT. All the available collections from various research institutes in India were donated to ICRISAT and about 5000 accessions have been obtained in this manner (Table'3). This material, which has been obtained with the excellent cooperation of many institutions and in particular with the Indian Council of Agricultural Research (ICAR), consists of many intro-

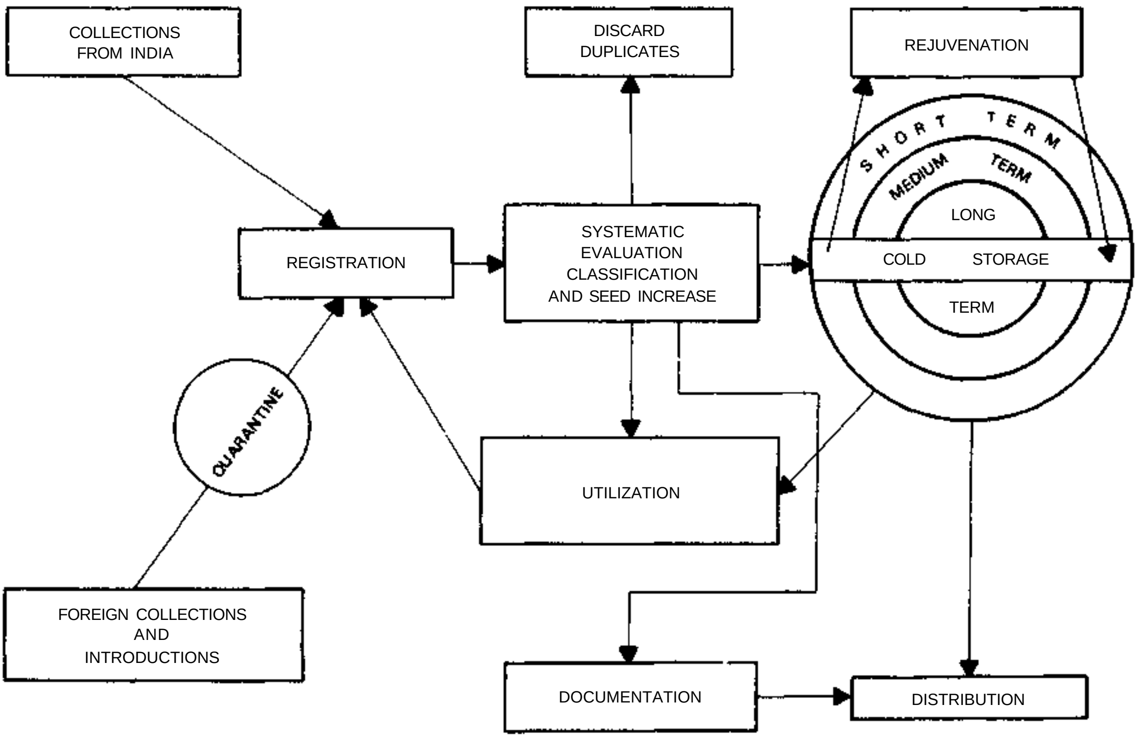

Figure 1. Genetic Resources Unit, ICRISAT — Operational flow chart.

ductions, reselections from such introductions, and experimental types developed within India. Similarly about 3000 accessions have been obtained from the USA, Japan, United Kingdom, Senegal, Malawi, USSR, Nigeria, Zimbabwe, South Africa and China (Table 4). ICRISAT has initiated a contractual arrangement with North Carolina State University, Raleigh, USA for the supply of groundnut germplasm held at that center.

In addition, ICRISAT has undertaken several collection expeditions within India and abroad, and a total of 598 accessions have been obtained so far (Tables 5 and 6). Generally random sampling technique is used for collection of seed from farmers' fields and seed is collected from as many plants as possible. During collection trips, apartfrom collection of seed material, information on cultivation practices, location, pests and diseases is also collected. For this purpose, a germplasm collection data sheet has been developed.

Table 3. Transfers from Indian centers.

Institute/location	Accessions
Andhra Pradesh Agricultural University, Kadiri & Karimnagar	1364
Rajendra Agricultural University, Ranchi	103
Mahatma Phule Krishi Vidyapeeth, Jalgaon	263
G.B. Pant University of Agriculture and Technology, Pantnagar	11
Agricultural Research Station, Durgapura	58
All India Coordinated Research Project on Oilseeds, Tindivanam and Pollachi	681
Gujarat Agricultural University, Junagadh	1154
Oilseeds Experiment Station, Tindivanam	368
Punjab Agricultural University, Ludhiana	495
National Bureau of Plant Genetic Resources, Amravati	159
Bhaba Atomic Research Center, Bombay	9
Punjabrao Krishi Vidyapeeth, Akola	112
Regional Wheat Rust Research Station, Mahabaleswar	5
Tamil Nadu Agricultural University, Coimbatore	29
Others	67
Total	4969

Table 4. Tansfers from centers abroad.

Country	Accessions
USA	2066
Japan	74
United Kingdom	20
Malawi	263
Senegal	16
USSR	3
Zimbabwe	151
South Africa	33
Nigeria	103
China	5
Total	2724

Table 5. Collection of local cultivars — India.

Month	Year	State	Accessions
Mar/Apr	1976	Bihar, Orissa, and Tamil Nadu	11
Nov/Dec	1976	Tamil Nadu, and Andhra Pradesh	23
Sept/Nov	1977	Rajasthan	7
Sept/Oct	1977	Karnataka (south)	35
Oct/Nov	1977	Andhra Pradesh	92
Apr	1978	Andhra Pradesh	4
Oct	1978	Maharashtra	1
Oct	1978	Karnataka (north)	151
Apr	1979	Andhra Pradesh	6
Apr/May	1979	Karnataka (south) and Andhra Pradesh	101
May	1979	Maharashtra	1
Aug/Sept	1979	Maharashtra and Gujarat	19
Oct	1979	Uttar Pradesh	1

Table 6. Collection of local cultlvars - abroad.

Month	Year	Country	Accessions
Mar/Apr	1979	Bolivia	12
Apr	1979	Nepal	13
Apr	1979	Malawi	33
Aug/Sept	1979	Somalia	5
June	1980	Zambia	83

Table 7. Yearly acquisitions.

Year	Accessions	Total
1976	2443	2443
1977	3565	6008
1978	925	6933
1979	1216	8149
1980 (August)	349	8498

Up to mid-1980, about 8500 accessions had been assembled and Table 7 gives the yearly acquisition of this material. Table 8 presents the available germplasm, by country. Apart from this, 1536 accessions from various countries are currently under quarantine inspection (Table 9).

ICRISAT has a special interest in the wild species of *Arachis* for cytogenetic and resistance breeding work. Some species (Table 10) have already been obtained from the Tamil Nadu Agricultural University, Coimbatore, India; North Carolina State University, USA; and Reading University, U.K. and have been established at ICRISAT. The collection from Reading University consists of material originally from North Carolina State University, Raleigh; Oklahoma State University, Stillwater; Texas A & M University, Stephenville; ARS-USDA, Tifton, Georgia, and the Division of Food Crops, Campinas, Brazil. More material is still being transferred. At the moment the wild species material is maintained jointly by the Genetic Resources Unit and Groundnut Cytogenetic Program.

Future Priorities

The IBPGR/ICRISAT ad hoc Committee on Groundnut Germplasm (September 1979) has assigned the following priorities for immediate collection:

Region	*Countries*
South Asia	Burma
Southeast Asia	Indonesia
Meso America	Mexico, Central America, and Caribbean Islands
West Africa	Senegal, Nigeria, Upper Volta, and Gambia
East Africa	Mozambique
South America	Brazil, Argentina, Peru, Bolivia, and Paraguay

Gregory et al. (1973) have described the distribution of the genus *Arachis* in South America, where more intensive collecting is necessary to obtain valuable germplasm. Efforts are being made to launch expeditions in collaboration with the IBPGR and CENARGEN/ EMBRAPA (Brazil).

Quarantine

The importation of exotic groundnut material is subject to strict quarantine regulations laid down by the Government of India in order to prevent the entry of new pests or diseases into the country. ICRISAT obtains the seed in the form of shelled seed accompanied by regular phytosanitary certificates. The seed is planted in plastic pots in the screen house at the Central Plant Protection Training Institute (CPPTI), Rajendranagar. CPPTI has been authorized by the Ministry of Agriculture, Government of India, to conduct quarantine work for ICRISAT mandate crops. The seedlings remain under close examination for 6 weeks. Then the material is transferred, and transplanted, in the Post Entry Quarantine Isolation Area (PEQIA) which is located in an isolated corner of the ICRISAT farm. The seedlings are inspected every week by a joint CPPTI-ICRISAT team and any plants showing suspicious symptoms are uprooted and destroyed. At maturity, the seed is harvested from the healthy plants and is released. These procedures allow an excellent working relationship between the Genetic Resources Unit and the quarantine authorities.

For export, seeds from healthy plants are collected. The seed is examined by the Indian quarantine authorities and is then despatched

Table 8. Groundnut germplasm — source countries (August 1980).

Country	Accessions	Country	Accessions
AFRICA		Brazil	243
Angola	2	Chile	12
Dahomey	6	Ecuador	2
Egypt	5	Paraguay	101
Gambia	5	Peru	62
Ghana	6	Uruguay	20
Guinea	2	Venezuela	8
Ivory Coast	24	Others	114
Kenya	28		
Liberia	10		813
Libya	1		
Madagascar	8	ASIA	
Malawi	65	Burma	16
Mali	9	China	162
Mauritius	7	Cyprus	5
Morocco	5	India	1715
Mozambique	10	Indonesia	25
Nigeria	167	Iran	6
Senegal	85	Israel	31
Sierra Leone	7	Japan	44
South Africa	42	Malaysia	13
Sudan	674	Philippines	6
Tanzania	110	Sri Lanka	17
Uganda	57	Taiwan	20
Upper Volta	10	Turkey	3
Zaire	11		
Zambia	10		2063
Zimbabwe	377		
Others	84	EUROPE	
	1827	Bulgaria	2
		Greece	4
N.C. AMERICA		Holland	5
Cuba	11	Spain	1
Costa Rica	1		12
Honduras	3		
Jamaica	1	OCEANIA	
Mexico	6	Australia	45
Puerto Rico	19	Fiji	1
USA	1240		
	1281		46
SOUTH AMERICA		USSR	49
Argentina	195		
Bolivia	56	Unknown	1991

Table 9. Accessions under quarantine.

Country	Accessions
Burma	5
China	10
Indonesia	60
Italy	27
Malawi	6
Malaysia	56
Nepal	1
Senegal	341
South Africa	133
USA	814
Zambia	83
Total	1536

Table 10. *Arachls* spp at ICRISAT.

A. duranensis	*A. glabrata*
A. batizocoi	*A. repens*
A. correntina	*A.* sp (10038 LL & SL)
A. chacoense	*A.* sp (C 565-66)
A. cardenasii	*A.* sp (C 9990, 9993, 10002)
A. villosa	*A.* sp (Man. 5)
A. stenosperma	*A.* sp (Man. 8)
A. monticola	*A.* sp (30008)
A. pusilla	*A.* sp (30098)
A. paraguariensis	*A.* sp (30093)
A. villosulicarpa	*A.* sp (30011)
A. rigonii	Many accessions of *Rhizomatosae*
A. hagenbeckii	

to the consignee with phytosanitary certificate issued by the Government of India. This work is carried out at thequarantine laboratory situated in the ICRISAT Center under the supervision of CPPTI personnel.

Maintenance

The procedures followed in conservation, maintenance, and storage present many problems. In maintaining the genetic purity of the conserved accessions, problems may arise due to differential survival in storage, selection during rejuvenation, out-crossing with other entries, and genetic drift (Allard 1970). Good storage conditions coupled with proper growouts are expected to reduce the effects of such problems.

At ICRISAT all the cultivated groundnut accessions and seed producing wild species are maintained by growing out In the case of the cultivated groundnut, only pods attached to the plants are harvested. In the case of seed producing wild species material, which are considerably space planted, all the pods are collected. The rhizomatous and nonseed producing wild species are maintained in either brick chambers or concrete rings to prevent contamination. Rejuvenation is carried out by rooting stem cuttings and rhizomes. As the long-term cold storage facilities are still under construction, about one-third of the collection is planted every year for multiplication and rejuvenation during the postrainy season when there is less incidence of pests and diseases.

Types of Collection

Though there is no recommendation regarding the types of groundnut collections to be maintained at ICRISAT, it is envisaged that the following types would be maintained:

ACCESSIONS COLLECTION. This includes all the available groundnut accessions at ICRISAT. It will be maintained in long-term cold storage.

WORKING COLLECTION. (BASIC COLLECTION) This includes lines chosen and stratified by botanical variety, geographical distribution and ecological adaptation. This would represent the genetic diversity available in the groundnut germplasm.

WILD SPECIES COLLECTION. This includes all the wild species of *Arachis* which have to be maintained separately due to problems of handling.

NAMED CULTIVAR COLLECTION. All the cultivars named and released by public and private institutions will be included in this collection.

GENETIC STOCK COLLECTION. This collection includes all the sources of resistance to pests and diseases, lines with specific desirable traits and stocks with known genes.

Storage

At present the collection is stored as unshelled pods in airtight containers in temporary stores which are not airconditioned. The medium-term cold storage facility which has been recently completed, with 4°C temperature and 35% relative humidity, is now available for storing groundnut germ plasm. The long-term facility (- 18°C) has been approved for construction and should be completed by the end of 1981.

Evaluation and Utilization

Collection, maintenance, and conservation have significance in elucidating taxonomic status and evolutionary relationships between and within the species. But the main justification for genetic resource conservation is for utilization in crop improvement. The key to successful utilization of variability from broad genetic pools requires the knowledge of desirable traits available in the germplasm. This requires a systematic evaluation of the germplasm. At ICRISAT, a multidisciplinary approach is followed and the available groundnut collection is evaluated by all the groundnut scientists.

The preliminary evaluation is carried out in the PEQIA and during the first grow out for multiplication. The material is evaluated for about 32 morphological and agronomic characters. Promising material is then evaluated by other disciplines. Table 11 gives some of the sources selected for resistance to pests and diseases. These lines are being extensively used in the breeding program to incorporate and improve the existing cultivars. Lines identified elsewhere as early maturing and high yielding, and which are in the ICRISAT collection are also being used in the respective breeding programs.

In the near future, germplasm will also be evaluated for other useful attributes such as drought tolerance, high oil content and sources of resistance to other pests and diseases. It is also intended that in future, multilocation testing of some of the germplasm lines will be carried out. At present, part of the ICRISAT groundnut germplasm is being evaluated in Vertisols in Junagadh, Gujarat, in collaboration with National Research Center for Groundnut.

Table 11. Promising groundnut germplasm lines.

	Promising lines	
Character	Cultivated (ICG Nos)	Wild species
Leaf Spot (*Cercosporidium personatum*)	2716, 7013, 4747, 6340, 6022	PI 338280 (*A.* sp HLK-410), PI 338448 (*A. pusilla*), PI 276233 (*A.* sp 10596), PI 276235 (*A. chacoense)* *A. chacoense* x *A. cardenasii,* *A. glabrata*
Rust	1697, 7013, 2716, 4747, 6340, 6022, 1703, 1705, 1704, 1707, 1710, 6280, 4746	PI 219823 (*A. duranensis),* PI 331194 (*A. correntina),* PI 262141 (*A. cardenasii),* PI 276235 (*A. chacoense)* *A. chacoense* x *A. cardenasii* PI 338448 *(A. pusilla),* PI 262848 (*A.* sp 9667), PI 276233 (*A.* sp 10596), *A. villosa, A. villosulicarpa,*

Continued

Table 11. *Continued*

Character	Promising lines: Cultivated (ICG Nos)	Promising lines: Wild species
		A. glabrata PI 298639 (A. *batizocoi),* PI 338280 (A. sp HLK-410)
Leaf Spot and Rust	2716, 7013, 4747, 6340	PI 338280 (A. sp HLK-410), PI 338448 (*A. pusilla*), PI 276233 (A. sp 10596), PI 276235 (*A. chacoense),* *A. chacoense* x *A. cardenasii* *A. glabrata*
Aflaroot rot	1326	Not tested
Collar rot	3263, 1326	Not tested
Aspergillus flavus	1326, 4749, 4750	Not tested
Pod rot	3336,3334,2951, 1326, 1711,2031	Not tested
Tomato Spotted Wilt Virus	1656,799	PI 262848 *(A.* sp 9667), PI 338448 *A. pusilla*), *A. glabrata,* PI 276233 (*A.* sp 10596)
Peanut Mottle **Virus**	2716, 4747 (Virus present in the plants but does not go to the seed)	Not tested
Clump Virus	7677,5123,5118, 8030, 3894, 6313, 5210, 949	Not tested
Thrips and Jassids	5042, 5044, 5041 5043, 5045, 5040, 2271	PI 276235 (A *chacoense*), PI 298639 (A *batizocoi*)
Aphids	Single plant selections from 5040	PI 276235 *(A. chacoense*), PI 298639 (*A. batizocoi*)
Termites	5045, 5929, 5040, 5143, 2316, 1326	Not tested
Leaf miner	1697, 1703, 1704, 5075, 2283, 2349	Not tested
Nodulation and BNF capacity	1561,2405,404	Not tested

Apart from this, the germplasm lines are evaluated systematically for yield and other attributes. Substantial amounts of such germplasm are being utilized in various breeding projects which would help to broaden the genetic base of the *material that* goes out *of* ICRISAT. Some of the earlier selections made from some accessions such as Robut 33-1, have been supplied to the breeders and promising lines have been selected from this material.

Documentation

Progress in the field of plant genetic resources is related to the conservation of eroding genetic resources and utilization of this material for crop improvement work. Success partly depends on the availability of information on the material being conserved. Withtheformation of international institutes, information exchange has assumed global importance, necessitating a certain amount of uniformity in data collection, recording, storage, and retrieval. The International Board for Plant Genetic Resources (IBPGR) is expected to play a key role in bringing an understanding among the workers in many countries on these aspects and in the international exchange of information.

A common descriptive language is imperative. Attempts *to* develop such a descriptive language for groundnut (genus *Arachis)* is under way, in close collaboration with IBPGR. The IBPGR/ICRISAT ad hoc Committee on Groundnut Germplasm which met during September 1979 appointed a subcommittee to finalize the descriptors for groundnut. The subcommittee met during July 1980 and has evaluated a list of critically prepared descriptors and a final draft for the approval of the members is under preparation. This list contains 32 descriptors for passport information and 40 descriptors of a morpho/agronomic nature. Descriptors on disease and pest reaction are to be added to this list. After approval the descriptors will be circulated among groundnut workers and then a finalized list will be published. A list of the descriptors used for groundnut germplasm at ICRISAT is shown in Table 12.

Since the descriptive language is under preparation, the data recorded during the last few evaluations in ICRISAT site have not been stored on the computer. However, these evalua-

Table 12. List of the descriptors used for groundnut germplasm at ICRISAT.

Passport Data:

1. ICG number
2. Synonym number - 1
3. Synonym number - 2
4. Synonym number - 3
5. Synonym number - 4
6. Sample type
7. Collector's name and number
8. Collection date
9. Sample source
10. Donor
11. Pedigree
12. Species, subspecies and variety
13. Cultivar
14. Pedigree
15. Origin
16. Province/state and nearest village
17. Altitude, latitude, and longitude
18. Local name
19. Soil type
20. Remarks

Morphological Data:

1. Branching pattern
2. Growth habit
3. Stem color
4. Stem hairiness
5. Peg color
6. Standard petal color
7. Standard crescent
8. Standard size
9. Leaf color
10. Leaf shape
11. Leaf size
12. Pod type
13. Pod beak
14. Pod constriction
15. Pod reticulation
16. Pod length
17. Pod size
18. Number of seed/pod
19. Seed color
20. Seed size
21. Seed shape

Agronomic Evaluation Data:

1. Date of planting
2. Days to emergence
3. Seedling vigor
4. Days to 50% flowering
5. Plant height (cm)

Continued

Table 12. *Continued*

6. Plant width (cm)
7. Total mature pods/plant
8. 100 seed weight (g)
9. Yield (g/plot)
10. Date of harvest
11. Days to maturity

Table 13. Distribution of groundnut germplasm.

Scientists in India	5383
Scientists abroad	3262
Scientists in ICRISAT	4914

tions, which used many of the proposed descriptors, can be computerized as soon as the descriptors and descriptor states are finalized. The computer file forms the base for a live catalog and only special lists will be published.

Distribution

The seed despatch to the scientists in India and abroad is one of the important activities undertaken by the Genetic Resource Unit Table 13 gives the details of seed distributed so far.

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Breeding Methodology for Groundnuts

A. J. Norden*

The development of improved cultivars is the major responsibility of the plant breeder. To accomplish this the breeder must have first, a knowledge of the botany, genetics, and ecological requirements of the crop; second, establish sound breeding objectives; third, collect or create a range of genetic variability; and fourth, develop or devise the most suitable breeding method to fulfill the objectives. It is in the performance of this last fundamental that breeders reach their best potential and accomplish their most important role.

Before proceeding into a discussion of groundnut breeding methodology, however, I want to first emphasize the importance of the first three fundamentals to the groundnut improvement process. The modern breeder is dependent to a large degree on the contributions and cooperation of researchers in many other disciplines. The heart of a breeding program is the evaluation *or* screening of breeding material, whether it is to find the most suitable parents to use in a cross for a particular objective, or to isolate the superior progeny resulting from a cross. Groundnut breeders are dependent on pathologists, entomologists, chemists, engineers, physiologists, nutritionists, etc., not only for providing basic knowledge on the subject, but also for assistance with the development of suitable screening techniques.

Only limited information is available regarding the breeding behavior of groundnuts, the nature of inheritance, and the physiological implications of important characteristics. In groundnuts, where the end product is utilized primarily for human consumption, additional data are required for reasonable certainty that the new cultivar will excel, not only in yield, but also in processing and end-use product quality.

Determining the inherent processing, flavor, and keeping quality of groundnut lines is one of the more difficult tasks facing breeders. Some of the older chemical tests are not completely applicable today, such as iodine value and fatty acid composition. Taste and flavor are affected by the environment and handling of the crop, as well as by the genotype. Processors and consumers have little interest in yield. Thus, some of the highest yielding lines are not being grown commercially today.

Breeding Objectives

The procedures involved in the development of new groundnut cultivars optimistically span a period of 10 to 20 years. In view of this and the changing trends in utilization and production methods, establishing sound objectives is extremely important in a breeding program. The broad objective is to develop cultivars that are currently in demand by the producer, the processor, and the consumer. It is important to eliminate the defects which hamper a cultivar's usefulness in a given region or period of time. It is only within the past couple of years that the energy requirements and/or contributions of groundnut cultivars in the form of nitrogen fixation have become objectives of improvement programs.

Branch (1979) with the aid of several U.S. groundnut breeders recently compiled a list of groundnut breeding goals. For the grower they include higher yields, more pest resistance, and more environmental stress-tolerance. To satisfy the *processor,* groundnut breeders are attempting to produce cultivars with more uniform maturity and more favorable mechanization and processing characteristics. The concern of the plant breeder for the consumer involves trying to incorporate nutritional seed properties into cultivars with fruit and seed of

* Agronomy Department, University of Florida, Gainesville, Florida 32611, USA.

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preferred shape, size, texture, color, flavor, and aroma.

Genetic Variability

It is a prerequisite to cultivar improvement. The previous paper by Dr. V. R. Rao concerned groundnut germplasm resources. Fortunately, there is a considerable amount of variability available in the cultivated species, especially in morphological and chemical characteristics. The oil content of different genotypes varies from less than 40% to over 60% and the fatty acid composition of the oil of different lines also shows considerable variability. Some groundnut lines have polyunsaturated to saturated oil ratios of almost 2:1, the ratio considered desirable for reduction of blood serum cholesterol. Genetic variability is also available within the species to increase some deficient amino acids, especially methionine, but more variation is needed.

More resistance to certain diseases, nematodes, toxin-producing molds, and to drought is also required. Progress in cultivar development will be enhanced as we improve our ability to identify and incorporate the desired characteristics into improved cultivars. A better understanding of the cytogenetics of *Arachis* species is needed in order to devise procedures that will enable the transfer of desirable traits from the wild species to be cultivated. This area is the subject of the next Session on the program of this Workshop.

Groundnut Breeding Methodology

An in-depth review of the literature on groundnut breeding prior to 1972 was published in *Peanuts — Culture and Uses* (Norden 1973) and a later review covering the period 1972 to 1977 in *Advances in Legume Science* (Norden 1980). As I had emphasized in the latter paper, "new and spectacular discoveries in plant breeding methodology, not only in groundnuts butalso in other crops, are rare, and that there had not been any major advances in groundnut breeding methods during the five years 1972 to 1977."

The breeding methods by which new cultivars of groundnuts originate are not unlike the methods used for many other self-pollinated crops. They are: (1) introduction and selection; and (2) hybridization or recombination. Backcrosses, multiple crosses and recurrent selection all utilize hybridization. In irradiation breeding, x-rays or other radiation is used to obtain mutant plants that may be helpful in the development of improved cultivars.

Introduction and Selection

In the early part of this century the objectives of groundnut improvement programs could be met by line selection from or direct use of cultivars from other countries. While this method is still satisfactory in some cases, such as the selection of Makulu Red from the Bolivian strain of groundnuts, Mani Pintar (Smartt 1978), it is inadequate in fulfilling most of the objectives of many breeding programs.

Because of the large investment in equipment, facilities, maintenance, and manpower required in full scale breeding programs, the need for cooperation between countries or territories is important. The groundnut improvement program at ICRISAT, which is the subject of the next paper, was designed with this in mind.

Hybridization or Recombination

Hybridization and selection among and within hybrid lines is currently the most widely used method of obtaining improved groundnut cultivars. Success in breeding hybridization depends on the availability of transferable genetic variation and will more likely occur if the objectives are clearly designated, the correct parents are selected, and if the hybrid populations are managed properly and selected successfully. Generally, the better and more adapted parents give better segregates or at least increase the likelihood for production of desirable new recombinations. In any regard, at least one parent in a cross should be a reasonably good performer in the production area to be considered. The rare but greatly superior segregate, however, is more likely obtained from crosses between plants with more diverse genotypes.

The general procedure tor handling segregating hybrid populations for a self-pollinating crop such as groundnut usually involves theuse of the bulk orthe pedigree system or numerous modifications of the two. Experimental evidence concerning the merits of using one of the systems to the exclusion of the other for breeding self-pollinating crops is contradictory. In groundnut breeding, no reports of comparisons were found and both methods are sometimes used by the same breeder.

The pressure to produce new cultivars which have pest resistance and other economically important traits has forced some breeders to modify their breeding systems in orderto speed up cultivar development. One such method is a modified pedigree method of selection using single seed descent, which was successfully used at North Carolina (Wynne 1976).

Breeding Techniques for Specific Objectives

Higher Yield

By necessity, much of the emphasis in groundnut breeding throughout the world is placed on improving yield. This is partly in response to the increased food requirements caused by an increasing population and limited land resources and partly due to the ever increasing costs of production. Producing higher yields per unit area is one of the ways that the grower has to counteract the costs of production.

The general procedures employed in breeding for higher yields following the hybridization method were reviewed by Norden (1973). Garet (1976) reported the response of eight characters from a diallel cross of five cultivars. He obtained heterosis compared with the better parent for several yield components. General and specific combining ability effects and reciprocal effects were significant for all characters except oil content, where general combining ability effects alone were significant. Additive effects predominated for all characters except seed yield, where nonadditive effects with dominance and epistasis were observed.

Stability in production over seasons and over a wide area is an important attribute of a commercial groundnut cultivar. An objective of the Florida groundnut breeding program is to mold the cultivar to fit the somewhat specific and restrictive U.S. marketing system, while at the same time making a conscious effort to avoid depleting the cultivar of its genetic versatility through compositing lines in early generations. Pressures for monocultural production and uniformity exist throughout the chain from farmer to customer. Hammons (1976) reported that the alloploid genetic structure of *A. hypogaea* and modified breeding procedures provide greater genotypic diversity for the economically dominant cultivars in the United States than that existing in the pure line cultivars they replaced. He cautioned, however, that further widening of the genetic base may require changes in cultivar seed certification standards and market-grading criteria in the United States.

Pest Resistance

There have been recent advances in groundnut breeding for resistance to pests but many complex problems still remain. For example, good resistance to some pests has been found only in the wild species, but these sources of germplasm have been largely unavailable because of certain inherent barriers to hybridization (Banks 1977; Simpson et al. 1975).

Theliteraturesince 1972 concerning breeding for pest resistance in groundnut is very extensive, and since groundnut pests and pest resistance are the subjects scheduled for the Workshop tomorrow I will curtail this portion of my presentation and illustrate with slides the groundnut breeding methods we are currently using in Florida.

Conclusion

The groundnut improvement project in Florida involves controlled hybridization followed by pedigreed selection within and between thousands of different lines. Most peanut crosses do not result in improved cultivars. The basic procedure is to discard the undesirable plants and lines early in the breeding program and save only those with apparent superiority in economically desirable characteristics. It is difficult to incorporate desirable characteristics into a variety without being overwhelmed by undesirable material. Often the desirable characteristic is associated with undesirable traits.

Although the groundnut is difficult to hybridize, making the cross is the least time consuming phase of the breeding program. The basic technique for crossing groundnuts has not been greatly changed over the years, but numerous aids and modifications have been reported (Norden 1980).

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Groundnut Breeding at ICRISAT

S. N. Nigam, S. L. Dwivedi, and R. W. Gibbons*

Breeding work on groundnuts started in mid-1976 after the acceptance of the detailed research proposal (Gibbons 1976) by the Governing Board of ICRISAT.

The main objective of the program is to produce high yielding breeding lines or populations with resistance to the main factors presently limiting production.

Much emphasis has been laid on disease resistance breeding — particularly for diseases such as leaf spots (*Cercospora arachidicola* and *Cercosporidium personation*) and rust (*Puccinia arachidis*), which are of international importance. Other priorities include breeding for earliness, high yield and quality. Since 1976, several more research projects have been started as and when necessary germplasm became available.

Groundnut growing environments vary greatly not only between but also within countries. In addition, there is considerable diversity in the uses to which the crop is put. Considering the diverse requirements, emphasis has been on supplying suitable early generation and advanced breeding material to cooperators in different countries of the Semi-Arid Tropics (SAT) for further selection in situ.

Program and Progress

Hybridization

The emasculation and pollination processes used at ICRISAT are basically the same as those described for Florida by Norden (1973). However at Hyderabad, emasculations can be made as early as 1.30 p.m compared with 5.00 p.m in Florida. Pollinations are carried from 7.00 a.m to 10.00 a.m in Florida, but the highest success rates are achieved at Hyderabad if they are made around 6.00 a.m.

* Plant Breeders and Principal Plant Breeder, Groundnut Improvement Program, ICRISAT.

The standard method of making crosses is to use large pots, containing single parental plants, which are placed on benches inside a glasshouse or screenhouse. However, it was realized that for the large numbers of crosses, which needed to be made for an international breeding program, there were severe limitations in using this method. In 1977 crossing was therefore extended to the field. Initial results were poor, but by improving insect control and using an irrigation system to maintain high humidity at the time of pollination, success rates of over 50% were obtained in the rainy season of 1979 and the postrainy season of 1979-80. During the current rainy season of 1980 the success rate averaged 67%, with some individuals achieving as high as 94%. During each of the two crop seasons some 30 000 pollinations are made in the field. As large number of crosses can now be carried out, specific combinations could be made for breeders in national programs who have limited facilities.

Initially the hybridization program mainly utilized germplasm lines but now after four years lines derived at ICRISAT are being used as parents to combine more desirable characters in breeding populations.

Rapid Generation Advance

The climatic conditions and the facilities at the ICRISAT Center provide opportunities to grow two full crops in a year. Many of the major pathogens and insect pests either occur, or can be induced, during both seasons and thus provide good opportunities for continuous screening.

The problem of postharvest dormancy in Virginia types (sub sp *hypogaea*) preventing immediate replanting in the second crop season, has been overcome. The seed is dressed with Ethephon, an experimental preparation in powder form of an ethylene-releasing compound (Amchem Products Ina, USA), before planting. In the laboratory more than 90% of treated seeds germinate within 24 hours. Using this technique under field conditions, 75-80% emergence is obtained within a few days.

Evaluation

The advanced breeding populations are evaluated in two different environments at the ICRISAT Center. The rainfed crop is grown under low fertility conditions (20 kg P_2O_5) and is not protected against diseases and insect pests. The irrigated crop is grown at higher fertility levels (40 kg P_2O_5) and is protected. Early generation segregating material, when enough seed is available, is also grown in both environments. Very little material is discarded in early generations. Most of the material is bulked into uniform groups for evaluation and further selection at cooperating centers.

Stability of yield is important overyears and across sites. Currently the breeding material is evaluated on a limited scale in different agroclimatic zones in India. An international testing network will soon be set up after the establishment of outreach programs.

Research Projects

Breeding for Resistance to Foliar Pathogens

At present the work on foliar diseases at ICRISAT is restricted to rust and *Cercospora* leaf spots as they are worldwide in distribution and cause serious economic losses (Bunting et al. 1974; Hammons 1977; Subrahmanyam et al. 1979).

SOURCES OF RESISTANCE. Rust resistance breeding started in 1977 with two sources of resistance, PI 259747 and PI 298115. Since then several other sources of resistance have also been incorporated in the breeding program (Table 1).

High levels of resistance to leaf spots occur within the wild species (Abdou 1966; Abdou et al. 1974). Leaf spot resistant tetraploid progenies, resulting from interspecific hybridization, will soon become available from the Cytogenetics subprogram for utilization by the breeders (see Singh et al. in this volume).

Recently more intensive searches within the cultivated groundnut have shown some usable sources of resistance or tolerance to leaf spot fungi (Sowell et al. 1976; Hassan and Beute 1977; Melouk and Banks 1978; Subrahmanyam et al. 1980b). Many of the germplasm lines earlier selected for rust resistance have also shown resistance to late leaf spot at the ICRISAT Center (Table 2). Several rust-resistant FESR selections made at ICRISAT are also resistant to late leaf spot (Table 3). A few rosette-resistant cultivars, such as RMP 91 and RMP 12, have also some resistance to late leaf spot (Subrahmanyam et al. 1980b). For resistance to early leaf spot, NC 3033 (Beute et al. 1976) and P1109839 (Hammons et al. 1980) are being utilized in the breeding program.

CURRENT STATUS. The breeding material for rust resistance, other than FESR selections, has

Table 1. Sources of rust resistance.

Cultivar	Source	Type	Reference
PI 259747	Peru	Valencia	Mazzani and Hinojosa 1961
PI 298115	Introduction to Israel from USA	Virginia Bunch	Hammons 1977
NC Acc 17090	Peru	Valencia	Subrahmanyam et al. 1980a
EC 76446 (292)	Uganda	Valencia	Subrahmanyam et al. 1980a
NCAcc 17133 (RF)	S. America	Valencia	Subrahmanyam et al. 1980b
DHT 200	Peru	Valencia	Hammons 1977
FESR selections	USDA rust nursery, Puerto Rico	Variable	Bailey et al. 1973; Subrahmanyam et al. (unpublished data)

Table 2. Rust resistant sources also resistant to lata loaf spot.

Cultivar	Source	Type	Reference
PI 259747	Peru	Valencia	Filho and de Moraes 1977; Subrahmanyam et al. 1980b
EC 76446 (292)	Uganda	Valencia	Subrahmanyam et al. 1980b
NC Acc 17133 (RF)	S. America	Valencia	Subrahmanyam et al. 1980b
FESR selections	USDA rust nursery, Puerto Rico	Variable	Subrahmanyam et al. (unpublished data)

Table 3. Rust and late leaf spot reactions of soma FESR selections in field screening trials at ICRISAT Center, 1978-1980.

Selection	Mean disease score[a]	
	Rust	Leaf spot
FESR 5-P2-B1	2.0	3.0
FESR 5-P17-B1	2.0	3.0
FESR 7-P13-B1	2.0	3.0
FESR 9-P3-B1	2.0	3.0
FESR 9-P4-B1	2.0	4.3
FESR 9-P7-B1	2.7	3.3
FESR 9-P7-B2	2.7	4.3
FESR 9-P8-B2	2.0	3.0
FESR 9-P12-B1	2.0	2.7
FESR 11-P11-B2	2.3	2.7
FESR 12-P4-B1	2.0	2.0
FESR 12-P5-B1	2.0	2.7
FESR 12-P6-B1	2.7	3.7
FESR 12-P14-B1	2.0	3.3
FESR 13-P12-B1	2.0	2.7
TMV-2 (Check)	9.0	9.0

a. Mean score of three seasons on a 1-9 scale. where 1 - no disease and 9 = 50-100% foliage destroyed.

been advanced to the F_6 generation generally by following pedigree and bulk pedigree methods. Backcrossing has been adopted in a few cases. The material is screened in the field for both rust and leaf spot resistance using the infector-row technique developed by Subrahmanyam et al. (1980a). The plants are broadly classified into resistant and susceptible groups based on field scoring using a 1-9 scale (where 1=no disease, and 9=50-100% defoliation). Single plants or bulks classified as high yielding but susceptible to foliar pathogens are retained for further screening and use in other breeding projects.

FESR SELECTIONS. Fourteen F3-derived rust-resistant lines (FESR 1-14), from a natural cross between PI 298115 and an unknown pollen donor in the USDA rust nursery in Puerto Rico were received at ICRISAT in 1977 (Bailey et al. 1973). These lines segregated not only for morphological characters but also for reaction to rust at ICRISAT Center. All the lines were progeny-rowed in the next generation when they again segregated for reaction to rust. This indicated that resistance to rust, though recessive, may not be governed by duplicate loci as has been reported by Bromfield and Bailey (1972). Since then the material has been advanced to the F_8 generation. Fifteen hundred and forty-six selections are currently being finally assessed in the field for yield and rust resistance.

Some of the resistant FESR selections, evaluated under rainfed and low-fertility conditions, have yielded more than the released Indian cultivars, J-11 and Robut 33-1, and the rust-resistant parent, NC Acc 17090 (Table 4).

Breeding for Earliness

Groundnuts, which are earlier maturing than currently released cultivars and possess high yield potential together with good quality, will be extremely useful in areas of the SAT which have short growing seasons or where an early maturing crop may escape certain pests and diseases. There is also scope for fitting early maturing groundnuts into relay or sequential cropping systems, particularly in Southeast Asia by utilizing residual moisture after the harvest of the rice crop (Gibbons 1980).

Table 4. Performance of FESR selections under low-fertility and rainfed conditions (rainy seeson 1979).

Selections	Yield (kg/ha)
FESR 8-P12-B1-B1-B1	1301
FESR 5-P20-B1-B2-B1	1127
FESR 9-P5-B1-B1-B1	1076
FESR 8-P9-B1-B1-B1	1076
FESR 8-P11-B1-B2-B1	1003
FESR 8-P13-B1-B2-B1	1001
FESR 5-P19-B1-B2-B1	996
FESR 8-P3-B1-B2-B1	987
NC Acc 17090[a]	978
Robut 33-1*	816
J 11[b]	524
LSD (0.05)	282.7

a. Rust-resistant check.
b. Susceptible checks.

SOURCES OF EARUNESS. The following cultivars are presently being utilized in the breeding program:

Chico — a very early Spanish type, maturing in 75-80 days, commercially unacceptable because of extremely small pods; 91176 and 91776 —Spanish types, maturing in 80-85 days, bred in Tamil Nadu (India); and Robut 33-1 — a Virginia type, maturing in 100 days, released in Andhra Pradesh (India).

CURRENT STATUS. The breeding material has been advanced to the F_7 generation by pedigree or bulk pedigree methods.

Several early maturing (100-105 days) selections have been identified and are currently being evaluated for yield potential (Table 5). Some of the early flowering material identified in the current rainy season is presented in Table 6.

The cultivars Robut 33-1 and Chico have proved to be very good combiners for high yield in certain cases. Late maturing, high yielding selections from this project are being utilized in the high yield and quality project.

Breeding for High Yield and Quality

The purpose of this project is to generate base material with high yield potential for disease resistance programs, and for areas of the world where diseases are not prevalent or protective measures are routinely followed.

Table 5. Early maturing selections (postrainy season 1979—80).

F_4 generation	F_5 generation
Argentine x Chico	JH 89 x Chico
2-5 x Chico	JH 171 x Chico
28-206 x Chico	Dh 3-20 x Chico
SM 5 x Robut 33-1	NC Acc 2748 x Chico
Tifspan x Robut 33-1	TMV 7 x Chico
2-5 x Robut 33-1	Virginia 72R x Chico
Virginia 72R x Robut 33-1	Dh 3-20 x Robut 33-1

Table 6. Early flowering selections (rainy season 1980).

Generation	Selection (P_1 x P_2)	Days to 75% flowering P_1	Selection	P_2
F_1	Ah 330 x 91176	28	18	17
	Chico x Ah 330	18	17	28
	Mani Pinter x 91776	24	17	17
	Chico x NC Acc 344	18	23	29
	Robut 33-1 x Jacana	24	21	20
	91176 x NC Acc 2123	17	23	29
F_3	M 13 x 91176	25	21	17
	Chalimbana x 91176	26	23	17
	DM 1 x 91176	26	18	17
	RMP 91 x Chico	23	22	18
	Ah 114 x 91176	24	20	17

SOURCES. The following material is being utilized in the hybridization program: Cultivars and landraces from different geographical regions; high yielding and adapted varieties from different countries; and high yielding breeding lines developed at ICRISAT.

CURRENT STATUS. The breeding material has been advanced to F_7 generation using pedigree or bulk pedigree methods. Several promising selections are being evaluated for yield potential in different environments during the current rainy season.

Some of the promising selections made in the F_4 and F_5 generations, during the postrainy season of 1979-80, are listed in Table 7.

Table 7. High yielding selections (postrainy season 1979-80).

F_4 Generation	F_5 Generation
NC Acc 529 x Shulamit	Ah 8254 x JH 62
NC-Fla-14 x TG 1	G 37 x Spanhoma
Ah 6279 x Spancross	Faizpur 1-5 x NC Acc 316
Florigiant x SM 5	NC Acc 63 x TG 17
GAUG 1 x NC Acc 310	148-7-4-3-12-B x Manfredi
Starr x NC Acc 1107	NC Acc 2750 x Ah 8189
Tifspan x SM 5	NC Acc 316 x NC Acc 310
Virginia 72R x NC Acc 1107	USA 20 x TMV 10
X14-4-B19-B x SM 5	

Five hundred and twelve F_6 bulks were evaluated in an 8 x 8 x 8 cubic lattice design as well as in a systematic design, which was superimposed over the lattice, during the post-rainy season of 1979-80. The purpose of the trial was to compare the efficiency of these two designs in evaluation of breeding material. The results obtained from the cubic lattice analysis are presented in Table 8. Four breeding lines significantly outyielded the checks, Robut 33-1 and J-11, and 68 more breeding lines were equal in yield to Robut 33-1.

A yield trial consisting of progenies of several plant selections made in the Indian cultivar Robut 33-1 was carried out during the post-rainy season of 1979-80. Eight selections significantly outyielded the Robut 33-1 (Table 9). This cultivar was developed in Andhra Pradesh, India and originated as a selection from a mutant or chance out cross in an exotic introduction.

New Research Projects

During 1979 and 1980 thefollowing new breeding projects were initiated:

Breeding for Resistance to *Aspergillus Flavus*

Three breeding lines, with dry seed resistance to invasion by the fungus, are presently being utilized as parents in the hybridization program

Table 8. F_5 yield evaluation (postrainy season 1979-80).

Selection	Type	Days to maturity	Yield (kg/ha)
(Robut 33-1 x NC Acc 2821) F2-B3-B1-B2-B1	SB	121	3827
(Robut 33-1 x NC Acc 2698) F2-B2-B1-B1-B1	SB	118	3686
(Dh 3-20 x NC Acc 2608) F2-B3-B1-B1-B1	SB	112	3598
(2-5 x NC Acc 741) F2-B4-B1-B1-B1	VB	122	3576
Robut 33-1[a]	VB	121	2949
J 11[a]	SB	112	2915
LSD (0.05)			634.5

a. Standard checks.

with a wide range of adapted but susceptible cultivars. The resistant germplasm lines are PI 337394F and PI 337409 (Mixon and Rogers 1973) and UF 71513 (Bartz et al. 1978).

Breeding for Resistance to Insect Pests

Two germplasm lines, NCAcc 2214 and NCAcc 2232, selected for resistance to thrips and jassids (Amin, unpublished data) are being used as parents in an attempt to incorporate resistance in commercially accepted cultivars.

Development of Cultivars for Vertisols

Groundnuts grown in Vertisols, or dark alluvial soils, often show symptoms of chlorosis due to lime induced iron chlorosis. Germplasm lines and advanced breeding populations are being screened for their reaction to iron, and other possible deficiency factors, in Vertisols at the ICRISAT Center.

Basic Studies

Some basic genetic studies are being conducted in cooperation with research workers in India and by postgraduate students at ICRISAT. Studies on breeding methods have shown high genetic divergence among Spanish and Valencia parents suggesting the utility of Spanish x Spanish, Spanish x Valencia and

Table 9. Natural hybrid trial (postrainy season 1979-80).

Selections from Robut 33-1	Type	Days to maturity	Yield (kg/ha)	Shelling (%)
11-7-B1-B1-B1	VB, SB, IB	119	2680	77
21-11-B1-B1-B1	SB	119	2683	66
10-3-B1-B1-B1	SB	119	2653	76
7-6-B1-B1-B1	VB, IB	119	2650	70
13-6-B1-B1-B1	VB, SB, IB	119	2628	71
12-10-B1-B1-B1	VB, IB	119	2620	75
50-1-B1-B1-B1	VB	119	2527	71
24-16-B1-B1-B1	SB	119	2488	72
Robut 33-1 (parent)	VB	119	2013	70
LSD (0.05)			389.4	

Valencia x Valencia crosses (Arunachalam et al. 1980).Similar results have been obtained in the USA by Wynne et al (1970).

Uniform non-nodulating lines of groundnuts have been developed through wide crosses and the genetics of non-nodulation has been determined (Nigam et al. 1980).

Some yield trials conducted during rainy and postrainy seasons at the ICRISAT Center have shown strong variety x season interactions. This suggests the need of identification of varieties for each season. This is particularly important for India where presently 8% of the total crop is grown under postrainy conditions.

Cooperation with National Programs

The breeding material, generated with desirable characteristics at ICRISAT, is freely distributed to breeders in national programs to enable them to carry out final selection under their local conditions. So far, 2792 selections have been supplied to breeders in 14 countries (Table 10). All the breeders, who received material, were able to make useful selections out of breeding populations supplied. Some selections have done exceedingly well in trials in Tamil Nadu (India). Another selection, maturing in 85 days, has been found suitable for summer cultivation in Maharashtra.

As the breeding program develops, a considerably greater volume of material will become available for distribution to any country which requests it.

Table 10. Breeding material supplied to cooperators by ICRISAT, 1978-1980.

Country	Number		
	High-yielding selections	Selections with earliness	Rust-resistant material
Bangladesh	6	14	
Benin	80	55	68
Burma	10	6	
China	8	2	40
Ghana	15		19
India	1121	858	288
Japan			3
Puerto Rico			14
Senegal	30	20	40
Sri Lanka	17	4	4
Tanzania	9	4	
Thailand	10	20	10
Upper Volta		5	6

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Session 3 — Genetics and Breeding

Discussion

T. P. Yadava

For screening material against drought and insects, do you depend upon natural infestation or some laboratory technique?

S. N. Nigam

Drought screening has not yet been started at ICRISAT. Development of a drought screening technique would be a main priority of the physiology program, which has recently started. Screening for resistance to insects depends to a large degree upon natural infestation, but some useful screening can be done in the screenhouse or laboratory.

K. S. Labana

Has ICRISAT got high-quality and high-yielding lines that are better than the M-13 spreading cultivar.

S. N. Nigam

High yield is not restricted to any one group of cultivars or botanical type. We have some high-yielding runner lines that are better than M-13 when tested at ICRISAT. Widescale testing of these lines in different environments has not been done as yet.

A. S. Chahal

When the 1-9 scale for scoring leaf spot diseases in groundnut is used, an entry showing 50 to 100% defoliation is scored as 9. Some leaves fall due to maturity and some leaves with even one spot may drop off the plant. Would such leaves be considered under defoliation due to disease? If not, what is the explanation?

P. Subrahmanyam

Defoliation or withering depends upon the cultivar, severity of disease and other environmental factors. Susceptible varieties wither very rapidly under high disease pressure whereas resistant varieties show slow disease development with perhaps a little withering towards maturity. It is comparatively easy to select resistant plants.

J. S. Chohan

in spite of all quarantine efforts, some pathogens do get moved from country to country. Has any new pathogen been introduced to India with groundnut germplasm?

V. R. Rao

No. PMV-infected plants have been found in the Plant Quarantine Glasshouses and were immediately destroyed. This serves as an example of how stringent quarantine resources do result in the interception of diseases.

V. Ragunathan

Was PMV introduced to India through ICRISAT germplasm introductions, or was it already present in India but had not been detected?

R. W. Gibbons

PMV has a worldwide distribution. It was first noted in India in the north of the country and it was also reported present in Pakistan some years ago, so it has probably been here for sometime. Because of the mild symptoms this disease has been overlooked in many countries.

K. S. Labana

Has ICRISAT got any groundnut lines showing determinate flowering?

V. R. Rao

The germplasm collection is yet to be checked for this character.

N. D. Desai

Has ICRISAT any accession available for use as donor parents with drought tolerance and dormancy in Spanish bunch types?

V. R. Rao

Screening for drought tolerance will commence shortly at ICRISAT but we have some drought resistant material from Senegal in our germplasm collection and we have a few lines of Spanish types showing about 15 days post harvest dormancy.

A. B. Singh

Is there any line resistant to bud necrosis and dry root rot? Are there any resistant or tolerant lines to white grub?

P. W. Amin

We have extensively screened our germplasm collection but we have not found any line resistantto bud necrosis. White grub does not occur in sufficient numbers to do any meaningful screening at the ICRISAT Center.

B. S. Gill

I would like to hear the views of Dr. Norden regarding plant types that can be utilized in selection for high yield.

A. J. Norden

A scale has been developed and is used in Florida. Many factors are involved.

S. H. Patil

Can Dr. Norden, from his great experience in breeding improved varieties of groundnut, indicate appropriate hypothetical ideotypes for obtaining the highest yields in different botanical groups of groundnut varieties?

A. J. Norden

No, I would not want to attempt to define a hypothetical ideotype for obtaining best yields in the different botanical groups of groundnut cultivars. It is dependent on too many variables, such as the climate, the soils, and the end-use of the crop. For example, the ideotype for obtaining best yields in a fully mechanized production would not fit a situation in which the crop is produced with hand labor. In the former, low-growing plants with spreading prostrate growth habit and vines entwined are preferred, but they would not be the ideal when the production, harvesting, and picking are accomplished by hand labor. However, I think one could define ideotypes for the different regions and periods in time.

Session 4

Cytogenetics and Utilization of Wild Species

Chairman: V. S. Raman

Rapporteurs: V. R. Rao
J. H. Williams

Cytogenetic Investigations in the Genus *Arachis*

H. T. Stalker*

The genus *Arachis* L. is a New World taxon native to South America. Species are distributed over a wide range of environments from south of the Amazon to 34°S latitude, and from the Atlantic shore to the eastern slopes of the Andes. Peanuts are mostly found in sandy soils in open grasslands or in broken forests (Gregory et al. 1980). Speciation has generally followed drainage basins and riverbeds, while the greatest diversity is found in the headwaters of the Paraguay River.

Twenty-two species have been described and possibly 50-80 other distinct taxa are found in nature. Gregory et al. (1973) grouped the species into seven botanical sections. Intersectional hybridization is uncommon while intrasectional hybrids are more easily produced under experimental conditions (Gregory and Gregory 1979). Barriers to interspecific hybridization are sometimes great and biosystematic relationships within some groups, i.e., section *Rhizomatosae,* are not fully understood.

The cultivated species, *Arachis hypogaea* L, belongs to the section *Arachis* along with at least one other tetraploid *(A. monticola* Krap et Rig.) and 10 diploid species, and hybridization between the cultivated species and other members of section *Arachis* is possible (Smartt and Gregory 1967; Raman 1967; Gregory and Gregory 1979). When the wild species of section *Arachis* are used as female parents, the success rate of producing hybrids is usually greater. *Arachis monticola* Krap. et Rig. and *A. hypogaea* are apparently completely compatible.

Cytogenetic studies over the past four decades have included counting the chromosome numbers of species and their interspecific hybrids, identifying cytologically rare plants such as aneuploids, and observing meiotic behavior of species and hybrids.

This paper attempts to summarize the accumulated cytogenetic evidence concerning *Arachis* species and their hybrid derivatives. Gregory and Gregory (1979) and Smartt (1979) have questioned the authenticity of many hybrids reported in the literature, especially those claimed to have been produced by Raman (1976) and Varisai Muhammad (1973a,b,c). Only hybrids of unquestioned identity *are* thus included in this report.

Cytogenetic information can conveniently be divided into studies of somatic and meiotic chromosomes, and each major group will be discussed separately in this report.

Somatic Chromosomes

Chromosome Numbers

The first cytogenetic information presented for *Arachis* was by Badami (1928) who reported a somatic chromosome number of 2n = 20 for the cultivated peanut, *A. hypogaea.* Other investigators later confirmed the true number as 2n = 40 (Kawakami 1930; Husted 1931). Gregory (1946) reported a chromosome number of 2n = 40 for a wild species, *A. glabrata* Benth, and one year later Mendes (1947) reported several diploid species in the genus. Poor quality preparations have hindered many analyses, and not until Fernandez (1973) published techniques for *Arachis* chromosomes were many of these difficulties overcome.

Listed in Table 1 are the named species and corresponding chromosome numbers. Although Gregory and Gregory (1979) did not list collection numbers with many of their parental assignments, they presented a general pattern

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* Assistant Professor, Department of Crop Science, North Carolina State University, Raleigh, North Carolina 27650, USA.

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for diploid and tetraploid species in the genus. Most *Arachis* species are diploid while a few members of section *Arachis* and most species of section *Rhizomatosae* are tetraploid. Because the tetraploid species of sections *Arachis* and *Rhizomatosae* will not hybridize, polyploidy probably evolved independently in each of the groups.

Table 1. Named spaces of *Arachis* and corresponding chromosome number.

Section/species	Chromosome No	Reference
Arachis		
A. batizocoi Krap. et Greg.	20	Smartt and Gregory (1967)
A. pusilla (correctly *A. duranensis*) Krap. et Greg. *nom. nud.*	20	Krapovickas and Rigoni (1957)
A. spegazzinii Greg. et Greg. *nom. nud.*	20	Gregory and Gregory (1979)
A. stenosperma Greg. et Greg. *nom. nud.*	20	Gregory and Gregory (1979)
A. ipaensis Greg. et Greg. *nom. nud.*	20	Gregory and Gregory (1979)
A. he/odes Martius ex Krap. et Rig.	20	Smartt and Gregory (1967)
A. villosa Benth.	20	Krapovickas and Rigoni (1949)
A. diogoi Hoehne.	20	Mendes (1947)
A. cardenasii Krap. et Greg. *nom. nud.* (10017 GKP)	20	Smartt and Gregory (1967)
A. chacoense Krap. et Greg. *nom. nud* (10602)	20	Smartt and Gregory (1967)
A. hypogaea L.	40	Kawakami (1930)
A. monticola Krap. et Rig.	40	Krapovickas and Rigoni (1957)
Erectoides		
A. guaranitica Chod. et Hassl.	20	
A. tuberosa Benth.	20	
A. benthami Handro	20	Smartt and Gregory (1967)
A. martii Handro	20	
A. paraguariensis Chod. et Hassl.	20	Smartt and Gregory (1967)
A. oteroi Krap. et Greg. *nom. nud.*	20	Smartt and Gregory (1967)
A. rigonii Krap. et Greg.	20	Krapovickas and Gregory (1960)
A. lignosa Chod. et Hassl. (10598) *Caulorhizae*	20	Smartt and Gregory (1967)
A. repens Handro	20	Conagin (1963)
A. pintoi Krap. et Greg. *nom. nud.*	20	
Rhizomatosae		
A. burkartii Handro	20	Gregory and Gregory (1979)
A. glabrata Benth.	40	Gregory (1946)
A. hagenbeckii Harms	40	Krapovickas and Rigoni (1957)
Extranervosae		
A. marginata Gard.	20	Mendes (1947)
A. lutescens Krap. et Rig.	20	Conagin (1963)
A. villosulicarpa Hoehne	20	Mendes (1947)
A. macedoi Krap. et Greg. (10127)	20	Smartt and Gregory (1967)
A. prostrata Benth.	20	Mendes (1947)
Ambinervosae		
None named	20	
Triseminalae		
A. pusilla Benth.	20	

Note. *nom, nud.* = species which are not validly described In the botanical literature.

Aneuploidy

Plants of *A. hypogaea* with 41 chromosomes plus a fragment were reported by Husted (1936). Spielman et al. (1979) found a series of 42-44 chromosome plants after observing plants grown from small seeds. Other aneuploids were found after ionizing radiation (Madhava Menon et al. 1970; Patil 1968; Patil and Bora 1961) and chemical treatments (Ashri et al. 1977).

Aneuploidy in *Arachis* is commonly observed after colchicine treatment of treating interspecific hybrids. Smartt and Gregory (1967) and Spielman et al. (1979) reported a range of chromosome numbers in colchicine-treated *A. hypogaea* x diploid section *Arachis* hybrids. After several generations of selfing a 6x *(A. hypogaea x* A *cardenasii* Krap. et Greg. *nom. nud.)* interspecific hybrid, Simpson (1976) re ported progeny with chromosome numbers ranging from 32-48. However, when selecting for agronomic fitness. Stalker et al. (1979) found all selected plants in the population had 40 chromosomes. Thirty-one and 32-chromosome plants also resulted from intersectional hybridization of 4x (section Erectoidesxsection Erectoides)x2x section *Arachis* species (Stalker 1978; in review). Trispecific hybrids of *A. hypogaea*x4x section *Arachis* amphidiploids also resulted in a few aneuploid progeny (Stalker, unpublished data).

Although a number of aneuploid plants have been documented, complete aneuploid series of genomes have not been produced. Sets of *A. hypogaea* aneuploids need to be created and maintained so that genetic analyses of chromosomes can be performed. Even though aneuploids recovered after interspecific hybridization (and recovered 40-chromosome interspecific hybrids) are suspected of having wild species chromosomes, the cytological make-up of hybrid derivatives is unknown. Karyotyping wild and cultivated species chromosomes along with maintaining cytologically unique plants will aid in the utilization of aneuploids.

Chromosome Morphology

The chromosomes of *A. hypogaea* are small with mostly median centromeres (Chimpu 1930). Although karyotyping *Arachis* chromosomes is difficult several distinctive chromosomes have been found. Husted (1933, 1936) reported one chromosome pair which was distinctly smaller than other chromosomes of the cultivated species (A chromosomes) and one pair with a secondary constriction (B chromosomes). He analyzed the chromosomes of several varieties but was unable to detect differences. Babu (1955) found several different types of secondary constrictions in 14 *A. hypogaea* varieties. Tennessee Red was the only variety without a secondary constriction in his study. D'Cruz and Tankasale (1961) were also able to cytologically distinguish four *A. hypogaea* varieties based on centromere positions and chromosome lengths.

The wild species *A. villosa* var *correntina* Benth has a small (A) chromosome similar to that found in *A. hypogaea* (Raman 1959; Smartt 1965). Smartt (1965) observed the small A chromosomes in several other members of section *Arachis;* this distinctive pair was not present in the section *Erectoides* species *A. paraguariensis* Chod. et Hassl. (9646 GKP). From photomicrographs produced by Krapovickas et al. (1974), *A. batizocoi* Krap. et Greg, apparently did not have the A chromosome found in other section *Arachis* species. Smartt et al. (1978) later confirmed the absence of this distinctive chromosome pair in *A. batizocoi.*

The chromosomes of eight section *Arachis* species range in length from 1-4µm in the metaphase stage of mitosis (Stalker and Dalmacio, in review). Each of the 10 homologous chromosomes of each species studied was identifiable based on centromere position, length, secondary constrictions, and differential staining of heterochromatic and euchromatic regions of the chromosomes. *Arachis batizocoi* had a unique karyotype with 1 submedian (S/L arm=0.33-0.64) and 6 slightly submedian (S/L arm=0.65-0.79) chromosomes and a secondary constriction on the long arm of chromosome 2. *Arachis cardenasii* had many slightly submedian chromosomes and was the only species observed with secondary constrictions on two chromosomes (5 and 10). Most of the other species of section *Arachis* mostly had median or slightly submedian chromosomes. Secondary constrictions were on the median chromosomes of *A. chacoense* Krap. et Greg. *nom. nud., A. duranensis* Krap. et Greg. *nom. nud., and A. stenosperma* Greg, et Greg. *nom. nud.,* while none were found for species *A. villosa, A. correntina* Krap. et Greg. *nom. nud., or A. spegazzinii* Greg, et Greg. *nom. nud.* After combining fertility data with karyotype analyses, Smartt et al. (1978a,b) and Stalker and Dalmacio (in review) proposed that section *Arachis* has two distinct genomes. Most species have the A genome while A *batizocoi* has the B genome. Based only on karyological evidence, subgroups of the A genome were also proposed as follows: A_1 =*A. cardenasii;* A_2 =*A. chacoense,A. duranensis, and A. stenosperma;* and A_3 = *A. correntina, A. spegazzinii,* and *A. villosa* (Stalker and Dalmacio, in review). Table 2 lists the eight species of section *Arachis* analyzed and corresponding chromosome morphological traits (Stalker and Dalmacio, in review).

Chromosome Behavior

Spacies

All diploid species of the genus Arachis have 10 bivalents and regular meiosis (Resslar and Gregory 1978; Smartt et al. 1978a,b; Raman 1976; Stalker and Wynne 1979). Tetraploids of section *Arachis, A. hypogaea,* and *A. monticola,* also behave cytologically like diploids and usually have 20 bivalents (Raman 1976). However, tetraploid members of section *Rhizomatosae* may have 1-4 multivalents *per* cell (Raman 1976).

Many intraspecific hybrids between subspecies of *A. hypogaea* produce sterile or "mutant" progeny in the second or later generations. Genetical or cytological divergence among subspecif ic groups may offer an explanation for the sterility. Husted (1936) observed bivalents plus a few univalents, trivalents, and quadrivalents in Virginia x Spanish varietal hybrids. Both Husted (1936) and Raman (1976) concluded that structural differences may be present between the two botanical types. To further characterize the meiotic behavior of intraspecific hybrids of *A. hypogaea,* Stalker (unpublished) cytologically analyzed parents and crosses of Spanish, Valencia, and Virginia varieties (Table 3). The parents in the study represented five gene centers of South America. Bivalents were observed in most parents and hybrids, but univalents and multivalents were also recorded at a low frequency. Only one hybrid combination, Valencia x Virginia, had a relatively high frequency of univalents (Table 3) which may indicate structural differences between the two botanical varieties. Further analyses, especially of somatic chromosome morphology, are needed before conclusions concerning specific chromosome differences among subspecific groups can be made.

Table 2. Chromosome variation among section *Arachis* species of the genus *Arachis* (abstracted from Stalker and Dalmacio, in review).

		Chromosomes				
Species	Proposed genomes*	With secondary constriction	Sub-median	Slightly sub-median	Total genome length	Ratio chrorn 10:1
A. cardenasii	A_1	5,10		2,4,5,6, 7,9,10	28.05	.63
A. chacoense	A_2	7	7	2,5,9,10	29.03	.56
A. duranensis	A_2	6	6	5,9	26.48	.41
A *stenosperma*	A_2	5		5,6,9,10	27.46	.44
A. correntina	A_3		9	1,2,5	29.89	.51
A. spagazzinii	A_3		9	10	24.29	.47
A. villosa	A_3		9	7,10	25.72	.50
A *batizocoi*	B	2	1	2,3,4,5, 6,9	25.49	.64

a. Subgroups at the A genome (A_1, A_2 and A_3) were proposed based on karyological analyses and do not necessarily correspond with plant habit nor hybrid fertility.

Table 3. Melotic behavior of Spanish, Valancia and Virginia varieties of *A. hypogaea* and their intraspecific hybrids.

Identity	Number			Avg chrom assoc/cell			
	Genotype	Plant	Cell	I	II	III	IV
Spanish (Sp)	3	3	75		19.85		0.05
Valencia (Val)	4	5	125	0.01	19.86		0.06
Virginia (Va)	3	3	75	0.08	19.96		
Sp x Sp	3	5	125		19.90		0.05
Val x Val	3	6	150	0.07	19.89	0.01	0.02
Sp x Val	4	5	111	0.14	19.89	0.01	0.01
Val x Sp	3	6	175	0.15	19.86		0.01
Val x Va	4	5	180	0.51	19.59	0.01	0.08
Va x Val	1	1	25	0.08	19.96		
Sp x Va	4	6	150	0.07	19.93		0.01
Va x Sp	1	2	50	0.12	19.94		

Meiotic Behavior of Interspecific Hybrids

Meiosis in F_1 hybrids between the two tetraploid species of section *Arachis, A. hypogaea* and *A. monticola,* is regular, and 20 bivalents are usually observed in pollen mother cells. *Arachis hypogaea* and *A. monticola* apparently havethe same genomes and gene exchange freely occurs in hybrids.

Arachis hypogaea also hybridizes with diploid members of section *Arachis.* The F_1 hybrids are sterile and cytological analyses reveal that univalents and bivalents are the most common chromosome configurations in pollen mother cells. The frequency of trivalents in meiotic cells is dependent upon the wild species parent used in crosses. For example, Smartt (1965) reported an average of 0.95 trivalents for *A. hypogaea x A. villosa* var. *correntina,* 2.15 trivalents for *A. duranensis hybrids,* and 3.40 trivalents when *A. helodes* was used as a parent. Meiotic analyses of triploid hybrids in *Arachis* do not reveal with which genome(s) the wild species were paired. At least in cells with trivalents, cultivated-cultivated, and cultivated-wild species chromosome associations occurred. Assuming *A. hypogaea* has two distinct genomes, the greater the chromosome homology between the wild and cultivated species, the fewer trivalents would be expected because homologous pairing among genomes would be restricted by the relatively rapid synapsis of homologues. A detailed analysis of pairing relationships between *A. hypogaea* varieties and the section *Arachis* diploid species would greatly add to our understanding of genomic relationships among the species.

Fertility can be restored after colchicine treatment of triploid interspecific hybrids. In 6x (*A. hypogaea* x *A. cardenasii)* hybrids, meiosis is apparently irregular with up to 32 univalents formed during meiosis in 60-chromosome plants (Spielman et al. 1979). The meiotically unstable gametes are apparently eliminated before seed set, however, because progeny from these hybrids are stable at the 60-chromosome ploidy level (P. Moss, personal communication). In 6x hybrids between *A. hypogaea* and *A. chacoense* between 2 and 18 univalents per cell were observed (Company and Stalker, unpublished). Since every chromosome has a homologue in the 6x plants, genes causing asynapsis must be present. Company and Stalker (unpublished) also observed progeny from 60-chromosome *A. hypogaea* x *chacoense* x *cardenasii,* and *x batizocoi* hybrid derivatives and the offspring are apparently stable at the 60-chromosome level. In the second to fifth generations after self-pollinating 6x (*A. hypogaea* x *A. batizocoi*) hybrids, the usual cytological configuration is bivalents and meiotic processes appear normal (Stalker, unpublished). Since strong selection pressure for viable seeds occurs in seed nurseries to maintain the germplasm, corresponding pressures are exerted in the interspecific hybrids for normal meiosis and viability. Diploidization would thus be expected to occur rapidly in polyploid interspecific hybrids.

Meiosis of most diploid x diploid section *Arachis* interspecific hybrids is normal and 10 bivalents are observed in F_1 pollen mother cells (Raman and Kesavan 1962; Resslar and Gregory 1979; Stalker and Wynne 1979). The exception is when *A. batizocoi* is used as a parent. These F_1 hybrids are sterile and have irregular meiosis (Gibbons and Turley 1967; Smarttetal. 1978a,b; Stalker and Wynne 1979). As indicated in the section concerning chromosome morphology, *A. batizocoi* has chromosome morphologies different from the other observed species of section *Arachis,* and meiotic and mitotic analyses confirm the presence of two genomes in section *Arachis.* Few analyses of interspecific hybrids in other botanical sections of the genus have been recorded, although in one section *Erectoides x* section *Erectoides* hybrid (10034 GKP x 9646 GKP), the F_1 was sterile and meiotic cells averaged 1.2 univalents and 9.4 bivalents per cell (Stalker, unpublished). Structural differences are apparently found between species of sections other than section *Arachis.*

Amphidiploids produced from diploid fertile section *Arachis* interspecific hybrids are male-fertile, but most plants do not produce many seeds. Amphidiploids behave meiotically either as diploids with 20 bivalents or may have as many as 9 quadrivalents per pollen mother cell (Stalker and Dalmacio, unpublished). Based on observations of only a limited number of plants, trispecific *A. hypogaeax4x* section *Arachis* amphidiploids have 40-60% fertility and many univalents per pollen mother cell. Meiosis is irregular with many laggards and bridges (Stalker, unpublished). The analysis of trispecific hybrids is compatible with previous evidence for *A. hypogaea* having two genomes with one being the A genome of many section *Arachis* diploid species.

Intersectionsl hybrids are difficult to produce and cytological analyses are correspondingly less frequent. Stalker (1978; in review) reported meiotic chromosome behavior in (4x section *Erectoides* amphidiploids x 2xsection *Arachis*) F_1 hybrids. The sterile A *rigonii* (10034 GKP) x *Arachis* sp 9841 GKP F_1 hybrid was colchicine treated after which a fertile amphidiploid was found. This plant was hybridized with *A. stenosperma* (410 HLK) and *A. duranensis* (7988 K). The resulting 30-32 chromosome offspring had mostly univalents and bivalents plus a few trivalents. The author concluded that intersectional chromosome associations were present in the hybrids and possibly a common genome was present between sections *Arachis* and *Erectoides.* Complex section *Erectoides* (E)x section *Rhizomatosae* (R) hybrids produce mostly bivalents during meiosis (Stalker, unpublished). Because of the ploidy levels and complexities of most existing hybrids, conclusions concerning intersectional chromosome associations are difficult to make. However, in one hybrid combination 4x[GKP 10034 (E)xGKP 9841 (E)] x4x [GKP 9841 (E)xGKP 9570 (R)] the normally 20 bivalents observed, most probably represented intersectional chromosome associations (Stalker, unpublished).

Discussion

Careful analyses of section *Arachis* chromosomes have revealed enough variation to identify the 10 homologues. As chromosomes become more condensed they are proportionately more difficult to karyotype. At least two genomes exist in the section *Arachis.* The A genome includes most species of the section and the known B genome currently consists of only *A. batizocoi.* At least five species can be cytologically identified in section *Arachis;* another three cytologically similar species (*A. correntina, A. spegazzinii,* and *A. villosa*) can only be distinguished after many cells are analyzed.

interpretation of chromosome pairing relationships of diploid interspecific hybrids is generally straightforward. In section *Arachis, A. batizocoi* hybrids have irregular meiosis and are sterile. All other diploid interspecific hybrids involving species of this section thus far analyzed have 10 bivalents at metaphase I. Semisterility is common in most interspecific hybrids even though meiosis is regular. More variation in chromosome morphology was found in somatic section *Arachis* species than expected, based on previous observations of meiotic chromosome associations in pollen mother cells. Homologous chromosome pairing must occur at a high frequency in interspecific hybrids of section *Arachis.*

Polyploidy is naturally present in two sections of the genus and colchicine treatment has resulted in induced polyploids in several others. Analyses of chromosome numbers to identify hybrids and then to determine intergenomic chromosome relationships in hybrids with 2x=40 to 60+ are desirable. Interpretation of chromosome pairing relationships in polyploids is sometimes difficult. Because of the small chromosome size, meiotic *Arachis* chromosomes are extremely difficult to identify. While multivalents in tetraploids may indicate intergenomic homologies, mostly only one or two quadrivalents per cell are observed. Also, the same or different chromosome may be pairing in different cells so the amount of possible gene exchange is difficult to determine in most hybrids. Bivalent formation in polyploids generally indicates distinct genomes and limited intergenomic interaction. However, when only bivalents are present, conclusions as to interaction cannot be easily drawn. While formation of pentavalents or hexavalents in allohexaploids indicates homology among all three genomes, formation of only quadrivalents would not prove nor disprove genomic relationships.

Based on the extensive hybridization program conducted by Gregory and Gregory (1979), at least five genomes have probably evolved in the genus *Arachis,* including: AM (*Ambinervosae*), C (*Caulorhizae*), E (*Erectoides*), EX (*Extranervosae*), and T (*Triseminalae*). Tetraploid members of section *Rhizomatosae* hybridize with sections *Arachis* and *Erectoides* in relatively high frequency. *Rhizomatosae* may thus have a common genome with *Arachis* and *Erectoides.* The relationships are somewhat confusing because section Arachis probably did not evolve from section *Rhizomatosae,* or vice versa. Present evidence indicates that section *Arachis* has two genomes and members with either the A genome (*i.e., A. duranensis* or A *spegazzinii*) or with the B genome (*i.e., A. batizocoi*) will hybridize with the same section *Rhizomatosae* collections. However, other members with the A genome (i.e., A *villosa, A. correntina, A.cardenasii,* and *A. chacoense*) will not hybridize with the same section *Rhizomatosae* collections (Gregory and Gregory 1979). The crossing relationships along with karyotyping data indicate a considerable amount of diversity exists within section *Arachis* species. For species outside section *Arachis,* the genomes are not cytologically verified nor completely identified. Many questions pertaining to chromosome pairing in hybrids, causes for incompatibilities (failures of hybrids may be due in part to single genes conditioning gametophytic or sporophytic incompatibilities), and further biosystematic analyses to identify additional viable hybrids will add considerably to the understanding of species relationships.

Progenitor species of *A. hypogaea* are as yet unidentified. Present indications are that the cultivated species combines the A and B genomes. However, only after extensive cytological analyses will questions of ancestry be clarified. Identifying progenitors of *A. hypogaea* is more than an academic question in the genus. If progenitor species were used in interspecific hybrid combinations, then pairing and gene exchange would be more likely to occur. For example, if 4x amphidiploid hybrids were crossed with the cultivated species, and one of the species was an ancestor of *A. hypogaea,* then pairing between the cultivated and wild species would more likely occur among all chromosomes in the trispecific hybrid.

Cytogenetic information has steadily accumulated during the past 40 years. Many species still need to be collected and also such basic information as chromosome numbers recorded. For the cultivated and a few wild species, especially in section *Arachis,* the useful cytogenetic information will soon help in manipulating chromosomes for improvement of peanut varieties.

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Utilization of Wild *Arachis* Species at ICRISAT

A. K. Singh, D. C. Sastri and J. P. Moss*

One of the possibilities for increasing the yield of groundnut, particularly in the Semi-Arid Tropics, is breeding varieties with resistance to pests and diseases. Some progress has been made in this field, but the improvements that can be made by breeders are limited by the availability of genes within *A. hypogaea.* Collections of wild species from South America have made available a wider range of genes, especially genes for disease resistance. The richness of *Arachis* germplasm collection offers a great opportunity for anyone interested in the improvement of this crop (Bunting et al. 1974, Simpson 1976; Smartt et al. 1978a, b; Gregory and Gregory 1979).

However the cytotaxonomy of the genus *Arachis* is such that it is difficult for a breeder to use wild species in groundnut improvement (Gregory and Gregory 1979; Moss 1980; Stalker 1980). The two major constraints to utilization of wild species are differences in ploidy level and incompatibility between some wild species and *A. hypogaea.* The small size of chromosomes of *Arachis* and the difficulty experienced by some workers in making good cytological preparations has deterred many people from attempting cytogenetic techniques in the improvement of *Arachis,* despite their successful application to many other crop plants, especially wheat and tobacco. The groundnut cytogenetics program at ICRISAT has attempted to overcome these difficulties, and to produce interspecific hybrids and to manipulate the ploidy level to produce tetraploid lines incorporating desirable characters which can then be utilized by breeders in the improvement of groundnut.

The program on utilization of wild species in *Arachis* was initiated at Reading University (U.K.) with three species which were known to cross with *A. hypogaea* and were resistant to leaf spots. These were *A. cardenasii* Krap. and Greg., nomen nudum, *A. chacoense* Krap. and Greg., nomen nudum, and *Arachis* species Coll. HLK 410 which were reported as immune to *Cercosporidium personatum,* highly resistant to *Cercospora arachidicola,* and resistant to both (Abdou 1966; Sharief 1972; Abdou et al. 1974; Hammons, personal communication).

The groundnut cytogenetics program at ICRISAT was initiated in April 1978 with the object of making the fullest possible use of the genus *Arachis.* Cooperation with the Genetic Resources Unit, pathologists, entomologists, and microbiologists has increased the number of wild species at ICRISAT and our knowledge of the desirable genes which they contain. Cytogenetic analysis provides information to improve the efficiency of incorporation of wild species genes into *A. hypogaea.* Thetechniques have been described by Singh et al. (1980).

In addition to *A. hypogaea,* section *Arachis* contains one other tetraploid. *A. monticola,* and several diploid species. All these species are cross compatible with *A. hypogaea* (Smartt and Gregory 1967; Stalker 1980). Nine diploid species and the two tetraploids have been studied in detail and a chromosome with a secondary constriction and a small satellite seen as chromosome 3 in *A. villosa, A. correntina, A. chacoense,* and *Arachis* species Coll. No. 10038, and a chromosome with a secondary constriction and a large satellite seen in *A. batizocoi* and in *A. duranensis* as chromosome 2, in *Arachis* species 338280 as chromosome 6 and in A *cardenasii* as chromosome 9. Chromosomes with secondary constrictions had only been reported previously in *A. batizocoi.* The small pair of chromosomes in *A. cardenasii* are larger than in the remaining species but still smaller than the smallest chromosomes of *A. batizocoi. A. monticola* and *A. hypogaea* are close karyomorphologically, though *A. monticola* has two pairs of chromosomes with secondary constrictions whereas *A. hypogaea* has only one, and the chromosome with a secondary

* Cytogeneticists, Groundnut Improvement Program, ICRISAT.

constriction in *A. cardenasii* is comparable to one of those of *A. monticola* and that of *A. hypogaea.*

Mahalanobis D^2 analysis and canonical analysis, using the arm ratio of each of the ten chromosomes of the diploid taxa investigated, resulted in two clusters within these. *A. batizocoi* is the only species in one of these clusters; there are eight taxa in the other cluster, which can be further subdivided (Fig. 1).

All the species of the section *Arachis* are cross-compatible, and differences in crossability are too small to be satistically significant. All the available nine diploid taxa have been crossed in all possible combinations and a large number of F_1 hybrids have been analysed cytologically. Results from these studies substantiate our grouping of the diploid species. The F_1 hybrids resulting from the cross of two species belonging to the two different clusters show a high frequency of univalents and a high pollen sterility, while F_1 hybrids between two species of the same cluster show a low frequency of univalents and a low pollen sterility.

D^2 distances among species of section *Arachis*

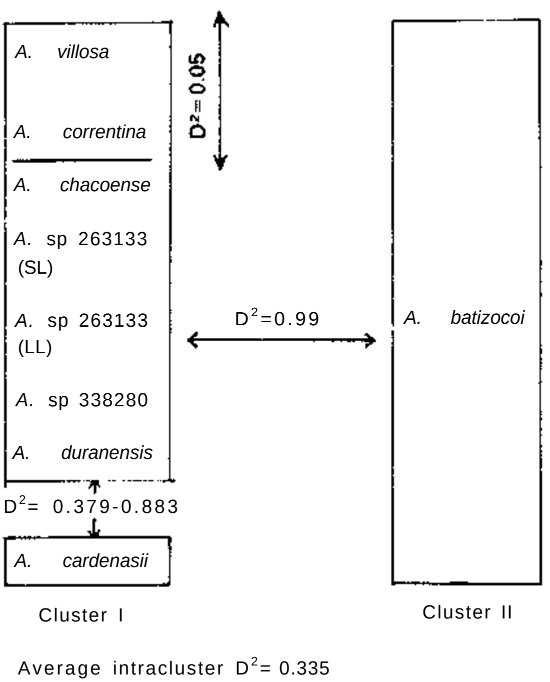


Figure 1. Cluster diagram.

These basic studies are designed to assist us in the main objective of the cytogenetics unit, i.e., the utilization of the wild species for the improvement of groundnuts. The two go hand in hand because many of the plants produced in the course of utilization of wild species are analyzed in detail, and plants which are analyzed are then used in crossing programs. The two main thrusts of the subprogram are the use of compatible species to transfer currently available genes, and the study of the barriers to hybridization and the means of breaking them to make the whole gene pool within *Arachis* available to breeders in the future.

Breeding in Compatible Species

The incorporation of genes from wild species involves the transfer of one or more wild species genomes to a hybrid where they can undergo recombination with *A. hypogaea* genomes, and subsequent transfer of the desired gene or genes into *A. hypogaea* with the elimination of all undesirable characters from the wild species. Five routes have been adopted to achieve these objectives (Fig. 2).

Triploid Route

Smartt and Gregory (1967), Moss and Spielman (1976), Raman (1976), and Moss (1977) have all produced hexaploids by chromosome doubling in a triploid hybrid. As early as 1976, ICRISAT received hexaploids from the program at Reading University. These hexaploids combined the genomes of *A. cardenasii, A. chacoense* and *Arachis* species No. 338280 with *A. hypogaea,* and were screened for leaf spot resistance at ICRISAT, which is mainly infested by late leaf spot (C. *personatum).* Resistant plants were selected from each type of hexaploid, and have been backcrossed to different cultivars of *A. hypogaea* (Moss 1980). These progenies are now in the fourth generation of backcrossing and tetraploid and near tetraploid plants are being screened for disease resistance. Many hexaploids were also resistant to rust. There is no correlation between leaf spot or rust resistance and defoliation in hexaploids derived from resistant wild species, as some hexaploids susceptible to disease do not defoliate. Conversely, some hexaploids with few small lesions suffer severe defoliation (Moss et al.

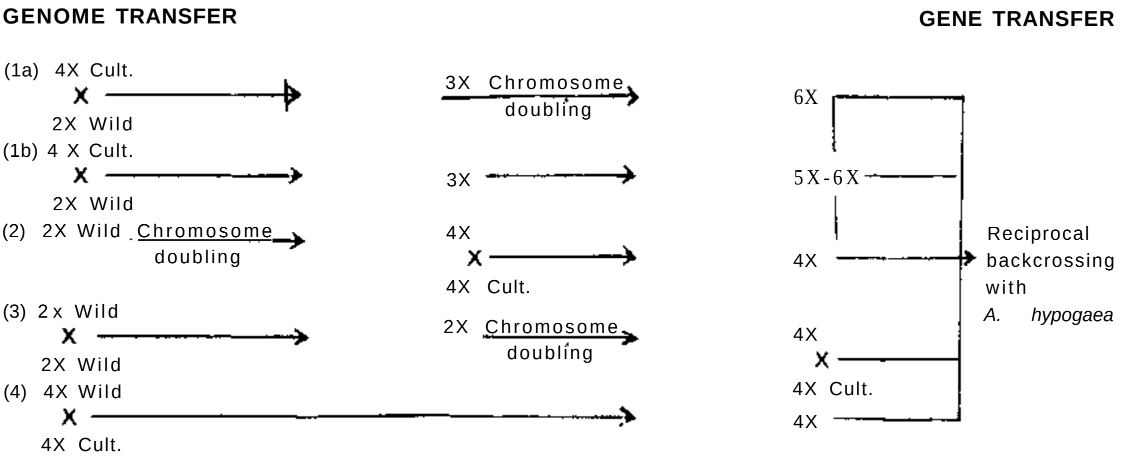


Figure 2. Utilization of diploid and tetraploid wild species.

1979). The fertility of the hexaploids and backcrosses ranges from nil, in some sterile but vegetatively vigorous plants, to highly productive. Some plants produce many pegs per node and pegs per plant, but few pods, whilst others have good reproductive efficiency.

Crosses between *A. hypogaea* and five diploid species have produced 92 pods (Table 1). Five triploids have been established from sprouts and the remaining seed will be used to produce hexaploids.

The artificial induction of polyploidy in a triploid to restore fertility, can be difficult and time consuming, so the development of a technique whereby large numbers of cuttings of the sterile triploid can be treated has increased the production of hexaploids (Spielman and Moss 1976; Nigam et al. 1978). Triploids can produce fertile gametes through the formation of a restitution nucleus and by segregation giving 2n or near 2n gametes. Studies of Anaphase I of meiosis show that 30, 20 and hyper-20 chromosome cells occurred; triploids have produced seed in the field at ICRISAT.

This process may be environmental and/or genotype specific; for instance high temperature in India may be one of the reasons for the formation of unreduced gametes, and the triploids differ in the frequency with which they produce seed. This latter may be due to the different wild species used, or an effect of the different *A. hypogaea* genotypes which are known to affect the amount of pairing in hexaploids (Spielman et al. 1979).

Autotetraploid Route

The production of an autotetraploid from a diploid wild species enables all hybridization and genome transfer to be done at the tetraploid level, and increases the dosage of wild species genes. Autotetraploids have been produced in seven taxa (Table 2). Of these only *A. batizocoi* (4x) has produced seed; many plants of the others remained sterile and eventually died. However, three autotetraploids were successfully used as male parents in crosses with *A. hypogaea* (Table 3). The resultant progenies are morphologically similar to *A. hypogaea,* but cytologically unstable, and sterile. A number of generations of selfing of the autotetraploids will increase the frequency of balanced gametes, and the likelihood of fertile hybrids with *A. hypogaea.* Hybrids will be backcrossed to *A. hypogaea* to restore fertility whilst selecting desirable recombinants.

Amphiploid Route

Chromosomedoubling in a hybrid between two diploid wild species produces an amphidiploid which combines the two wild species, which is thesame ploidy level as tetraploid *A. hypogaea,* and increases the number of genomes in the hybrid and therefore the number of possible recombinants. If the two wild species used are the ancestors of *A. hypogaea,* the amphidiploid will be a synthetic *A. hypogaea,* and this may be the most promising tetraploid derivative of the

Table 1. Crossability between *A. Hypogaea* and diploid species of section *Arachis.*

Cross	No. of Pollinations	No./% of pegs	No./% of pods
A. hypogaea x *A. correntina*	63	24/38	22*/35
A. hypogaea x *A. batizocoi*	64	20/31	16/25
A. hypogaea x *A. villosa*	87	38/44	26/30
A. hypogaea x *A. duranensis*	58	19/33	14*/24
A. hypogaea x *A.* sp 338280	44	15/34	14/32
Total	316	116/37	92/29

* Sprouts produced.

Table 2. Production of autotetraploids from wild diploid *Arachis* species.

Species	Seedlings treated	Plants survived	2x plants	4x plants
A. villosa	17	14	11	4
A. correntina	18	16	10	2
A. chacoense	5	1		
A. sp 338280	19	12	3	3
A. sp 263133	8	5	4	1
A. duranensis	7	6	2	2
A. cardenasii	15	14	1	3
A. batizocoi	26	21	11	10

Table 3. Crossability between *A. hypogaea* and autotetraploids of section *Arachis.*

Cross	No. of pollinations	No./% of pegs	No./% of pods
A. hypogaea x *A.* sp 338280 (4x)	132	16/12	13*/10
A. hypogaea x *A. villosa* (4x)	139	30/22	20*/14
A. hypogaea x *A.* sp 263133 (4x)	113	19/17	17/15
Total	384	65/17	50/13

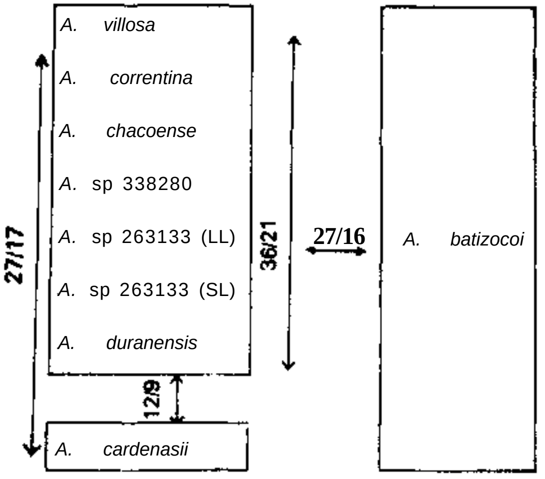
* Sprouts produced.

wild species with regard to the genetic improvement of *A. hypogaea.* Intracluster crosses are much more successful than intercluster crosses (Fig. 3).

Fifty-one amphiploids have been raised from 17 different cross combinations of wild species, including *A. batizocoi* (Table 4), and eight different combinations have been successfully crossed with *A. hypogaea* (Table 5). The resultant progenies are being analyzed morphologically and cytologically; their behavior is similar to the progenies obtained through the autotetraploid route. The amphiploids involving three species are the most fertile.

Use of Tetraploid Wild Species

A. monticola has been crossed with *A. hypogaea* and fully fertile hybrids have been produced.



Total no. of pollinations	5348
Total no. of pegs	1453
Total no. of pods	901

Figure 3. Percentages of peglpod production in interspecific crosses in section Arachis.

Gene Transfer

By Chromosome Pairing

Our cytological analysis of the diploid wild species, F1 hybrids and triploids resulting from crosses of wild diploid species with A *hypogaea* has indicated that there is chromosome homology or homoeology among the genomes of all the wild diploid species studied and between these genomes and A *hypogaea.* This means that there is a good probability of gene transfer through chromosome pairing in these hybrids and backcrosses producing new gene combinations in progenies, enabling selection of the desired plants.

Induced Translocation

Such chromosome pairing may not always occur, either because of the incorporation of a nonhomologous genome, or because the genetic background of the hybrid prevents pairing of homologous genomes. In such cases translocation of chromosome segments has to be induced through mutagenesis.

Barriers to Hybridization and Means of Breaking Them

A *hypogaea* has not been successfully and repeatably crossed with any species outside section *Arachis* (Gregory and Gregory 1979). Many species in other sections have potential as gene sources in groundnut improvement (Moss 1980). Tetraploid wild species are found in section *Rhizomatosae* (Gregory and Gregory 1979) and these species are of special interest as they are immune to many pathogens. Several attempts have been made by many people over the years to achieve an intersectional hybrid but these have not been successful (Gregory and Gregory 1979). Recent advances in the knowledge of the physiology and development of pollen, factors involved in pollination and advances in the technology of

Table 4. Number of amphiploids established in section *Arachis.*

♂ Parents / ♀ Parents	*A. villosa*	*A correntina*	*A sp 338280*	*A duranensis*	*A. sp 263133*	*A chacoense*	*A. batizocoi*	*A. chacoense x A. cardenasii*
A villosa			6				2	
A. correntina	4		1					5
A sp 338280	2							2
A. duranensis	1	1			3	5		
A. sp 263133			2	3				
A. batizocoi	2		1			8		

Table 5. Crossabllity batween *A. hypogaea* and amphlploids.

Cross	No. of pollinations	No./% of pegs	No./% of pods
A. hypogaea x *[A. correntina* x *[A chacoense* x *A. cardenasii)]*	160	26/16	22*/14
A. hypogaea x *[A.* sp. 338280 x *(A. chacoense* x *A. cardenasii)]*	164	42/26	32*720
A. hypogaea x *{A. correntina* x *A. villosa)*	199	62/31	42*721
A, hypogaea x *{A. villosa* x *A.* sp 338280)	135	15/11	15*/11
A. hypogaea x (A *duranensis* x *A. chacoense)*	96	9/9	7»/7
A. hypogaea x (A *batizocoi* x *A. villosa)*	29	8/28	7/24
A. hypogaea x (A *batizocoi* x *A. duranensis)*	18	7/39	5*/28
A. hypogaea x *[A. batizocoi* x *A. chacoense)*	10	7/70	3*/30
Total	811	176/22	133/16

* Sprouts produced.

tissue culture have increased the possibility of producing hybrids between species which were previously considered to be genetically isolated (Heslop Harrison 1978; Vasil 1978, 1980; Shivanna et al. 1979; Sala et al. 1980).

In June 1979 a project was initiated to investigate the barriers to intersectional hybridization. Fluorescent microscopic comparison of the compatibly and incompatibly pollinated pistils showed that in the former, the pollen tubes were smooth with small callose patches distributed evenly along the lengths of the pollen tubes. In the incompatibly pollinated pistils, however, the callose depositions along the pollen tube were uneven and in larger quantities indicating a retarded growth of the tubes. However, a small frequency of incompatible pollinations induced peg initiation and elongation, though these usually dried and degenerated before they penetrated the soil.

A number of techniques have been tested for their efficiency to overcome such incompatibility. Plant growth hormones applied to the ovary were found to increase the frequency of peg formation in incompatible crosses. The initial trials, using cytokinin at 10^{-6}M applied to cotton webs wrapped round the ovaries, were followed by trials using four concentrations of kinetin and three of benzylamino purine, as well as auxins and gibberellic acid. The effects of these treatments are shown in Table 6. Kinetin, naphthaleneacetic acid and gibberellic acid have all significantly increased the pegging percentage.

Some of these pegs have been left to form pods in the soil. Others have been excised from the plants for aseptic culture of the tip of the peg, or the ovule, or the embryo. We have so far been able to culture immature embryos successfully into seedlings using Murashige and Skookg's 1962 medium. Our attempts to culture pegs according to Ziv and Zamsky (1975), or ovules according to Martin (1970), even from compatible crosses, have not given satisfactory repeatable results. We were able to induce normal embryogeny in one ovule culture up to the cotyledonary stage of the embryo by using an aqueous peg extract in the medium.

While excising the embryos from seed for culture, the cotyledons were also cultured. We observed that the end of the cotyledon proximal to the embryo is a highly embryogenic tissue which gives rise to roots, shoots, embryoids or whole plants depending upon the hormonal balance in the medium. We have also been trying to regenerate plants from leaflet segments and have been able to induce roots but not shoots or embryos, although we have tried four different basic media, White (1943), Murashige and Skoog (1962), Gamborg et al. (1972) and Kao and Mickayluk (1975), with a range of auxins and kinetins, as well as supplementing with coconut milk, casein hydrolysate, yeast extract, malt extract or gibberellic acid.

Conclusion

Considerable progress has been made with a

Table 6. Effect of soma plant growth hormones on pegging after pollination of tetraploid species of section *Anchls* with *Arachis* sp PI No. 276233 of section *Rhizomatotae.*

		♀ *Arachis monticola*		♀ *A. hypogaea* var. Robut33-1	
Cross	Treatment	No. of pollinations	Pegs formed (%)	No. of pollinations	Pegs formed (%)
Compatible (self)	None	201	34.33	156	34.62
Incompatible (control)	None	314	17.20	147	15.65
Incompatible	Kinetin, 10^{-4} M			21	14.29
"	Kinetin, 10^{-5} M	90	15.56	82	25.00
"	Kinetin, 10^{-6} M	75	18.67	55	25.46
"	Kinetin, 10^{-7} M	95	14.75	87	40.23
"	Benzyl Adenine, 10-^{5}M	134	22.39		
"	Benzyl Adenine, 10-^{6}M	191	20.42		
-	Benzyl Adenine, 10-^{7}M	98	19.39		
- "	Indole Acetic Acid (25 ppm)	107	13.08	53	24.53
»	Napthalene Acetic Acid (25 ppm)	129	17.83	52	42.31
-	2, 4-Dlchloro Phenoxy-acetlc Acid (25 ppm)	73	17.81	18	22.22
*	Gibberellic Acid (25 ppm)	37	48.65		
-	Kinetin 70-^{4}M + Indole Acetic Acid (25 ppm)			89	24.72

number of different ways of utilizing wild species. The number of plants produced, and the range of variation they show, indicate that there is good potential for transferring desirable characters from wild species. Although the wild species were originally considered solely as sources of disease resistance, the progenies from interspecific crosses have potential as a means of expanding the gene pool of *Arachis* with respect to a number of other desirable characters.

Results of attempts to break the barriers to hybridization hold promise for utilization of characters from species outside section *Arachis.*

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Session 4 — Cytogenetics and Utilization of Wild Species

Discussion

C. Raja Reddy

The cytology and pollen fertility of the hybrid between *A. villosa* xA *correntina* point to their close similarity, which is also substantiated by the D^2 analysis. In view of this, is the separation of the two species into distinct ones justified?

H. T. Stalker

The two species are recognized in taxonomy based on the differences in external morphology. In fact, most species of *Arachis* are delineated from considerations of morphological differences. A biosystematic classification of the species of *Arachis* is no doubt desirable, but this has to wait till an extensive study of their cytogenetics is carried out.

K. S. Labana

Have any monosomicornullisomic lines been developed in *Arachis?*

H. T. Stalker

Studies on monosomic and nullisomic plants in *Arachis* have been meager. The limited investigations have shown their cytological instability. The development of such lines in *Arachis* will entail intensification of research on this aspect.

P. S. Reddy

Many methods of interspecific gene transference from the wild species *of Arachis* to the cultivated *A. hypogaea* are cited but not one on development of haploid plants of *A. hypogaea* through pollen culture and utilizing such plants in hybridization with diploid species. Does this not appear to be a profitable approach?

J. P. Moss

The information on induction of haploidy in *A. hypogaea* through pollen culture gained from studies carried on in this country and elsewhere are awaited.

U. R. Murty

Attempts at culturing the pollen of triploid hybrids between *A. hypogaea* and diploid species are likely to lead to the realization of aneuploids.

A. K. Singh

Although this route may not be very fruitful on theoretical considerations, it is worth a trial.

R. W. Gibbons

Hexaploids generally suffer from low pod yields. Has there been any attempt to study the progeny behavior of the hexaploids from this angle?

H. T. Stalker

The hexaploids have been found to be low yielders. But exception to this generalization has also been noticed. In the case of the progenies developed from the hexaploid of A *hypogaea* x A *cardenasii,* plants in the 9th generation showed an improvement in pod yields comparable to that of cv NC-5.

R. 0. Hammons

Would it be feasible to pursue cytogenetic research through the use of haploid plants isolated from twin seedlings?

H. T. Stalker

Twin seedlings from seeds of A *hypogaea* are known to occur at a low frequency and these were found to be tetraploid in constitution. Efforts are under way to locate haploid seedlings from haploid-diploid twins.

J. P. Moss

Experience has shown that small and shriveled seeds have given aneuploids rather than haploids. The significance and importance of haploids in cytogenetic analysis is well-realized, and exercises to isolate haploids are under way.

What is the basis of differentiation of the genomes as A1, A2, and A3?

H. T. Stalker

The differentiation is based on the karyomorphology of the species, nature of chromosome pairing in hybrids, and their levels of fertility. Such a genomic differentiation is only tentative and more evidence has to be gathered to confirm it.

C. Raja Reddy

The karyological features of nine diploid species have been taken into consideration for the D^2 analysis. A larger array of material should have been included in this analysis.

A. K. Singh

The necessity to draw more species of D^2 analysis is recognized, and as and when additions are made, the analysis will be continued but not on a priority basis.

H. T. Stalker

In view of the importance attached to cytogenetic investigations of applied value, studies on D^2 analysis may be left to be pursued by academic institutions rather than by ICRISAT.

V. S. Raman

Let me give my understanding of this D^2 analysis that has been done with reference to nine diploid species. In group 1, eight species are accommodated and in group 2, A *batizocoi* stands out prominently. With reference to the origin of A *hypogaea* as currently understood, A *batizocoi* is one of the parents involved in the origin. So this analysis justifies the stand taken in the hypothesis that A *batizocoi* is one of thediploid parents involved in the origin of the tetraploid. Even with this analysis, the piece of fundamental information can be drawn.

Session 5

Crop Nutrition and Agronomy

Chairman: A. Narayanan

Rapporteurs: P. W. Amin
R. W. Gibbons
V. K. Mohan

Increasing Nitrogen Fixation of the Groundnut by Strain and Host Selection

J. C. Wynne, G. H. Elkan and T.J. Schneoweis*

As the cost of nitrogen fertilizer derived from fossilfuelscontinuestorise, biological nitrogen fixation will become more important for the continued productivity of agricultural crops. In the immediate future, successful increases in biological nitrogen fixation most likely will come from improvements in the symbiotic fixation by legumes.

Groundnuts *(Arachis hypogaea* L), since they are grown on about 18 million hectares in 82 countries, should contribute to the increase in dinitrogen fixed. Increases in dinitrogen fixed by groundnuts can be accomplished by the selection of more effective strains of *Rhizobium* and/or selection of more efficient host plants.

Selection of Effective Strains of *Rhizobium*

Groundnuts are a member of the cowpea cross-inoculation group. Rhizobia isolated from a diverse group of legumes *are* capable of nodulating groundnuts (Burrill and Hansen 1917; Walker 1928; Carroll 1934; Raju 1936; Mostafa and Mohmoud 1951; Berenyi 1962; Rajagopalan and Sadasivan 1964; Doku 1969; Gaur et al. 1974a). Not all rhizobial strains are equally effective in fixing nitrogen in symbiosis with groundnuts (Allen and Allen 1940; Collins 1943; Erdman 1943; Berenyi 1962; Denarie 1968; Vidyasekaran et al. 1973; Dadarwal et al. 1974; Weaver 1974). Therefore, effective rhizobial strains should be identified and used to inoculate groundnuts to ensure an effective symbiosis (Erdman 1943; Schiffmann 1961; Schiffmann and Lobel 1970; Gaur et al. 1974a; Lopes et al. 1974; Weaver 1974; Burton 1976). However, to be useful, effective strains must survive in and colonize the soil into which they are introduced. Unfortunately many effective strains have been unable to survive and colonize under field conditions (Schiffmann 1961; Shimshi etal. 1967; Schiffmann and Alper 1968b; Pant and Iswaran 1970; Gaur et al. 1974b; Iswaran and Sen 1974; Kumara Rao etal. 1974). Introduced strains which survive must also be able to compete for infection sites on the root with less effective native strains. Frequently introduced strains are not very competitive (Berenyi 1962; Denarie 1968).

Significant responses to inoculation with effective strains have largely been restricted to controlled conditions (Chomchalow 1971) and field experiments *on* virgin groundnut soils (Duggar 1935b; Collins 1943; Schiffmann 1961; Berenyi 1962; Shimshi et al. 1967; Schiffmann and Alper 1968a,b; Denarie 1968; Burton 1976). When inoculation with effective strains has been successful, the result has been increased yields of fruit, plant dry matter, nodulation, percentages of large fruits and seeds, and nitrogen content of foliage and seed.

The collection, identification, and use of superior strains of rhizobia should be *an* integral part of a groundnut research program. Inoculants produced from superior strains specifically tailored to the local environment should be used where nodulation is not adequate for good growth and high yields. These inoculants should also be used where nodulation appears adequate but a growth response to nitrogen fertilizer is observed si nee this suggests that the strains producing the nodules may not be efficient.

* Associate Professor of Crop Science, Professor and Research Assistant of Microbiology, respectively, North Carolina State University, Raleigh, North Carolina, 27650, USA.

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Nodule Collection, Strain Isolation, and Maintenance

Strains of *Rhizobium for* groundnuts are maintained at several international and national centers such as ICRISAT; USDA, Beltsville, Maryland, USA; and NifTAL, University of Hawaii, USA. Because of the limited research on the groundnut-Rhizobium symbiosis, only a few of the available strains have been tested with groundnuts. For example, the USDA *Rhizobium* culture collection catalog (1979) lists 16 strains for groundnuts of which only four are recommended for symbiotic effectiveness. The NifTAL catalog (1978) recommends five strains and lists 11 additional strains that are effective with groundnuts.

Because of the limited number of recommended strains of *Rhizobium* and the lack of knowledge about their performance in symbiosis with the groundnut germplasm growth in North Carolina, we concluded that one of the principal goals of our program should be to isolate and identify effective rhizobial strains.

Initially we obtained strains of rhizobia from other researchers. Additional strains of *Rhizobium* were isolated from nodules collected from centers of diversity for the genus *Arachis* in South America. The nodules were obtained from *Arachis* collecting expeditions sponsored by IBPGR and led by W. C. Gregory (North Carolina State University, Raleigh) and C. E. Simpson (Texas A & M University, Stephenville). After sampling, the nodules were placed in 7.5 ml plastic vials containing anhydrous calcium chloride, covered with a cotton plug, and mailed to our laboratory in North Carolina. After the nodules were received from South America, they were rehydrated in sterile water for 4 hours at 5°C. They were then aseptically dissected, and a nichrome wire was used to streak some of the tissue on yeast extract mannitol agar in previously poured petri plates. Cultures were incubated at 28°C and examined daily for raised mucoid colonies typical of rhizobia. These colonies were restreaked until pure cultures were obtained. Using these techniques, 234 bacterial isolates representing 78 germplasm collections were obtained from nodules collected in 1976-77 (Tables 1,2). Additional strains are now being isolated from nodules collected in 1979 and the spring of 1980.

The *Rhizobium* culture collection is maintained in screw-capped tubes containing yeast mannitol agar and stored at 5°C. These cultures are maintained in duplicate with one.set being the working collection. In addition to agar slants, the mother collection is also preserved on porcelain beads with silica gel and in lyophilized form. These latter two techniques limit loss of culture viability with minimal risk of mutation or contamination. Transfers of this *Rhizobium* collection are provided upon request to interested investigators. Additional cowpea strains from the diverse environment where groundnuts are grown need to be collected.

Evaluation of Effectiveness of Strains

We use siratro *(Macroptilium atropurpureum)* for preliminary screening of isolates. This small-seeded legume is grown in the growth chamber in 30 ml serum bottles capped with plastic bags. The roots are examined for nodulation after 21 days. Strains capable of nodulating siratro are increased for testing with groundnuts. This further evaluation of these rhizobia is usually completed in stages. We first test rhizobia in the greenhouse with two host genotypes of different origin. Those strains that are effective in greenhouse studies must then be tested in the field in competition with indigenous rhizobia.

Greenhouse Evaluation

Argentine (Spanish type) and NC-4 (Virginia type), two cultivars representing the two subspecies of groundnuts, are used as host plants (Wynne et al. 1980). Plants are grown in modified Leonard jars similar to those proposed by Wacekand Aim (1978). The jars and a 2:1 sand: vermiculite medium are autoclaved before use to prevent contamination.

Seeds of each genotype are surface-sterilized by soaking in calcium hypochlorite solution (10 gin 150 ml water) for 10 min followed by rinsing with sterile water five times. The groundnuts are then pregerminated in sterilized vermiculite and placed 25 mm into the medium in the jars. Before covering the seed, a 1 ml suspension of the proper rhizobial strain (approximately 10^9 cells/ml) is added aseptically to the seed for all treatments except for an uninoculated control where sterile culture medium alone was added

Table 1. Origin of *Rhizobium* isolates collected from *Arachis* species growing in South America.

Coll. No	Isolated from	Lat	Long.	Elevation (m)	Soil description	Date collected
1	*Arachis* sp	19°02′S	56°39′W	80–100	Light sandy soil	7 Dec 1976
3	*Arachis* sp	20°22′	56°58	100–200	Red, black soil weathered from limestone	11 Dec 1976
6	*Arachis* sp	25km W of Mburucuya				26 Dec 1976
7	*A. diogoi* Hoehne	17°40′	57°45′	0–100	Reduced argillaceous soil and calcareous gravel	6 Dec 1976
22	*A. helodes*	16°03′	57°13′	170	Brown sand	17 Dec 1976
23	*Arachis* sp				Calcareous origin	17 Dec 1976
56	*Arachis* sp	24°04′	65°24′	1565	Dark alluvial gravel	30 Mar 1977
59	*Arachis* sp	23°04′	63°53′	350–400	Alluvial reddish sand	2 Apr 1977
62	*Arachis* sp	22°51′	63°56′	350	Sandbank of alluvium	4 Apr 1977
70	*Arachis* sp	21°41′	63°45′	1000	Light brown, alluvial clay-loam-gravel	8 Apr 1977
71	*Arachis* sp	21°41′	63°44′	870–1000	Light red alluvial sandy loam	8 Apr 1977
83	*Arachis* sp	20°17′	63°28′	900	Light brown sandy loam	14 Apr 1977
93	*Arachis* sp	17°19′	63°18′	350	Deep sand in "matorral"	20 Apr 1977
99	*Arachis* sp	15°44′	63°05′	250	Brown to gray alluvial soil	27 Apr 1977
120	*Arachis* sp	26°22′	57°05′	ca 65	Deep white sand banks	16 June 1977
123	*Arachis* sp	25°23′	57°16′	ca 175	Light-colored sand	17 June 1977
134	*Arachis* sp	22°15′	57°28′	ca 210	Light sand	24 June 1977
136	*Arachis* sp	22°23′	56°27′	ca 220	Brown sandy soil	24 June 1977
178	*Arachis* sp	21°34′	57°15′	ca 225	Red iron-gravel and granite boulders- "cerrado"	29 June 1977
181	*Arachis* sp	21°30′	57°01′	ca 350	Brown sandy gravel loam	29 June 1977

Table 2. Origin of *Rhlzoblum* isolates collected from South American groundnuts.

Coll. No.	Isolated from	Area collected	Soil description	Date collected
77	Colorado Chico del Palmai' (red seeds)	Cototo, 10 km E of Villa Montes		11 Apr 1977
92	Overo Colorado Blanco (grande)	Saavedra, Sta. Cruz	Dark black loam	19 Apr 1977
138	Overo	Puento de Mataral, Sta. Cruz		25 Apr 1977
146	Overo	Valle Abajo, Mairana		28 Apr 1977
150	Palido	Teneria — Aiquile, dept. Cochabamba	Brown sandy loam	29 Apr 1977
151	Sara Mani	Mesa Rancho —Aiquile	Medium heavy, dark brown	29 Apr 1977

to the seeds. Anitrogen control (10 ml of a 1 mg N/ml solution of NH_4NO_3 applied three times during the test) is also included. The seed and inoculum are then covered with sand. The jars are watered through the glass tube into the bottom storage area. The distilled water moves through a 6 mm thick nylon wick up into the media in the upper jar. Treatments are replicated five times with plots arranged in a randomized block design in the greenhouse. Nutrient solution (150 ml) is added twice during the growing period. The nutrient solution consisted of Bond's Stock salt mixture supplemented with zinc, molybdenum and cobalt micronutrients. After 50 days of growth, the plants are harvested. Plant color is rated on a scale of 1 -3 with 1=green and 3=yellow. Nitrogenase activity is measured for the root system of each plant using acetylene reduction methodology. Nodules are counted and removed so that nodule mass can be determined. The root and plant tops are dried, weighed, and the tops are ground for determination of nitrogen using the Kjeldahl technique.

We have evaluated several strains of *Rhizobium* in the greenhouse for their ability to fix nitrogen. Rhizobial strains have been found to significantly influence plant color, plant dry weight, nodule number, nodule mass, percent nitrogen, total nitrogen, and nitrogenase activity (Table 3). Strains often perform differentially on the two host genotypes giving a significant host x strain interaction for traits indicative of their nitrogen fixing ability. This strain-host specificity suggests that rhizobial strains must be screened in symbiosis with diverse hosts or with the host genotype with which they are going to be used.

Total nitrogen accumulated is the best measure of the efficiency of a rhizobial strain. However, both plant color and plant dry weight are significantly correlated with total nitrogen suggesting that the measurement of these two traits is sufficient in evaluating strain efficiency in greenhouse studies (Table4). Thesetraits can be utilized by researchers with limited resources to screen rhizobia for effectiveness in symbiosis with local groundnut genotypes.

From the more than 100 unique isolates that we have evaluated in the greenhouse, we have identified several strains that fix more nitrogen than the commercial strains used as checks. Although additional testing is needed, these strains are now available to other rhizobiologists interested in cowpea rhizobia.

Field Evaluation of Rhizobia

After greenhouse evaluation, we test the nitrogen fixing ability of rhizobial strains in the field in the presence of endemic rhizobia (Elkan et al. 1980). In a preliminary study we evaluated strains previously tested in the greenhouse for their nitrogen fixing ability in thefield in orderto compare field and greenhousetest results. Nine strains of *Rhizobium* in symbiosis with 48 genotypes were tested in a field previously planted to groundnuts.

The rhizobial strains applied in a water suspension significantly influenced nodulation (0.05 level of probability) and nitrogen fixed as measured by nitrogenase activity (0.01 level). When averaged over the 48 host genotypes, the greatest nodulation was produced by strain 176A34 (Table 5). Strains 176A22 and 3G4b4 also produced significantly more nodules than

Table 3. Strain and control means for nitrogen-fixing traits for greenhouse trials.

Strain	Plant		Nodule		N content/ plant (%)	Total N/ plant (mg)	Nitrogenase activity (μmol C_2H_4/hr per plant)
	Color[a]	Weight (g)	No.	Mass (g)			
				Study 1			
176A22	1.67ab[b]	3.12ab	58.9b	.120ab	3.69a	93.0a	6.68abc
3G4b4	2.11bcd	2.00de	25.0cd	.059c	2.82cd	42.9c	3.81d
42B2	2.30cde	1.80e	58.5b	.094bc	2.91cd	38.9c	5.08cd
3G4b21	2.11bcd	2.47cd	31.9cd	.062c	3.20bc	64.5b	5.64bcd
32H1	1.78bc	2.59bc	56.8b	.098abc	3.63ab	73.7b	5.30bcd
3G4b5	2.40de	2.01e	22.1d	.056c	2.76d	42.1c	3.70d
176A34	1.80bc	2.56cd	43.6bc	.085bc	3.25abc	67.8b	7.67ab
32Z3	2.67def	1.99e	32.9cd	.107abc	2.23e	34.2c	4.54d
3G4b20	1.33a	3.65a	80.1a	.140a	3.69a	107.3a	8.32a
Control	3.00ef	1.56e	0e	0d	1.59f	17.3d	0e
				Study 2			
32H1	1.11a	2.84a	37.3bc	.068c	3.69a	94.1a	4.49bc
29C2	1.80b	2.15bc	61.1a	.110a	2.74b	51.4c	7.60a
3I6N18	2.56c	1.42d	47.7ab	.045bcd	1.24d	15.0d	0.08d
3G4b9a	2.57c	1.35cd	0.7f	.001e	1.33d	14.0d	0d
3I6N9	2.56c	1.70bcd	53.6a	.072ab	1.21d	17.2d	0.09d
3G4b10	2.44c	1.98bcd	16.0de	.029de	1.73cd	31.5d	1.48d
RP182-13	1.10a	2.78a	52.3ab	.079ab	3.52a	88.4a	5.51ab
3I6N22	1.70b	2.24abc	28.7cd	.050cd	3.23a	62.6bc	4.14bc
3G4b19	1.80b	2.30ab	47.4ab	.062bc	3.61a	74.0ab	6.03ab
Control	2.20c	1.49cd	7.1e	.014de	1.97c	23.7d	2.74cd

a. Rating 1 = green and 3 = yellow.
b. Means with different letters are significantly different (.05 α-level) according to t-test.

Table 4. Correlation coeffleiants for nitrogan-flxlng traits in two graanhouso studies.

Trait	Study	Trait: Plant weight	Nodule number	Nodule mass	Percent nitrogen	Total N2	Nitrogenase activity
Plant color*	1	-.93**	-.84**	-.75*	-.95**	-.95**	-.89**
	2	-.93**	-.44	-.54	-.94**	-.97**	-.78**
Plant weight (g)	1	—	.79**	.54	.83**	.99**	.83**
	2	—	.45	.61	.90**	.97**	.73*
Nodule number	1			.89**	.83**	.82**	.75*
	2	—	—	.92**	.33	.39	.47
Nodule mass (g)	1				.89**	.67*	.68*
	2	—	—	—	.49	.54	.68*
% Nitrogen of plant	1	—	—	—		.81**	.57*
	2	—	—	—	—	.97**	.86**
Total N2 of plant (g)	1	—	—	—		—	.86**
	2	—	—	—	—	—	.78**

a. Rating 1 = green and 3 - yellow.
* ** Indicates simple correlation coefficients significant at 0.05 and 0.01 levels of probability.

Tabla 5. Maan nodulation rating and nl-troganaaa activity for strains of *Rhiz oblum* and an uninoculated control for fiald grown groundnuts.

Strain	Nodulation rating*	Nitrogenase activity[b]
3G4b20	2.81	39.1
176A34	3.10	38.7
176A22	3.07	35.1
3G4b5	3.06	35.8
3G4b4	3.07	31.0
3G4b21	2.98	32.8
42B2	3.06	33.8
32H1	2.93	35.7
32Z3	3.04	31.0
Control	2.89	32.5
LSD (0.05)	0.17	3.0

a. Rated 156 days after planting with 1 = little and 5 - heavy nodulation.
b. μmol C_2H_4/plant per hr. Mean over 48 genotypessampled 91, 95,100, 119 and 127 days after planting.

the inoculated controls which were inoculated with the naturally occurring strains. The greatest nitrogenase activity, however, occurred with strain 3G4b20. Strains 176A34, 3G4b5 and 32H1 also had significantly higher nitrogenase activity than the naturally occurring strains. Conversely, strains 3G4b4 and 3273 had slightly but insignificantly lower nitrogenase activity than the endemic strains.

The nitrogenase activity for the rhizobial strains when applied to Florigiant, a Virginia cultivar that is grown on most of the acreage in North Carolina, was determined for five sampling dates (Table 6). All plots of Florigiant including the uninoculated control were heavily nodulated. Six of the nine strains, however, had slightly higher mean nitrogenase activity than the naturally occurring strains (control), although only strain 3G4b21 was significantly better than the control. These data indicate that some strains are able to compete for infection sites and are more effective than naturally occurring strains. Strain 42B2 successfully competed for infection sites but produced less effective nodules than the naturally occurring strains. This strain was also ineffective in greenhouse evaluations.

Nitrogenase activity measured in the greenhouse forthese same strains in symbiosis with a Spanish and Virginia cultivar was correlated (r = 0.73*) with mean nitrogenase activity

Table 6. Nltroganaaa activity (μmol C_2H_4/hr par plant) for strains of *Rhlzoblum* and an unlnoculated control for peanuts of cv Florlgiant for five sampling datas.

Strain	Days after planting 91	95	100	119	127	Mean
3G4b20	49	70	64	69	28	56
176A34	45	50	61	49	20	45
176A22	52	60	68	65	30	55
3G4b5	49	52	74	61	32	54
3G4b4	58	50	73	48	30	52
3G4b21	55	71	69	74	33	60
42B2	44	47	45	49	18	41
32H1	38	50	71	66	39	53
32Z3	37	56	56	62	26	47
Control	48	51	54	64	26	49
Mean	47.4	55.6	63.6	60.6	28.3	51.1

LSD (0.05) Sampling date 8
LSD (0.05) Strain 12

in the field. This indicates that screening of rhizobial strains in the greenhouse is effective as a preliminary predictor of rhizobial strain performance in the field.

A similar field study conducted during 1979 involved 10 rhizobial strains and two groundnut cultivars, Florigiant and Spantex, (Spanish type). The strains significantly influenced nodulation, nitrogenase activity and plant weight but not yield of fruit (Table 7). A significant (0.05 level) genotype x strain interaction was found for plant weight, indicating that rhizobial strains were not equally effective for the two groundnut cultivars (Table 8). These results strongly suggest that the host genotype must be considered in rhizobial strain selection.

These field data are not very dramatic but they are very encouraging. Considering that soil fertility and endemic rhizobial populations are high enough to produce high yields, results under these test conditions can be translated into spectacular yield increases on nitrogen deficient soils with ineffective or low rhizobial populations.

Identification of Cowpea Miscellany Subgroups

The identification of effective strains of rhizobia through plant tests in the field and greenhouse is slow and tedious. It would be advantageous if it were possible to identify a subgroup of the cowpea rhizobia whose primary host cuitivar is

Table 7. Strain and control means for yleld and nitrogen-flxlng traits for field-grown groundnuts.

Strain treatment	Nodule[a] Number	Nodule[a] Dry wt (mg)	Nitrogenase activity (μmol C_2H_4/plant per hr)	Shoot weight (g)	Yield per plant (g)
Control (endemic strain)	396abc	475bcd	1.67abc	54.1abc	718a
Nitrogen control	276c	370d	1.17c	59.7abc	646a
32H1	427abc	442bcd	1.51abc	62.5ab	726a
CB 756	334bc	378cd	1.87a	56.3abc	562a
3G4b5	485abc	503a-d	1.70abc	53.9abc	562a
3G4b21	593a	727a	1.88a	70.2a	695a
NC 146.1	642a	625abe	1.44abc	54.0abc	541a
NC 92	584a	642ab	1.78ab	53.6abc	634a
NC 7.1	553ab	465bcd	1.28bc	51.9bc	654a
NC 3.1	458abc	488a-d	1.65abc	53.1be	597a
NC 71	437abc	322d	1.62abc	44.5c	542a
NC 56	396abc	501a-d	1.94a	61.4ab	650a
176A22	545ab	538a-d	1.64abc	55.7abc	595a
NC 120	500abc	494a-d	1.67abc	67.6ab	686a

a. Nodule number, weIghtand shoot weight are means for plants sampled 59 and 166 days after planting. Nltrogenase activity, 59 days after planting, and fruit weight, 166 days after planting, are means for single sampling date.
Means with different letters are significantly different at 5% level according to Duncan's multlple range test.

Table 8. Ranking of strains of *Rhizobium* as thay affact plant waight for a Spanish and Virginia groundnut cultivar.

Rank	Florigiant	Spantex
1	32H1	NC 120
2	CB 756	3G4b21
3	NC 146.1	NC 56
4	NC 3.1	32H1
5	NC 7.1	176A22
6	3G4b21	CB756
7	3G4b5	NC 146.1
8	NC 120	3G4b5
9	NC 92	NC 3.1
10	NC 56	NC 71
11	176A22	NC 92
12	NC 71	NC 7.1

the groundnut or a specific cultivar-group of groundnuts.

We have adapted for use with *Rhizobium* sp two DNA-DNA hybridization techniques which allow us to rapidly determine the genetic relationship of isolates within this group of rhizobia. Isolates from individual legume cultivars nodulated with cowpea miscellany rhizobia are being compared using these hybridization techniques to determine if there is (or are) any subgroup/s of cowpea rhizobia favoring groundnuts. Conversely, if this host-isolate interaction is determined to be truly wide spectrum, we hope to determine if the more ineffective and effective isolates can be genetically grouped. This study is in the preliminary stages. The genetic diversity of this group of bacteria is apparent from the DNA-DNA hybridizations. Early evidence points to the possibility that bacteria more efficient in nitrogen fixation with groundnuts are identifiable. If the presence of subgroups (or subspecies) is confirmed, then it would be relatively easy to identify subgroups of the cowpea miscellany, thus reducing the need for plant tests. This work is continuing and is being expanded in our laboratory.

Selection of Efficient Host Plants

A second approach to increasing nitrogen fixed by groundnuts, which is applicable regardless of whether plants are well nodulated by native rhizobia or whether inoculation is required for adequate nodulation, is to develop host genotypes that are more efficient in fixing nitrogen. Although symbiotic nitrogen fixation has been studied for almost a century, little effort has been given to increasing nitrogen fixation in legumes through breeding. Enhancing the nitrogen fixing process in a leguminous crop through breeding requires (1) ample genetic variability, (2) an understanding of the genetic control of the process, (3) a technique for measuring the desired trait indicative of nitrogen fixation, and (4) a breeding strategy to efficiently utilize the variation.

Genotypic Variation in Nitrogen Fixing Traits

Differences in nodulation for groundnut genotypes in the field were first reported by Duggar (1935a). Duggar (1935c) found that a runner (ssp *hypogaea)* genotype developed larger and more nodules than a Spanish (ssp *fastigiata)* genotype. Inoculation with a single strain of *Rhizobium* increased nodulation of the Spanish line but not of the runner. Albrecht (1943) observed significant increases in fruit yield of a Spanish line when inoculated with three single strains of *Rhizobium* and a commercial inoculum, while a runner type did not respond to any of the treatments.

Burton (1976) found differences in nitrogen accumulation among peanut cultivars grown in the greenhouse with fixation being the only nitrogen source. Inoculated with single strains of *Rhizobium* isolated from plants of four genera, cv Florunner, a Virginia type, was consistently higher in nitrogen content than the Spanish cultivars, Comet, Starr and Spantex.

We have found host plant differences in nodulation and nitrogen fixing activity in both greenhouse and field studies (Wynne et al. 1978). Genotypic differences in nodulation by the native rhizobia found in North Carolina groundnut fields have also been observed. The nodulation for 48 genotypes shown in Table 9 is typical of the response observed in North Carolina. Virginia types such as cvs Florigiant, Va-72R, NC-5 and NC-6 are more heavily nodulated than Spanish or Valencia types such as cvs Spanhoma, Spantex, Starr, Argentine, Tennessee Red or New Mexico Valencia.

Table 9. Ganotyplc maans for nodulation in North Carolina flald study during 1977 at tha Uppar Coastal Plain Research Station.[a]

Genotypes	Modulation X	Genotypes	Nodulation X
1. Starr	1.45	25. PI 221068	4.45
2. Tamnut 74	2.25	26. PI 241633	2.45
3. Georgia 255	2.60	27. PI 158850	3.00
4. G-169	2.45	28. PI 158852	3.25
5. EM 12	1.65	29. Spanhoma	2.25
6. Florunner	2.75	30. Spantex	2.40
7. Florigiant	4.90	31. Dixie Spanish	2.85
8. Va 72R	4.85	32. Starr	2.20
9. Early Bunch	4.30	33. Argentine	2.10
10. UF 714021	3.90	34. Schwarz 21	2.05
11. NC 6	3.75	35. Chico	2.05
12. Tifrun	3.65	36. PI 337396	3.10
13. A 69	4.10	37. PI 261954	2.85
14. UF 75102	3.00	38. PI 261955	3.00
15. Va 70-64	4.50	39. Tennessee Red	2.80
16. NC 5	4.35	40. N. M. Valencia	3.15
17. NC 2	3.45	41. PI 275743	2.20
18. NC-Fla 14	3.35	42. PI 275744	3.05
19. NC 4	3.90	43. PI 275078	2.50
20. PI 268837	3.00	44. Greg. #182	1.30
21. PI 313946	3.50	45. Greg. #190	1.15
22. PI 313947	3.80	46. 71 SAN 290	2.10
23. PI 313950	4.45	47. 71 SAN 291	1.90
24. *A. monticola*	2.80	48. NC 3033	3.25

a. Nodulation rated 156 days after planting with 1 = little and 5 - high.

Nodulation for the genotypes listed in Table 9 was measured at a single harvest date near maturity. We have found estimates of nitrogen fixing traits at a single harvest may not be reliable as an indicator of the relative performance of a genotype. For example, when eight cultivars were sampled four times during the growing season for their nitrogen fixing ability, both cultivars and harvest dates significantly influenced nodulation and nitrogenase activity (Table 10). The dateXcultivar interaction was also significant for all three traits. The two genotypes from the ssp *fastigiata,* Tennessee Red and Spanhoma, had lower mean nodule number, nodule weight, and nitrogenase activity when averaged over all harvest dates. Florigiant, the predominant cultivar in North Carolina, had the highest mean nodule number, nodule weight, and nitrogenase activity when averaged over all sampling dates. However, the ssp *fastigiata* cultivars were not lowest at all sampling dates nor was Florigiant highest for all sampling dates. These and other unpublished data suggest that selection of a genotype based on a single evaluation of nitrogen fixing ability during the growing season may not always identify the superior genotype.

The seasonal pattern of nodulation and $N_2(C_2H_2)$ fixed was similar in this and other field studies. The pattern is better illustrated from bimonthly sampling dates for the cultivars Florigiant and Argentine (Figs. 1 and 2). Nodulation increased during the growing season until a peak was reached 84 days after planting for Argentine and 98 days after planting for Florigiant. Plants of Florigiant averaged 1470 nodules compared to 908 for Argentine at the time of maximum nodulation. Nitrogen fixation increased during the growing season until a peak was reached 84 days after

Table 10. Maana for datas by cultivara for nitroganaaa activity and noduiation (Lawiaton, North Carolina, 1978).

Cultivar	Sampling date (days after emergence) 28	56	84	117
	Nitrogenase activity (μ moles C2H4/plant per hr)			
Tennessee Red	4.21	15.59	24.66	17.01
Spanhoma	3.35	13.79	21.69	13.44
Florunner	3.86	23.04	37.33	24.69
B1	1.77	6.04	28.87	27.62
Florigiant	5.51	18.83	35.12	34.57
NC 4	1.76	15.59	41.55	26.66
NC 6	3.93	20.13	33.99	34.18
Early Bunch	4.68	17.64	29.56	24.51
	Nodulation (nodules/plant)			
Tennessee Red	200.6	666.0	923.1	857.6
Spanhoma	162.1	492.4	613.0	494.0
Florunner	213.9	771.9	1380.3	1051.8
B1	151.5	460.9	1315.9	950.1
Florigiant	178.3	771.3	1440.3	1445.1
NC 4	202.9	600.7	1273.9	1659.0
NC 6	187.2	948.5	1265.8	1302.5
Early Bunch	254.0	909.5	1320.4	1266.7
	Nodul e weight (g/plant)			
Tennessee Red	0.20	0.75	1.09	1.13
Spanhoma	0.26	0.60	0.90	0.80
Florunner	0.23	1.26	2.37	1.45
B1	0.27	0.57	1.55	1.44
Florigiant	0.21	1.11	2.90	2.77
NC 4	0.41	0.87	2.10	2.50
NC 6	0.46	1.28	2.34	1.78
Early Bunch	0.45	1.21	1.47	1.37

planting. Nitrogen fixed decreased after this date. Maximum N2(C2H2) values exceeded 70 *umol* C2H2/plant per hr for Florigiant compared to less than 50 for Argentine. Unfortunately, total nitrogen analyses have not been completed and the relationship of noduiation and N2(C2H2) valuestototal nitrogen are not known. The rapid increase in nitrogen fixation during the growing season corresponds to the time of fruit formation and filling, and the decrease corresponds to maturation.

These data suggest that a single evaluation of the nitrogen fixing ability of a genotype using acetylene reduction if taken during the period of peak activity might be effective for preliminary screening of genotypes for nitrogen fixation. However, selection using total nitrogen accumulated or dry matter accumulated through

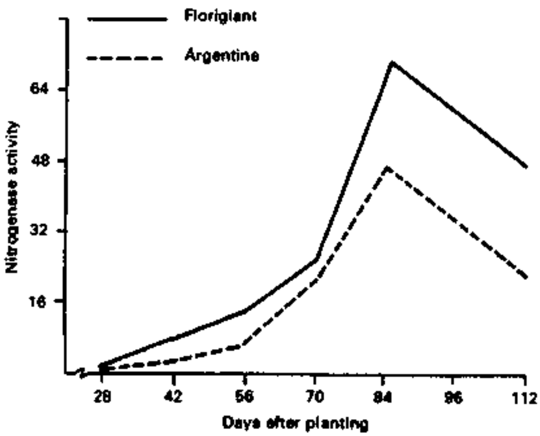

Figure 1. Means of cultivars for nitrogenase activity (µ mol C2HAlplant per hr) over harvest dates (Clayton 1978).

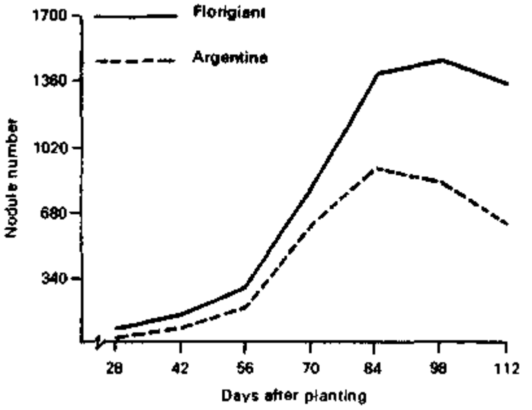

Figure 2. Means of cultivars for nodulation (nodule number/plant) o ver harvest dates (Clayton 1978).

the growing season is almost certain to be more effective than N2(C2H2) measured once or even several times during the growing season. However, several N2(C2H2) measurements during the growing season might be useful in choosing parents. Two lines producing similar amounts of nitrogen but having different peak periods of activity as determined by acetylene reduction might produce transgressive segregates.

Quantitative Genetics of Nitrogen Fixation

We have investigated the genetic control of nitrogen fixation using a diallel cross in the greenhouse and a population of late generation lines in the field.

Early Generation: Greenhouse

The F1 generation of a diallel cross of 10 cultivars from South America was evaluated in an analysis of gene action for traits related to nitrogen fixation. Hybrid progenies were significantly different for all traits (Table 11). General combining ability, which is usually indicative of additive gene action, was significant and greater than specific combining ability for nodulation, N2(C2H2) fixed, plant weight, nitrogen content and total nitrogen. Correlations between parental and general combining ability effects were nonsignificant for all traits, so simple evaluation of lines for nitrogen fixing capacity in the greenhouse may not identify superior parents for use in breeding programs.

Late Generation: Field

Thirty F4 generation lines from a Virginia x Spanish cross were grown at two field sites in order to determine the genetics of traits indicating nitrogen fixation for a population of late generation lines. The Virginia parent (NC-6), a high yielding Virginia cultivar, is well nodulated by the indigenous rhizobial strains in North Carolina, while the Spanish parent (922) is poorly nodulated. Plot means for N2(C2H2) fixed, nodule number, nodule weight and dry weight of plant were analyzed considering locations and entries as random effects. Although the study when completed will consist of several sampling dates over years, parental and line means for one sampling date 90 days after planting suggest that sufficient variability exists for progress from selections in this population (Table 12). The Spanish line is lower in nodulation, has less nitrogenase activity and smaller plant weight than the Virginia parent. The range of means for the 30 lines generally equal or exceed the range of the parents. Genotypic variance was estimated from the variance among the means for the 30 late generation lines. These estimates were used to estimate heritability as follows:

$$h^2 \approx H = \frac{\hat{\sigma}^2_G}{\hat{\sigma}^2_G + \frac{1}{sr\ell}\left[\sigma^2_E + S^2_G + Sr\sigma^2_{LG}\right]}$$

Where: $\hat{\sigma}^2_G$ = estimate of genotypic variance,

σ^2_E = estimate of error variance, and

$S = 2$, $r = 3$ and $\ell = 2$.

Heritability estimates ranged from 0.45 for nodule numberto0.80forN2(C2H2) fixed (Table 13). These estimates indicate that selection for traits indicative of nitrogen fixation should be effective for this population. Selections will be made and the response to selection for nitrogen fixing traits and the effect of selection for nitrogen fixation on productivity will be determined.

An Alternative Breeding Strategy

It has been suggested that the nitrogen fixation in the field may be limited to a large extent by the availability of photosynthate. Enrichment of the atmosphere in the foliar canopy of

Table 1 1 . Maan squares from the diallal analysis of characters Indicative of nitrogan-fIxIng ability.

Source	df	Nodule number	Nodule mass (mg)	Nitrogenase activity (*µmnol* C2H4/plant per hr)	Plant weight (g)	Nitrogen content (%)	Total nitrogen (mg/plant)
Blocks	3	4742**	64505**	73.85**	7.85**	0.5965**	5780**
Genotypes	98	1477**	10030**	6.47**	1.92**	0.1418**	2190**
Parents	9	726	8543	6.09	0.60	0.1508	534
Hybrids	88	1562**	10132**	6.58**	2.08**	0.1423**	2378**
General Combining Ability	9	4216**	26950**	17.10**	3.72**	0.4910**	3327**
Specific Combining Ability	35	1533**	263**	4.68	1.97**	0.0699	2252**
Maternal	9	1433**	16796**	3.74	2.32**	0.2197**	3674**
Reciprocal	35	941	5964	6.50*	1.69	0.1052	1954**
Parents vs hybrids	1	723	14423	0.08	0.27	0.0143	479
Error	280	742	4825	3.97	0.53	0.0845	619

Table 12. Parental means and range of means for single sample 90 days after planting of groundnut parents and F4 generation population.

	Means over locations			
Identity	Nodule number	Nodule weight (g)	Nitrogenase activity (µmol C_2H_4/plant per hr)	Plant dry weight (g)
Spanish parent (922)	255	0.245	1.783	20.3
Virginia parent (NC 6)	474	0.518	4.028	29.9
F_4 lines	152-391	0.156-0.453	1.112-4.103	12.7-29.5

Table 13. Herltaboility estimates for nitrogen fixation traits for late generation lines from cross of Spanish and Virginia lines sampled 90 days after planting.

Trait	Estimate
Nodule number	0.45
Nodule mass (dry wt/plant in g)	0.63
N2 (C2H2) in µmol C_2H_4/plant per hr	0.80
Dry weight/shoot (g)	0.74

groundnuts with 1500 ppm carbon dioxide during daylight hours increased nitrogen fixation, measured by the acetylene reduction assay, by 60% and also increased plant growth and nodulation supposedly because of larger amounts of available photosynthate (Hardy and Havelka 1976; Havelka and Hardy 1976). Diurnal studies and shading experiments at ICRISAT (Dart 1977) and leaf removal studies at North Carolina (unpublished) also suggest that the rate of nitrogen fixation is governed by the availability of photosynthate. Once the groundnut plant enters the reproductive stage the nodules, as a photosynthate sink, must compete not only with the growing vegetative parts, but also with the developing fruit. Hardy et al. (1971) reported that over 90% of the total amount of nitrogen fixed occurred during the period of fruit formation and maturation with rate of fixation entering an exponential phase at or about the time of pegging. Since variation in photosynthetic rates and net photosynthate accumulation has been demonstrated for groundnuts (McCloud et al. 1977; Pallas and Samish 1974; Pallas 1973; Williams et al. 1975; Emery et al. 1973), it should be possible to select photosynthetically superior genotypes which fix more nitrogen.

Preliminary analysis of several field studies conducted in North Carolina indicates that there is adequate variability in net photosynthetic efficiency (biological yield) to select genotypes that are more efficient in accumulation of photosynthate (Ball et al. 1979). Furthermore, we have found biological yield (total dry matter), economic yield (fruit) and nitrogen fixed $N_2(C_2H_2)$ to be positively correlated (r = .48**-.72** with 38 df). This suggests that groundnut breeders can indirectly select for greater nitrogen fixation by selecting for biological and/or economic yield. Thus selection for economic yield may be an effective method of increasing nitrogen fixation when groundnuts are well nodulated by native rhizobia. This hypothesis is presently being tested in studies at North Carolina.

Summary

The atmospheric nitrogen fixed by groundnuts can be increased dramatically by the selection and use of effective strains of *Rhizobium* if the groundnut plants are poorly nodulated or nodulated with ineffective strains. Because of a significant genotype x strain interaction, the host genotype must be considered in strain selection. Strains can be selected after they have shown broad adaptation in symbiosis with a number of diverse host genotypes or they may be selected in symbiosis with the single host genotype to be grown.

Sufficient variability exists for selection of host genotypes with greater nodulation and greater nitrogen fixing potential. Preliminary estimates of heritability for late generation lines from a Virginia x Spanish cross suggest that selection should be effective for traits indicative of nitrogen fixation. However, since biological yield and economic yield appear to be correlated with nitrogen fixation, it may be possible to select for higher nitrogen fixation by selecting for biological yield and/or economic yield.

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Studies on Nitrogen Fixation by Groundnut at ICRISAT

P. T. C. Nambiar and P. J. Dart*

Symbiotic nitrogen fixation depends on an interaction between the *Rhizobium* strain, host plant genome and environment. We are examining all the three components with the objective of increasing biological nitrogen fixation by groundnut.

Rhizobium: Isolation, Strain Testing and Inoculation Response

Groundnut is promiscuously nodulated by *Rhizobium* of the cowpea miscellany (Fred et al. 1932). When nodulated with effective (nitrogen fixing) rhizobia, groundnut nodules fix most of the nitrogen requirements of the plant (Pettit et al. 1975; Schiftman et al. 1968). Substantial increases in the yield have been obtained following inoculation in fields where peanuts had not been grown before (Burton 1976; Pettit et al. 1975; Schiftman et al. 1968; Sundara Rao 1971). In fields where groundnuts had been grown earlier, inoculation sometimes resulted in increased yield, increase in seed quality, higher protein and oil content (Arora et al. 1970; Chesney 1975). A decrease in yield following inoculation has also been reported (Subba Rao 1976). Allen and Allen (1940) described differences between *Rhizobium* strains in nodulation and nitrogen fixation in groundnut. Surveys in farmers' fields in the southern states of India showed considerable variation in nodulation with 52 out of 96 fields surveyed having poor nodulation. Nodulation and nitrogen fixing activity, as measured by acetylene reduction, was ten times less in some farmers' fields than that observed in fields at ICRISAT Center at the same stage of growth of the plant. These observations indicate that it should be possible to increase biological nitrogen fixation in these fields by inoculating with effective and competitive *Rhizobium* strains.

We collected nodules from farmers' fields in Karnataka and Andhra Pradesh states in India and from them have purified 50 authenticated *Rhizobium* strains. We also maintain a collection of *Rhizobium* strains for groundnut obtained from all other known major collections in the world such as USDA (Beltsville), North Carolina State University (Raleigh), NifTAL (Hawaii), Dept. of Agriculture, Zimbabwe, and the Australian Inoculants Research and Control Service. As a part of our collaborative project with North Carolina State University (NCSU) on biological nitrogen fixation, we are testing the suitability for use as inoculants of *Rhizobium* strains which have been isolated and characterized at NCSU from nodules obtained during *Arachis* germplasm collection trips in South America (Wynne et al. these Proceedings).

Our experiments show that in nitrogen-free sand: vermiculite media in pots, *Rhizobium* strains vary in their ability to nodulate and fix nitrogen with groundnut (Figs. 1, 2). Although the magnitude of the shoot dry weight was often related to nodule dry weight (e.g. strain IC 6006, Figs. 1, 2), this relationship was not consistent with the array of the strains. Because of the variability in germination in Leonard jars, pot culture assembly was used for strain testing. We sterilize by autoclaving or steaming or heating to 150° C the rooting media and apply nitrogen-free nutrient solution through a permanent 6 cm diameter watering tube which is covered with a metal cap when not in use. The pot surface is covered with heat-sterilized gravel (3-6mm) to protect from aerial contamination (Fig, 3). Six seeds are sown per pot and thinned to three plants/pot.

We have observed a relationship between shoot growth, and the amount of inoculum applied up to 10^7 *Rhizobium* per seed when

* Microbiologist and Principal Microbiologist respectively, Groundnut Improvement Program, ICRISAT.

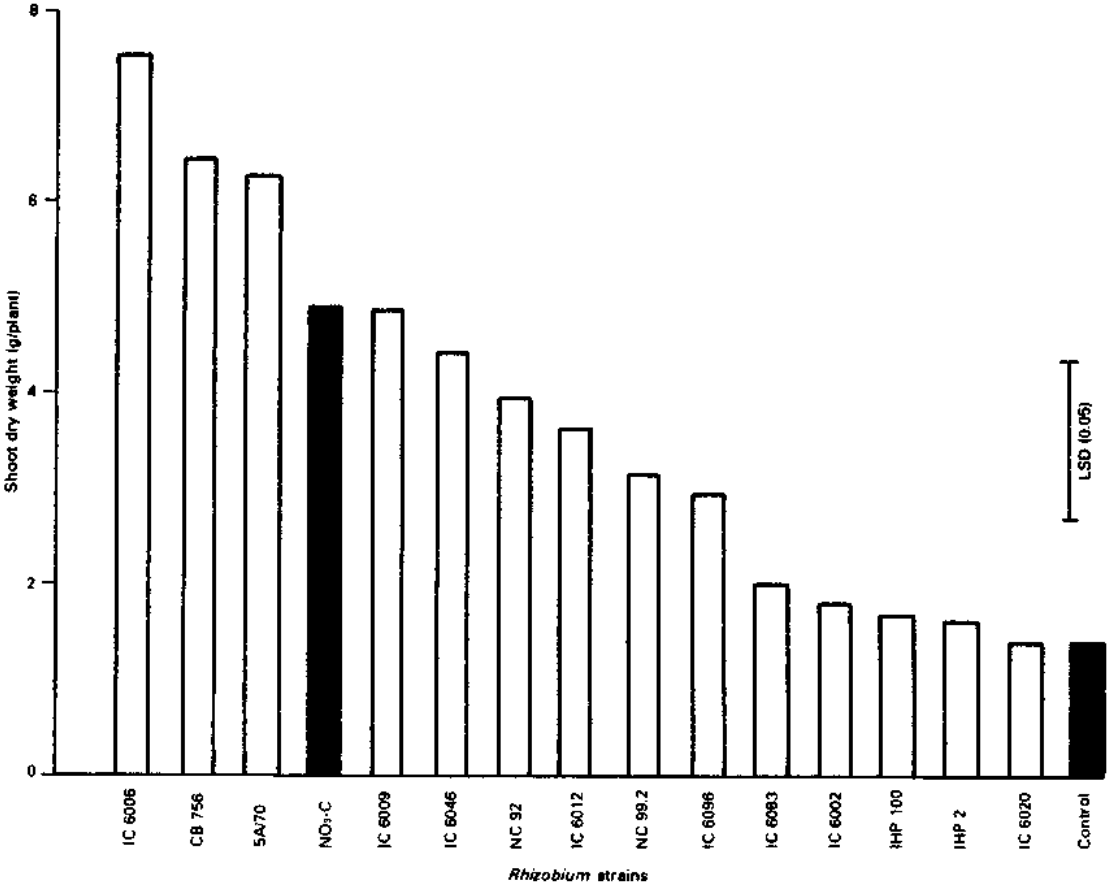

Figure 1. Shoot production by groundnut inoculated by different Rhizobium *strains. Three plants per 20 cm dia pot were grown in a sand.vermiculite (2:1) medium, inoculated with broth culture at the rate of* 10^{s} *rhizobialseed, watered with nitrogen-free nutrient solution and harvested 64 days after planting. Controls received no inoculum; NO3-C received 240 ppm N continuously.*

groundnut was grown in pots of sterilized sand: vermiculite. Nodulation followed the same trend (Table 1). This is in marked contrast to the situation in soybeans where nodulation and plant growth was reduced in both field and pot trials only if the inoculum was less than 15 x 10^3 per seed (Burton 1975). This indicates that one has to ensure an adequate *Rhizobium* inoculum size in pot trials measuring nitrogen fixation. It also demonstrates the need to examine the interaction between inoculum size and nodulation response in field experiments.

Groundnut and soybean differ in the infection process in nodule formation (Dart 1977), and this may be the cause of the difference in response to inoculum size.

Table 2 summarizes the results of eight inoculation trials at ICRISAT Center. Although a response was not always obtained, Robut 33-1, a cultivar which is about to be released in Andhra Pradesh, gave substantial increases in pod yield when inoculated with a strain NC 92. Strain NC 92 was obtained from NCSU and isolated from nodules collected in South

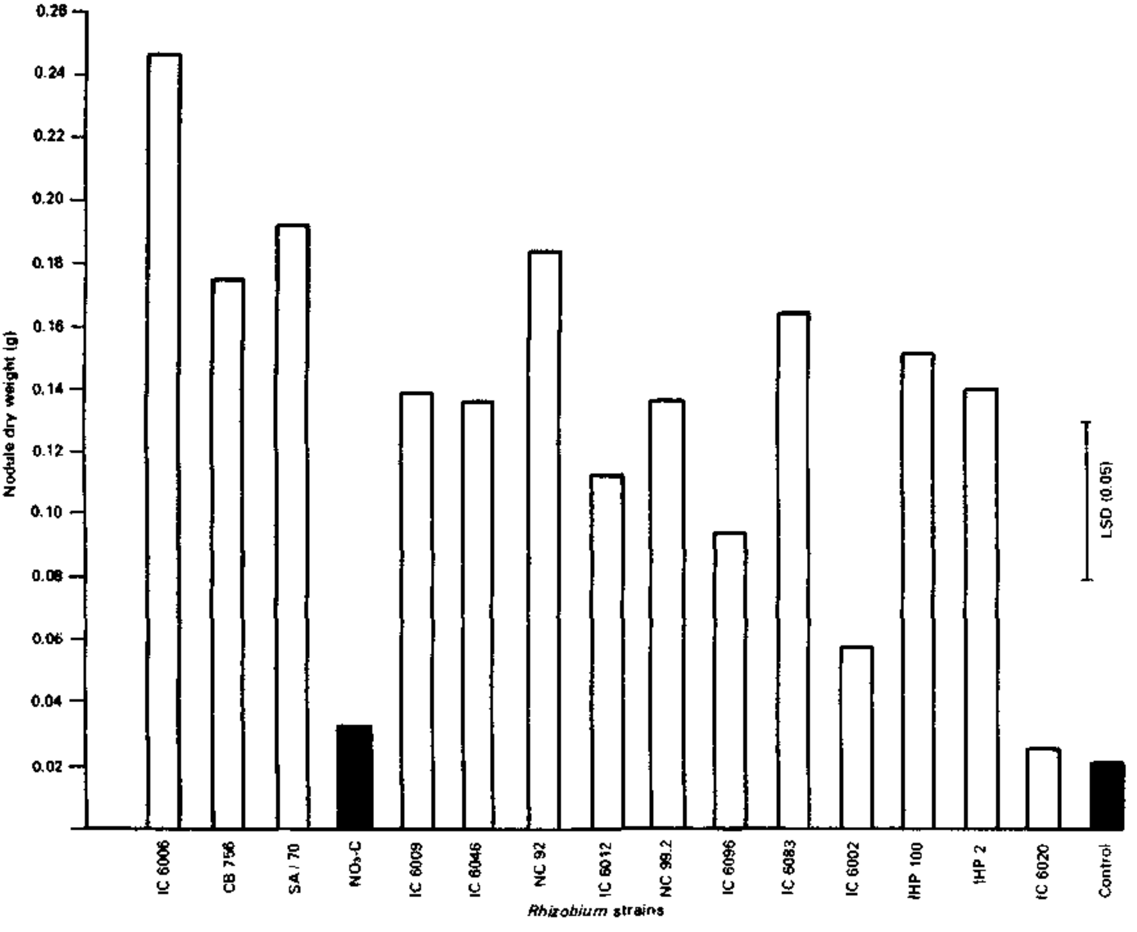

Figure 2. Nodule formation by different Rhizobium *strains. Conditions as in Figure 1.*

America. Robut 33-1 was the variety which most commonly responded to inoculation and in two of the inoculation trials this response was best with strain NC 92. It may be worth developing an inoculum with NC 92 specifically for use with Robut 33-1 provided the evidence of poor competition ability against strain IC 6009 (Table 3) is not found with other *Rhizobium* strains.

Since seed treatment with fungicides is a recommended practice, the inoculum for groundnut needsto beseparated from the seed. We do this by applying a granular inoculum below each seed, the granules being made by inoculating 1-2 mm sand particles with peat inoculum using methyl cellulose as the sticker.

Nitrogen Fixation by Groundnut

Nitrogenase Activity Assay

We have studied several parameters that influence acetylene reduction by groundnut root nodules in our efforts to standardize the assay for measu ring nitrog enase activity of field grown plants. There is a marked diurnal variation in the nitrogenase activity of field grown plants (Fig. 4). The increase in activity after daybreak suggests a close link with photosynthesis. Thus plants which produce more photosynthate are likely to fix more nitrogen. It will be interesting to see if photosynthesis declines in

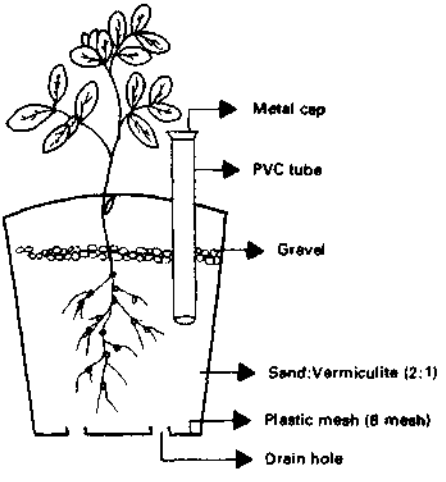

Figure 3. Cross section of a pot system.

Table 1. Influanca of *RMxoblum* Inoculum level *on* nodulation and nltrogan fixation by groundnut.

Level of *Rhizobium* applied as broth (number/seed)	Shoot dry wt* (g/plant)	Nodule dry wt* (g/plant)
3.2×10^9	3.38*	0.13[a]
5.5×10^7	2.38*	0.12[a]
4.8×10^4	1.08*	0.03*
6.1×10^2	0.97*	0.02*
Nitrate control	4.34	0

* Data in each column followed by the same letter are not significantly different at the 0.05 level.

Note: Kadlrl 71-1 plants inoculated with strain NC-92 were grown under semlsterile conditions watered with nitrogen-free nutrient solution and harvested 57 days after planting.

Table 2. Summary of Inoculation trials conducted at ICRISAT Center.

Year/ Season	Soil type	Cultivars	Strain	Pod yield response
Rainy season 1977	HF, Alfisol	TMV-2 Kadiri 71-1	5a/70	Nil
Rainy season 1977	LF, Alfisol	Kadiri 71-1 Robut 33-1, TMV-2	5a/70	TMV-2, 25%, Robut 33-1, 32%
Rainy season 1977	HF, Vertisol	Kadiri 71-1 TMV-2	5a/70 IC 6006	Nil
Rainy season 1978	HF, Alfisol	Robut 33-1 Argentine AH-8189	5a/70 ICG-60 IC6006 Mixture	Nil
Rainy season 1978	LF, Alfisol	MH-2 Argentine Robut 33-1	5a/70 ICG-60 6S Mixture	Robut 33-1, 26% (NS)
Postrainy season 1979	HF, Alfisol	MH-2 Robut 33-1 AH-8189	NC92 IC6009 Mixture	Robut 33-1, 28.5% (NC 92)
Rainy season 1979	HF, Alfisol	Kadiri 71-1 Robut 33-1 AH-8189	5a /70 IC6006 NC 43.3 NC7.2 NC92	Robut 33-1, 25.7% (NC 92)
Postrainy season 1980	HF, Alfisol	Robut 33-1	NC92	Nil

HF - High Fertility LF = Low Fertility

Table 3. Response of groundnut to *Rhixobium* Inoculation In an Alfisol (1978-79 postrainy season).

Cultivars	Pod w light (kg/ha)			
	Uninoculated	IC-6009	NC 92	Mixture (IC 6009 + NC 92)
MH-2	2222	1888	1944	2027
Robut 33-1	3500	3333	4500**	2805*
AH-8189	2833	2861	2694	2805

CV (%) 15.51 **Slg nilficant at 1% level *Significant at 5% level

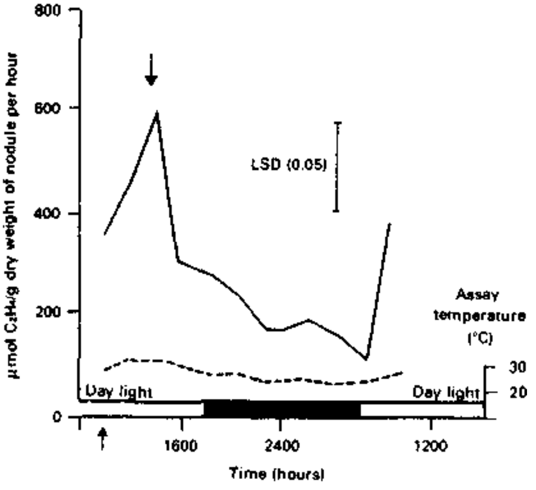

Figure 4, Nitrogenase activity (μmol C2H4/g dry weight of nodule per hour) in groundnut cultivar Kadiri 71-1. after 81 days of planting, ICRISA T Center, postrainy season 1976.

the same way as nitrogenase activity in the early afternoon, when leaf vapor pressure deficits are likely to be greater. A preliminary acetylene reduction assay of 14 groundnut lines selected for variability in foliage production, showed significant interaction in acetylene reduction between lines and time of measurement of nitrogenase activity — day time assay at 0900-1100 hr and night time assay at 2100-2300 hr (Table 4).

Temperatures in the assay bottle greater than 25° C decreased nitrogenase activity of nodulated roots of groundnut cv Kadiri 71-1 (Table 5). Excess or insufficient moisture also de-

Table 4. Mean squares from Anova for nltrogenase activity (μ moles C2H4/ plant par hr) of selected germplasm linea assayed during day and again at night.

Source of variation	df	Mean square
Replication	3	5500**
Time of assay	1	374254**
Germplasm lines	13	16314**
Interaction	13	5659**
Experimental error	81	1321

** Significant at 1% level

Table 5. Effect of incubation temperature on acetylene reduction by peanut roots.

Incubation temperature	μmoles C2H4/ plant per hr
25°C	46.34
30°C	33.97
35°C	32.52
CV (%) 42	
LSD (0.05) 9.8	

creased acetylene reduction activity (Fig. 5). We have observed that shading causes a rapid decrease in nitrogenase activity. When 109-day old Kadiri 71-1 plants were shaded to 60% of ambient light intensity, nitrogenase activity was reduced within a day by 30% (Fig. 6). Plants grown during the dry season, which received fewer irrigations but were not allowed to wilt, produced about half the pod yield of plants irrigated every 7-10 days. There were indica-

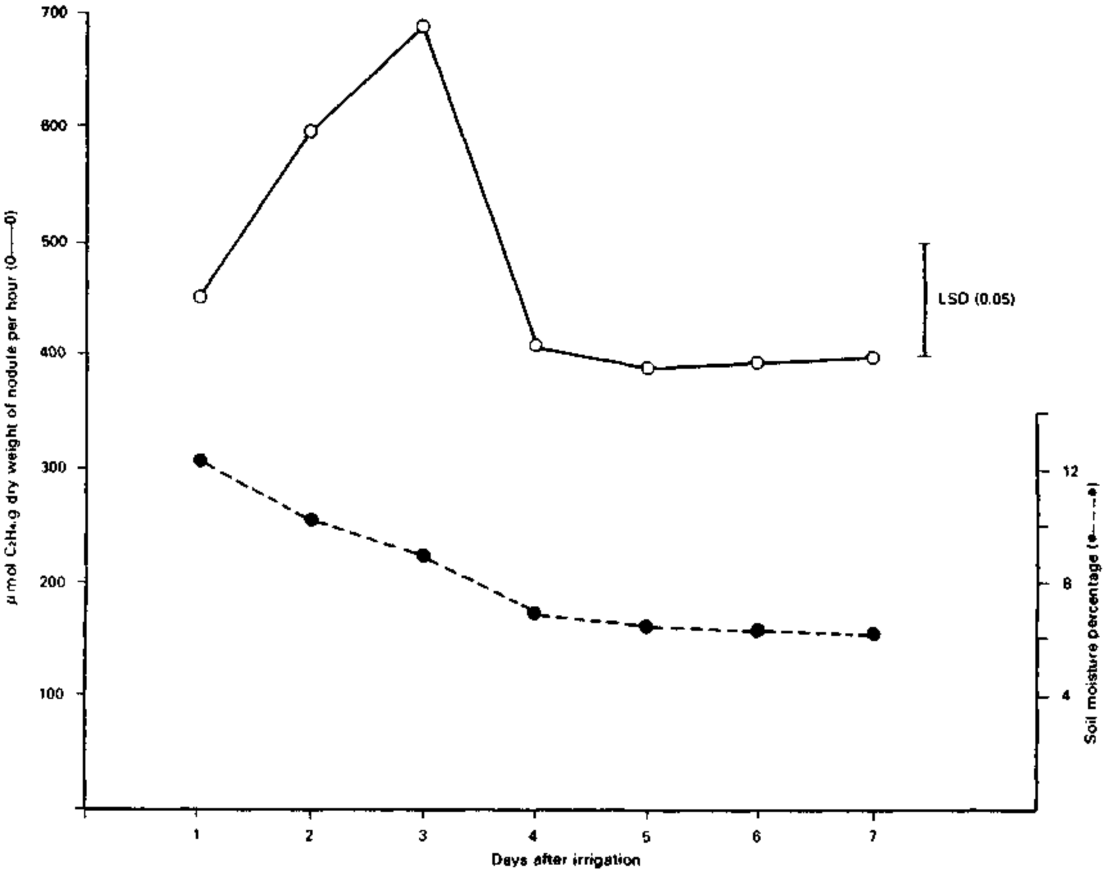

Figure 5. Effect of soil moisture on nitrogenase activity. Sixty days old Kadiri 71-1 plants were assayed on different days after an irrigation.

tions of differences between varieties in response to water stress. Nodule development and nitrogenase activity were much reduced by the water stress. Nitrogenase activity recovered rapidly after an irrigation.

Seasonal and Cultivar Differences

Figure 7 shows the nodulation and nitrogen fixing activity of cv Kadiri 71-1 (A *hypogaea* subsp *hypogaea,* a long-season runner cultivar) and of cv Comet (A *hypogaea* subsp *fastigiata,* a short duration erect-bunch cultivar) when grown in the rainy season 1976 and under irrigation in the postrainy season 1977. In 1976, a 57 day dry period beginning 39 days after planting had an overriding effect on nodule formation and nitrogenase activity. For the rainy season planting, nodules formed rapidly during the first 25 days, but the drought restricted further nodule formation with little difference between cultivars. For Comet, nodules changed little in size after 25 days but for Kadiri 71-1, nodules continued to grow so that by 75days nodule mass per plant was twice that of Comet.

In the postrainy season, nodule formation was slower to start but then increased until 80 days after planting when three times as many nodules had formed as in the rainy season. New nodules were still forming on Kadiri 71-1 at 128 days. Nodule dry weight per plant reflected the pattern for nodule number.

Nitrogenase activity per plant and the efficiency of the nodules (nitrogenase/g nodule tissue) differed significantly between cultivars

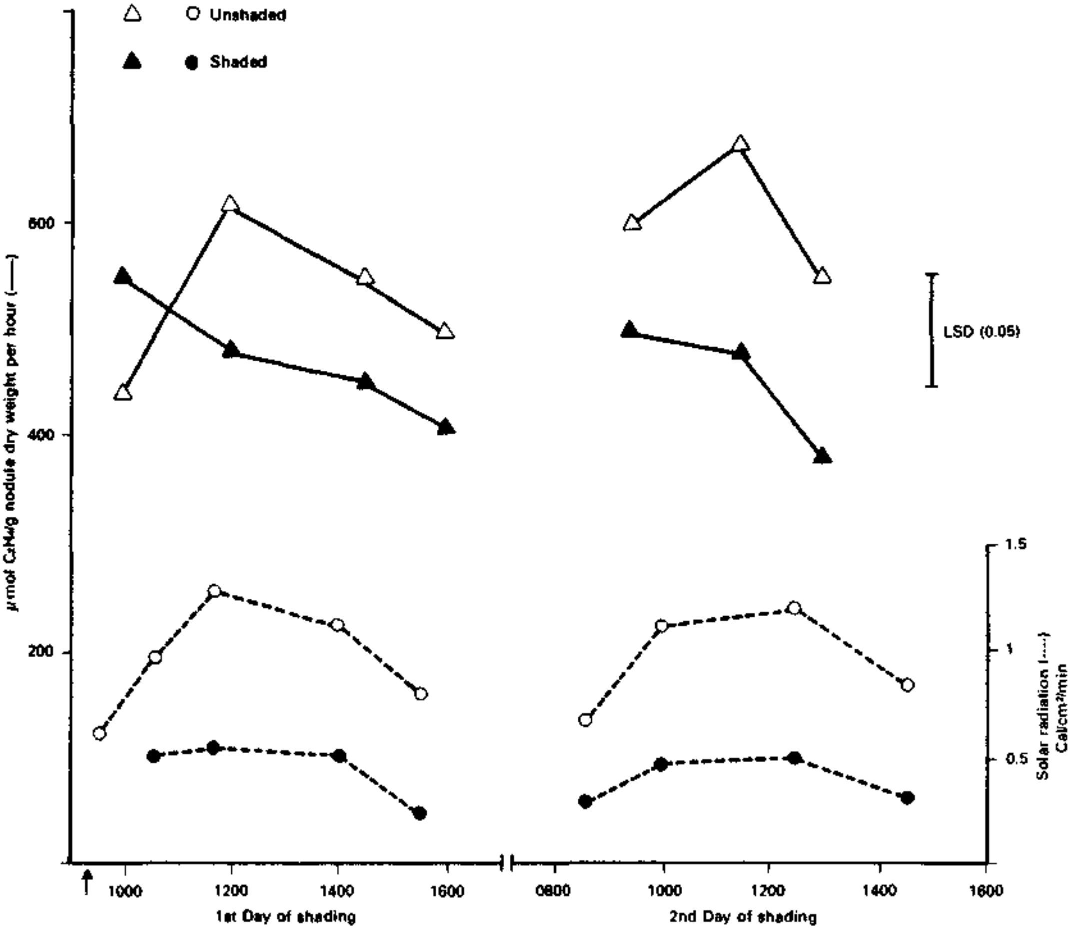

Figure 6. Effect of shading on nitrogenase activity of groundnut. Plants grown as an irrigated crop were shaded in replicated plots at 109 days after planting. Acetylene reduction assays were carried out on the same day and on a subsequent day. | indicates the start of shading treatment.

and seasons. In rainy season 1976, nitrogenase activity was at a maximum by 25 days, but from about 40-70 days, Kadiri 71-1 nodules were more active than those of Comet. It was only after 40 days without appreciable rainfall that the nitrogenase activity of Kadiri 71-1 nodules decreased. The pattern of nitrogen fixation in the irrigated season was quite different, increasing until about 75 days, then decreasing rapidly, with differences developing between cultivars. Kadiri 71-1 nodules at 128 days were still more active than at any stage during the rainy season. Peak activity per plant during the irrigated postrainy season was more than twice that of the rainy season.

The difference in symbiotic performance of Kadiri 71-1 and Comet under the drought stress of 1976, as well as between seasons, suggests that we can select cultivars which are better adapted to fix nitrogen under stress conditions.

Nodulation and nitrogen fixation of two cultivars MH-2, a dwarf mutant, and Kadiri 71-1 was followed throughout the postrainy season (Figs. 8, 9). There were marked differences in the weight of the nodules per plant and nitrogenase activity per plant of these two cultivars. Except for a short period, however, nitrogenase activity per gram of shoot weight was very similar for the two cultivars (Fig. 10). This may indicate that in dwarf cultivars such as

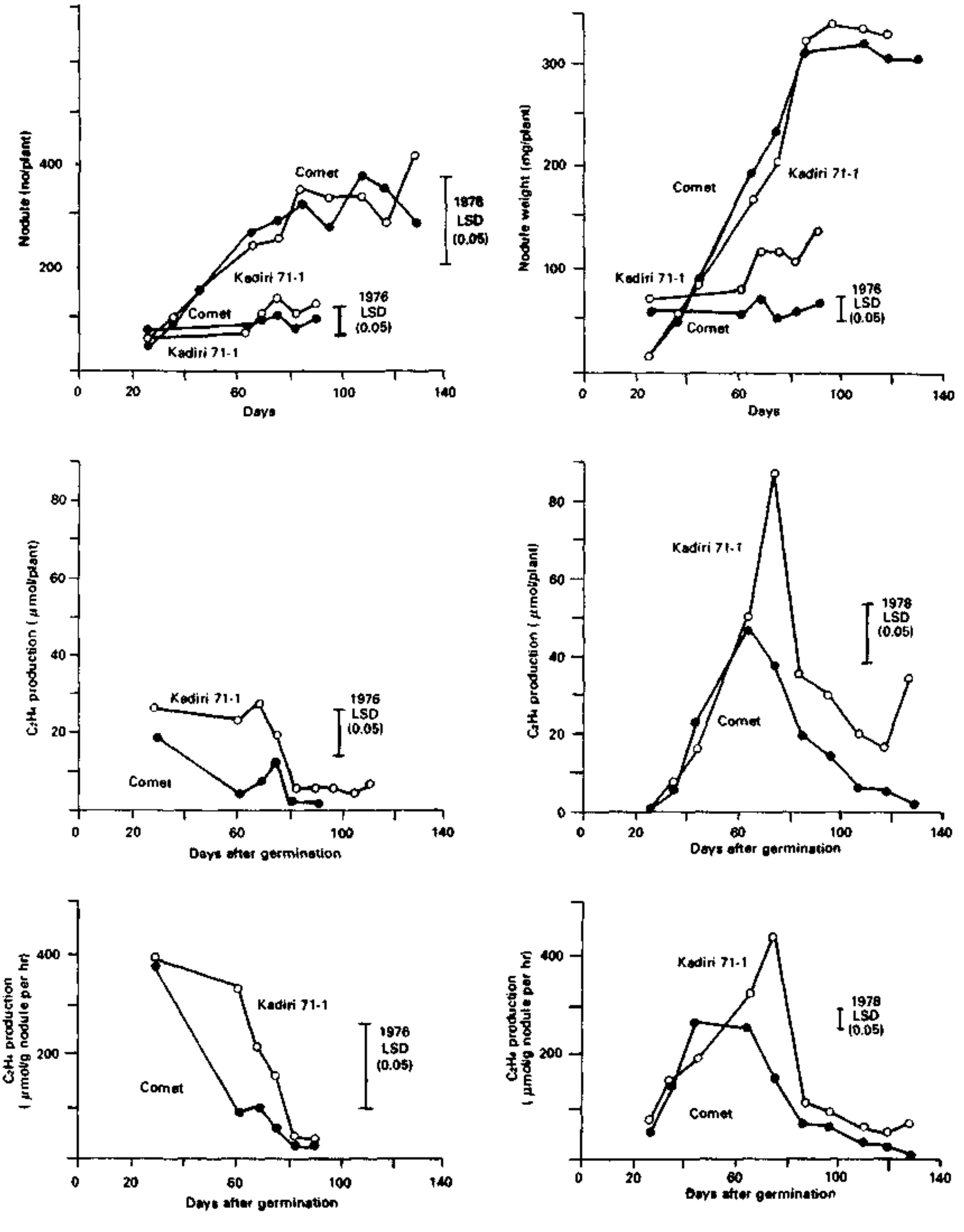

Figure 7. Seasonal variation in nodule number and nodule weight per plant and nitrogenase activity per gram nodule weight and per plant in cv Kadiri 71-1 and Comet grown during rainy season 1976 and postrainy season 1977 at ICRISAT Center. The postrainy season planting was irrigated.

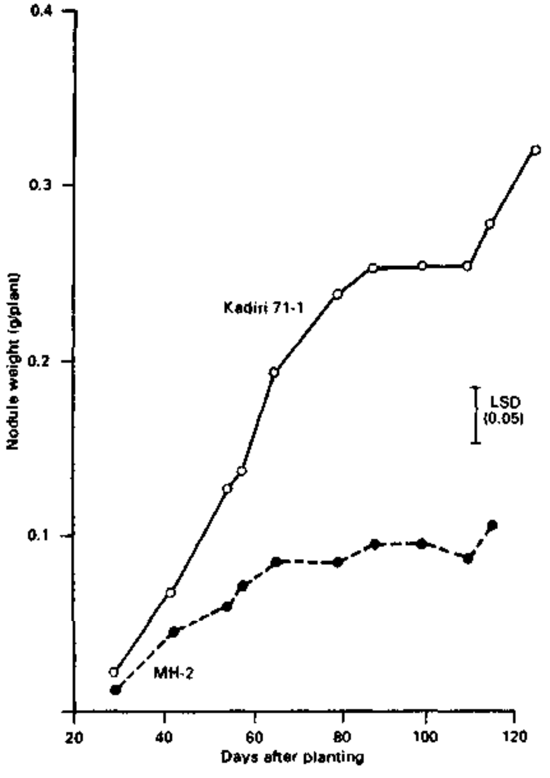

Figure 8. Nodulation of Kadiri 71-1 and MH-2 during irrigated postrainy season.

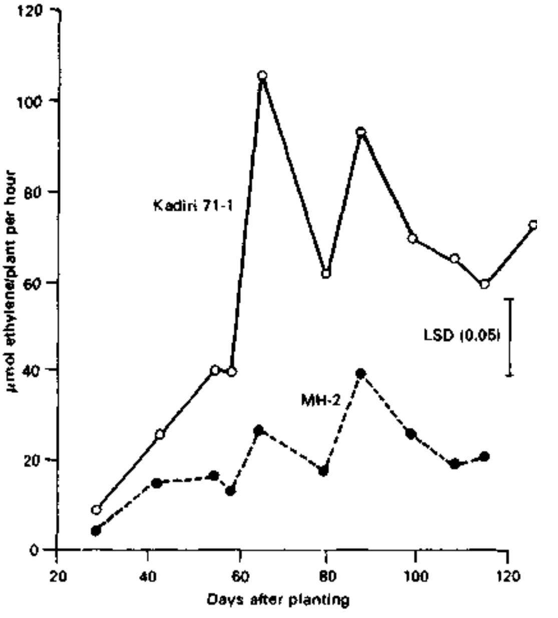

Figure 9. Nitrogenase activity of Kadiri 71-1 and MH-2 during irrigated postrainy season.

MH-2, nitrogen fixation is limited by photosynthate supply, if we assume that net photosynthesis and plant top dry weight are correlated.

Effect of Intercropping

During the 1978 rainy season, we observed that groundnuts when intercropped with pearl millet, nodulated poorly and fixed less nitrogen than the sole crop (Fig. 11). Three rows of groundnut were intercropped with one row of millet which, as commonly practiced, received N fertilizer at the rate of 80 kg N/ha, a level giving near optimum intercrop advantage. During the 1979 rainy season (Table 6) we observed a similar trend in groundnut intercropped in a normally spaced maize stand (two rows of groundnut between maize rows). Interestingly, sole groundnut and groundnut intercropped with maize which received no N fertilizer, had similar nodule number and nitrogenase activity.

The decrease in nitrogenase activity in intercropped groundnut could be due to: (1) the inhibition of nodulation by the nitrogen fertilizer added to the cereal crop (we have observed that fertilizer nitrogen reduces nodulation and nitrogen fixation), and/or (2) the light available to the groundnut in the intercrop decreases as more N fertilizer is added to the cereal.

Observations from an experiment in groundnut/sorghum intercropping where different shading intensities were created by graded defoliation of the sorghum support this (Table 7).

We plan to study the intercropping system more carefully. It may be possible to increase the nodulation and nitrogen fixation of intercropped groundnut by selecting cereal cultivars which allow more light to the groundnut. It may also be possible to select groundnut cultivars more tolerant of reduced light availability. An ideal cereal/legume intercropping situation would utilize the maximum nitrogen fixation ability of the legume while minimizing nitrogen fertilizer addition to the cereal (for other details of these intercropping experiments, see Reddy et al. these Proceedings).

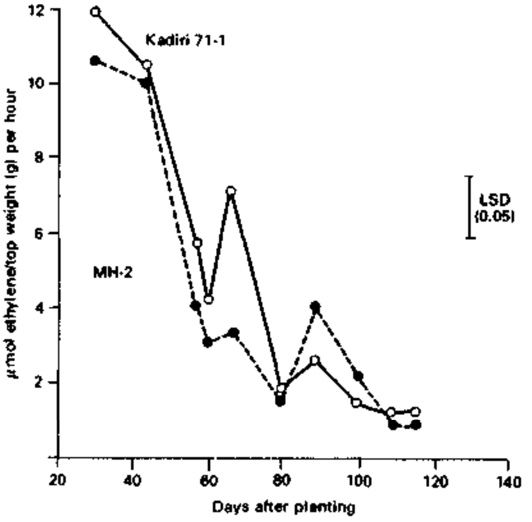

Figure 10. Nitrogenase activity per gram of top dry weight for Kadiri 71-1 and MH-2 during irrigated postrainy season.

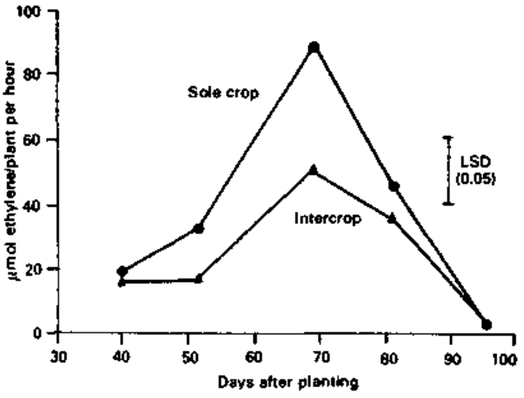

Figure 11. Nitrogenase activity of sole and intercropped groundnut.

We have not observed any interaction among five groundnut cultivars for nodulation and nitrogen fixation in intercrop and sole crop (Table 7). In soybeans it has been suggested that urea has a less harmful effect on nodulation than nitrate (Harper 1975). We plan to study the effect of different sources of N fertilizer applied to the cereal crop and their effect on nodulation and nitrogen fixation of groundnut as the intercrop.

Residual Effects

Rainy season groundnut, when compared with maize, had a large positive residual effect on growth and yield of millet in the subsequent, irrigated postrainy season with an increase in yield of 650 kg/ha, i.e., 45%. All groundnut and above-ground maize material and the groundnut main roots were removed from the field prior to the millet planting. This seems to be an effect of groundnut on N uptake by the millet, and would be consistent with the extremely high nitrogen fixation rates associated

Table 6. Nodulation and nltrogen fixation by groundnut intercropped with maize.

Treatment	Nodule Number/plant	μ moles C_2H_4/ plant per hr
Sole groundnut	171	21.3
Intercropped groundnut Nitrogen added to maize (kg/ha)		
0	164.70	20.10
50	159.50	9.36
100	150.0	7.00
150	134.15	3.52
CV (%)	19.71	30.30
LSD (0.05)	18.90	5.75

Table 7. Nitrogenase activity of sola and Intercropped groundnut.

	Nitrogenase activity[a] (μmoles CzH4/plant per hr)		
Cultivars	Sole crop	Intercrop (low density)	Intercrop (high density)
Chico-17200	15.2	11.8	6.8
TMV-2	18.1	12.6	8.3
MK-374	25.8	23.6	12.2
MH-2	15.4	7.9	9.1
Gangapuri	15.7	10.6	6.5
CV (%) 42			

a. Intercrop treatment effects ere significantly different for all cultivars.

Note: Groundnut end sorghum were planted in a ratio of 2:1 in the Intercrop. Low density Intercrop wes obtained by removing alternate pairs of leaves of sorghum. Plants were hervested 70 days after planting. Sorghum was fertilized with 80 kg N/ha.

with groundnut. The effect could be due to the N left in fine roots in the soil or due to exudation of N into the soil or due to less removal of available soil N by groundnut when compared with maize (Table 8).

Genetic Variability in Groundnut Germplasm Lines for Nodulation

Varietal differences in nodulation among groundnut were reported by Duggar as early as 1935(Duggar 1935). We found large differences among germplasm lines for nodulation (nodule dry weight) and nitrogenase activity during the 1977-78 postrainy season and the 1978 rainy season. The data on nodule weight and nitrogenase activity were analyzed by the Scott-Knott procedure (Gates et al. 1978). The clusters formed were classified into low, medium, and high nodulating and nitrogen fixing (as measured by acetylene reduction) lines (Tables 9, 10). The comparison over season indicated an interaction between cultivar and season for nodulation and nitrogen fixation.

Similar host plant differences in nodulation and N2 (C2H 2) reduction have been documented in North Carolina peanut fields containing native rhizobia (Wynne et al. these Proceedings). From the variation present in the germplasm lines, it seems possible to develop genotypes with greater nitrogen fixing ability by selecting parents that consistently have high nitrogen fixing ability over seasons. Isleib et al. (1978) from a 10 x 10 diallel study indicated significant additive gene action for nodulation, nitrogenase activity and plant weight.

We have also found groundnut cultivars which consistently nodulate on the hypocotyl, often with a subtending lateral root, whereas others form few or no nodules in this region (Fig. 12). For example, during the 1977 rainy season, cv NC Acc 10 formed 175 nodules per plant on the hypocotyl (23% of the total nodules formed) whereas cv NC Acc 770 formed only 12 nodules (2% of the total) in this region. Some cultivars such as MK-374, nodulate further up the stem, beyond the crown of the plant. We have observed that cultivars belonging to the botanical variety *hypogaea* nodulated better in the hypocotyl region than those from *fastigiata*

Table 8. Residual effect of groundnut and maize on millet grain yield in an Alfisol.[a]

First crop	Yield (kg/ha)
Groundnut	1980
Maize unfertilized	1325
Maize 20 kg N/ha	1456
LSD (0.01)	360

a Groundnut and maize grown In rainy season 1977 at ICRISAT Center, followed by irrigated millet, In dry winter season 1977-78.

Table 9. Symbiotic characters in 48 groundnut germplasm entries (85 days after planting).

	Range
Nodule number	247-628
Nodule weight	0.30-0.75 g/plant-'
Nitrogenase activity	
μ mol C2H4 plant-'h-[1]	36-176
μ mol C2H4/gdry wt nodule/hr	95-386

and *vulgaris.* We are presently studying the heritability of this location difference in nodule formation.

Non-Nodulating Groundnut

The *host-Rhizobium* interaction in legumes is well documented. The genetic basis for non-nodulation has been described in soybeans, red clover and peas (Williams et al. 1954; Caldwell 1966; Nutman 1949; Holl 1975). Recently Gorbetand Burton reported non-nodulating lines of *Arachis hypogaea* (L) in the progenies of a cross 48 7 A - 4 - 1 - 2 X PI 262090.

During the 1978 rainy season we observed that F2 plants in the rust screening nursery were segregating for non-nodulation. All the parents of the crosses were found to nodulate normally. Later during the rainy season in 1979, non-nodulating lines were found in 14 additional crosses (Table 11). All these crosses have a rust resistant, Valencia groundnut as one of the parents [PI 259747; NC Acc 17090, EC 76446

Table 10. Nodulation and acetylene reduction of groundnut cultivars.

Cultivar	ICG No.	Botanical type	Postrainy season 1977-78				Rainy sceason 1978	
			1st sampling		2nd sampling			
			Nodu-lation	Nitro-genase	Nod il-lation	Nitro-genase	Nodu-lation	Nitro-genase
Ah 3277	1218	Spanish	L	L	L	L	L	L
Ah 3275	1216	Spanish	L	L	L	L	L	L
No. 421	3158	Valencia	L	L	L	L	-	-
Ah 39	1161	Spanish	L	L	M	H	L	L
Ah 5144	1235	Spanish	L	L	M	M	M	-
NC Acc 888	359	Spanish	L	L	L	L	M	L
Ah 61	1173	Spanish	L	L	L	M	L	M
Ah 3272	1213	Spanish	L	L	L	M	L	M
No. 3527	1524	Spanish	L	-	L	M	L	-
Faizpur-1-5	1102	Spanish	L	M	L	L	M	M
No. 418	1500,2202	Spanish	L	L	L	M	-	-
NC Acc 1337	358	Valencia	L	L	M	M	M	L
NC Acc 516	279	Valencia	L	-	M	M	L	-
NC Acc 945	366	Valencia	L	L	M	M	M	-
NC Acc 699	1630	Spanish	L	L	L	M	L	M
148-7-4-3-12-B	1573	Spanish	L	-	L	M	-	-
No. 1780	1508	Spanish	L	L	M	L	-	-
NC Acc 738	331	Valencia	L	-	M	M	M	-
TG 17	2976	Spanish	L	L	L	M	L	L
No. 3270	1489	Spanish	L	L	L	L	-	-
NC Acc 51	263	Valencia	L	M	L	L	L	-
TG 8	95	Valencia	L	L	M	M	L	L
Ah 42	1163	Valencia	L	-	M	L	M	-
NC Acc 2651	402	Spanish	L	L	L	M	M	-
NC Acc 1002	380	Valencia	L	-	M	M	M	-
NC Acc 524	283	Valencia	L	M	M	M	M	M
GAUG 1	-	Spanish	L	-	M	M	L	L
NC Acc 2734	420	Valencia	L	L	*M*	M	M	L
NC Acc 495	1623	Spanish	M	M	L	M	L	L
Spancross	3472	Spanish	M	-	M	M	M	L
NC Acc 1286	389	Valencia	M	L	M	M	M	L
NC Acc 17149	475	Valencia	M	L	M	M	M	M
Ah 1069	1196	Spanish	M	M	M	M	L	L
Kadiri 71-1		Virginia runner	M	M	M	M	L	L
Ah 6279	2983	Spanish	M	-	M	M	-	-
NC Acc 2600	400	Virginia Bunch	M	L	M	M	L	M
POL 2	154	Spanish	M	M	M	M	L	L
JH 171	3375	Spanish	M	M	M	M	L	L
NC Acc 1303	393	Spanish	M	L	M	M	M	M
NC Acc 975	376	Valencia	M	M	M	M	M	*M*
Sm-5	2956	Spanish	M	M	M	*M*	L	L

Continued

Table 10. *Continued*

Cultivar	ICG No.	Botanical type	Postrainy season 1977--78 1st sampling Nodu-lation	Postrainy season 1977--78 1st sampling Nitro-genase	2nd sampling Nodu-lation	2nd sampling Nitro-genase	Rainy season 1978 Nodu-lation	Rainy season 1978 Nitro-genase
Argentine	3150	Spanish	M	M	M	L	L	L
Tifspan	3495	Spanish	M	M	M	L	L	L
Robut 33-1	799	Virginia Bunch	M	M	M	M	M	"
Pollachi 1	127	Spanish	M	L	M	M	M	M
NC Acc 17113	1699	Spanish	M	M	M	M	M	M
Ah 8254	2962	Spanish	M	M	M	M	M	L
Ah 7436	1547	Spanish	M	M	M	M	M	-
NC Acc 490	274	Valencia	M	M	M	M	M	M
X-14-4-B-19-B	1561	Spanish	H	M	M	M	M	-
NC Ace 2821	2405	Virginia	H	M	H	M	M	M
NC Acc 2654	404	Valencia	H	M	M	H	M	-

Range of nodulation and nitrogenase activity for the clusters formed

Season	Nodulation (g nodule/plant) Low (L	Medium (M)	High (H)	Nitrogen fixation (µ moles C2H4/plant per hr) Low (L)	Medium (M)	High (H)
Postrainy season 1978						
1 Sampling	0.08-0.11	0.11-0.16	0.188-0.19	16-28	30-44	-
2 Sampling	0.3 -0.38	0.38-0.6	0.6 -0.75	36-64	65-132	166
Rainy season 1979	0.11-0.14	0.14-0.17	-	68-92	93-117	-

Table 11. Crosses In which non-nodulatIng progenies were observed.

Shantung Ku No. 203 x NC Acc 17142
NC Acc 2731 x NC Acc 17090
NC Acc 2731 x EC 76446 (292)

NC Acc 2768 x NC Acc 17090
NC-17 x NCAcc 17090
Shantung Ku No. 203 x NC Acc 17090

Shantung Ku No. 203 x EC 76446 (292)
Shantung Ku No. 203 x PI 259747
NC-17 x EC 76446 (292)
NC-F1a-14 x NC Acc 17090

Rs-114 x NC Acc 17090
NC-17 x PI 259747
NC Acc 2731 x PI 259747
Shantung Ku No. 203 x PI 259747

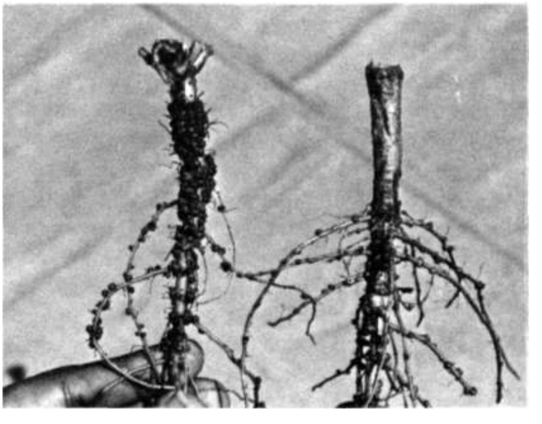

Figure 12. Differential distribution of nodules on groundnut root. Left, cv NC Acc 10 has many nodules on the hypocotyl. Right, cv NC Acc 770 has only few nodules.

[292]. Interestingly some segregants formed only a few, very large nodules, much larger than the parents or normally nodulating F2 plants. Acetylene reduction assays showed that their nitrogen fixing activity on a nodule weight basis was similar to that of normal nodules on the parents. A preliminary genetic analysis based on segregation for nodulation vs no nodulation showed that a pair of independent duplicate genes control nodulation and that non-nodulation is governed by recessive genes (Nigam et al. 1980)

Summary

1. Groundnut yield can be increased by inoculating with *Rhizobium.*
2. Nodulation and nitrogen fixation increased with increase in the number of *Rhizobium* inoculum cells per seed.
3. Nodulation and nitrogen fixation decreased when groundnut was intercropped with millet, maize or sorghum.
4. Photosynthesis is one of the major limiting factors in nitrogen fixation as evidenced by diurnal variation in nitrogenase activity, reduction of nitrogenase activity on shading groundnuts, and reduction of nitrogenase to different degrees when groundnut is grown in an intercrop with variable leaf area index of the companion crop.
5. There is genotypic variation in nodulation and nitrogen fixation.
6. Non-nodulating lines observed in the F2 populations of some crosses have been purified and advanced to Fe.

Acknowledgments

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Physiological Basis for Increased Yield Potential in Peanuts

D. E. McCloud, W. G. Duncan, R. L. McGraw, P. K. Sibale, K. T. Ingram, J. Dreyer and I. S. Campbell*

This work is part of a concerted effort at the University of Florida and in Malawi to understand the physiological basis for yield potential in peanuts. While some idea of the yield potential can be obtained from a comparison of recent varieties with older ones, the yield formation process is dynamic, and one needs to conduct a growth analysis, taking frequent harvests throughout the season, to understand crop growth. Simulation modeling (Duncan et al. 1978) is necessary to understand the dynamics of yield formation.

Peanut Production Model

Dry-matter production in plants is derived from solar radiation through the photosynthetic process, and temperature governs the speed of development (Fig 1.). There are three phenophases in our peanut production model (PNUTS): expansion, podding, and filling. The expansion phenophase spans from emergence until canopy closure when ground cover reaches 100%. Crop growth during this phase is exponential, and is entirely vegetative. The podding phenophase begins 2 weeks after the first flowers appear and in most of the improved cultivars this coincides with the stage when full ground cover is reached. Pods are added linearly until a full pod load has been set (Fig 2). The filling phase begins when a full pod load has been set, and continues until maturity.

To aid in understanding growth dynamics, we have developed a computer simulation model for use with a small, hand-held minicomputer (Ingram et al. 1980). Two climatological inputs — total daily solar radiation and mean daily temperature — are used to simulate dry-matter production. Other factors such as moisture, soil fertility and disease control are assumed adequate for optimum yields. Five equations are used in our peanut production model.

Temperature regulates the rate of crop development according to the developmental units required for each particular phenophase. Development units are accumulated by the formula:

$$\Sigma DU = \Sigma\ (TEMP-10) \qquad (1)$$

where TEMP is mean daily temperature in °C.

Daily assimilate is calculated as:

$$DAS = RAD.PNE.GC \qquad (2)$$

where RAD is expressed in $MJ.m^{-2}.day^{-1}$ photosynthetic efficiency (PNE) = 1.0, with no factors limiting photosynthesis. GC is the ground cover coefficient. The ground cover coefficient is calculated by:

$$GC = \frac{(\Sigma DU)\ EXP}{(\Sigma DUE)\ EXP} \qquad (3)$$

where ΣDU is the sum of the developmental units from emergence, EXP is the expansion exponent, and Σ DUE is thetotal developmental units for the expansion phenophase. When podding begins, pod dry matter is calculated by:

$$PDM = DAS.PLPCF.PART \qquad (4)$$

where PL is the pod load coefficient, PCF is the

* Professor, University of Florida, Gainesville, Florida, USA (USAID contract in Lilongwe, Malawi); Professor, University of Florida, Gainesville, Florida, USA; Assistant Professor, University of Minnesota, St. Paul, Minnesota, USA; Senior Research Officer, Ministry of Agriculture and Natural Resources, Lilongwe, Malawi; Postdoctoral Research Assistant, University of Florida, Gainesville, Florida, USA; Chief Physiologist, Department of Agriculture and Technical Services, Potchefstroom, South Africa and formerly Graduate Research Assistant, University of Florida, Gainesville, Florida, USA; International Intern, ICRISAT, Hyderabad, India, respectively.

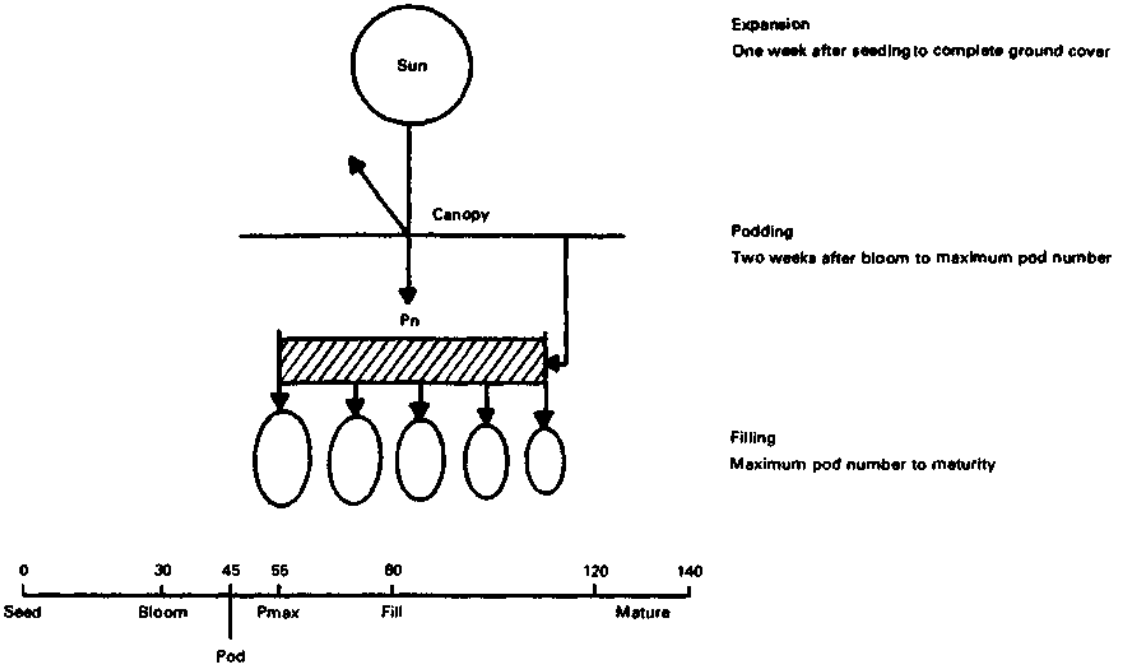

Figure 1. Diagrammatical representation of the peanut production model.

pod composition adjustment factor (0.606) which accounts for the greater photosynthate needed to produce pods high in oil and protein content compared to the vegetative component. PART is the ratio of daily assimilate flow to pods compared to the total assimilate.

Vegetative dry matter is calculated by:

$$VDM = DAS - (PDM/PCF) \quad (5)$$

When a full pod load has been set, filling begins and it continues until maturity is reached. Pod dry matter is calculated by equation (4) using the pod load coefficient of 1.0.

Our objective for the peanut production model is to simulate potential vegetative and pod dry matter production where the soil fertility, moisture, and plant pests are optimum for maximum productivity.

Climatological and Physiological Inputs

Two climatological inputs — daily total solar radiation and mean daily temperature are used in our peanut production model for calculating potential productivity. If desired, a soil moisture loop can be added as we have done for the IBM computer. However, we find potential productivity a useful measure of the uncontrollable climatic factors.

Physiological parameters which are input into the model are: the expansion exponent, developmental units for the expansion, podding and filling phenophases, and the partitioning and pod weight factors. Initially in each environment for each cultivar a growth analysis study with percent ground cover estimates, counts of pod numbers, and measurements of vegetative and pod dry weights at weekly intervals will be necessary. From these measurements, the developmental units for each phenophase can be determined using equation (1).

During the expansion phase, the expansion exponent should be selected by trial and error giving the best fit for the increase in vegetative dry weight — equation (3). We used an exponent of 2.5 for the Florida data. During the podding phase, pod load increases in a linear relation to I DU until a full pod load has been set.

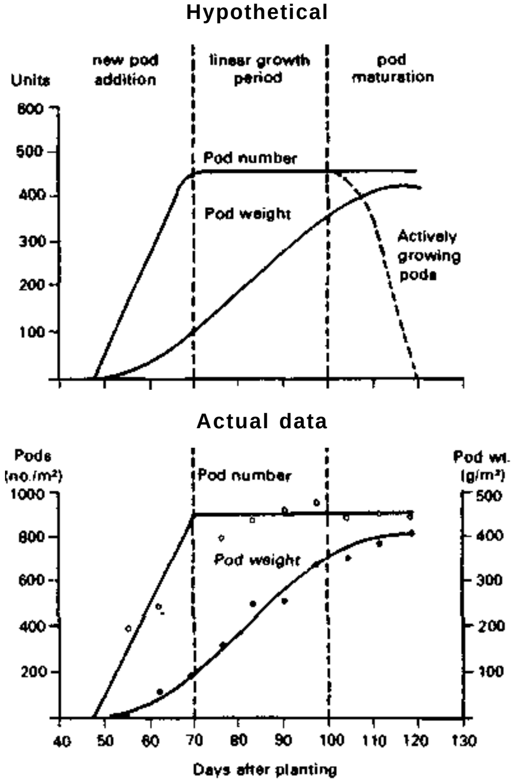

Figure 2. Hypothetical vs actual pod loading in Sellie peanuts grown in Florida in 1979.

Partitioning is determined from growth analysis measurements from the formula:

$$PART = \frac{PGR}{PCF} \div CGR$$

where PGR is the pod growth rate fitted to the linear portion of the pod dry weight curve, PCF is the pod composition adjustment factor and CGR is the crop growth rate from the linear portion of the vegetative dry weight curve before podding begins. Partitioning is the division of daily assimilates between reproductive and vegetative plant parts. Partitioning should not be confused with harvest index which is a static end-of-season computation, inadequate to explain the dynamic growth process; with the canopy senescence of legumes, harvest index is inaccurate and useless for evaluation of breeding materials.

The pod weight factor can be determined from representative samples of mature pods.

The physiological factors are then used as initial inputs in the PNUTS model. For weekly growth analysis, weekly averages are computed for temperature and solar radiation, and these are then entered in the hand-held minicomputer. Calculations of the weekly data for each of the 19 harvests in our study take about 20 minutes. If a printer is used, much less time is required.

Growth Analysis — Simulation Modeling in Florida

In a growth analysis simulation modeling study, Duncan et al. (1978) reported the results which are summarized in Table 1.

We found that total dry-matter production among the four cultivars did not change; the four dry matter curves could be superimposed. The crop growth rates did not differ significantly among cultivars and 191 kg/ha per day was computed as the pooled cultivar mean rate.

Partitioning was the major factor which changed among the cultivars and it brought a step-wise yield improvement. Dixie Runner, a 30-year old cultivar produced 2.47 t/ha; Early Runner, 20 years old, produced 3.84 t/ha; Florunner, 10 years old, produced 4.64 t/ha; and Early Bunch, the newest cultivar from the Florida peanut breeding program, produced 5.39 t/ha. Partitioning in the Florida-bred cultivars has been increased from 40% thirty years ago to 98% in the newest cultivar. However, no further increases are possible through increased partitioning since the upper limit has been reached in the Early Bunch cultivar.

Growth Analysis — Simulation Modeling in Malawi

This year in Malawi we have just completed a similar growth analysis experiment to determine the partitioning coefficients for three widely grown Malawi cultivars compared to Florunner. This should aid plant breeders in gauging how much improvement is possible in the Malawi cultivars.

Mani Pintar is a very old, high-yielding introduction into the United States from Bolivia. The variety was later sent to Malawi. For Mani Pintar, the VDW regression produced a crop

Table 1. Crap growth rates, pod growth ratae, and partitioning for four paanut cultlvars grown at Gainesville, Florida In 1976.

Cultivar	Crop growth rate (kg/ha per day)	Pod growth rate (kg/ha per day)	Partitioning (%)	Yield (kg/ha)
Dixie Runner	189 ± 22	40.5 ± 1.6	40.5	2472
Early Runner	185 ± 20	74.1 ± 6.0	75.7	3843
Florunner	212 ± 15	95.0 ± 4.2	84.7	4642
Early Bunch	191 ± 20	98.7 ± 6.0	97.8	5378

growth rate of 13.4 g/m^2 per day (Fig. 3) The PDW regression was 6.6 g/m^2 per day and a partitioning coefficient of 0.81 was obtained. The dashed line represents the adjusted assimilate flow to pods. Mani Pintar produces high yields largely because of high partitioning of assimilates to pods. It is not surprising that Mani Pintar has been in the parentage of several high-yielding cultivars such as Makula Red, Apollo, and RG-1.

Chalimbana (Fig. 4) had a crop growth rate of 14.4 and a pod growth rate of 5.0 g/m^2 per day, which produced a partitioning coefficient of 0.57. Plant breeders should be able to achieve considerable yield improvement in this cultivar.

RG-1 (Fig. 5) had a crop growth rate of 12.3 and a pod growth rate of 6.3 g/m^2 per day, which produced a partitioning coefficient of 0.84, similar to Mani Pintar which was used in breeding the RG-1 cultivar.

Florunner (Fig. 6) was used as a comparison cultivar to determine if the partitioning coefficient differed between the environments in Florida and Malawi. Florunner had a crop growth rate of 12.3 and a pod growth rate of 5.7 g/m^2 per day which produced a partitioning coefficient of 0.76, somewhat lower than 0.85 produced in Florida.

However, both the crop growth rates and the pod growth rates were lower in the Malawi experiment than in Florida. In Malawi the crop growth rate was 69% and the pod growth was 60% of that in Florida. In Malawi, some factor restricted photosynthesis; quite likely the factor was a deficiency of magnesium. This restriction necessitated using a PNE factor less than 1.0 in

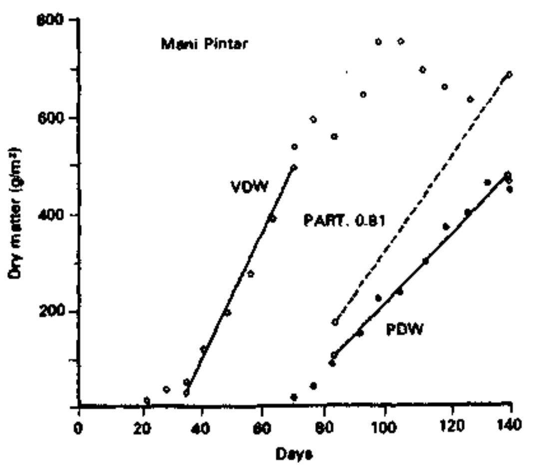

Figure 3. Vegetative dry weight, pod dry weight, and partitioning of assimilates for Mani Pintar grown in Malawi in 1979-80.

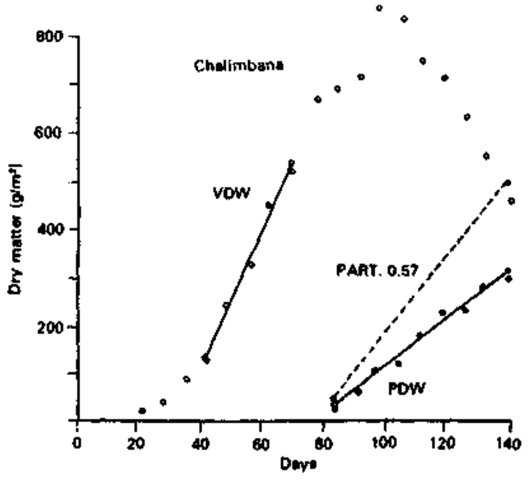

Figure 4. Vegetative dry weight, pod dry weight, and partitioning of assimilates for Chalimbana grown in Malawi in 1979-80.

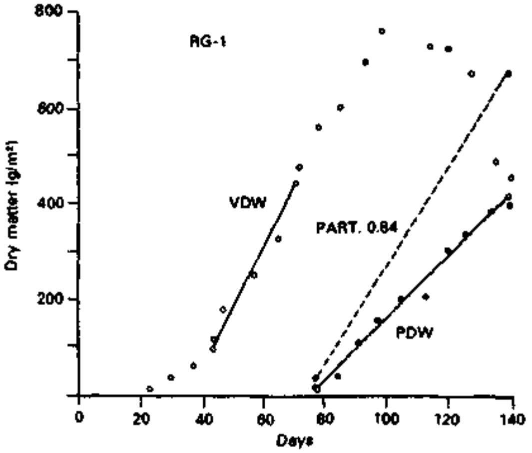

Figure 5. Vegetative dry weight, pod dry weight, and partitioning of assimilates for RG-1 grown in Malawi in 1979-80.

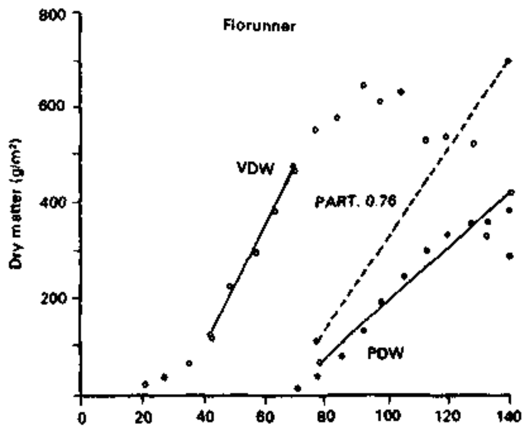

Figure 6. Vegetative dry weight, pod dry weight, and partitioning of assimilates for Florunner grown in Malawi in 1979-80.

the model. Soil tests showed very low magnesium and calcium levels and a low pH, and since no dolomitic limestone was available in Malawi, calcic limestone was applied at planting and did not alleviate the magnesium deficiency. The *appi cation of gypsum at pegging* partially alleviated the magnesium deficiency, and in our model the photosynthetic rate (PNE) after pegging had to be increased to85% of that for Florida (1.0) in order to produce vegetative and pod dry weights which would match the Malawi growth analysis data.

We believe this is an example of the value of simulation modeling. We want to know if the low magnesium affected the photosynthetic rates and if the low crop and pod growth rates affected partitioning. We will be testing this in an experiment during the 1980-81 growing season.

A comparison of the actual growth analysis of Mani Pintar data with the data from the PNUTS model (Fig. 7) showed very high correlation between vegetative dry weights for the linear portion of the curve until podding began — 0.998. For the linear portion of the pod dry weight curve the correlation was 0.992. Thus, the model is excellent for predictingdry weights over these periods.

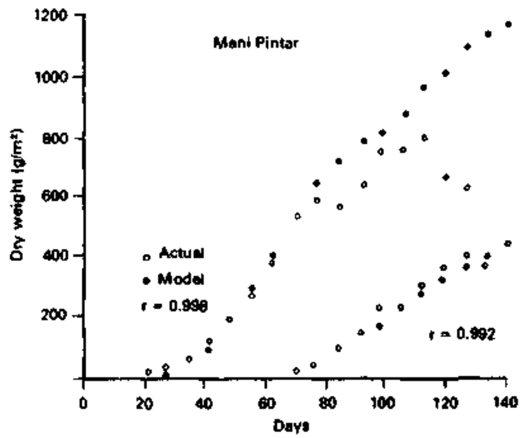

Figure 7. Actual data vs the simulation model for Mani Pintar grown in Malawi during 1979-80.

The discrepancies between actual vegetative dry weight and the model's prediction after podding begins are due to the loss of leaves from disease and senescence. We believe that the difference between the model and the actual *data is a reasonabie* estimate of leaf loss.

Temperature vs Pod Number

Another experiment which we conducted in Florida is summarized in Table 2 (Dreyer et al. 1980). This experiment was conducted to test our hypothesis that the number of pods established per plant should be inversely proportional to the growth rates of the individual pods Peanuts were chosen as the test plant because we could vary the pod growth rates in the field by cooling or warming the small soil volume occupied by the growing pods.

As predicted by the hypothesis, slower growth rates per pod, obtained by cooling the pod-zone soil, increased the total number of pods established per plant. Warming the pod-zone did not increase the pod growth rates and caused no reduction in the number of pods. When harvest was delayed until maturity for each treatment, average single pod weights were the same for each soil temperature. Thus, slower pod growth rates produced largeryields, but a longer filling period was required.

We feel that the particular method used to slow pod growth rate is incidental. The same results could have been attained by breeding for slower growing pods or by chemical treatments to achieve the same end, as long as the method used did not reduce mature pod weight. Presumably, an increase in the final pod weight without affecting the individual pod growth rate would have affected a similar enhancement of yield although maturity would also have been delayed. The mean pod growth rate was 8.4 g/m^2 per day across all temperature treatments. The higher yield for the lowest soil temperature treatment resulted from the longer pod filling period required.

Physiological Specifications for High Yields

Our work on the physiological basis for yield improvement in peanuts clearly shows there are four aspects that promote high yields: (1) a rapid expansion phenophase, (2) a short podding phenophase, (3) a long filling phenophase, and (4) a high partitioning of assimilates to pods. Our work shows that these four are the physiological aspects which, under optimum growing conditions, are most important in promoting high peanut yields. Under SAT conditions with restricted moisture and fertility, physiological specifications such as drought and low fertility tolerance must be considered. In addition to these physiological specifications, there are of course the usual disease resistance, quality, and other factors for the breeder to consider.

A rapid expansion phenophase, thetime from planting to full ground cover, promotes better weed control. When the length of the growing season is fixed by temperature or moisture, a rapid expansion phase saves time which can be used to lengthen the pod filling period thereby producing higher yields. Flowering and podding should begin before full ground cover is reached. This early flowering and podding also saves time and helps shorten the podding period.

A short podding phenophase is a desirable physiological attribute. Pods should be added rapidly until a full pod load is set. However, if all pods were set in a single day, and if that day were cloudy or in a drought-stress period, less photosynthate would be available for the pods and the plant would respond by setting fewer

Table 2. Fruiting tone soil temperature, pod number, and pod growth rate for Sellle peanuts grown in Florida, USA, 1979.

Soil temp. (CO)	Pods harvested (no./m^2)	Single pod growth rate (mg/pod per day)	Mean pod growth rate (g/m^2 per day)
23	1060	7.9	8.4
27	845	9.9	8.4
30	840	10.0	8.4
34	830	10.1	8.4
37	790	10.6	8.4

pods and the final yield would be lower. Peanuts then would be more like corn which has a very short critical period at silking when grain numbers are irreversibly determined. For peanuts, the final few days of podding are critical; however, peanuts, unlike corn, can resume podding when conditions become more favorable. Even under optimum conditions, peanuts have an excess of flowers and pegs, but this does not mean an "extra" yield potential. Pod load is adjusted to the photosynthate flow to the pods during the last few days of pod loading, and under optimum conditions this load is set by solar radiation and partitioning.

A long filling phenophase is another physiological attribute which contributes to high yield in peanuts. We feel that a longer filling period can be achieved in two ways: by a lower individual pod filling rate, *or* by a larger seed size with the same pod filling rate. The combination of a lower individual pod filling rate and a larger seed size would promote even higher yields, but the penalty would be a much delayed maturity.

A high partitioning of assimilates to pods promotes high yields in peanuts. The stepwise yield improvement in the Florida breeding program was largely achieved by increased partitioning. The latest cultivar Early Bunch partitions all of its assimilates to pods, and during late pod filling, the vegetative canopy shows stress effects of this assimilate drain.

Selection Criteria for the Plant Breeder

How can the plant breeder utilize this physiological inforamtion? Some examples of selection criteria for the plant breed er for rapid expansion would be: lack of dormancy, rapid germination, seedling vigor, and rapid spread.

A short podding phase is more difficult to select for, especially using individual wide-spaced plants. In solid stands the date at the beginning of flowering when the first 10% of the plants are blooming, and before flowering terminates the date at which the last 10% of the plants remain in flower, should be recorded. The difference between these two dates in days can be used as a podding index. The lower this index, the shorter the podding period.

Perhaps the best index for length of filling period is the days from the final 10% cut-off of flowering to maturity. The longer this period, the longer the filling period. Later maturity alone is not specific enough. What the breeder needs is an index of the actual days spent in filling. In the United States, hybrid corn breeders were at this stage 30 years ago. I recently asked an eminent U.S. corn breeder how breeders had achieved higher yields during the last 30 years. He replied that they have more effectively utilized the available growing season by selecting for earlier silking without changing the days to maturity, which is set by frosts in the spring and fall. In physiological terms, this means lengthening the filling period. For peanuts, the breeding objective from a physiological standpoint should be to select the new cultivar for the expected length of the particular growing season to which it will be adapted (which is generally set either by moisture or temperature) and to use the largest possible proportion of the available growing season for pod filling. This is fine-tuning of a cultivar. It is difficult to select for high partitioning. Selections for yield can be made, but yield selection often may not be specific for partitioning. Perhaps the best approach for the breeder is to select the parents in crossing programs for high partitioning. In many SAT countries, rapid yield improvement can be made by selecting for higher partitioning; however, selection for very high partitioning can lead to reduced yields under conditions of environmental stress.

Plant breeders can make rapid progress by selecting for improved partitioning with cultivars which have a low partitioning coefficient although caution should be exercised for adverse conditions. Selecting for rapid expansion, short podding, or long filling periods will be much more difficult, time consuming, and will take considerable innovative ingenuity. There is little evidence in peanuts or other crop plants that the basic photosynthetic process can be improved; selecting for phtosynthetic efficiency is unlikely to be successful.

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Groundnut in Intercropping Systems

M. S. Reddy, C. N. Floyd and R. W. Willey*

In the developing world, groundnuts are commonly grown in intercropping systems, especially by small farmers who use traditional combinations often involving up to 5-6 crops. Detailed statistics of farming practice are difficult to obtain, but it has been estimated that 95% of the groundnuts in Nigeria and 56% in Uganda are grown as mixtures with other crops (Okigbo and Greenland 1976). In the Northern Guinea Savanna Zone of Nigeria, Kassam (1976) reported that only about 16% of the total area under groundnut was in sole cropping while about 70% was in 2-4 crop mixtures. Underplanting tree crops such as coconut, oilpalm, and rubber trees with groundnuts in the early years of the plantation is also a common feature in S.E. Asia (Hardwood and Price 1976) and India (Aiyer 1949).

This paper considers the intercropping of groundnut only with other annual crops; it deals mainly with the cereal intercrops (millet, maize, and sorghum), which are by far the most important intercrops grown with groundnut. It also considers briefly a further important group — the long-season annuals such as pigeonpea, cotton, castor, and cassava.

Intercropping of Groundnut with Cereals

Groundnut/Pearl Millet Intercropping

The groundnut/millet combination has been chosen for special emphasis at ICRISAT because it involves two ICRISAT mandate crops and the combination is an especially important one on the lighter soils of the semi-arid tropics, notably in West Africa and India.

A series of crop physiological experiments has been carried out since 1978 in four different seasons at ICRISAT Center, to study the growth patterns and the resource use in this combination to determine how yield advantages are achieved. The first experiment, conducted during the rainy season of 1978, compared sole crops with a single intercrop treatment of 1 row millet: 3 rows groundnut. Results have been presented in detail elsewhere (Reddy and Willey 1980a) so they are only briefly summarized here.

Growth patterns are plotted in Figure 1. Sole millet showed a very rapid rate of growth, achieving 8134 kg/ha of dry matter in 85 days (Fig. 1b). Sole groundnut growth rate was somewhat slower, and this crop achieved 4938 kg/ha of dry matter in 105 days (Fig. 1a). Dry matter yield of each crop in intercropping is given in comparison with an expected yield, this being the yield that would be achieved if the crop experienced the same degree of competition in intercropping as in sole cropping. Groundnut growth very closely followed the expected dry matter yield of 75% of its sole crop yield, whilst millet produced approximately twice its expected dry matter yield of 25% of its sole crop yield. In effect, this means that groundnut produced about the same yield per plant in intercropping as in sole cropping, while the much more dominant millet approximately doubled its yield per plant in intercropping.

The combined dry matter yield in intercropping is given in comparison with the yield expected, if there was no yield advantage (or disadvantage) of intercropping, i.e.,of the LER = 1 (LER = Land Equivalent Ratio, or the relative land area required as sole crops to produce the yields achieved in intercropping). Figure 1c shows that with time there was an increasing dry matter yield advantage for intercropping; at final harvest the actual LER was 1.29, i.e., an advantage of 29% for intercropping. Grain and pod yields closely followed this pattern and actual LERs were 0.71 for groundnut and 0.55 for millet, giving a total LER of 1.26, or an overall yield advantage of 26% for intercropping.

* Agronomist, Research Intern, and Principal Agronomist, respectively. Cropping Systems, ICRISAT.

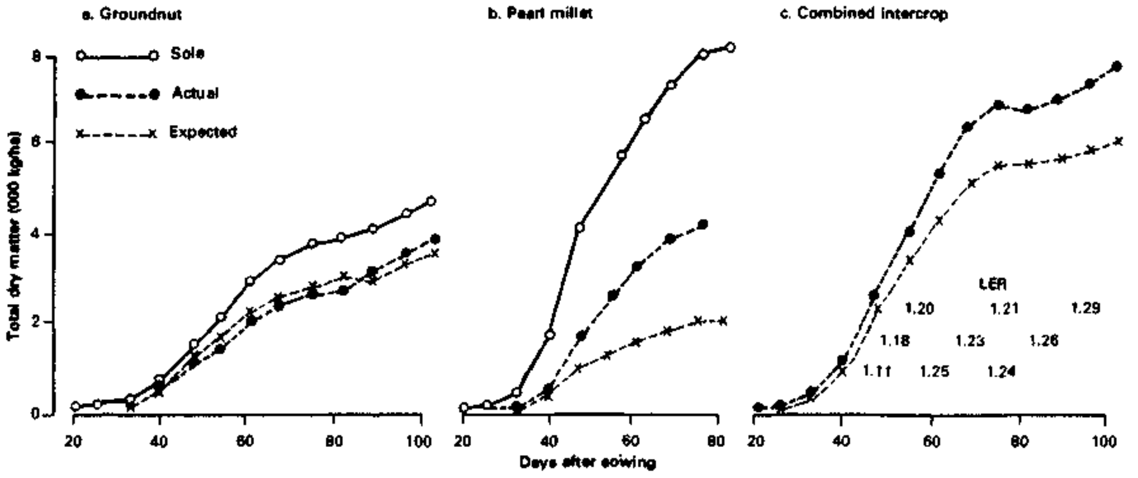

Figure 1. Sole crop yields and actual and expected intercrop yields of groundnut and millet.

Resource use was of particular interest in this combination. Considering moisture use first, the amounts of water transpired through the sole crops and the intercrop are presented in Table 1. (The amount for the intercrop could not be apportioned between the crops.) For the combined intercrop, an expected moisture use was also estimated by calculating for each component the amount of moisture which would have been used if dry matter had been produced at the same efficiency as the respective sole crops. It can beseenthatthiscaiculated moisture use was very similar to the actual moisture use, thus there was no evidence that intercropping was able to produce more dry matter per unit of water transpired through the crop.

Light interception patterns are presented in Figure 2. Sole millet showed a particularly rapid development of light interception, but the sole groundnut was rather slower. The combined intercrop was intermediate to the two sole crops in the early stages, but by about 60 days it was similar to both the sole crops; thereafter it declined because of senescence and removal of the millet and then senescence of the groundnut. Light use by the individual components in intercropping could not be distinguished. But the estimated amount of light energy which would have been needed to produce the intercrop yields, assuming the same level of efficiency as the sole crops, was appreciably higher than the measured amount intercepted (Table 1). Calculation showed that the intercrop appeared to use light with 28% greater efficiency. This agrees very closely with the LERs given earlier, suggesting that the yield advantages of intercropping were due very largely to more efficient use of light. In fact, during the period of maximum leaf area, the intercrop supported a leaf area that was approximately 30% greater than the sole crops. Thus the greater efficiency of light use may at least partly have been because light was more evenly distributed over more leaves. It could also have been partly due to the combination of a C_4 crop in the upper canopy layers and a C_3 one in the lower canopy layers.

An important feature of this first experiment, however, was that it was conducted at a relatively high level of fertilization (80 kg N/ha and 50 kg P20s/ha) and the season turned out to be particularly wet with rainfall well above average. Thus it was considered that a major reason why the higher intercropping yields appeared to be especially associated with increased efficiency of light use could have been because nutrients and water were not limiting. A main objective of subsequent experiments was to re-examine the relative importance of this light factor in situations where the below-ground resources were more limiting. Results have been

Table 1. Efficiency of resource use in pearl millet/groundnut intercropping.

	Millet		Groundnut
Water use			
Sole cropping			
Dry matter (kg/ha)	8134.00		4938.00
Water used (transpiration, cm)	15.86		19.63
Water-use efficiency (kg/cm)	513.00		252.00
Intercropping			
Dry matter (kg/ha)	4129.00		3821.00
Water used at sole-crop efficiencies (cm)	8.05	23.24	15.19
Expected water-use efficiency (kg/ha)		342.00	
Actual water used (cm)		22.79	
Actual water-use efficiency		349.00	
Light-energy conversion			
Sole cropping			
Dry matter (kg/ha)	8134.00		4938.00
Total light intercepted ($kcals/cm^2$}	14.26		19.25
Efficiency of conversion (mg/kcal)	5.70		2.57
Intercropping			
Dry matter (kg/ha)	4129.00		3821.00
Energy required at sole crop conversion rate ($kcals/cm^2$)	7.24	22.14	14.90
Expected conversion efficiency (mg/kcal)		3.59	
Actual interception ($kcals/cm^2$)		17.25	
Actual conversion rate (mg/kcal)		4.60	

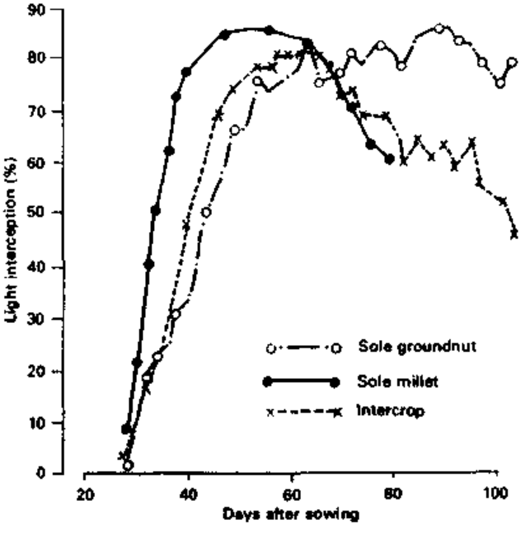

Figure 2. Light interception by sole crops and an intercrop of pearl millet and groundnut.

presented in detail elsewhere (Reddy and Willey (1980b), so again they are only briefly summarized here.

During the postrainy season of 1978, an experiment was conducted to study the effect of no-stress and stress moisture regimes (Table2). The pattern of intercrop results in no-stress was similar to that reported in the previous experiment and the reproductive yield advantage was 25%. Under stress the reproductive yield advantage was rather higher at 29%. The efficiency with which light energy was converted into dry matter was calculated as in the previous experiment; in no-stress the intercrop was 21% more efficient than expected, while in stress it was only 7% more efficient. Thus the results suggest that when moisture is more limiting, the efficiency of light use may be a less important factor in determining the yield advantage of this particular crop combination.

During the rainy season of 1979, an experiment was carried out to study the effect of two

Table 2. **Grain or pod yields and land equivalent ratios in pearl millet/groundnut Intercropping under two different moisture regimes (1978 postralny season).**

Treatments	Millet grain yields (kg/ha)	Millet LER	Groundnut pod yields (kg/ha)	Groundnut LER	Total LER
NO STRESS (Irrigated every 10 days)					
Sole crop	2674	-	2441	-	-
1 : 3 Intercrop	1220	0.46	1928	0.70	1.25
STRESS (Irrigated every 20 days)					
Sole crop	2114	-	2040	-	-
1 : 3 Intercrop	937	0.44	1734	0.85	1.29
LSD (0.05) within a moisture regime	109		146		0.09
LSD (0.05) across moisture regimes	133		217		0.08
CV (%) Main plots	3.26		4.95		2.57
CV (%) Split plots	3.60		4.03		4.38

different nitrogen levels on the millet (Table 3). The pattern of results was again similar to the previous experiments in that at a high level of nitrogen (Nso) the reproductive yield advantage was 21% but this increased under stress (nil N) to 32%. Dry matter yield advantages were even higher (Table 3). The efficiency of light energy conversion of the intercrop compared with the sole crops was calculated as in the earlier experiments. At Nso, the intercrop was only 14% more efficient, which was a rather smaller effect than in the previous experiments. At nil N, however, the improved light use efficiency of the intercrop was even higher, being 21%. At first, this effect at nil N is rather surprising, as it seems to contradict the earlier suggestion from the moisture regime experiment that when a factor other than light is more limiting, the efficiency of light use is less important. But the results may simply indicate some essential differences between the moisture stress and nitrogen stress situations which were created. One notable difference of course was that the moisture stress appiied to both component crops, whereas the nitrogen differences applied only to millet Current studies are examining situations where phosphate levels are also varied so that nutritional stress also applies to the groundnut.

Groundnut/Maize Intercropping

Groundnut is very commonly intercropped with maize in Southeast Asia and Africa. Mutsaers (1978) reported that in western Cameroon, the farmer grows groundnut as the main crop with maize interplanted at a fairly low density. Experiments carried out during three seasons in the Yaound'e area, Cameroon, to evaluate groundnut/maize mixtures, gaveyield advantages over pure stands ranging from 6-16%. Evans (1960) obtained yield advantages ranging from 9-54% from five different experiments conducted at two different locations in Tanzania during 1957 and 1958. In Ghana, Azab (1968) studied groundnut/maize intercropping by varying the sowing time of each crop. He observed that the mean yield of groundnuts was significantly higher when sown 4 weeks earlier than maize. The traditional practice of sowing both crops *at* the same time *gave* an intermediate yield. Koli (1975) reported that the yields of groundnuts in mixed cropping treatments were

Table 3. Grain or pod yields and land equivalent ratios in pearl millet/groundnut Intercropping under two different levels of nitrogen applied to the millet (1979 rainy season).

Treatments	Pearl millet grain yields (kg/ha)	Pearl millet LER	Groundnut pod yields (kg/ha)	Groundnut LER	Total LER
Sole groundnut	-	-	2998	-	-
Sole pearl millet (0 kg N/ha)	1968	-		-	-
Sole pearl millet (80 kg N/ha)	2872	-	-	-	-
1:3 Intercrop (0 kg N/ha)	1063	0.54	2345	0.78	1.32
1:3 Intercrop (80 kg N/ha)	1436	0.50	2131	0.71	1.21
LSD (0.05)	233		117		0.12
CV(%)	8		4		6.71

one-third to one-half the yields obtained from sole crops, but yield of maize was not reduced to the same extent. The general observation in all reports on the maize/groundnut combination is that groundnut yield is readily depressed by competition from the maize.

A groundnut/maize experiment was conducted on an Alfisol at ICRISAT in the rainy season of 1978 to study whether there was any beneficial transfer of fixed nitrogen from the legume to the cereal. Treatments consisted of maize at 0, 50, 100, and 150 kg/ha of applied nitrogen, and with and without a groundnut intercrop. With no applied nitrogen, maize growth was very poor and obviously nitrogen deficient, and there was no visual evidence of growth being any better if the groundnut intercrop were present. This observation was supported by maize grain yields which were unaffected by the groundnut at any level of nitrogen. The relative yield advantage of intercropping compared with sole cropping was 44% at zero nitrogen level but this decreased with increase in applied nitrogen and it was zero at the highest nitrogen level (Rao et al. 1979). Since there was no evidence that these differences in yield advantage could be due to differences in nitrogen transfer, it is possible that they occurred because intercropping was more efficient in using soil nitrogen, an effect that was more evident at lower levels of applied nitrogen. This finding agrees with the general trend observed in the groundnut/millet experiment referred to above (Table 3) and it has important implications in practice because it suggests that intercropping may be more advantageous in low fertility situations.

This groundnut/maize experiment was followed by a post rainy season crop of sorghum to study the residual effect of sole versus intercropped groundnut. The results showed that if no nitrogen were applied to the groundnut/maize intercrop, there was a beneficial residual effect on the following sorghum. Where nitrogen was applied to the maize, however, the groundnut growth was suppressed and the residual benefit rapidly diminished (Rao et al. 1979).

Groundnut/Sorghum Intercropping

In India and Africa, groundnut is very commonly intercropped with sorghum. Some reports have emphasized that significant yield reductions of groundnuts have been obtained when they have been intercropped with sorghum. John et al. (1943) reported that sorghum depressed the yield of groundnut by about 50% and Bodade(1964) obtained reductions of 52%. But despite reductions in groundnut yields, there are many reports of overall benefits when the yields of both crops are considered.

Bodade (1964) reported that mixed cropping of sorghum and groundnut gave higher yields than sole cropping and two rows of sorghum with eight rows of groundnut was one of the best treatments. Lingegouda et al. (1972) reported that three rows of groundnut and one row of sorghum was more profitable (Rs. 3918/- per ha) than pure sorghum (Rs. 3123/-) or pure groundnut (Rs. 2672/-). A positive benefit was shown in almost all experimental combinations of groundnuts with sorghum in East Africa (Evans 1960). Experiments conducted at ICRISAT with this combination have given yield advantages as high as 38% (Rao and Willey 1980) while Tarhalkar and Rao (1979) have reported yield advantages up to 57%.

Groundnut Genotypes for Groundnut/Cereal Intercropping

As in sole cropping, it seems likely that groundnut performance in intercropping could be improved by identification of suitable genotypes. Indeed it can be argued that the potential for genotype improvement could be greater in intercropping because of possible interactions with the associated cereal crops. It has also been emphasized that for crops growing with a more dominant associated crop, there may be particular need for identification and selection of genotypes within the actual intercrop situation because genotype performance in intercropping may not be very closely related to genotype performance in sole cropping (Willey 1979).

At ICRISAT, studies on the identification of groundnut genotypes for intercropping with pearl millet have been carried out since 1977. To date, results are only available for a relatively few genotypes of groundnut, and these have been examined in combination with only a few pearl millet genotypes (Table 4). All studies were in simple replacement series treatments of 3 groundnut rows: 1 pearl millet row. Results have indicated that with increasing groundnut maturity, and the associated change from bunch to runner habit, the groundnut contribution in intercropping (i.e. groundnut LER) tends to increase (Table 4). This is probably because of the increasing time for compensation of the groundnut after cereal harvest.

However, this increasing groundnut con-

Table 4. The affact of groundnut ganotypa and ganaral typa of millat ganotypa on groundnut LER and total LER in groundnut /pearl millat Intarcropping.

		Groundnut Genotypes						
		1. Chico	2. MH2	3. TMV2	4. R33-1	5. MK374	6. M-13	
Pearl millet genotypes		Spanish bunch 85 days	Valencia dwarf 95 days	Spanish bunch 100 days	Virginia semi-spreading 110 days	Virginia semi-spreading 125 days	Virginia runner 130-140 days	Means (Genotypes 3-6)
GAM73/GAM75	g nut LER		0.51*	0.63[d]	0.72[d]	0.80[c]	0.81[d]	0.74
(dwarf, late)	Total LER		1.13	1.25	1.22	1.27	1.33	1.27
BK560/WC-C75	g nut LER	0.48[s]	0.48[a]	0.61[e]	0.63[6]	0.80[c]	0.80[e]	0.71
(medium/medium)	Total LER	1.03	1.17	1.27	1.23	1.25	1.39	1.29
PHB-14/IVSAX75	g nut LER			0.67*	0.70*	0.68*	0.74*	0.70
(tall/medium)	Total LER			1.09	1.18	1.01	1.28	1.14
Ex-Bornu	g nut LER			0.90*	0.90*	0.80[a]	0.90*	0.88
(all, late)	Total LER			1.25	1.22	1.15	1.28	1.23
Means	g nut LER	0.48	0.50	0.70	0.74	0.77	0.81	
	Total LER	1.03	1.15	1.22	1.21	1.17	1.32	

a. Mean of 1 trial *b.* Maan of 2 trials *c* Mean of 3 trials *d.* Moan of 4 trials a. Mean of 5 trials tribution is not so clearly reflected in increasing yield advantages for the combined effect of both crops (i.e. total LER); although the latest maturing groundnut M-13 (130-140 days) was associated with the highest mean value for total LER, there were no real differences in total LER observable between the three genotypes TMV2 (100 days), Robut33-1 (110 days), and MK-374 (125 days). There was also little difference in groundnut or total LER for the different millet genotypes, though the range of millet genotypes was admittedly limited.

In these initial stages of identification, simultaneous screening of genotypes of both crops was carried out because there appeared to be scope for selecting more suitable genotypes of both crops. No marked interaction between genotypes of the two crops has been observed so work is now concentrating on examining a larger number of genotypes of each crop against a standard genotype of the other crop.

With the groundnuts, a more detailed study is also being carried outtodeterminethe extentto which the better intercrop performance of the longer maturing genotypes is due to greater time for compensation after cereal harvest or to some other characters which allow better growth and production in the dominated intercrop situation. In the summer season of 1980, groundnut genotypes were grown with a standard cereal (Sorghum CSH-8); the duration of cereal competition was examined by removing thesorghum at differenttimes, and the intensity of cereal competition was examined by means of a treatment in which alternate pairs of sorghum leaves were removed. First results suggest that increased groundnut contribution with reduced cereal duration was of the same order for all groundnut genotypes and both levels of competition. Differences in groundnut performance were small at a given cereal duration, though there was a tendency for the bunch types to do less well than the late runner types.

Groundnut Intercropped with Long Season Annual Crops

No growth studies have been reported for combinations of groundnuts with any of the long season annuals. However, it is evident from the general growth patterns of the crops that considerable temporal complementarity of growth occurs. The groundnuts can give reasonably efficient use of resources during the early period when the long season annuals are slow to establish; after groundnut harvest, the long season annuals are able to make use of later resources, especially of the residual soil moisture.

Groundnut/Pigeonpea Intercropping

This combination is particularly prevalent on red soils of the southern States of India. A common practice here is that if rains commence at the normal time a groundnut/sorghum or groundnut/millet intercrop is grown, but if rains are delayed groundnut/pigeonpea is grown. Pigeonpea rows are usually wide-spaced up to 5 m apart with up to 8-10 groundnut rows in between. This traditional practice helps to obtain high yields of the groundnut cash crop but the overall advantage of intercropping may not be high because pigeonpea is too sparsely distributed to make efficient use of late season resources and produce a worthwhile yield contribution. Most studies have examined this predominantly groundnut situation.

John et al. (1943) reported from a 3-year study that groundnut/pigeonpea in 8:1 proportion was 43% more profitable than sole groundnut. Similar results were reported from studies at Tindivanam over a 7-year period during 1942-49 (Seshadri et al. 1956). Veeraswamy et al. (1974) and Appadurai et al. (1974) showed that the arrangement of 6 groundnut: 1 pigeonpea was more economical than 8:1; groundnut gave 99% of its sole crop yield and pigeonpea 37% of its sole crop yield, totaling an advantage of 36%.

At the other extreme, an alternate row arrangement at ICRISAT gave an LER of 1.53 comprising 95% pigeonpea and 58% groundnut (Rao and Willey 1980). This may not be ideal economically because of the reduced groundnut contribution, but it illustrates that higher yield advantages can be obtained with higher proportions of pigeonpea.

A good compromise situation is indicated by some studies on five Alfisol locations within ICRISAT in 1979-80. Pigeonpea was grown in 135 cm rows with five very close-spaced rows of groundnut between. The population of each crop was equivalent to its sole crop optimum. Intercrop yields averaged 82% of groundnut and 85% of pigeonpeas, i.e. 67% total advantage.

Groundnut/Cotton Intercropping

Joshi and Joshi (1965) reported that a combination of 2-3 rows of groundnut between cotton rows spaced 6 feet apart gave significantly higher monetary returns compared to either sole crop. Varma and Kanke (1969) reported that growing cotton with groundnut was much more remunerative than growing it alone; yields of groundnuts were additional to the cotton yields usually obtained. Similar intercropping of cotton and groundnut has been recommended for the northern districts of Madras by Narayan Reddy (1961). In the Sudan, Anthony and Wilmott (1957) also found higher yields from groundnut and cotton intercropped together.

Groundnut/Castor Intercropping

Reddy et al. (1965) reported that growing castor mixed with groundnut was better than raising a pure crop of castor, and monetary returns were 61.9% higher than pure castor. They also reported that the yield of castor was more when it was grown mixed with groundnut compared to castor grown mixed with greengram, cowpea, *Setaria,* millet or sorghum. In East Africa, Evans and Sreedharan (1962) showed that there was a clear increase in production when castorbean and groundnuts were planted together compared to sole cropping. Tarhalkar and Rao (1975) reported that intercropping of castor/groundnut gave monetary returns up to Rs 4394 per hectare compared with Rs 3317 per hectare obtained from a pure castor crop.

Groundnut/Cassava Intercropping

Introducing an additional crop like groundnut between the traditionally wide-spaced cassava plantings would increase the production efficiency of cassava-planted land as well as conserving soil moisture and fertility. An experiment conducted at Khon Kaen University, Thailand in 1977, produced higher yields of cassava (26 756 kg/ha) when intercropped with groundnuts compared to sole crop of cassava (24 538 kg/ha). The experiment indicated that presumably intercropped groundnut increased the yield of cassava by supplying additional nitrogen from nitrogen fixation. This groundnut/cassava combination gave around double the net income compared with the sole cassava planting. Contrary to this, the Department of Agriculture, Tanganyika (1959) reported that when early sown groundnuts were intercropped with late-planted cassava, the yield of groundnuts was not seriously affected, but the yields of cassava were reduced to less than one-fifth of the sole crop. Potti and Thomas (1978) reported that trials conducted in the farmers' fields in Kerala, India gave an average of 1263 kg/ha of groundnut in addition to the cassava yield.

Conclusions

There is good evidence that groundnut/cereal intercropping can give worthwhile yield advantages over sole cropping. The ICRISAT studies suggest that these advantages can be due partly to more efficient use of light, but further research is needed to determine the importance of this light factor when below-ground resources are limiting. The more rapid early growth of the cereals, and the later maturity of groundnut compared with the early cereals, may also be an important factor giving some complementarity between the crops and allowing better use of resources.

Other ICRISAT studies have shown that the later maturing, semi-spreading or runner types of groundnut have given the highest groundnut yields in intercropping, but this has not always resulted in improved yield benefits from the whole system.

Although there has been little detailed work on the intercropping of groundnuts with the long season annuals, pigeonpea, cotton, castor, and cassava, there is good agronomic evidence that these systems can give very substantial yield advantages. The general growth patterns of these crops suggest that the main factor responsible for these advantages is that the use of early resources by the groundnut complements the use of late resources by the longer season crops.

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Session 5 — Crop Nutrition and Agronomy

Discussion

Microbiology

J. S. Saini

In a trial in the Punjab we found that when winter wheat was planted either after groundnuts, hybrid maize, or local maize we got better wheat yields after the local maize. This was surprising. What explanation can be offered?

P. T. C. Nambiar

It is difficult to generalize on this. One likely explanation is that in this instance, nitrogen was not limiting. At ICRISAT we have obtained a 30% yield increase in pearl millet when it followed groundnuts.

N. D. Desai

When do nodules form and when does fixation commence?

P. T. C. Nambiar

Initiation varies from season to season. In the rainy season they form as soon as 11 days after planting. In the postrainy season, they may not form until 18 days after planting. Nitrogenase activity commences 20 days after planting in the rainy season.

P. J. Dart

There are large nitrogen reserves in the seed and therefore a shorter dose of *nitrogen* may not be needed. Water also limits nodulation and the uptake of nitrate.

D. J. Nevill

We heard a lot about host and *Rhizobium* strain interactions. What about higher order interactions such as strain x host x environment interactions? In other words, does a successful combination of strain and host behave the same way in North Carolina as it does in India?

P. T. C. Nambiar

We are doing such trials but we have no results yet.

J. C. Wynne

We are cooperating in these trials with ICRISAT. We do not have results yet, but I would suspect that the combinations would be specific to sites. A lot would depend on the variety and the photosynthetic activity of the variety in the different environments.

S. N. Nigam

In one of the slides that showed analysis of several characters, there was no significance for nodule number for the host cultivars. I would have expected that there was a large amount of variability for nodule number, unless very few genotypes were in the study. Secondly, regarding the use of plant color in evaluating fixation by different strains of *Rhizobium,* the different botanical types of groundnuts themselves vary in leaf color. Could we say in general that the Virginia types have better nodulation than Valencia and Spanish types?

J. C. Wynne

The nodule varies with genotype, and if enough genotypes are used then significant differences are recorded. The results shown were limited and were not for all the experiments we have conducted. We would not use leaf color for selection purposes. When we evaluate strains we use nitrogen-free soils and we remove the cotyledons also. Color is then a useful parameter for comparison of strains on a single cultivar. Generally in North Carolina, we find that Virginia cultivars are the best nodulators followed by Spanish and then Valencia botanical types.

R. 0. Hammons

Nonnodulating lines were found by Dr. G or bet in Florida and now ICRISAT has isolated more nonnodulating types. What use will be made of these nonnodulating lines?

J. C. Wynne
I want to produce isogenic lines so we can determine how much nitrogen is taken up from the soil and how much is fixed by the plant. Or. Elkin wants to study the nodulation processes.

P. S. Reddy
You say that nodulation is genetically controlled; how many genes are involved?

J. C. Wynne
Dr. Nigam reported yesterday that two recessive genes were involved in nonnodulation. In other processes, quantitative genes are involved.

M. V. R. Prasad
I have a comment to make rather than a question. We have isolated an EMS-induced mutant from the TMV-2 cultivar which has a different nodulation pattern. The parent has more nodules in the peripheral regions of the root whereas the mutant has more nodules in the deeper zones of the root.

A. Narayanan
Dr. Nambiar's results indicated yesterday that nitrogen fixation occurs in groundnuts during the pod filling stages. This is in contrast to many other legumes in which fixation ceases during the reproductive phase.

P. T. C. Nambiar
We believe there is genotypic variation in this phenomenon as far as groundnuts are concerned. Some cultivars do continue to fix nitrogen during this stage.

M. A. Ali
What are the effects of soil-applied pesticides and herbicides on rhizobial activity and on other microbes in the soil?

J. C. Wynne
We found that in North Carolina some systemic insecticides actually increased nodulation either directly or indirectly. Some fungicides do decrease nodulation.

P. T. C. Nambiar
It depends on which chemical is used; we cannot generalize.

P. J. Dart
It has been found that if the herbicide affects the physiology of the plant then the nodulation is affected, but if the plant grows normally then it is not affected. Not enough work has been done on groundnuts but with *Vicia faba,* nematocides do not inhibit nodulation.

D. H. Smith
Is there mycorrhizal activity in groundnuts and is there any interaction between *Rhizobium* and the mycorrhiza?

P. J. Dart
Groundnut is mycorrhizal and some work has been done on this in Bangalore. We hope to start studies here soon. The big problem is that the fungus cannot be successfully cultivated yet. Chopping and applying the roots to the soil may be a possibility but much more work is needed on this aspect.

V. Ragunathan
The method of applying *Rhizobium* to the seed and then drying the seed in theshadedoes not seem to be very satisfactory. Germination seems to be affected by this method. What are the other possibilities?

P. T. C. Nambiar
We are experimenting with sand as a carrier at ICRISAT and this is placed below the seed at planting. This is important when seed dressings may prevent direct application of inoculum to the seedcoat due to the danger of the seed dressing adversely affecting the rhizobia.

P. J. Dart
In the USA, the granular inoculum is delivered through a separate tube on the planter and is placed below the seed. In Australia, soya is inoculated by a liquid inoculum again delivered from a separate coulter. At ICRISAT, the farm machinery section is experimenting with single machinery for delivering inoculum. Groundnuts need a large number of rhizobia to effectively nodulate them. Many of the commercial inoculants in many countries do

not meet the required quality and quantity standard we know are necessary for groundnut.

Physiology

H. M. Ishag

We found that net assimilation rate (NAR) is negatively correlated with leaf area index (LAI) from sowing to pegging and then there is a steady increase in NAR after pegging. What do you consider are the reasons for this?

D. E. McCloud

I do not like the term NAR and I do not think it has any physiological significance in groundnuts. Leaf area increases beyond the time that full ground cover is achieved. The total canopy photosynthetic rate is more important, and I base my judgment on that.

R. P. Reddy

For your model did you use the temperature recorded in the root zone or above ground around the plant?

D. E. McCloud

We used soil temperature around the pegging zone. We achieved this by using thermocouples. We made no attempt to control the actual temperature, which fluctuated during the season, but two of the treatments were warmer and one was lower than ambient. The actual figures shown were averaged for the season.

R. P. Reddy

The length of the podding period varies. Spanish and Valencia have a shorter pod filling period and they should be more efficient translocaters.

D. E. McCloud

In our model, potential yields were looked for and we did not take into account pests, diseases or drought. Spanish peanuts have a short pod filling phase and have a lower yield potential than Virginia types, because only so much photosynthate is available.

J. Gautreau

You have stated that there are two main factors for pod yield — good partitioning and a longer period for pod filling. I agree butthese criteria are not valuable everywhere, particularly for low rainfall areas. Your criteria relate to areas with assured rainfall or where irrigation is available. The haulms are also important in the SAT for cattle feed, so we must look for good foliar growth as well as good production of pods.

D. E. McCloud

Thank you for those comments and I agree with them. Partitioning can go too high and you can lose flexibility. In fact, in Florida the cultivar Early Bunch is only recommended for the top growers who can manage their crop well because this cultivar has a very high partitioning rate.

M. V. K. Sivakumar

Is it possible to put soil data into your model?

D. E. McCloud

Yes, it could be put into our model. Dr. Ducan's big computer model in Florida does have this capacity.

Intercropping

H. T. Stalker

Given the differences in crop values in both cash and food value, do you recommend that the farmer should intercrop?

M. S. Reddy

Yes, intercropping is a form of insurance and there are socioeconomic reasons for it as well. In a dry year there is a good chance that one of the crops at least will survive to produce some sort of yield. Farmers are interested because there is a compensation effect in the total crop raised.

G. D. Patil

Dr. Reddy uses the term intercropping, when he should be using the term mixed cropping as he is varying the number of rows of the main crop.

M. S. Reddy

I disagree. The term mixed cropping is defined as taking more than one crop within a single row. Intercropping is when you grow crops in different row proportions. We have used a replacement series technique for cereal/groundnut intercrop experiments. It is important to consider both crops in varying row numbers.

C. Harkness

For the peasant farmer, intercropping is very important and there is strong evidence that the best use of the growing season is made by adopting this system. In Nigeria, for example, millet is planted on the first rains and can be replanted if necessary. This is the early food crop for the farmer. When the rains are established, then groundnuts are planted in the gaps of the millet field. Later, if there are still gaps, then other quick-maturing species, such as *Voandzeia* (groundbeans), can be planted. This system is, of course, not for the large-scale, mechanized farmer. More work is needed on the pest and disease situation of the intercropped groundnut compared to the sole crop groundnut.

Session 6

Groundnut Entomology

Chairman: W. Reed

Rapporteurs: D. V. R. Reddy
P. Subrahmanyam

Resistance of Groundnuts to Insects and Mites

W. V. Campbell and J. C. Wynne*

Plants have the ability to repel attack by a myriad of pests. In some instances the level of resistance may be low, but due to the ability of the plant to replace leaves or fruit, the plant will compensate for damage by the pest and survive. Other plants may posses high resistance, even approaching immunity to a pest. Immunity to an insect pest is rare among commercially acceptable crops unless the concept of non-host is considered immunity.

Plants with resistance to insects and mites offer the most economical method of combating pests. Unfortunately, pest-resistant cultivars must be competitive in the market to be successful. A pest management approach to insect control, however, opens the way for use of more germplasm that offers low to moderate resistance to pest complexes. In the search for pest resistance most of the cultivars, breeding lines or species identified as resistant will have either low or moderate resistance levels. Low moderate or high resistance are relative terms. A plant cultivar with low resistance exhibits less damage from a pest than other cultivars grown in the area but may still suffer extensive pest damage. In general, a groundnut plant with low resistance may show 10-35% less insect damage than the susceptible cultivar, a moderately resistant plant may show 35-65% less damage, and a plant with high resistance to an insect will exhibit greater than a 65% reduction in insect damage compared with the local susceptible cultivars.

Mechanisms of Resistance

They have been defined by Painter (1951) as non-preference (= antixenosis), antibiosis, and tolerance. Plant resistance may be due to any one mechanism or any combination of thethree mechanisms.

Non-preference is a negative response by a pest to a plant as a source for food, shelter, oviposition or any combination. Those plant characteristics that either repel or cause the insect to leave the host after a brief contact will contribute to the host possessing a high level of non-preference resistance. Characteristics possessed by a plantthat may be mediated through the insects sensory system to cause a minor disruption in feeding or oviposition will result in low resistance by non-preference mechanism.

Antixenosis has been suggested as a substitute term for non-preference by Kogan and Ortman (1978).

Antibiosis is an adverse effect of the plant on the normal metabolism of the insect. Those plants that cause higher mortality in any stage of insect development, shorten the life span of the adult, or reduce fecundity as compared with known susceptible plants, are said to possess antibiosis as a mechanism of resistance.

Tolerance is the response of the plant to insect damage by compensation or replacement so that it can support an insect population that would cause extensive damage to other plants that are considered susceptible.

Painter (1951) used the term pseudoresistance to describe a transitory reaction of susceptible plant to environmental stress. He distinguished three types of pseudoresistance: (1) *Host evasion* is a lack of synchrony between plant phenology and pest so that the plant is in a growth stage that is less susceptible to pest damage when the pest is most abundant; (2) *Induced resistance* is a temporary resistance brought about by some physiological change in the plant in response to soil moisture or soil fertility; (3) *Escape* is a lack of infestation and damage due to a low pest population or unequal pest distribution. Some insects for example cause heavy damage on field borders

* Professor of Entomology, and Associate Professor of Crop Science, respectively, North Carolina State University, Raleigh, North Carolina 27650, USA

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and damage may decrease or become diluted as the distance into the field increases.

Pseu do resists nce can be inconvenient and time consuming by causing susceptible germplasm to be retested. A retest should identify lines that were selected as resistant but were actually susceptible due to pseudoresistance.

Nature of Resistance

The basis of resistance may be biochemical or biophysical (morphological). A pest-resistant cultivar may be developed without a knowledge of the nature of the resistance. For the best use of resources to aid the farmer, resistant germplasm needs to be identified first, then the mechanisms for pest resistance can follow.

Biochemical agents that may be associated with resistant plants have been identified for many crops and summarized by Norris and Kogan (1980). This research requires the close cooperation of a natural-products chemist, an entomologist with a reliable bioassay method, and a good supply of the pest that is destructive to the crop. The various chemicals identified as responsible for resistance include the alkaloids, isoprenoids, aromatics, glycosides, and acetogenins.

Biophysical characters that have been identified as associated with resistant cultivars include toughness and thickness of leaves, stems, or roots, trichome type, and trichome number. Trichome characteristics have been most often cited as a morphological character responsible for resistance of the host to pest species. It is no wonder that this character has been exploited often since it may be observed more readily than internal characters such as thickness, sclerotization or lignification. Gross morphological characteristics of the plant associated with resistance such as plant growth habit, plant part abnormalities, leaf surface texture, size and solidness of stem and shape may be readily identified with a minimum of special equipment other than hand lens or dissecting microscope.

Observations of discrete differences in leaf, stem or pod thickness, solidness and internal organization, as well as the presence and location of lactifers will require histological preparation and staining to differentiate parenchyma and sclerenchyma. The scanning electron microscope has added an important dimension to the study of plant surface features that may contibute to pest resistance or susceptibility.

Methods of Evaluation for Plant Resistance to Pests

A number of general methods for evaluation of germplasm for pest resistance may be used for various pests with slight modification. Field methods, however, will be quite different from laboratory or greenhouse methods for selecting pest-resistant germplasm because field tests involve multiple plants while laboratory tests usually are limited to individual plants or plant parts. Regardless of whether the evaluation for resistance is conducted in the field or laboratory, a knowledge of the biology, seasonal history, and damage potential of the pest as well as methods for maintaining or rearing the test species is essential.

Field Evaluation

If the insect pest is so destructive that it causes death to the plant, then individual plants that either survive or exhibit low damage may be selected for retesting. If the experiment is planted in a randomized block design with single or multiple rows, then entries may be evaluated for susceptibility to the pest by counting the number of pests, the number of damaged plants, the number of damaged leaves, stems, or fruit, or by working outthe percentage damage to a specific plant part.

Individual plant evaluations for pest resistance are desirable for F1 and F2 generation breeding lines. If seed supply is abundant, it is desirable to plant more advanced generation material in three-row plots, especially if the pest under investigation moves readily from row to row. Data then can be collected from the central row with the first and third rows acting as buffers to absorb excess damage from adjacent plots.

Groundnuts attacked by sucking plant pests such as the leafhopper or jassid and spider mites may be evaluated for resistance by counting the number of pests per plant or number per leaf or number for 5 or 10 leaflets. Resistance rating may also be based on the number or percentage of leaves with leafhopper "hopperburn" or chlorosis from spider mite feeding (Campbell et al. 1976).

Evaluation of groundnuts for resistance to soil insects presents a greater challenge. When the insect kills the plant, or causes it to wilt, or causes an abnormal color or size or growth pattern then plants must be dug and sampled for damage and for the pest. Most soil insects only move a few inches in the soil, therefore, a high population of well distributed adults of the pests species is desirableforthe best resistance ratings.

Natural field populations of the pest are often not adequate to obtain reliable evaluations for resistance without retesting excessive escapes. Trap cropping with alternate or very susceptible hosts in or around the field will attract higher pest populations. If this technique does not provide an adequate pest population, then a limited amount of the most important germplasm in the test may be planted in short rows and covered by a walk-in cage and followed by the release of a sufficient number of the desired pest in the cage (Campbell, unpublished).

Greenhouse Evaluation

Greenhouse tests are desirable for evaluating a small number of breeding lines or cultivars intensively where insects or mites are available in good supply from field sources or rearing. The entire greenhouse may be used as a large cage where a single or a complex of pests may be released. Most often the plants are caged for a seedling evaluation test for resistance, or leaf cages are used to confine a small insect or colony on selected leaves to study the effect of the host plant on the feeding, survival, or oviposition of insects.

Resistance to aphids may be evaluated in the greenhouse by placing a known number of aphids on each test plant and then determining survival and rate of reproduction. A known number of insect eggs or larvae of soil pests may be placed in the soil of each groundnut cultivar being evaluated for resistance to determine insect damage and survival.

Laboratory Evaluation

Initial evaluation of large amounts of germplasm is usually not conducted in the laboratory due to limited space, excessive time required to complete tests, and the need for a strong colony of rapidly reproducing pests. Laboratory evaluation for resistance is most often conducted on germplasm that has been previously determined to be resistant in the field or greenhouse and for which information on the mechanisms of resistance is desired.

Excised leaves or leaf discs cut with a cork borer from selected lines are often used in preference to whole plants for space conservation. A susceptible standard must be used in a two choice or multiple choice feeding or oviposition test for nonpreference evaluation. Another test should be conducted at the same time called a forced feeding or isolation test where each plant entry is isolated and separately infested so the pest does not have a choice of germplasm for feeding or oviposition.

Plant maturity as well as leaf age on the same plant has a marked effect on the pest feeding and oviposition. Therefore, all plant parts evaluated for resistance should be collected from plants of the same age and from leaves or fruit on the same position on the plant or same age. Often mature leaves or mature fruit are unacceptable for food or oviposition regardless of the plant susceptibility to the pest. Most insects prefer the younger, succulent leaves and fruit. There are exceptions, however, such as stored product pests.

Plastic shoe boxes, sweater boxes or refrigerator hydrator boxes make suitable cages for conducting nonpreference tests. Isolation tests are often conducted in 100 or 150 mm diameter petri dishes. Known numbers of insects are introduced for a period of time, usually 1-5 days for evaluation of feeding damage, larval development time, generation time, and reproduction.

Antibiosis studies often conducted in the greenhouse or laboratory involve isolation of individual insects on the plants being evaluated for resistance. Measurements are made of such parameters as larval weight gain, pupal weight or survival, adult weight or survival, or length of time for insect development. Longevity data may be appropriate for some pests. Abnormally high pest mortality, poor weight gain, slow development, or reduced fecundity are all indicative of resistance due to an antibiosis mechanism.

Resistance of Groundnuts to Foliage Feeding Insects

Tobacco Thrips *Frankllniella fusca* Hinds.

It attacks the plant as soon as it cracks the ground and causes deformed leaves, small leaves, stunted plants, and sometimes a delay of several weeks in flowering and pod formation. High populations of thrips will reduce yield if they attack groundnuts when plants are small and have only a few terminal leaves (Campbell, unpublished). Some very susceptible breeding lines have been killed by thrips in North Carolina.

Field populations of thrips are always adequate for evaluating cultivars and breeding lines for resistance in North Carolina. Ratings for resistance have been made by counting the number of thrips damaged leaves, or the percentage of leaves with thrips damage or the percentage of the leaf area with thrips damage. The varieties NC-GP342 and NC-GP343 as well as NC-6 (NC-GP343XVA 61R) have low level resistance to thrips. Susceptible commercial cultivars exhibited two or three times more thrips damaged leaves than resistant lines (Table 1).

Kinzer et al. (1972) developed a rearing method for the thrips using an artificial diet that yielded a higher percentage of adult thrips than groundnut foliage. This rearing method would be useful for laboratory antibiosis tests and nonpreference studies.

Table 1. Differences among advanced breading linas in thripv damage. North Carolina.

Identity	No. thrips damaged leaves[a]
NC-GP 342	85.3
Florigiant x AC 342	98.0
NC-6	102.0
AC 301 x NC-2	130.0
NC-GP 343 x Florigiant	136.0
NC-GP 343	146.7
NC-GP 343 xNC-5	156.3
NC-2	214.0
NC-5	273.3
Florigiant	285.3
Florunner	296.7
LSD (0.05)	58.62

a. per 30 row ft.

Potato Leafhopper *Empoasca fabae* Harris.

In the USA the potato leafhopper flies north from the Gulf Coast region to infest peanuts. Leafhopper populations will vary each year but the population pressure is sufficiently high every year in North Carolina to obtain good field evaluation for pest resistance.

Since the potato leafhopper causes "hopperburn," a characteristic V-shaped yellowing on the apical end of the leaflets, the number of yellowed leaves, or the percent yellowed leaves or the percent leafhopper damage may be counted or visually estimated for assessing leafhopper resistance. Several North Carolina accessions were rated as having high resistance to the leafhopper. They showed a 99% reduction in damage compared with NC-2 cultivar (Table 2).

During the period since 1960 only a low level of resistance to thrips has been observed among the domestic *peanutsArachis hypogaea* L. However, a number of wild species in sections *Rhizomatosae* and *Arachis* appeared nearly immunetotobacco thrips and the potato leafhopper (Table 3). The wild species serve as an untapped reservoir for pest resistance until the necessary breeding techniques are developed.

Fall Armyworm *Spodoptera frugiperda* (J. E. Smith)

The fall armyworm prefers monocotyledonous plants but they will infest groundnuts when populations are high or suitable grasses are not available. Sometimes fall armyworms are attracted to groundnut fields due *to* excess grass where they also feed on the groundnut foliage. The fall armyworm is a migrating, sporadic pest of groundnuts that is more important in the Georgia-Florida-Alabama production area than in the Virginia-Carolina region.

Leuck and Skinner (1971), using laboratory-reared fall armyworms reported adult

Table 2. Resistance of groundnut accessions to the potato leafhopper. North Carolina.

Accession	Pedigree*	AVg. no. leaf-hopper damaged leaves/30 row ft.	Avg. % leaf-hopper damage/ 30 row ft.
10207	Recurved x (C12 x C37)	4.0	0.3
10247	(C12 x C37) x Recurved	10.0	1.0
10211	(C12 x C37) x Recurved	13.3	0.7
10277	(C12 x C37) x Recurved	31.7	2.0
15729	(C12 x A18) $M_7M_5M_3M_1$	42.7	4.0
15730	(C12 x A18) M7M5M3M1	49.7	3.0
15745	(C12 x A18) $M_7M_5M_1$	69.0	3.3
15744	(C12 x A18) $M_7M_5M_1$	84.3	5.3
15736	(C12 x A18) M_7M_1	92.9	9.3
15739	(C12 x A18) $M_7M_5M_1$	97.3	11.7
10272	(C12 x C37) x Recurved	142.7	10.7
343	C12 x C37	157.7	15.0
323	NC 2	493.0	66.7
LSD (0.05)		43.0	6.1

a. C12, C37 = NC Bunch x PI 121067; A18 = NC-4 x Spanish 2B; Recurved = irradiation mutant from NC-4.

Table 3. Resistance of wild species of groundnuts to tobacco thrips and potato leafhopper (LH), North Carolina, 1979.

Collection name	PI	Collection	Section	No. thrips damaged leaves[a]	No. LH damaged leaves*
A. sp	276233	GK 10596	*Rhizomatosae*	0	4.0
A. glabrata Benth.	262797	GKP 9830	*Rhizomatosae*	0.5	0.5
A. macedoi Krap. et Greg, *nom nud*	276203	GKP 10127	*Extranervosae*	0	0
A. villosa Benth.	331196	B 22585	*Arachis*	0	0
A. stenosperma Greg, et Greg. *nom nud*	338280	HLK 408	*Arachis*	1.5	0.5
A. batizocae Krap. et Greg. *nom nud*	298639	K9484	*Arachis*	0	0
A. monticola Krap. et Rig.	219824	K 7264	*Arachis*	18.5	0
A. hypogaea		NC-6	*Arachis*	39.0	20.0
A. hypogaea		Florigiant	*Arachis*	44.0	57.0
LSD (0.05)				16.17	14.31

a. par 30 row ft.

emergence was significantly reduced on Southeast Runner 56-15 as compared with the susceptible cultivar Starr. They reported PI 196613 shortened the life cycle of the fall armyworm by 2 days and caused high larval and pupal mortality. They concluded the mechanisms of resistance were nonpreference or antibiosis.

Corn Earworm *Hellothis* zea Bodie.

The corn earworm invades groundnut fields usually during the peak bloom or fruit production period. It feeds primarily on the foliage but also cuts off pegs. Low to moderate resistance to the corn earworm has been observed among the North Carolina breeding lines and in Early Bunch and NC-6 cultivars (Table 4). When the moth population is high, field screening for resistance is very successful. Evaluation for resistance may include a visual estimate of earworm defoliation or larvae may be dislodged from plants with a wood dowel and counted on the ground between rows.

A laboratory experiment was conducted to determine if low *H. zea* field damage observed on NC-6 cultivars was due to antibiosis. Five, 4-day old larvae were isolated on NC-6, NC-2, and Florigiant. In 10 days, larvae fed young leaves from NC-2 and Florigiant weighed approximately three times more than larvae fed young leaves from NC-6 (Table 5). This is evidence that a mechanism of corn earworm resistance in NC-6 is antibiosis.

Table 4. Resistance of groundnuts to the corn earworm (CEW) *(Hallothis* xea Bodie), North Carolina.

Entry	%CEW foliage damage
Early Bunch	4.7
NC-6	7.3
Shulamit	13.0
NC-5	13.3
Avoca 11	15.0
NC-2	18.0
Florigiant	19.3
LSD (0.05)	5.48
CV(%)	23.25

Table 6. Antibiosis as a mechanism of resistance of NC-6 to the com earworm (CEW), North Carolina.

Cultivar	CEW avg. weight (g)
NC 6	0.0192
NC 2	0.0534
Florigiant	0.0663
LSD (0.05)	0.0208

Spider Mite

Twospotted Spider Mite *Tetranychus urticae* Koch.

The twospotted spider mite causes extensive damage to groundnuts grown in light, sandy soil that are under drought stress, especially following a multiple application of foliage-applied fungicides and insecticides. Due to the high reproductive potential and multiple generations within a growing season, there always exists a good possibility of a mite population showing resistance to a chemical miticide. Mite populations have developed resistance to some organophosphorus insecticides. There is a need to search for mite resistance in the cultivated and wild species of groundnuts.

Natural infestations of mites are not always dependable; therefore it is desirable to maintain colonies of mites for field distribution or for laboratory or greenhouse experiments. Mites may be reared on lima bean plants in the laboratory by inoculating the beans with mites 7 days after planting. Lima beans *are* more suitable for mass rearing than groundnuts due to *the* large amount of foliage produced in a short time. Plants may be infested in the field by transferring two or three bean leaves to the center of each entry. Resistance then may be based on the mite buildup from the release point and measured by counting the number of mites on a 5 or 10 leaflet sample.

Laboratory or greenhouse experiments should be more precise in the number of mites released, for example, the release of one female, one pair, 100 eggs, or 50 adults. The smaller number would be released on excised leaves or leaflets and the larger number on whole plants.

Representatives of seven sections of the genus *Arachis* weretested in the greenhouse in North Carolina for resistance to the twospotted spider mite. The highest mite resistance was found in the section *Rhizomatosae.* Resistant *Rhizomatosae* exhibited as much as 90% less mite damage than the most susceptible entries (Table 6). Leuck and Hammons (1968) also reported high resistance among the wild species to a closely related mite *Tetranychus tumidellus* Prichard and Baker. They reported that PI 262841 and PI 263396 possessed high resistance.

Soil Insects

Lesser Cornstalk Borer
***Elasmopalpus lignosellus* (Zeller)**

This pest occurs throughout the peanut growing area in the USA and is most abundant in sandy soils and most destructive under drought stress conditions. Loss of young plants may occur if the infestation is early or the crop is planted late. The larvae tunnel into the stems, root, pegs and pods.

Plant introductions were tested in North Carolina in single row, replicated plots under natural field infestations. PI 269116, 269118, and 262042 exhibited the lowest damage (Table 7) but there was no evidence of high field resistance to the lesser cornstalk borer.

Leuck and Harvey (1968) collected eggs of the lesser cornstalk borer on cheesecloth and artificially infested greenhouse plots of groundnut introduction with eggs. There was a wide range in seedling survival but the best plant introductions had 26-29 plants surviving from 30 seeds planted.

Southern Corn Rootworm
***Diabrotlca undecimpunctata howardi* Barber**

Unlike the lesser cornstalk borer, the rootworm

Table 6. Resistance of wlld spacies of groundnuts to the twospotted spldar mlte.Graanhousetast, North Carolina, (Johnson at al. 1977).

Collection name	*PI*	Collection	Section	% mite damage[a]
A. monticola	219824	K 7264	*Arachis*	96.5a
A. stenosperma Greg, et Greg. *nom nud*	338279	HLK 408	*Arachis*	93.5ab
A. hypogaea		Florigiant	*Arachis*	83.7a-d
A. hypogaea		NC-5	*Arachis*	72.5cd
A. villosa	331196	B 22585	*Arachis*	45.0fg
A. sp	276233	GK 10596	*Rhizomatosae*	24.2h-j
A. correntina Krap. et Greg. *nom nud*	331194	GKP 9548	*Arachis*	21.0ij
A. glabrata Benth.	262797	GKP 9830	*Rhizomatosae*	15.7ij
A. macedoi Krap. et Greg. *nom nud*	276203	GKP 10127	*Extranervosae*	15.2ij
A. sp	338317	HLO 335	*Rhizomatosae*	9.2j

a. Means with the tame letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Table 7. Differences among groundnuts in lesser cornstalk borer damage. North Carolina.

Identity	No. damaged pegs + pods[a]
PI 269116	22.7
PI 269118	23.0
PI 262042	28.7
NC-4	30.0
PI 275744	30.7
Schwartz 21	36.7
PI 275743	37.3
PI 269005	39.3
New Mexico Valencia	44.7
NC-5	50.7
NC-15745	54.0
NC-2	57.0
Florigiant	89.0
Starr	99.0
NC-6	111.3
Comet	125.7
Florunner	129.3
LSD (0.05)	44.4
CV(%)	41.0

a. per 3 plant sample.

prefers moist, heavy, high organic matter soil and cannot tolerate dry sandy soil. The adult rootworm causes minor damage to the terminal, unopened leaves but the larvae are capable of destroying ail the pegs and pods. Severe rootworm damage occurred in some areas in North Carolina when the rootworm developed resistance to a popular insecticide.

In 1960 research was initiated to find rootworm resistant germplasm. Plant introductions and selections from the North Carolina germplasm collection were screened in field tests. Tests were established in soil with good moisture retention properties and generally with an organic matter content of 1.5-3.5%. Promising lines were tested for 5 years, crossed with commercial cultivars, and then retested and selected for 10 more years. In 1976 a cultivar with high resistance to the rootworm was released as NC-6, a cross between the insect resistant parent NC-GP 343 and Va 61R (Campbell et al. 1977).

The yield and acre value of NC-6 were superior to Florigiant in fields where the rootworm was a problem and it competed favorably in the market for quality and price (Wynne et al. 1977). NC-6 and other accessions with NC-343 germplasm exhibit approximately 80% less rootworm damage than Florigiant (Table 8). This level of resistance is sufficiently high to eliminate the need for chemical control of the rootworm in most North Carolina soils.

Table 8. Resistance of groundnuts to the southern corn rootworm. North Carolina.

Accession number	Identity	No. rootworm damaged pegs + pods[b]
17201	AC 343 X VA61R	10.0
17167	NC-6[a]	13.3
17205	AC 343 x NC-5	18.7
15973	Florunner	23.0
17215	NC-5 X VA 61R	34.0
17163	NC-5 x Florigiant	40.3
323	NC-2	58.7
333	NC-5	69.3
348	Florigiant	105.8
17211	NC-5 x Florigiant	108.7
LSD (0.05)		24.4
CV(%)		33.4

a. AC 343 x Va 61R
b. 5 plant sample.

Multiple Insect and Multiple Pest Resistance

Cultivar NC-6 is unique in that it possesses multiple insect resistance. It was developed for high rootworm resistance but it also has a low level of resistance to thrips, moderate resistance to the potato leafhopper and moderate resistance to the corn earworm. NC-6 is susceptible to the lesser cornstalk borer and does not offer any special advantages against the two-spotted spider mites.

NC-6 has now been crossed with a North Carolina breeding line NC-3033 that has resistance to *Cylindrocladium* black rot (CBR), a destructive disease in many fields in the Virginia-Carolina production areas. Some NC-6xNC-3033 progeny have multiple insect resistance that is equivalent to NC-6 (Table 9). Selec-

Table 9. Evaluation of breeding lines for multiple pest resistance. North Carolina.

Entry	Identity[a]	No. thrips damaged leaves/30 ft.	No. LH[b] damaged leaves/30 ft.	% CEW[c] damage/30 ft.
13	NC-6	173.3	68.7	1.3
8	IMC-6 x NC-3033	184.7	95.7	1.7
4	NC-6 x NC-3033	193.3	43.7	1.3
6	NC-6 x NC-3033	213.3	45.3	2.7
1	NC-6 x NC-3033	229.7	31.7	1.3
14	NC-2	334.3	414.7	9.0
12	Florigiant	493.7	310.0	7.3
LSD (0.05)		71.86	59.27	2.62

a. NC-6 has multiple Insect resistance and NC-3033 Is resistant to *Cylindrocladium* black rot (CBR).
b. Potato leafhopper *Empoasca fabae.*
c. Corn earworm *Heliothis zee.*

tions are made among the progeny of NC-6x NC-3033 with multiple insect resistance and CBR resistance. The objective is the release of a high yielding, multiple pest resistant groundnut. Care must be exercised to avoid the release of a cultivar that is resistant to one pest but very susceptible to other important pests.

Although pest problems differ from country to country, many of the insects discussed occur worldwide. Closely related species have similar habits and similar destructive potential. Concepts are useful and modification in techniques may be needed with specific local populations and resources.

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Groundnut Pest Research at ICRISAT

P. W. Amin and A. B. Mohammad*

Initially research was concentrated on those particular pest problems which were of immediate concern at the ICRISAT Center. Simultaneously, information was collected on the most important pest problems of the crop in the Semi-Arid Tropics (SAT). This paper briefly reviews the progress made since groundnut pest research started at ICRISAT in late 1977.

Identification of Pest Problems

Groundnut Pests at ICRISAT

At ICRISAT the insect fauna from groundnuts was collected from 10x10 meter sized plots of three cultivars with erect bunch (cv TMV-2), spreading bunch (cv Robut 33-1), and runner (cv M-13) growth habits replicated three times in pesticide-free and pesticide-affected areas. Over 70 insect and other pests of groundnuts were collected.

The seasonal abundance of the various insects was also studied in plots of the groundnut cv TMV-2 raised at several locations on both Alfisols and Vertisols on the ICRISAT farm. The crops were sown monthly from June through February, individual plots being sited at least 400 m away from other groundnuts. Information on the abundance of insects in relation to locations, soil types, pesticide-free or affected areas, seasons, and years was recorded.

Termites and wlreworms were most abundant in Alfisols while earwigs and millipedes were more abundant in Vertisols. In Vertisols leaf miner was more prevalent in some locations than others. Thrips injury was more pronounced windward than leeward locations. Barriers across the prevailing winds affected thrips distribution; smaller numbers of thrips were observed on the plants in the vicinity of field bunds to the leeward side. Some insects became more abundant in drought years; *Caliothrips indicus,* leaf miner, *Aproaerema modicella,* and aphid *Aphis craccivora* were more abu ndant in th e drought year of 1979 th an in the good rainfall year of 1978. In normal years, insects such as thrips *(Scirtothrips dorsalis* and *Frankliniella schultzei)* were abundant in both rainy and postrainy seasons, *Spodoptera litura* and *Aproaerema modicella* in the postrainy season, *Aphis craccivora* in the summer season, and *Empoasca kerri* in the rainy season. *Heliothis armigera* was an important flower feeder in both rainy and postrainy seasons. (Fig. 1).

Groundnut Pests in India

In India insect pests are major constraints on yields, being particularly important in the states of Andhra Pradesh, Tamil Nadu, Punjab, Rajasthan, Gujarat and Maharashtra. About two decades ago, only a few insects were regarded as important pests (Rai 1976) but the situation has changed considerably. Insects like *Spodoptera litura, Frankliniella schultzei, Scirtothrips dorsalis* and *Empoasca kerri* which were not considered important pests then, are now so recognized (Table 1).

Insects such as leaf miner have been spreading and considerable damage by this insect was reported for thefirsttimefrom Gujarat and from the Dhuliadistrict of Maharashtra in 1978. White grubs *(Lachnosterna consanguinea)* have compelled many farmers to abandon groundnut cultivation in sandy soils of Gujarat, Rajasthan, Uttar Pradesh, and Punjab.

Groundnut Pests in SAT

On the world scene, over 300 species of insect pests have been recorded from groundnuts but only a few are important worldwide and a few others in restricted regions (Table 2). Some are important as vectors of viral diseases (Table 3). Insects are important as quality reducers and

* Entomologists, Groundnut Improvement Program, ICRISAT.

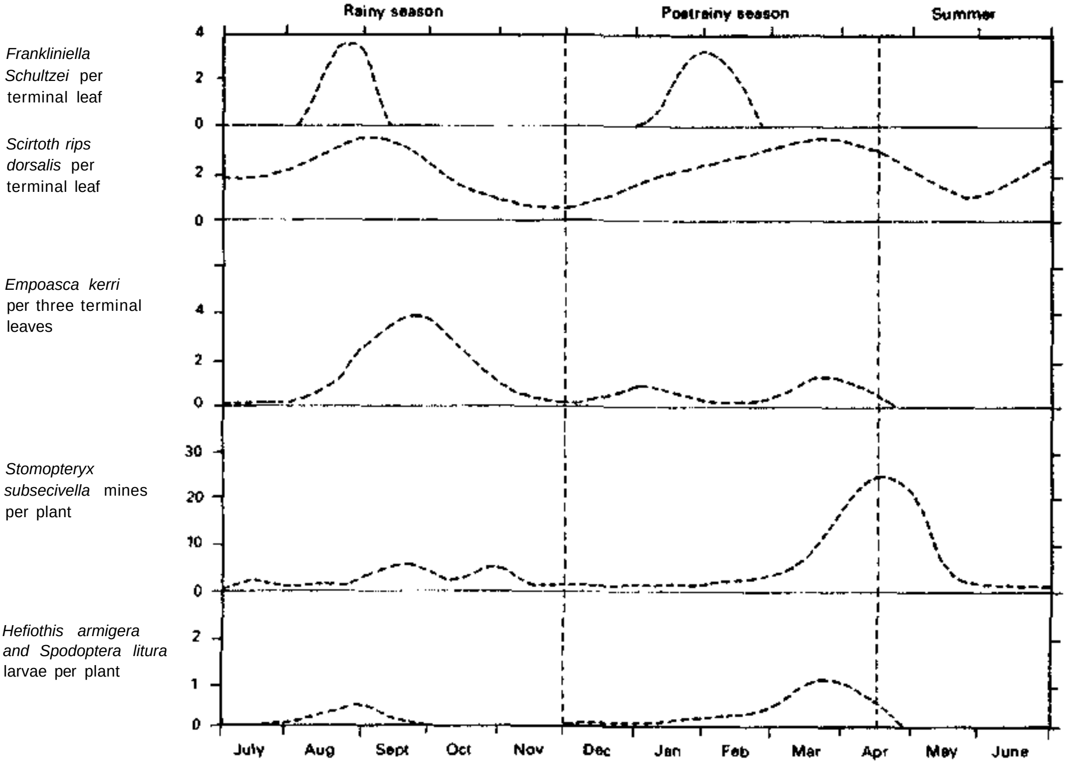


Figure 7. Major pests of groundnut at ICRISAT and their seasonal distribution.

Table 1. Major pasts of groundnut in India.

Year 1968[a]	Year 1979[b]
1. *Aphis craccivora*	1. *Lachnosterna consangumea*
2. *Aproaerema modicella {Stomopteryx subsecivella)*	2. *Aphis craccivora*
3. *Amsacta spp*	3. *Aproaerema modicella [Stomopteryx subsecivella)*
4. *Microtermes sp* and *Odontotermes sp*	4. *Amsacta albistriga*
	5. *Heliothis armigera*
	6. *Spodopetera litura*
	7. *Frankliniella schultzei*
	8. *Scirtothrips dorsalis*
	9. *Empoasca kerri*
	10. *Odontotermes obesus*
	11. Pod scarifying termites

a. Rai, B. K. 1976. Pests of oilseed crops In India and their control. Indian Council of Agricultural Research, New Delhi.
b. From field trips, literature, and correspondence.

there are many storage pests against which strict quarantine is in vogue, e.g., *Caryedon serratus, Trogoderma granarium.* The literature on groundnut insects from Commonwealth countries has been reviewed by Feakin (1973), for the USA by Bass and Arant (1973), and brief review of world pests by McDonald and Raheja (1980).

Studies on the Thrips Vectors of Bud Necrosis Disease

Thrips-borne bud necrosis disease caused by tomato spotted wilt virus is an important disease in India (Table 4) and ICRISAT (Table 5). A higher incidence was observed in the rainy season than in the postrainy season. A major epiphytotic occurred in 1979 when the infection level in unsprayed crops reached 80-95%. In the subsequent postrainy season less than 30% infection was recorded in unsprayed plots. Infection levels were lowest in crops sown in September and October and from February - May.

Table 2. Major Arthropod pesta of groundnut.[a]

	Regions where serious			
	Asia	Africa	Americas*	Australia
Sucking pests	*Aphis craccivora* *Empoasca kerri* *Scirtothrips dorsalis* *Frankliniella schulaei* *Caliothrips indicus*	*Aphis craccivora* *Empoasca dolichi* *Empoasca facialis*	*Empoasca fabae* *Ennoethrips flavens* *Frankliniella fusca*	*Austrasca* sp *Paraplobia* sp
Foliage feeders	*Spodoptera litura* *Heliothis armigera* *Aproaerema modicella* *Amsacta* spp	*Spodoptera littoralis*	*Spodoptera fungiperda* *Heliothis zea* *Feltia subterranea* *Anticarsia gemmatilis*	*Spodoptera litura* *Heliothis armigera*
Root feeders	*Lachnosterna* sp *Odontotermes* sp	*Hilda petruelis* *Microtermes* thoracalus		*Rhopaea magnicornis* *Heteronyx* sp
Pod feeders	*Microtermes* sp *Etiella zinckenella* *Elasmolomus sordidus*	*Microtermes* sp *Elasmolomus sordidus* *Peridontopyge* sp. *Caryedon serratus*	*Diabrotica undecim-punctata* *Pangeas bilineatus*	

a. Feakin, S. D. 1973. Pest control in groundnut, PANS Manual No. 2. COPR, London.
b. Mainly from Bass, M. H. and Aran!, F. S. 1973. Pages 383-428 *In* Peanuts-culture and uses.

The epiphytotics of the disease were associated with an abundance of the major vector *Frankliniella schultzei.* Investigations over the last three years have given some useful information:

1. The major vector, *Frankliniella schultzei* is a polyphagous thrips species. Populations of these thrips are lowest during summer months when they survive mainly in flowers of wild plants, cultivated summer crops, and ornamentals. *Cassia* sp, *Ageratum conyzoides, Tridax* sp, *Tribulus* sp, and *Calltropis* sp are some of the important weeds that harbor *F. schultzei* while greengram, black gram, and cowpea are important crop hosts, and marigold and chrysanthemums are important ornamentals. The thrips migrate to the crops which are sown early or to the weeds particularly *Cassia* sp and *Ageratum* sp that emerge soon after the first few monsoon showers. The populations build up on these hosts.
2. Migrations to groundnuts take place throughout the season but the large scale migrations occur in August and January. The thrips are carried on the prevailing winds and mainly at dusk. The disease infection is associated with immigrant thrips and secondary spread is not important Crops sown early largely escape from the disease (Fig. 2). The number of immigrant thrips is independent of the number of plants per unit area. A

higher plant stand results in a proportional decrease in the percentage of infected plants.

3. Early infection can lead to a total yield loss.

Infection during flowering and pegging stages results in substantial reduction in the numbers of flowers produced, the duration of

Table 3. Insect vactors of virus/mycoplasma diseases of groundnut.[a]

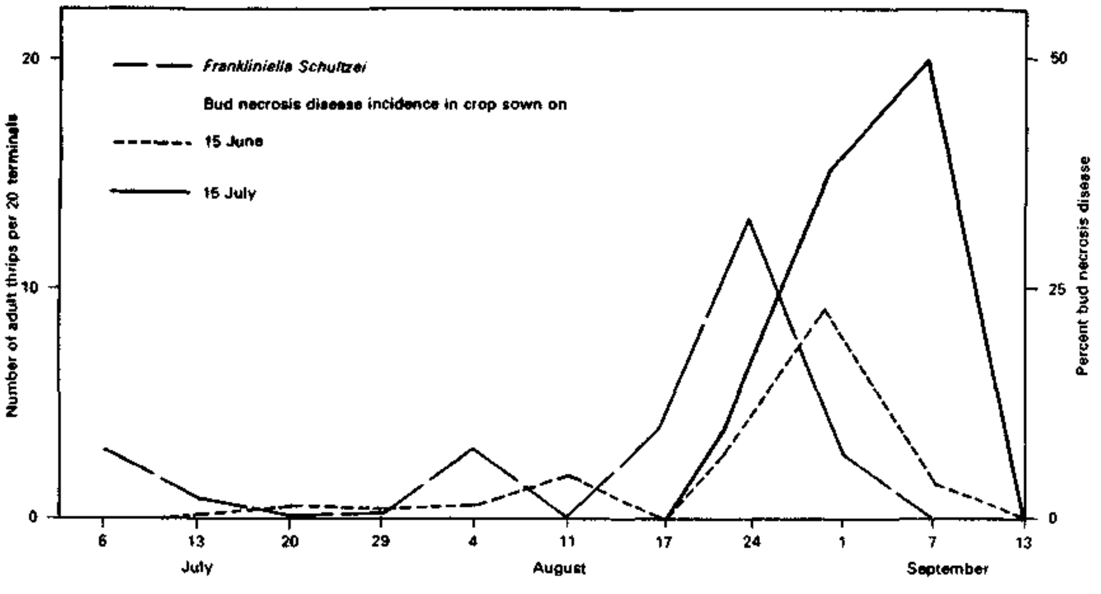
Diseases	Vectors	Regions
Rosette	*Aphis craccivora*	African continent
Peanut spotted wilt*	*Thrips tabaci*	Brazil, South Africa and Australia
Bud necrosis[b]	*Frankliniella*[c] *schultzei*	India
Yellow spot	*Scirtothrips dorsalis*[c]	India
Peanut mottle	*Aphis craccivora*	USA, China, Malaysia
Peanut stunt	*Aphis craccivora*	USA
Witches' broom	*Orosius* sp	Indonesia, Java
Rugose leaf curl	Not known	Australia
Marginal chlorosis	Not known	Papua New Guinea

a. Feakin, S. D. 1973. Pest control in groundnut, PANSManual No. 2. pp.197 - Centre for Overseas Pest Research, London.
b. Caused by tomato spotted wilt virus.
c. Amin, unpublished.

Table 4. Bud necrosis disease incidence on groundnut crops in India."

States	Region	Percent disease incidence	Year
Andhra Pradesh	Hyderabad	50-60	1978
		50-90	1979
	Coastal	0-5	1978
	Central	0-20	1979
Karnataka	Eastern	0-2	1978
	Southern	0-2	1978
Maharashtra	Eastern	0-5	1977
		0-5	1978
		0-5	1979
	Western	0-5	1977
		20-50	1980
Punjab		2-10	1977
Uttar Pradesh	Western	10-25	1978
		40-50	1979
		0-5	1980
Tamil Nadu	Western	15-20	1978
Gujarat	Saurashtra	0-10	1977
		0-5	1979
		0-5	1980
	North Eastern	0-5	1977
		20-60	1980

a. Estimates from field trips of Groundnut Program scientists of ICRISAT.



Date of observation

Figure 2. Effect of sowing dates on bud necrosis disease incidence, rainy season 1979.

Table 5. Incidence of bud necrosis disease on groundnut at ICRISAT Center.[a]

Year	Season	Percent disease incidence
1977	Rainy	50-60
	Postrainy	45-56
1978	Rainy	60-80
	Postrainy	45-55
1979	Rainy	90-100
	Postrainy	20-30
1980	Rainy	80-90

a. Figures for unprotected plots.

Table 6. Bud necrosis disease incidence in standard cultivars during different seasons in unsprayed plots.

	Percent disease Incidence		
Season	TMV-2	Robut 33-1	M-13
Rainy 1978[s]	86.8	33.6	60.6
Postrainy 1978*	48.5	28.2	37.0
Rainy 1979*	100.0	50.2	57.1
Postrainy 1979[c]	34.4	20.5	27.8
Rainy 1980[b]	93.8	35.3	40.8

a. Nonreplicated plots
b. 3 replications
c. 4 replications

the flowering period, peg length, and pod growth. Infection in the late stages reduces yield but to a lesser extent than does early infection.

4. Some cultivars appear less susceptible than others to field infection by the disease. Robut 33-1 is one such cultivar; it has a high yield potential and is commercially acceptable (Table 6).

5. Insecticides are generally not effective in reducing the disease incidence, unless applied twice a week throughout the season. Insecticide applications during thrips immigration, requiring 3-4 sprays, is as effective as 12 sprays applied at weekly intervals through the cropping season.

Based on the above findings, a combination of cultural and insecticidal methods was recommended to reduce damage from the disease. This consisted of: (1) early sowing (about 6 weeks before mass immigration of thrips), (2) higher plant density, (3) use of less susceptible cultivars, and (4) use of insecticides during thrips immigration. When all these practices are followed, substantial reductions in disease are obtained (Table 7).

Screening Germplasm for Pest Resistance

Four insects which are important worldwide and also occur at ICRISAT were selected for screening. The general screening procedure and objectives are given in Figure 3. The insects were thrips *(Frankliniella schultzei),* jassids *(Empoasca kerri),* and termites which caused pod scarification. Screening against aphids *Aphis craccivora* was done in the glasshouse because populations of aphids were not high enough in the field, except during June and the early part of July.

Thrips

Frankliniella schultzei infestation resulted in a scarring of foliage and distortion of leaf margins. An injury rating scale of 1-9 was used in initial trials (1 = no injury; 9 = distortion of margins). Promising lines were advanced and selections were made by visual scoring. The lower susceptibility of some of these lines and wild Arachis sp was confirmed in the laboratory by studying the fecundity of thrips (Tables 8a, 8b). Some ofthe promising lines have been sent to the USA and Brazil for further testing where *Frankliniella fusca* and *Enneothrips flavens* are important thrips pests.

Jassids

The major jassid pests of worldwide impor-

Table 7. Effect of various cultural practices and insecticldal regimes on the incidence of bud necrosis disease.

Sowing date	Plant density (000/ha, approx)	Cultivar	Basis for insecticide* treatment	Percent disease incidence
Early (15 June)	120	Robut 33-1 (T)	Thrips invasion*	28.5
			Weekly schedule	23.9
		TMV-2(S)	Thrips invasion	57.2
			Weekly schedule	60.4
	80	Robut 33-1(T)	Thrips invasion	36.1
			Weekly schedule	32.1
		TMV-2(S)	Thrips invasion	83.5
			Weekly schedule	81.3
Normal (15 July)	120	Robut 33-KT)	Thrips invasion	48.0
			Weekly schedule	59.8
		TMV-2(S)	Thrips invasion	92.5
			Weekly schedule	94.2
	80	Robut 33-KT)	Thrips invasion	51.1
			Weekly schedule	49.9
		TMV-2(S)	Thrips invasion	92.8
			Weekly schedule	94.8

T. Cultivar with tolerance to virus
S - Cultivar susceptible to virus
a. Dimetheate 400 ml/ha
b. Based on thrips catches In suction trap.

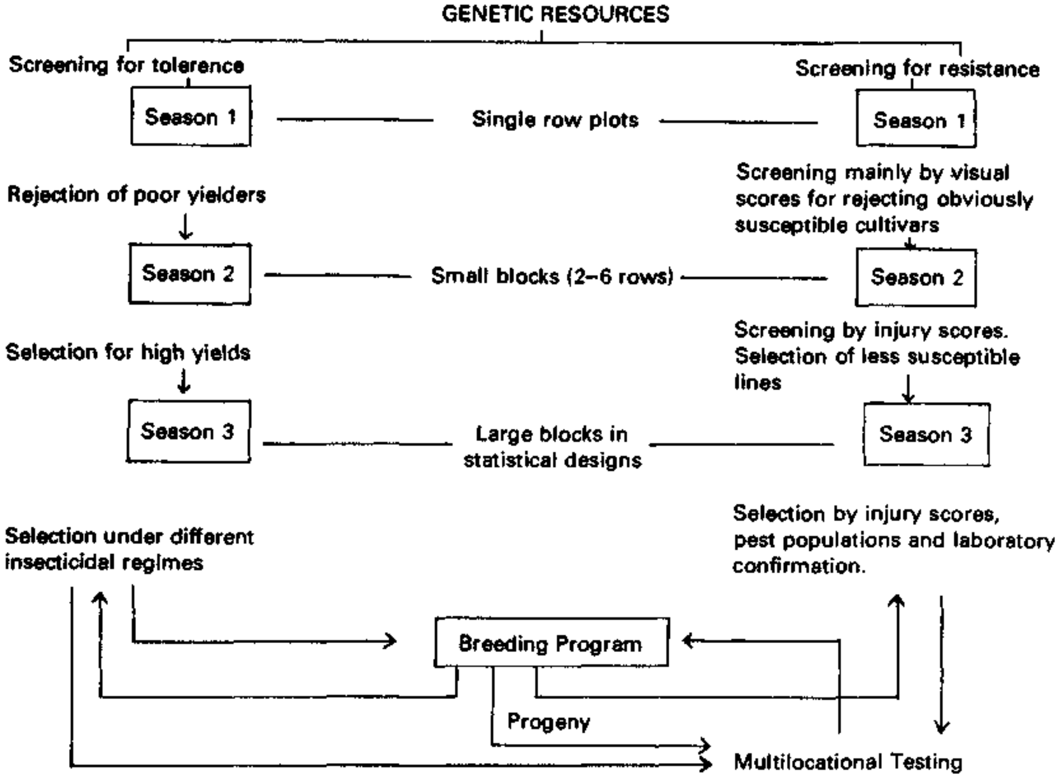


Figure 3. ***Basic scheme for identification and utilization of multiple pest resistanceltolerance.***

Table 8a. Fecundity of *Franklinlella achultzai* on some cultivars of groundnut.

Cultivar	No. eggs/female
NC Acc 2243	4.0
NC Acc 2232	4.8
NC Acc 2214	8.5
TMV-2	15.0

Table 8b. Fecundity of *Franklinlalla schulttml* on different *Arachis* species.

Species	No. eggs laid by 10 females in 24 hours
A. chacoense	0
A. glabrata	0
A duranensls	4
A. hypogaea (cv TMV-2)	44

tance belong to the genus *Empoasca.* In India and at ICRISAT, *Empoasca kerri* is the dominant species. Jassid injury results in tip yellowing and tip burn. Initial evaluations were done on the basis of the number of leaflets showing injury in 100 randomly collected leaflets, and subsequent evaluations by counting the number of jassid nymphs on three terminal leaves of 10 plants of individual accessions. Some promising lines with resistance to jassids are given in Table 9.

Recently, it has been observed *that Empoasca kerri* nymphs and adults cause irreversible wilting in seedlings. Further laboratory screening trials are planned.

Aphids

In preliminary glasshouse trials, five potted plants of each accession were subjected to high aphid attack by placing them near aphid-infested

Table 9. Some promising germplasm against *Empoasca karri.*

Cultivar	Growth habit	Average no of jassid nymphs[a]	Range*	Susceptibility
NC Acc 2214	Runner	2	0-5	R
" 2232	"	3	2-6	R
" 2243	"	5	3-13	R
" 2240	"	5	1-8	R
" 2242	"	5	3-10	R
" 343	"	13	9-20	MR
M-13	"	19	10-43	S
NC Acc 2462	Spreading bunch	15	10-19	MR
" 2477	" "	14	10-17	MR
Robut 33-1	" "	39	17-41	S
NC Acc 2663	Erect bunch	17	12-25	MR
" 2888	" "	15	9-20	MR
" 406	" "	14	5-19	MR
" 489	" "	15	11-18	MR
TMV-2	" "	31	15-57	S

a. Nymphs were counted from three terminal leaves each from ten plants. Average for three replications.
b. Number of nymphs per ten plants.
B = Resistant, MR - Moderately resistant, and S = Susceptible.

plants. The accessions showing more than 25 aphids per plant were rejected. The same procedure was applied to wild relatives of *Arachis.* One accession and several wild species that showed promise were tested in the laboratory. The results are shown in Table 10.

Termites

At ICRISAT, pod scarifying termites (species not identified) occur in pesticide-free Alfisols. A one-hectare plot where the termite population was high was set aside for screening. Termite build-up was encouraged by avoiding the use of pesticides and deep cultivation, and by supplying bamboo pegs for food during off seasons. The distribution of termites was studied by distributing bamboo pegs throughout the plot. Many pegs were attacked indicating a fairly uniform distribution of termites. The scarification of pods was studied in pods attached to plants as well as in detached pods. The

Table 10. Number of progeny produced by *Aphis cracclvora* on the detached shoots of two cultivars of *Arachis hypogaaa* and *Arachis chacoansa.*

Cultivars/ wild species	No. of trials	Total no. of adults used	Total no. of nymphs produced	Nymphs/ female
A. chacoense[a]	9	92	30	0.3
A. hypogaea:				
NC Acc 2214(8)	4	54	61	1.1
NC Acc 2214(7)	15	143	319	3.2
TMV-2[b]	10	94	1308	14.0

a. Resistant check
b. Susceptible check

technique of testing detached pods has been further improved by baiting the pods with a cowdung slurry which attracts termites. Such pods are buried near the bamboo pegs that have been attacked by termites. Some cultivars had much less termite damage than others. A few lines that showed very low damage for two seasons are being further tested.

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Session 6 — Groundnut Entomology

Discussion

M. V. R. Prasad

You have mentioned that the number of sprays for controlling bud necrosis disease were reduced from 16 to 4. How did you achieve this? How it is applicable to the farmers?

P. W. Amin

This was done by monitoring thrips using suction traps and applying the insecticidal sprays during thrips migration. Earlier we were using a fixed schedule of weekly sprays, and thus up to 16 sprays were applied. However, it is difficult for farmers to know when the thrips are invading the crop. Thus it is advisable to follow early sowing and to use less susceptible cultivars.

S. M. Misari

You have mentioned that pegs were also infested by aphids. What effect does this have on pegs?

P. W. Amin

Usually aphids infest groundnuts in late August and on an average seem to cause 15% damage through desapping of plants and affecting the growth.

S. M. Misari

What is the nature of damage? Are the ovaries aborted due to aphid infestation or the pod formation occurs but leads to decreased shelling percentage?

P. W. Amin

This has not been specifically investigated.

N. D. Desai

Do you have any program for screening germplasm for resistance against white grubs? And can you suggest any good chemical control for white grubs?

P. W. Amin

Groundnut crop at ICRISAT is not infested by white grubs and therefore we are not working in this area yet. But, several scientists in India are working on the control of white grubs.

D. R. C. Bakhetia

We have been working on the control of white grubs in Punjab. We found that the application of granular insecticides such as isofenphos and carbofuran was very effective.

P. W. Amin

White grubs are polyphagous and it may be difficult to find sources of absolute resistance. However, it should be examined.

D. R. C. Bakhetia

In the screening trials the criterion that you have used, percent plant damage, to assess the resistance of a cultivar may not be very accurate. Is it necessary to take into consideration the different levels of damage under specific environmental conditions?

W. V. Campbell

It is important to use the extent of damage as a criterion because it shows a sum total of all factors, e.g., insect number, cultivar, environment, etc.

T. P. Yadav

You rely mainly on natural infestation for screening. Is it acceptable?

P. W. Amin

We do prefer screening under field conditions; however, we also do laboratory testing for locating sources of resistance as in the case of aphids.

W. Reed

Assessment of damage in the field is a straightforward and reliable criterion.

Session 7

Groundnut Pathology

Chairman: J. S. Chohan

Rapporteurs: I. S. Campbell
A. B. Mohammad
D. J. Nevill
A. K. Singh

Cylindrocladium Black Rot (CBR) Disease of Peanut *(Arachis hypogaea)*

Marvin K. Beute*

Cylindrocladium black rot (CBR) of peanut [*Arachis hypogaea* L.) caused by *Calonectria crotalariae* (Loos) Bell & Sobers *(Cylindrocladium crotalariae* [Loos] Bell & Sobers), was first described as occurring in Georgia, USA in 1965 (Bell and Sobers 1966). It was reported to occur in South Carolina in 1968 (Garren et al. 1972) and North Carolina and Virginia in 1970 (Garren et al. 1971, Rowe et al. 1973). CBR was found *on* peanut in Japan in 1970 and was subsequently regarded as a major disease of peanut in 1971 (Misonou 1973). Although CBR now occurs in certain areas of Alabama and Florida as well as Georgia and South Carolina, CBR is only considered a disease of serious economic importance in the USA in North Carolina and Virginia.

The effect of CBR on peanut is reported to vary from debilitative to destructive depending on host resistance, environmental conditions, and inoculum density in soil. First symptoms of CBR in the field ranged from chlorotic, stunted plants to slight wilting of larger plants (Rowe et al. 1973). In newly infested fields symptoms were usually confined to one or several irregular areas within a field. In fields with a prior history of CBR, diseased plants were evenly distributed, giving a ragged appearance to an entire field. Tap roots of chlorotic, stunted plants were severely blackened and usually severed by decay at the junction of the hypocotyl and tap root, approximately 4-6 cm below the soil surface. Lateral roots on susceptible peanuts were either blackened or completely severed 1-2 cm from the tap root. Diagnosis of CBR was aided by the abundant production of red perithecia which occur at the base of infected stems under moist conditions in fields. In areas under drought stress or in fields with severely stunted plants, perithecia were observed sparingly, if at all. Perithecia were found on intact stems, pegs, and pods on and under the soil surface, but never *on* decaying plant debris in proximity to infected tissues.

Extensive efforts to develop chemical control for CBR have not been productive (Rowe et al. 1974). Resistance to CBR in peanut genotypes was reported in 1975 (Wynne et al. 1975), but progress in development of resistant cultivars was initially hampered by lack of knowledge concerning the biology of *C. crotalariae* and epidemiological aspects of the disease.

Biology

Fungus Reproduction

C *crotalariae* produced conidia, ascospores and microsclerotia (ms) in culture and infected plants (Jackson and Bell 1969). Conidia were rarely observed under field conditions but were capable of causing necrosis of roots and pods of peanut (Beute and Rowe 1973). Conidia were not considered to be important in the spread of CBR because of their infrequent occurrence in the field and limited viability due to a high susceptibility to desiccation.

Perithecia of *C. crotalariae* were reported to form abundantly on infected stems, pegs, pods, and hypocotyls of peanut at the soil line if sufficient moisture was present (Rowe and Beute 1975). Under high moisture conditions ascospores could be detected in the field oozing from 2-3 week old perithecia in a cream to bright yellow, viscous droplet that clings to the tip of each perithecium. Spores discharged in

* Professor of Plant Pathology, North Carolina State University, Raleigh, North Carolina 27650, USA.
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this manner were presumably dispersed by rain-splashing.

In histological studies of inoculated peanut stems, perithecia with a few nearly mature asci were observed after 13 days and fully mature asci containing mature ascospores were commonly observed 2-3 weeks after inoculation. Ascospores were forcibly ejected from a single perithecium for 2-3 weeks after maturity, prior to being exuded in a viscous ooze. Development and discharge of ascospores seemed to be more closely related to water relations of the fungus than to temperature. Viability of ascospores was similar to conidia, i.e., they were extremely sensitive to desiccation. The most likely role of ascospores in CBR epidemiology was suggested to be short-distance, within-field spread of the disease.

C. crotalariae was shown to produce microsclerotia (average size = 53 x 88 *µm)* abundantly in decaying peanut tissue. Microsclerotia (ms) first appeared in infected roots 55 days after inoculation in the field and numbers increased rapidly after 90 days (Rowe et al. 1974); Microsclerotia formed within CBR-infected peanut roots were shown to be effective long term survival propagules. As disintegration of root tissues progresses, the propagules are released into the soil, and spread locally during tillage and aqueous runoff (Krigsvold et al. 1977). Aerial dissemination of ms of *C. crotalariae* in windblown plant parts was observed. Root fragments containing ms were found in debris expelled from peanut combines operating in infested fields in North Carolina. Fragments large enough to carry microsclerotia were trapped 225 m downwind from combines on relatively calm days. Although it was considered unlikely that airborne ms could explain the apparent rapid spread of CBR across the southeastern United States, once the fungus has become established in a locality, airborne ms could be effective in regional dispersal.

Infection Process

Early stages of pathogenesis of peanut by *C. crotalariae* involved the formation of infection cushions on the epidermis, followed by complete hyphal colonization of the cortex (Johnston and Beute 1975). Collapse of the epidermal cells beneath infection cushions and necrosis of surrounding cortical cells appeared to be a prerequisite for fungal invasion, suggesting the possible involvement of phytotoxins. Natural periderm formation appeared to effectively limit *C. crotalariae* growth to the cortex under certain circumstances and plants with only cortical decay were capable of recovery.

A histological study on the nature of resistance to CBR in peanut germplasm suggested the involvement of efficient formation of additional effective periderms in the resistance mechanism(s). Susceptible peanut cultivars sustained more breachments of the original periderm per length of taproot tissue than did resistant lines. Susceptible cultivars were also less efficient in formation of additional (walling-off) periderms than resistant lines, and the additional periderms were ultimately less effective. Resistant lines were observed to initiate phellogen in the pith and essentially slough an entire quadrant of infected taproot. Emerging fibrous roots disrupted the protective periderm cylinder of the peanut taproot and provided favorable infection courts of the fungus. Primary branch roots of resistant genotypes were capable of periderm formation when infected by *C. crotalariae.* No periderm was observed in fibrous roots of susceptible cultivars. Microsclerotia were found only in the cortex of necrotic taproot and fibrous roots.

Host Renge

All legumes tested to date appear to be hosts for *C crotalariae* (Mesonou 1973). A partial list of susceptible hosts included peanut, clover, alfalfa, *Crotalaria,* soybean, lupine, bean, and pea. Considerable variability in susceptibility was reported to exist between host species, e.g. soybean was much more resistant to C. *crotalariae* than was peanut. Certain non-leguminous crops (tobacco and cotton) normally included in peanut rotations in North Carolina have also been shown to be susceptible to *C. crotalariae* when grown in fumigated soil in greenhouse tests (Rowe and Beute 1973), but no increase in inoculum occurred under field conditions (Phipps and Beute 1979). Corn and small grains appeared highly resistant to *C. crotalariae* and should be useful as rotational crops in infested fields to minimize inoculum increase (Phipps and Beute 1979; Rowe and Beute 1973).

Inoculum Quantification Techniques

Isolation Procedure

Development of a semi-selective isolation medium was essential for the study of the ecology of soilborne pathogens. Repeated attempts to quantify ms from peanut soil using procedure and medium reported for quantitative isolation of other *Cylindrocladium* species were unsuccessful. Phipps et al. (1976) developed the following medium for use with the elutriation procedure described below:

Basal constituents of the isolation medium included glucose, 15 g; yeast extract, 0.5 g; KNOa, 0.5 g; KH2PO4,1.0g;MgSC<4.7H2O, 0.5 g; agar, 20 g; and deionized water, 1 liter. After autoclaving, 200 ml aliquots of the medium were amended with Tergitol NP-10 (Union Carbide, Atlanta, Ga.), 0.21 ml; thiabendazole, 0.2 mg; chloramphenicol, 20 mg; and chlorotetracycline, 8 mg. Tergitol was added directly to the medium, whereas the following amounts of the other agents were added from stock solutions: thiabendazole (16.6 mg of 60% wettable powder formation suspended in 50 ml water), 1 ml; chlorotetracycline (0.4 g dissolved in 50 ml 50% ethanol), 1 ml. Tergitol was used to suppress growth of fungi (Krigsvold et al. 1977) and lower the surface tension of the medium which permitted the pouring of a thin agar layer in each plate. Thiabendazole served primarily to inhibit growth by certain undesired fungi (Hadley et al. 1979), and the antibacterial compounds, chloramphenicol and chlorotetracycline, prevented development of bacterial colonies.

Plant debris larger than 425 µm and organic matter 38-425 µm were eluted from soil and collected on 425 µm (35 mesh) and 38 µm (400 mesh) sieves, respectively, using a semiautomatic elutriator designed for extracting nematodes from soil (Byrd et al. 1976). Plant debris collected on the 425 *µm* sieve was blended for 2 minutes in 200 ml of water to release bound ms. Each fraction was exposed for 1 minute to 0.25% NaClO prior to enumeration using a selective medium. Both fractions were suspended in approximately 160 ml of water using a mechanical stirrer. Quantitative assays for ms in the suspended fractions were made by pipetting 5 ml subsamples into 100 ml of test media at 47°C. The media was then swirled immediately and dispensed into 10 petri dishes. Plates were incubated under continuous light at room temperature (25-28°C) until colonies developed (5-8 days) and readings were taken.

An alternativeCBR medium wasdeveloped in Virginia to be used with a wet sieving procedure similar to that of Krigsvold and Griffin (1975). The new selective medium (Griffin 1977), designated sucrose-QT medium had thefollowing composition: 70 g of sucrose (to give an osmotic potential of about-10 bars), 0.4 g of DL-tyrosine, 1 g KH2PO4, 0.5 g of MgSC$_4$7H_2O, 50 mg of streptomycin sulfate, 50 mg of chlorotetracycline HCl, 4 g oxgall, 75 mg of pentachloronitrobenzene (PCNB), 2.3 mg of 2-(4-thiazolyl)-benzimidazole (thiabendazole, TBZ), 750 mg of dimethyldicoco ammonium chloride (added as 1.0 ml of Adogen 462, Ashland Chemical Co., Columbus, OH), 400 mg of methyldodecylbenzyltrimethyl ammonium chloride, 100 mg of methyldodecylxylenebis (trimethyl ammonium chloride), added as 1.0 ml of Hyamine 2389, a mixture of the two quaternary ammonium compounds (Rohm and Haas Co., Philadelphia, PA), 20 g of agar, and 1 liter of water. The medium was adjusted to pH 4.0.

Environmental Effects

Field observations in Georgia indicated that CBR was most severe under conditions of excessively high soil moisture followed by extreme moisture stress to infected peanuts, both with concomitant high soil *temperature* (Bell 1967). Inoculation tests in North Carolina under these conditions were inconsistent, suggesting that both moisture and temperature could be limiting factors in disease development. Knowledge of conditions conducive for disease initiation and development was required for effective screening of plants in a breeding program and subsequent selection of resistant genotypes.

In greenhouse tests using 10 ms/g soil, root rot on peanut was most severe when plants were grown in wet soil (field capacity) at 25°C (Phipps and Beute 1977). Soil temperatures of 20° and 30°C resulted in moderate and low root rot severities, respectively, in infested wet soil. At each temperature, a lesser degree of root rot resulted in infested, dry soil. Biopsied tissues from plants indicated that more root infection by *C crotalariae* occurred in infested, wet soil at all temperatures. In experiments using naturally-infested field soil (1.1 to 2.0 ms/g soil) disease severity was similar to that observed in artificially infested soil. Root rot was most severe in wet soil at 25°C. At each temperature, root rot was less severe in dry soil. It was observed in North Carolina that high rainfall early in the growing season was necessary for severe root rot since most peanut field soils are well drained and sandy in texture. A subsequent period of moisture stress was thought to enhance the expression of above ground symptoms due to the absence or limited number of functional roots after infection and root rot.

The survival of C. *crotalariae* ms in soil did not appear to be affected by moisture or temperature during the growing season (Phipps and Beute 1979). Incubation of soil samples in Virginia at temperatures simulating winter conditions (6°C), however, decreased germinability of *C. crotalariae* ms (Roth et al. 1979). Incubation of naturally-infested soil under field conditions from October to February (1978) indicated that a similar low-temperature-induced phenomenon exists in nature. When soil samples were transferred to 26°C for 4 weeks, the low temperature effect was partially reversed.

Population Dynamics

Microsclerotia were considered to be primary survival propagules for C. *crotalariae* in field soil. Development of semi-selective media with utilization of wet sieving and/or elutriation techniques for extraction of ms from soil provided the opportunity for enumeration of populations of *C. crotalariae* in soil over time and cropping sequence. Fallow soil, nonhost rotational crops and CBR-resistant peanut germplasm were compared with susceptible peanut cultivars for effect on ms populations in field plots.

Only slight reductions in ms densities were detected in fallow soil and soil planted to nonhost crops each year over two years testing (Phipps and Beute 1979). Incorporation of crop residues (both host and nonhost) in soil after harvest did not change ms densities after 5 months. After one growing season, populations of ms at harvest were 9.6, 5.2, and 1.6 times preplant densities in soils planted to the CBR-susceptible cultivar Florigiant, CBR-resistant Argentine and NC 3033, respectively. Microsclerotia densities increased 3.7 times in soil planted to soybean.

Disease severity in the field was shown to reflect sensitivity of susceptible and resistant peanut cultivars to inoculum densities of *C. crotalariae* ms in soil (Phipps and Beute 1977). CBR-susceptible cultivars were severely diseased in soils having 0.5 ms/g soil or greater inoculum densities if the environment were conducive for infection. Resistant cultivars, however, grew and survived in soils having as high as 1000 ms/g soil. Resistant cultivars did sustain moderate to severe root rot and extensive root infection when inoculum densities were greater than 50 ms/g soil.

Nematode Interactions

Although a precise relationship had been described between inoculum density and disease severity for both CBR susceptible and resistant peanuts, response of peanut genotypes in infested fields was frequently different from that predicted on the basis of ms densities. Nematode populations were shown to be a major factor in modification of the disease incidence x inoculum density relationship.

Sequential inoculation with nematodes and C. *crotalariae* increased CBR severity on both CBR-susceptible (Florigiant) and CBR-resistant (NC 3033) peanuts in greenhouse tests. The ED_{50} values (microsclerotia/cm^3 soil to give 50% diseased plants) for Florigiant and NC 3033 were decreased from 0.35 and 17.5, respectively, in fungus-only soil to 0.05 and 1.6, respectively, in soil containing *Meloidogyne hap/a* (Northern root knot nematode) and the fungus. Two populations of root knot nematode *M. arenaria* (Race 2) which do not reproduce on peanut, also enhanced CBR on NC 3033 in greenhouse tests. Correlations between populations of *M. hapla* and *C. crotalariae* with CBR severity weresignificant in field tests conducted from 1976-1978. In greenhouse tests the EDeo values for Florigiant were decreased from 0.42 in fungus-alone soil to 0.05 in soil containing *Macroposthonia ornata* (ring nematode). *M.*

ornata reproduced on NC 3033 in similar tests but did not enhance CBR severity on NC 3033. In microplot tests in the field where M. *ornata* was used in combination with *C. crotalariae* on both cultivars, more diseased plants occurred with *M. ornata* + *C. crotalariae* than with either pathogen alone on Florigiant but not on NC 3033, although the nematode reproduction factor was higher on NC 3033 than on Florigiant.

Fungal Genetics

Evaluation of peanut germplasm in field plots over several years indicated that some genotypes did not perform consistently at different locations (Wynne et al. 1975). Extreme variability in CBR severity under field conditions and the prevalence of the sexual stage (perithecium) of *C. crotalariae* suggested the possibility of physiological specialization in the fungus (Rowe and Beute 1975). All isolates of the fungus tested prior to 1974, regardless of diverse geographic origins, elicited the same general pattern of host response on six peanut varieties chosen to represent a range of CBR resistance. A wide range of virulence among isolates did appear to be inherent in the fungus. This variability was not related to linear growth rate in culture nor was it correlated with geopraphic distribution of the pathogen.

A subsequent test was initiated to re-evaluate the variability in virulence of *C. crotalariae* isolates by using CBR resistant and susceptible peanut genotypes as host differentials to determine the effect of resistant host plant selection on degree of differential interactions between host and pathogen isolates (Hadley et al. 1979). The mean virulence of isolates of C. *crotalariae* from susceptible peanut cultivars did notdifferfrom that of isolates from resistant peanuts when selection pressure was applied only for one growing season. Differences were noted, however, among isolates from resistant peanuts when ranked for virulence. Isolates from the resistant peanuts showed the highest level of virulence on resistant peanut, but were no more virulent on the susceptible peanut than isolates originating from susceptible peanuts. According to a pathogen virulence model, isolates originated from susceptible peanut had about eight times more general virulence than specific virulence. In only one cropping cycle of CBR-resistant peanuts, specific virulence increased fourfold in the previously nonselected pathogen populations. It was suggested that a potential exists for change in fitness in *C. crotalariae,* even though corresponding resistance in the host appears to be quantitatively inherited.

A later experiment indicated that information for individual isolates may not be representative of phenomenon in naturally occurring heterogenous fungus populations. Disease readings in the field for composites of isolates (chosen as specific for susceptible peanuts or specific for resistant peanuts) suggested that an interaction and/or recombination may be occurring among composited isolates of *C. crotalariae* during the growing season.

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Sclerotinia Blight of Groundnut — A Disease of Major Importance in the USA

D. Morris Porter*

A disease of the groundnut {*Arachis hypogaea* L.) caused by a *Sclerotinia* sp was reported first in Argentina in 1922 (Marchionatto 1922). In 1933, *Sclerotinia* spp were reported attacking groundnuts in China (Chu 1933) and in 1948 S. *minor* Jagger was the causal agent of a serious groundnut disease in Australia (Anon. 1948). A root and pod rot disease of groundnuts caused by *S. minor* and *S. sclerotiorum* (Lib.) de Bary was reported again in Argentina in 1960 (Frezzi 1960). A wilt of peanut caused by S. *miyabeana* Hanzawa was reported in Taiwan in 1972 (Jan and Wu 1972). *Sclerotinia* was observed first on peanuts in the United States in 1971 (Porter and Beute 1974) and has since become widespread in Virginia, North Carolina and Oklahoma. In fact, it is nowthe most serious disease problem in Virginia (Powell etal. 1976; Porter etal. 1977). *Sclerotinia* blight has not been observed in Georgia, Florida, Texas or Alabama where groundnuts are grown commercially.

Symptoms

The first symptom of *Sclerotinia* blight is usually the sudden wilting of a lateral branch of a groundnut plant (Porter and Beute 1974). Infection of the main branch usually occurs by growth of the fungus into the main branch from an infected lateral branch. The foliage on infected branches becomes chlorotic, turns dark brown and withers, followed by death and defoliation of that branch. These symptoms result in a blight of the foliage characteristic of *Sclerotinia* disease (Fig.1-A). Once infection has been initiated and environmental conditions conducive to disease development persist, white, fluffy mycelium (Fig. 1-B) will develop on the diseased tissue.

The infection process appears to be both intra- and inter-cellular with enzymatic activity concentrating in the middle lamella, resulting in tissue shredding. Shredding of the branch tissue is a characteristic sign of *Sclerotinia* blight (Fig. 1-C). Shredding of the peg tissue also occurs and results in severe pod shed (Fig. 1-D). Branch lesions are initially light tan and elongated along the axis of the branch (Fig. 2-D). As lesions develop and age, they become dry and dark brown with a distinct demarcation zone separating infected and healthy tissue. Black, irregularly shaped sclerotia (0.02-3.0 mm) are produced abundantly on the outside of all infected groundnut plant parts including the branches (Figs. 2-B, 2-D), pegs, and shells, and on the inside of branches, tap roots and under the epidermal layers of the pods (Fig. 2-B) and in the pod, both on the pod interface and on the seed (Porter and Beute 1974).

Causal Organism

Speciation of *Sclerotinia* usually is based in part on host range and size of sclerotia. *Sclerotinia* spp including both small and large sclerotium-producing isolates, attack a wide host range of crops (Abawi and Grogan 1979). The impracticality of separating *Sclerotinia* species based on sclerotia! size was demonstrated by Purdy (1955) who showed thatthe small sclerotial type

* Plant Pathologist, AR, SEA, U.S. Department of Agriculture, Suffolk, Virginia 23437, USA.
Cooperative investigations of Agricultural Research, Science and Education Administration, U.S. Department of Agriculture, and Research Division, Virginia Polytechnic Institute and State University, (VPI & SU). Contribution No. 414, Department of Plant Pathology and Plant Physiology, VPI & SU, Blacksburg, USA.

This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation by the USDA nor does it imply registration under FIFRA.

(*S. minor),* the intermediate sclerotial type (*S. trifoliorum* Eriks.) and the large sclerotial type (*S. sclerotiorum)* often produced sclerotia of intermingling sizes among groups. Purdy, therefore, synonymized several species of *S. sclerotiorum.*

In Virginia, the species of *Sclerotinia* pathogenic to groundnuts produced small sclerotia ranging in size from 0.02-3.0 mm which were similar to those described by Jagger (1920). Both small and large sclerotium-producing isolates of *Sclerotinia* were found in groundnut fields where *Sclerotinia* was prevalent in Oklahoma (Wadsworth 1979). Apothecia of *S. minor* and *S. sclerotiorum* have been observed in Oklahoma but not in Virginia and North Carolina. To resolve the taxonomic position of the genus *Sclerotinia,* Kohn (1979) used several taxonomic characters including the development of a free, discreet sclerotium, absence of functional conidia, production of ascospores and orientation of the cells in the outermost layer of the apothecium to delineate three species of *Sclerotinia :-S. sclerotiorum, S. minor* and *S. trifoliorum.* Using a neotype specimen obtained from a diseased groundnut showing symptoms of *Sclerotinia* blight in a field in Virginia in 1974, Kohn identified the causal organism as *S. minor.*

Disease Cycle and Epidemiology

Infection of groundnuts by *S. minor* is myceliogenic, that is, it originates from mycelia of germinating soil-borne sclerotia (Beute et al. 1975; Wadsworth 1979). *Sclerotinia minor* usually invades groundnut tissue including branches, leaflets and pegs at points of soil contact. In Oklahoma, Wadsworth (1979) found a few infection sites some distance from soil contact points and suggested the possibility of ascospore involvement in disease development.

Under moist conditions defoliated groundnut leaflets or senescing leaflets still attached to the plant, but in contact with the soil, are easily colonized by mycelia from germinating sclerotia of *S. minor.* This food base enhances disease development but is not a necessary prerequisite for infection since infection sites commonly appear on branches in contact with the soil but without the presence of such food bases. For some diseases caused by *Sclerotinia* spp a source of nutrition is a prerequisite for penetration and infection of host tissue (Purdy 1958). Volatile stimulants from remoistened leaves greatly influenced the germination of sclerotia of 5. *minor* over a wide pH range, with optimum germination occurring at pH 6.5 (Hau et al. 1980).

The incidence and severity of *Sclerotinia* blight can be detected by aerial infrared photography (Fig. 1-E). *Sclerotinia* blight of groundnut, characterized by a unique spectral signature, can be detected on infrared imagery taken at altitudes of about 20 000 meters, but lower altitudes (3500 meters) provided better resolution for detailed study (Powell et al. 1976). The severity *of Sclerotinia* blight as detected in infrared imagery can be correlated with actual pod losses in the field (Porter et al. 1977). Areas on infrared photographs that were interpreted as slightly, moderately or severely damaged by *S. minor,* had groundnut pod losses due to the disease which were 2, 5, and 7 times greater, respectively, than nondiseased areas. In severely damaged fields, groundnut losses due to S. *minor* often exceed 50% of expected yield.

Infection by most *Sclerotinia* species is generally dependent upon low temperatures (10-25℃) and high soil moisture (Abawi and Grogan 1979). The severity of *Sclerotinia* blight of groundnuts in Virginia can be correlated with temperature (D. M. Porter, unpublished data). The number of days the mean temperature dropped to 21℃ and below during July, August and September in Virginia was 23,13,26,12,18 and 21, respectively, in 1974 through 1979. *Sclerotinia* blight was more severe in years having the greater number of cool days. It was most severe in 1974 and 1976 and almost nil in 1975. The disease was much widely spread in 1976 than in 1974. Disease losses were minimal in 1977, but were severe in 1978 and 1979. Patterns of disease severity during each year were verified with infrared photography (Cobb et al. 1977).

Mechanically injured groundnut foliage is very susceptible to colonization by S. *minor* (Porter and Powell 1978). Groundnut plants, injured by tractor tires during pesticide application, were colonized by *S. minor* at twice the frequency of noninjured plants. At one location where *Sclerotinia* blight was severe, 152% in-

Figure l. *A, groundnut field exhibiting typical symptoms of* Sclerotinia *blight; B. characteristic white, fluffy mycelium growing on infected groundnuts; C. typical shredding of plant tissue following colonization by* S. minor; *D, groundnut pods remaining in soil following harvest of plants severely infected with* S. minor; *and E, infrared photograph showing distribution of symptoms of* S. minor *in a groundnut field (red color = healthy plants and gray color represents diseased areas).*

crease in disease was noted in plants injured by tractor tires. Pod yield losses can also be correlated with plant injury. At two locations where *Sclerotinia* was severe, yields averaged 1736 kg/ha in injured rows and 2658 kg/ha in non-injured rows. Aerial infrared photographs readily show *Sclerotinia* blight in row middles injured by tractor tires (Fig. 2-A).

From studies on the ecology and the survival of sclerotia of *S. minor* it was found that sclerotia are produced abundantly on infected groundnuts. Sclerotial populations, recovered by sieving (Fig. 2-E), were 10 times greater in soil from severely infected areas of the field than from slightly infected areas (Porter et al. 1977). Sclerotia *of S. minor can* be observed on groundnut debris 6 months following harvest (Fig. 2-B). At time of seeding, sclerotial counts made from the top 2.5 cm of soil may be less than one sclerotia per 100 g soil (D. M. Porter, unpublished data). Immediately after harvest and following a severe infection by *S. minor,* sclerotial counts may exceed 50 sclerotia per 100 g soil from the top 2.5 cm soil layer.

Sclerotia can be recovered from thetop 20 cm of soil from fields having histories of *Sclerotinia* blight. Sclerotia of *S. minor* can survive in the soil for several years. In a field having a history of *Sclerotinia* blight, but planted to a nonhost cropforthreegrowing seasons, sclerotial populations declined only slightly and sclerotia germinated readily.

Many genera of fungi can be isolated from sclerotia of *S. minor.* However, the mycoflora of surface-sterilized sclerotia is usually dominated by species of *Trichoderma* which can be readily observed on the sclerotia in groundnut pods left in the field following harvest.

Sclerotinia minor can be transmitted by seed, but at a low frequency (D. M. Porter, unpublished data). Pods obtained from groundnut plants exhibiting severe symptoms of *Sclerotinia* blight were shelled, disinfected for three minutes and plated on several media. After incubation for 14 days, *S. minor* grew from less than 1% of the seed.

Soybean *{Glycine max* L Merr.) plants are susceptible to *Sclerotinia* spp. Both *S. minor* and *S. sclerotiorum* were isolated from diseased soybean plants growing in close proximity to groundnut fields (Phipps and Porter 1977). In greenhouse inoculation tests, both species were pathogenic to groundnuts. However, S. *sclerotiorum* has not been observed in Virginia but has been observed in Oklahoma (Wadsworth 1979).

Control

Differences in susceptibility of 36 groundnut cultivars, breeding lines and plant introductions to *S. minor* ranged from slight to severe (Porter et al. 1975). Florigiant, a cultivar currently planted on over 90% of the groundnut acreage in Virginia and North Carolina, was the most tolerant to *S. minor* of any cultivar tested. A North Carolina breeding line, 17165, and PI 343392 were more tolerant than any of the other lines tested. In a 3-year study under severe disease pressure in Virginia, PI 371521 and a breeding line, Virginia 71—347, were not immune to *S. minor* but exhibited significantly fewer symptoms of this disease than other cultivars, breeding lines and plant introductions screened (Coffelt and Porter 1980).

Botran (2, 6-dichloro-4-nitroaniline) provided partial control of *Sclerotinia* blight in groundnuts in Virginia and North Carolina (Beute et al. 1975). Benomyl (methyl 1-[butylcarbamoyl]-2-benzimidazolecarbamate), applied at high rates (4.48 and 6.62 kg a.i./ha) provided some control of *Sclerotinia* blight (Porter 1977). Procymidone (3-[3, 5-dichlorophenyl]-1, 5-dimethyl-3-azabicyclo[3.1.0]hexane-2, 4-dione), a Dupont experimental fungicide (DPX 4424) not registered for use on groundnuts and recently withdrawn from testing by the company, provided almost complete control of *Sclerotinia* blight (Porter 1980b). Pod yields in plots treated with procymidone (0.56 kg a.i./ha x four applications applied directly to the groundnut foliage as a broadcast spray) averaged 4904 kg/ha compared to 2603 kg/ha in the untreated plots (Fig. 2-C). Fungicides closely related to procymidone such as Ridomil (methyl D, L-N-[2, 6-dimethylphenyl]-N-[2-methoxyacetyl]-alaninate) and Rovral (1-isopropyl-carbamoyl-3[3-5 dichlorophenyl] hydantoin) were not effective against *Sclerotinia* blight (Phipps 1980). The use of metham (sodium N-methyldithiocarbamate) applied in irrigation water for control of *Sclerotinia* blight was recently demonstrated (Krikun et al. 1980).

Sclerotinia blight of groundnuts can be suppressed with dinitrophenol herbicides (Porter and Rud 1980). Oinoseb (2-sec-butyl-4,6-dinitrophenol) and naptalam (sodium N-1-naphthylphthalamate) + dinoseb applied broadcast at 0.84 kg/ha significantly reduced the severity of *Sclerotinia* blight and increased groundnut yields. Crop value was increased by about 18% in herbicide-treated plots.

Plant nutrients such as zinc and copper sulfates applied to the groundnut foliage significantly suppressed the development of *Sclerotinia* blight (Hallock and Porter 1979). These same nutrients applied to the soil had no effect on disease suppression. Several other plant nutrients, including N, K, *Ca,* Mg, P, Mn, Fe, B, S and CI, had little or no effect on disease.

Some fungicides currently recommended as standard production practices to control leaf spot *(Cercospora arachidicola* Hori and *Cercosporidium personatum* [Berk, and Curt.] Deighton) of groundnut enhance the severity of *Sclerotinia* blight. In fungicide screening tests conducted in Virginia in 1974, the severity of *Sclerotinia* blight was significantly greater in plots treated with chlorothalonil (tetrachloroisophthalonitrile) than in nontreated plots (Beute et al. 1975). In later studies, chlorothalonil applied at rates recommended for leaf spot control not only increased the severity of *Sclerotinia* blight but also significantly reduced pod yield (Porter 1977). At other field locations, captafol (cis-N-[{1,1,2,2,-tetrachloroethyl} thio] 4-cyclohexene-1,2-dicarboximide), as well as chlorothalonil, enhanced the severity of *Sclerotinia* blight and significantly decreased pod yield (Porter 1980a).

At harvest, two and four times more plants weredead in plots treated with chlorothalonil or captafol, respectively, than in untreated control plots. Pod yields averaged about 500 kg/ha greater in untreated plots than in chlorothalonil, or captafol treated plots. *Sclerotinia* blight was significantly greater in all breeding lines, plant introductions and cultivars treated with chlorothalonil than plants *treated with* benomyl (Coffelt and Porter 1980). Both fungicides were used at rates recommended for leaf spot control. The reason(s) for enhancement of *Sclerotinia* blight following usage of chlorothalonil and captafol is not known. The soil microflora from plots treated with chlorothalonil and captafol was not different from that obtained from nontreated plots (Lankow et al. 1980). In greenhouse-grown plants, inoculation with chlorothalonil-treated inoculum enhanced the virulence of S. *minor* (M. K. Beute, personal communication). Oxalic acid production was over 2.5 times greater in medium amended with chlorothalonil and captafol than in similar nonamended media. The increased production of oxalic acid by *S. minor* following application of either chlorothalonil or captafol may partially explain the enhancement of *Sclerotinia* blight under field conditions where these fungicides are utilized.

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Figure 2. A. infrared photograph showing relationship of mechanical injury and subsequent colonization of injured groundnut foliage by S. minor *(note alternating bands of red and gray representing healthy and diseased tissue, respectively); B. over-wintering of sclerotia of* S. minor *on groundnut debris; C. control of* Sclerotinia *blight of groundnut with experimental fungicide; D, typical stem lesions on groundnuts caused by* S. minor; *and E. sclerotia of* S. minor *on sieve.*

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Groundnut Foliar Disease in the United States

D. H. Smith*

Fungal Diseases

Although several groundnut foliar diseases have been reported in the United States, early and late leaf spot are the most widely distributed foliardiseasesofgroundnuts. Theearly and late leaf spot pathogens are seen primarily in their imperfect states, i.e., as *Cercospora arachidicola* Hori, and *Cercosporidium personatum* (Berk. & Curt.) Deighton. The perfect states of both pathogens have been reported in the United States, but there is no convincing evidence that ascospores are an important source of initial inoculum.

Since 1976, there has been a gradual shift from a predominantly early leaf spot population to a substantial amount of late leaf spot in the southeastern United States (Smith and Littrell 1980). A totally satisfactory explanation for this change is not available, but some plausible explanations are worthy of consideration.

First, the groundnut crop has been harvested later in recent years, and this may have contributed to an increased inoculum potential of *C. personatum.* Second, the use of highly effective fungicides for early leaf spot may have altered the leaf surface microflora, thereby providing a competitive advantage for the late leaf spot fungus. Third, the extensive cultivation of one susceptible cultivar (Florunner) in Alabama, Florida, and Georgia may have favored a shift from early to late leaf spot. Other possible contributing factors include nutrient status of the crop, drought stress, previous crop sequence, increased use of irrigation in groundnut production, and unsatisfactory fungicide application schedules and methods of application.

The shift in the relative abundance of early and late leaf spot is not a new phenomenon. During a 5-year period in the late 1920's and early 1930's in Georgia, Woodruff (1933) reported that early leaf spot contributed to severe defoliation during only two of five years. A few years later, again in Georgia, Jenkins (1938) reported that early leaf spot reached epidemic proportions in August and early September, whereas late leaf spot was most destructive from September through harvest. Late leaf spot was of minor importance in Georgia from 1967-1976 (Smith and Littrell 1980). In 1947, Miller (1953) collected groundnut leaves from ten southern states, and he reported that 82% of the lesions were caused by *C. arachidicola.* During the 1979 growing season, the incidence of early and late leaf spot was monitored in a small-plot field test in Georgia. Late leaf spot was not observed until the second week in July, but by the end of the season more than 99% of the lesions were those of *C. personatum* (Smith and Littrell 1980).

Groundnut rust, caused by *Puccinia arachidis* Spegazzini, occurs annually in the groundnut producing areas of southern Texas. Groundnut rust has been observed in all the groundnut producing states, but the onset of rust is usually late in the season. Therefore, with the exception of southern Texas, rust does not usually contribute to groundnut crop losses.

Only the uredial state of P. *arachidis* has been observed in United States, and the fungus does not survive during the intercrop period. Airborne uredospores are introduced annually from outside of the United States (Van Arsdel 1972). Harrison (1972) observed groundnut rust in southern Texas during the first week of July in 1971. This is probably the earliest that groundnut rust has ever been observed in the United States. During 1971, rust reached epidemic proportions in southern Texas (Harrison 1972). During the same growing season, Thompson and Smith (1972) reported rust in 24 groundnut producing counties in Georgia.

Web blotch, caused by *Phoma arachidicola,* Marasas, Pauer & Boerema was first reported in Texas during the 1972 growing season (Pettit

* Associate Professor, Texas A&M University, Texas Agricultural Experiment Station, Plant Disease Research Station, Yoakum, Texas 77995, USA.

et al. 1973). However, the fungus was present in groundnut hay which was produced in Florida during the 1971 crop year (Smith, unpublished). Since then, web blotch has been observed in several states, but epidemics of web blotch have been limited to Texas and Oklahoma. During recent years the incidence of web blotch has been diminishing in the United States. We believe this is at least partially associated with the decreasing amount of highly susceptible Spanish type cultivars and an increasing amount of Florunner, a cultivar with moderate resistance to web blotch (Smith et al. 1979). Both the perfect and the imperfect states of the web blotch fungus have been reported in the United States (Philley 1975).

Leptosphaerulina crassiasca (Sechet) Jackson & Bell is a ubiquitous fungus in the groundnut producing areas of the United States, but it is usually a minor foliar pathogen. In contrast with the early and late leaf spot fungi, only the perfect state of *L crassiasca* is known to plant pathologists. *L. crassiasca* produces two distinct symptoms, i.e., pepper spots and wedge-shaped leaf scorch symptoms. Frequently, leaf scorch symptoms are accompanied by early or late leafspot lesions at or near the midvein in the scorched portion of the leaf, indicating that *L crassiasca* may be only a secondary invader of the leaflet. Smith and Crosby (1973) studied the aerobiology of *Leptosphaerulina crassiasca.* They reported that large numbers of *L crassiasca* ascospores were trapped within 1-4 hours after sunrise, when air temperature was rising and foliage was drying on days without rain. On days with rain, concentrations of *L. crassiasca* ascospores increased rapidly with the onset of rainfall. Mercer (1977) reported *L trifolii* as a foliar pathogen of groundnuts in Malawi, but we are unaware of any reports of *L trifolii* as a groundnut foliar pathogen in the United States.

Phyllosticta leaf spot, a minor foliar disease of groundnuts, has been reported in Georgia (Jackson and Bell 1969), and we have observed a low incidence of this leafspot disease in Texas each year. Jackson and Bell observed the disease early in the growing season, but we have observed it throughout most of the growing season. We have frequently been able to find *Phyllosticta* sp in groundnut fields infested with johnsongrass. On the basis of similar symptoms on johnsongrass, we think that this grass may be a host for *the Phyllosticta* sp that invades groundnut foliage. However, cross inoculation studies have not been conducted.

Several other minor fungal pathogens of groundnut foliage have been reported in the United States. Smith (1972) reported that *Cristulariella pyramidalis* caused a leaf spot disease of groundnuts in Georgia. Littrell (1974a) reported that a foliar blight of groundnuts in Georgia was caused by *Rhizoctonia solani.* Jackson and Bell (1969) found that a species of *Colletotrichum,* closely related to C. *dematium,* was consistently associated with leaf scorch symptoms, but their attempts to produce leaf scorch symptoms with this *Colletotrichum* sp were not successful. Jackson and Bell (1969) reported that *Phomopsis* sp was usually associated with *L crassiasca, Cercospora* spp or *Colletotrichum* cf *dematium* in marginal necrotic leaflet lesions. We have isolated *Alternaria* spp from leaf scorch lesions, but inoculations have been unsuccessful (Smith, unpublished).

Virus Diseases

Groundnut mottle is the most widely distributed groundnut virus in the United States. Kuhn (1965) published the first report on groundnut mottle in the United States. Demski et al. (1975) reported that groundnut mottle virus occurred in all the major groundnut producing states, i.e., Georgia, Florida, Alabama, Texas, Oklahoma, New Mexico, North Carolina, and Virginia.

In Georgia the incidence of peanut mottle virus varied from 1 to 79% (Paguio and Kuhn 1974). Paguio and Kuhn conducted a groundnut mottle virus survey in 1973, and they reported a crop loss greater than 12 dollars per acre in 46% of the fields surveyed; moreover, the estimate of the Georgia groundnut crop loss attributed to groundnut mottle virus was more than 11 million dollars in 1973. Demski et al. (1975) reported a low incidence of groundnut mottle virus in Texas and Oklahoma, and they suggested that the appropriate aphid vectors may be absent in these groundnut producing areas.

Miller and Troutman (1966) observed groundnut stunt in Virginia in 1964, and Cooper (1966) observed the disease during the same year. Epidemics of groundnut stunt developed in North Carolina and Virginia in 1965 and 1966 (Cooper 1966; Hebert 1967; Miller and Troutman 1966). Since then, groundnut stunt has been a minor disease of groundnuts in the United States. Groundnut stunt has also been reported in Alabama and Georgia (Rogers and Mixon 1972; Kuhn 1971). In 1967, Choopanya (1968) found groundnut stunt virus in white clover throughout most of South Carolina. However, Choopanya did not find the disease in South Carolina groundnut fields.

Spotted wilt of groundnuts was reported in Texas by Halliwell and Philley (1974). Since their report, this author has observed a few infected plants in Texas each year, but there has been no tendency for the disease to increase in Texas, and spotted wilt has not been reported in other groundnut producing states.

Physiological Disorders

Various types of foliar symptoms are occasionally observed on groundnuts in the United States. In Texas and Oklahoma a symptom described as atmospheric scorch (Home 1974) is probably caused either totally or partially by ozone. The first evidence of ozone injury is a slight burn on the adaxial leaf surface, and this progresses to a dark brown scorched area. Cells of the upper epidermis are usually most affected, but injury sometimes proceeds rapidly when secondary organisms invade the damaged tissue. Spanish market type peanuts are generally more susceptible than runner market types. Davis and Smith (1976) compared the reaction of ten groundnut cultivars to ozone under controlled conditions. Severity ratings ranged from O to 83.5, with Valencia A being most susceptible to ozone damage in contrast with a severity rating of 0.5 for Florunner.

Variegated leaves resulting from a genetic abnormality are occasionally observed. There seems to be a slightly higher incidence of this in Spanish market types, but we have also observed this variegated symptom on Florunner.

Various kinds of foliar symptoms induced by pesticides have been observed. Sometimes these symptoms closely resemble *Cercospora* leaf spot. In questionable instances we incubate leaves on moist filter paper to induce sporulation. The absence of sporulation provides circumstantial evidence that the symptom is associated with phytotoxicity instead of *Cercospora* leaf spot.

Management of Fungal Diseases of Groundnut Foliage

Several crop management practices reduce the amount of inititial inoculum. Burial of crop residue with a moldboard plow is especially important when crop rotation is not part of the crop management system. Crop rotation is effective for reducing the inoculum potential of both soil-borne fungal and nematode pathogens. In addition, when groundnuts are planted on land that has not been planted to peanuts for one or more years, the onset and rate of disease progress for early and late leaf spot are delayed as contrasted with disease progress in a program of continuous groundnut culture.

In the groundnut producing area of southern Texas, growers can avoid the impact of groundnut rust epidemics by planting groundnuts in early March. Since rust has never been observed prior to the first week in July in southern Texas, a crop planted in early March is usually exposed to rust for less than a month prior to harvest. Therefore, crop losses attributable to rust are avoided by early planting. In addition, fewer fungicide applications are required for management of early and late leaf spot when groundnuts are planted in early March.

In southern Texas the groundnut planting season ranges from early March to mid-July. Because inoculum concentration increases as the season progresses, foliar diseases are partially managed by planting successively later groundnut crops in fields that are not adjacent to previously planted groundnut fields and not located in the direction of prevailing winds. The direction of prevailing wind is extremely relevant to the development of rust epidemics, because uredospores are well adapted to long distance dispersal.

Fungicides

Management of foliar diseases with fungicides is a routine crop management practice in the United States. Prior to 1971, dust formulations of copper, sulfur, and copper plus sulfur were routinely used for suppression of foliar diseases. However, after the introduction of benomyl, chlorothalonil, and fentin hydroxide there was a rapid transition from dusting to spraying.

Chlorothalonil is the most widely used fungicide for management of groundnut foliar diseases in the United States. It is effective against early leaf spot, late leaf spot, rust, and web blotch. Benomyl, captafol, copper ammonium carbonate, copper hydroxide, fentin hydroxide, mancozeb, maneb, and sulfur are currently registered for use in managing one or more foliar diseases of groundnuts in the United States.

Thefirstfungicideapplication is usually made within 30-40 days after planting, with subsequent applications at intervals of 10-14 days until 14-21 days prior to the anticipated date of harvest. Fungicides are currently applied with various kinds of *tractor* propelled sprayers, fixed-wing aircraft, and sprinkler irrigation systems.

Fungicide Tolerance

Benomyl-tolerant strains of *C. arachidicola* and *C. personatum* developed in the southeastern United States after three years of extensive use of benomyl for control of groundnut foliar diseases (Clark et al. 1974; Littrell 1974b). Groundnut crop losses were probably averted by changing to the use of protectant fungicides in 1974.

Smith et al. (1978) reported benomyl-tolerant strains of *C. arachidicola* and *C. personatum* at one research station in Texas. They attributed the development of tolerant strains to the annual evaluation of benomyl-alone foliar sprays in small plot field tests since 1967 and the subsequent selection pressure for the development of benomyl-tolerant strains of *C. arachidicola* and *C. personatum.* There are no reports of the benomyl-tolerant strains of *C. arachidicola* and *C. personatum* strains in Texas grower fields. A plausible explanation for this fact is that Texas growers have not extensively used benomyl alone because of its ineffectiveness against rust and web blotch.

Smith and Searcy (1975) tested 57 isolates of *C. arachidicola* from 11 states and 5 foreign countries for benomyl tolerance. All isolates were collected prior to the use of benomyl, and no tolerant strains were found. In addition, we have monitored a groundnut field where no fungicides are used and no benomyl-tolerant strains of *C. arachidicola* have been isolated (Smith, unpublished). On the basis of the previous circumstantial evidence, it appears that the incidence of benomyl-tolerant strains of *C. arachidicola* is probably very low or absent prior to the intensive use of benomyl.

Some effects of fungicides on nontarget organisms have been reported. Backman et al. (1975) observed a consistently higher level of *Sclerotium rolfsii* Sacc. when Florunner foliage was sprayed with benomyl. Porter (1980) reported that foliar sprays of captafol and chlorothalonil increased the severity of *Sclerotinia* blight on VA 72 R groundnuts. Campbell (1978) reported that foliar sprays of either fentin hydroxide or copper ammonium carbonate suppressed populations of the two-spotted spider mite. Backman et al. (1977) reported that Guazatine Triacetate, a fungicide with efficacy against *Cercospora* leaf spot, repelled lepidopterous larvae.

Research on resistance to early and late leaf spot has been accelerated in recent years (Abdou et al. 1974; Sowell et al. 1976; Hassan and Beute, 1977; Sharief et al. 1978; Kornegay et al. 1980). Sources of rust resistance have been reported (Bromfield and Cevario 1970; Hammons 1977; Subrahmanyam et al. 1980). Smith et al. (1979) reported some sources of web blotch resistance. Porter et al. (1971) evaluated breeding lines and cultivarsfor resistance to pepper spot and leaf scorch under field conditions. However, in spite of the increased emphasis on resistance to fungal diseases of peanut foliage, there are currently no agronomically acceptable cultivars with adequate resistance to eliminate the use of fungicides for management of the principal foliar diseases of groundnuts.

Management of Virus Diseases of Groundnuts in the United States

There is no satisfactory control measure for groundnut mottle virus. Since the symptoms are frequently inconspicuous, growers are often unaware of this disease in their fields. Kuhn et al. (1968) found no immunity to PMV when they screened 37 peanut cultivars and 428 plant introductions in the greenhouse. Screening was done by mechanical inoculating groundnut plants and then subinoculating *Phaseolus vulgaris* Topcrop' a local lesion host. In a 1978 report, Kuhn et al. indicated that PI 261945 and PI 261946 were tolerant, because infection did not reduce pod yield.

The production of groundnut mottle virus-free seed is a potential control measure. Demski et al. (1975) reported a low incidence of groundnut mottle in Texas and Oklahoma, and they suggested that these may be good locations for groundnut mottle virus-free seed production, probably because of the absence or paucity of aphid vectors in that area.

Kuhn and Demski (1975) discussed the possibility of controlling groundnut mottle by insecticidal control of aphid vectors. However, they were doubtful about the practicality of this strategy because the groundnut mottle virus is transmitted in a stylet borne fashion. The virus is acquired with one probe into an infected epidermal cell. Therefore, the virus can be transmitted immediately and only for a short period of time. It is also probable that the first aphids arrive from outside of the groundnut field and thus cannot be easily eliminated prior to acquiring the virus from infected groundnut plants that originated from infected seed.

Tolin et al. (1970) reported that the incidence of groundnut stunt was reduced when groundnut fields were isolated from white clover. Culp and Troutman (1968) rated several hundred A *hypogaea* cultivars, breeding lines, and introductions for their reaction to groundnut stunt. No immunity was reported, but symptoms were less severe on several entries. Because of the low incidence of groundnut stunt in the United States there is no active interest in the development of *control* measures.

Since spotted wilt is a minor groundnut disease in only one groundnut producing state, no efforts have been made to develop control measures. The possibility of disease resistance is being considered by Ghanekar et al. (1979) at ICRISAT.

Future Research Priorities

Because of the increasing costs of purchasing and applying fungicides for management of foliar diseases in the United States, there is a need for new cultivars with multiple foliar disease resistant, high yielding, good quality, and early maturing traits. Rapid techniques for screening large numbers of genotypes for resistance should be developed.

Additional information on the epidemiology of individual foliar pathogens and interactions among foliar pathogens will be useful in the development of new foliar disease management strategies. A thorough study of the ecology of the non-pathogenic microflora of the groundnut leaf surface may shed new light on our knowledge of the epidemiology of foliar pathogens.

There seems to be a growing sense of optimism that new groundnut cultivars with multiple pest resistance can be developed. The attainment of this objective will be a major achievement in the area of groundnut crop improvement.

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Research on Fungal Diseases of Groundnut at ICRISAT

P. Subrahmanyam, V. K. Mehan, D. J. Nevill and D. McDonald*

Many fungal diseases of groundnut are known (Jackson and Bell 1969; Garren and Jackson 1973) and many fungi are reported to be closely associated with groundnut fruits and seeds. Some of the diseases are of restricted distribution but most are of common occurrence throughout the Semi-Arid Tropics (SAT). At ICRISAT the main concern is with those widespread diseases that cause economically important losses in yield, and in this paper investigations carried out during the past 4 years on important foliar and soilborne diseases are briefly reviewed.

Foliar Diseases

Rust *(Puccinia arachidis* Speg.)

Previously unimportant outside the Americas (Bromfield 1971), rust is now of economic importance in almost all groundnut growing areas of the world (Hammons 1977; Subrahmanyam et al. 1979). Yield losses from rust may be substantial and damage is particularly severe where the crop is attacked by both rust and the longer established *Mycosphaerella* leaf spots.

Investigations were carried out on the biology of the rust fungus so as to determine what factors were likely to influence perpetuation and spread of the disease. Biological data were also needed for development of methods for screening germplasm for resistance to the disease.

A wide range of crop and weed species were checked for possible collateral hosts of rust but none was found outside the genus *Arachis.*

The uredial stage only of the rust has been found although constant examination was made of many germplasm lines and some wild *Arachis* species at ICRISAT. Groundnut plants from various parts of India have also been examined at every opportunity. Attempts to induce teliospore formation by modification of environmental factors were not successful. It was concluded that uredosporeswerethe main, if not the only, means of rust carry-over and dissemination in India.

Laboratory experiments showed that uredospores could be stored for long periods at low temperature without loss of viability but that at high temperatures, they rapidly lost viability. For instance, when stored at 40°C they lost viability within 5 days. Uredospores on exposed crop debris lost all viability within 4 weeks under postharvest conditions at ICRISAT. Pods and seeds from rust affected crops are commonly surface-contaminated with uredospores. Tests on uredospores taken from surface-contaminated seeds stored at room temperature showed viability to decrease from an original 95% to zero after 45 days. Implications for disease carry-over and for plant quarantine are obvious. Rust is particularly severe in South India where groundnuts are grown in some areas at all times of the year.

Light was found to inhibit uredospore germination and germ-tube elongation, indicating that field inoculation might be more successful if carried out in the evening rather than through the day.

The presence of liquid water on the leaf surface was found to be necessary for uredospore germination and infection.

Preliminary rust resistance screening of the ICRISAT germplasm collection (now over 8000 entries) was carried out in the rainy seasons of 1977, 1978 and 1979 under natural disease pressure in the field. Infector rows and check plots of the highly susceptible cv TMV-2 were arranged systematically throughout the trials. Entries which were rated between 1 and 5 on a 9-point disease scale (where 1 = no rust, and 9 = 50-100% offoliagedestroyed by rust) were

* Pathologists, International intern, and Principal Plant Pathologist, respectively, Groundnut Improvement Program, ICRISAT.

selected for advanced field screening. This was done either in the rainy season as described or in the postrainy season when artificial inoculation with uredospores and overhead irrigation to maintain high humidity were required to ensure good development of rust. Genotypes found to show good resistance to rust at ICRISAT are listed in Table 1 together with their mean rust scores on the 9-point scale. Scores for two susceptible cultivars are included for comparison.

Table 1. Genotypes resistant to rust at ICRISAT.

Genotype	Rust Score[a]
NC Acc 17090	2.0
PI 414332	2.0
PI 405132	2.5
PI 341879	2.5
PI 393646	2.5
NC Acc 17133-RF	3.0
EC 76446 (292)	3.0
PI 259747	3.0
PI 350680	3.0
PI 390593	3.0
PI 381622	3.0
PI 393643	3.0
PI 407454	3.0
PI 315608	3.0
PI 215696	3.0
PI 393641	3.0
PI 314817	3.0
PI 393517	3.0
PI 414331	3.0
PI 393527-B	3.0
NC Acc 927	3.3
PI 390595	3.5
PI 393531	3.5
NC Acc 17127	3.8
PI 393526	4.0
NC Acc 17129	4.0
NC Acc 17132	4.0
NC Acc 17135	4.0
NC Acc 17124	4.0
PI 298115	4.0
PI 393516	4.5
NC Acc 17142	5.0
Krap Str 16	5.0
TMV-2[b]	9.0
Robut 33-1*	9.0

a. Rust score on 9-polnt disease scale.
b. Standard susceptible cultivars.

Wild Arachis species being grown in the field in close juxtaposition with severely rust affected groundnuts were examined at intervals through the season for evidence of rust infection. Those species which showed no development of rust are listed in Table 2. Although rust did not develop on *Arachis stenocarpa,* some necrotic lesions were formed that may have resulted from arrested invasion by the pathogen.

Using artificial inoculation, potted plants and rooted detached leaves were used in screening trials in glasshouse and laboratory, respectively. The methods were effective in separating genotypes with large differences in resistance, e.g., highly resistant as opposed to susceptible, but were not suitable for showing any intermediate reactions.

In studies on components of resistance, it was found that neither size nor frequency of stomata was correlated with resistance. Infection frequency was lower in resistant than in susceptible genotypes and the incubation period was longer. Irrespective of whether genotypes were immune, resistant, or susceptible, uredospores germinated on the leaf surface and germ-tubes entered the leaf via stomata. In immune genotypes, the germ-tubes died without further development. Differences in resistance were manifest by differences in rate and degree of development of the rust mycelium in the substomatal cavities and in invasion of leaf tissues.

Table 2. Wild *Arachis* spp on which no rust developed in the field despite heavy disease inoculum.

Species	PI Number	Section	Source
A. duranensis	219823	*Arachis*	Argentina
A. correntina	331194	*Arachis*	Argentina
A. cardenasii	262141	*Arachis*	Bolivia
A. chacoense	276235	*Arachis*	Paraguay
A. chacoense x *A. cardenasii*	-	F_1 hybrid	USA
A. pusilla	338448	*Triseminalae*	Brazil
A. sp 9667	262848	*Rhizomatosae*	Brazil
A. sp 10596	276233	*Rhizomatosae*	Paraguay

Mycosphaerella or *"Carcospora"* Leaf Spots (Early Leaf Spot - Cercospora *arachldlcola* Hori; Late Leaf Spot — *Cercosporidium personatum* [Berk, and Curt.] Deighton)

The *Mycosphaerella* leaf spots are probably the most important diseases of groundnuts on a worldwide scale. Both are commonly present and their relative importance is determined by crop and environmental factors. At ICRISAT, the disease incited by *C. personatum* is of regular occurrence and reaches high levels on rainy season groundnuts but that incited by *C. arachidicola* is much less common and rarely reaches levels high enough to permit field resistance screening.

Field screening for resistance to the leaf spots was carried out simultaneously with the rust screening and a similar 9-point disease scale was used. Entries rated between 1 and 5 were selected for advanced field screening. All field screening utilized natural inoculum. The diseases developed more rapidly and screening was more effective in the rainy season than in the irrigated postrainy season crops. Genotypes found to have resistance to *C. personatum* at ICRISAT are listed in Table 3.

Genotypes with field resistance to *C. personatum* were further tested for resistance in glasshouse screening trials. Good correlations were found between field and glasshouse tests in respect of defoliation, lesion size and sporulation index. Laboratory screening in which rooted detached leaves were inoculated with *C. personatum* also proved useful. The latter method was also useful in the study of resistance mechanisms.

Both high resistance and immunity have been found among wild *Arachis* species (Table 4). The ICRISAT Groundnut Cytogeneticists have produced hybrids between some of the resistant wild species and the cultivated groundnut, and by backcrossing have obtained near tetraploid material which is being tested at all stages for resistance to leaf spots and to rust.

With leaf spots as with rust, germination of spores and entry into the leaf via stomata did not appear to be in any way inhibited in resistant genotypes. Resistance was again manifest in the postentry phase.

Table 3. Genotypes resistant to C. *parsonatum* at ICRISAT.

Genotype	Leaf spot score*
EC 76446 (292)	3.2
NC Acc 17133-RF	3.3
PI 259747	3.3
PI 350680	3.3
NC Acc 927	4.0
NC Acc 17127	4.3
Krap Str 16	4.3
RMP-91	4.7
NC Acc 17090	4.8
NC Acc 17130	4.8
NC Acc 17129	4.8
NCAcc 17132	4.8
NCAcc 17135	4.8
NC Acc 17124	4.8
RMP-12	5.0
TMV-2[b]	9.0

«. Leaf spot score on 9-polnt disease scale.
b. Standard susceptible cultlvar.

Table 4. Wild *Arachls* spp — reaction to *Carcospora arachidicola* and *Cercosporidium paraonatum.*

Species	PI Number	Reaction to	
		C. arachidicola	*C. personatum*
A. chacoense	276325	Highly resistant	Highly resistant
A. cardenasii	262141	Susceptible	Immune
A. sp 10596	276233	Immune	Immune
A. stenosperma	338280	Highly resistant	Highly resistant

Yield Losses from Rust and Leaf Spots and Multiple Resistance

Rust and leaf spots normally occur together and it is difficult to allocate individual responsibility for the resulting damage to the crop. In the 1979 rainy season we attempted to estimate yield losses by applying fungicides to susceptible and disease resistant genotypes; Daconil to control leaf spots and rust, Bavistin to control only leaf spots, and Calixin to control only rust. Loss estimates are shown in Table 5. Losses were less in the resistant than in the susceptible genotypes.

Comparison of Tables 1 and 3 will show that some of the genotypes resistant to rust are also resistant to *C. personatum* leaf spot. Also, some new sources of resistance to both diseases have recently been found in Federal Experiment Research Station — Puerto Rico (FESR) breeding lines (Table 6). These lines originated from a natural hybrid selected for resistance to rust in Puerto Rico by USDA scientists.

Some of the resistant genotypes can outyield established Indian cultivars when grown without protective fungicide treatment at ICRISAT. Further work is required of breeders to incorporate higher yields and better agronomic characters into the resistant materials.

Table 6. Genotypes resistant to rust and laaf spot — FESR lines tested at ICRISAT.

Genotype	Mean disease scores (9-point scale) Rust	Leaf spot
FESR 5-P2-B1	2.0	3.0
FESR 5-P17-B1	2.0	3.0
FESR 7-P13-B1	2.0	3.0
FESR 9-P3-B1	2.0	3.0
FESR 9-P4-B1	2.0	4.3
FESR 9-P7-B1	2.7	3.3
FESR 9-P7-B2	2.7	4.3
FESR 9-P8-B2	2.0	3.0
FESR 9-P12-B1	2.0	2.7
FESR 11-P11-B2	2.3	2.7
FESR 12-P4-B1	2.0	2.0
FESR 12-P5-B1	2.0	2.7
FESR 12-P6-B1	2.7	3.7
FESR 12-P14-B1	2.0	3.3
FESR 13-P12-B1	2.0	2.7
TMV-2[a]	9.0	9.0

a. Standard susceptible cultivar.

Other Foliar Diseases

Some preliminary investigations have been made on what are at present regarded as minor foliar pathogens. These include diseases incited by *Leptosphaerulina crassiasca* (Sechet) Jackson and Bell, *Alternaria alternata* (Fr.) Keissler, and *Myrothecium roridum* Tode ex. Fr.

Table 5. Yield losses from rust and leaf spots at ICRISAT.

Genotype	Mean percentage loss of pod yield from: Leaf spots	Rust	Leaf spots and rust
Robut 33-1[a]	59	52	70
PI 259747	30	23	37
EC 76446 (292)	10	12	30
NC Acc 17090	18	14	29

a. Standard auscaptlble cultivar.

Soilborne Diseases

Seed and Seedling Rots

Seed rots and seedling diseases of groundnut are of common occurrence in the SAT and may cause serious losses in yield. The diseases may develop from fungi already established in the seeds before sowing, or may result from direct invasion of seeds or seedlings by soil fungi. Many species of fungi have been reported to cause seed rots and several are known to cause diseases of seedlings. Some fungi causing diseases at ICRISAT are listed in Table 7.

Two important diseases of groundnut seedlings are Crown Rot which is caused *by Aspergillus niger* van Tiegh and Aflaroot which is caused by toxigenic strains of *Aspergillus flavus* Link, ex Fr. Initial screening of the ICRISAT germplasm collection has indicated

Table 7. Fungi associated with seed and seedling diseases at ICRISAT.

Aspergillus flavus Link, ex Fr.
Aspergillus niger van Tiegh.
Botryodiplodia theobromae Pat.
Fusariurn spp
Macrophomina phaseolina (Tassi) Goid.
Penicillium spp
Rhizoctonia solani Kuehn
Sclerotium rolfsii Sacc.

that some genotypes may possess resistance to these diseases.

Pod Rot

Pod rot diseases are widespread in the SAT and are known to cause severe damage in a number of countries (Abdou and Khadr 1974; Frank 1972; Mercer 1977; Porter et al. 1975). High levels of pod rot were observed in the 1978-79 postrainy season crop at ICRISAT and screening of germplasm for resistance was initiated. Some 2000 genotypes have now been screened under natural field disease conditions. Standard local cultivars had 20-25% of pods rotted while disease levels in germplasm lines ranged from 4 to 72%. Genotypes with pod rot scores of 10% or lower were selected for advanced screening in disease sick plots.

The etiology of the disease is still being investigated. Fungi commonly isolated from rotted pods at ICRISAT are listed in Table 8.

Table 8. Fungi Isolated from rotted pods a ICRISAT.

Dominant species	*Fusarium solani* (Mart.) Sacc. *Fusarium oxysporum* Schlecht
Subdominant species	*Macrophomina phaseolina* (Tassi) Goid. *Rhizoctonia solani* Kuehn
Associate species	*Aspergillus flavus* Link, ex Fr. *Aspergillus niger* van Tiegh. *Fusarium acuminatum* Ell. & Ev. *Fusarium equiseti* (Corda) Sacc. *Fusarium fusaroides* (Frag. & Cif.) Booth *Gliocladium roseum* Bain. *Trichoderma viride* Pers. ex Fr.

The Aflatoxin Problem

Contamination of groundnuts with aflatoxins is a serious problem in many parts of the SAT. The ubiquitous *Aspergillus flavus* which produces these toxic and carcinogenic substances may invade groundnut seeds before harvest, during postharvest drying, and during storage if the seeds are wetted. From the continued appearance of reports of aflatoxin contamination of produce it would appear that SAT farmers have not adopted the crop handling and storage methods designed to reduce aflatoxin contamination in groundnuts. It has therefore become necessary to investigate the possibilities of genetic resistance in the hope of developing cultivars with pods or seeds which *A. flavus* cannot invade, or which if invaded, do not support aflatoxin production.

Workers in the USA (Mixon and Rogers 1973; Bartz et al. 1978) have shown some genotypes to have high levels of resistance to A *flavus* invasion and colonization of dry seeds. This dry seed resistance is dependent upon the testa being entire and undamaged. The test is a simple one. Mature undamaged seeds that have been dried and stored for several weeks are placed in a petri dish and hydrated to 20-25% water content. A suspension of *A. flavus* spores is added to them, and they are incubated for about 8 days. The percentage of seeds which are colonized by the fungus indicates the degree of dry seed resistance possessed. The ICRISAT germplasm collection is now being screened. The reactions of three genotypes reported resistant in the USA and some Indian cultivars are given in Table 9.

Table 9. Dry seed resistance to *A. flavus* colonization.

Genotype	Percentage of seeds colonized by *A. flavus* and disease testing	
Resistant lines from USA		
UF 71513	7.0	Resistant
PI 337394 F	9.1	
PI 337409	9.2	
Indian cultivars		
Junagadh 11	11.6	
TMV-2	35.0	Susceptible
OG 43-4-1	96.0	Highly susceptible

There is no evidence th at the genotypes so far found with dry seed resistance have any special degree of resistance to invasion of pods or seeds before harvest or during postharvest drying. Investigations have started into possible resistance during these phases, and particular attention is being given to genotypes which have shown resistance to pod rots.

Some early research (Tulpule 1967; Kulkarni et al. 1967) indicated that certain cultivars had resistance to the production of aflatoxin. However, these findings were not confirmed by further research (Doupnik etal. 1969; Aujla et al. 1978), although there were indications that slight differences might exist between cultivars in their ability to support aflatoxin production. In dry seed resistance testing at ICRISAT, toxigenic strains of *A. flavus* are used and genotypes are being checked for possible differences in efficiency, as substrates for anatoxins production.

Other Soilbome Diseases

A number of soilbome diseases occur regularly at ICRISAT but at low incidence. These include wilt and root rot caused by species of *Fusarium;* a black root rot caused by *Macrophomina phaseolina* (Tassi) Goid; a root rot caused by *Rhizoctonia solani* Kuehn; and stem rot caused by *Sclerotium rolfsii* Sacc. Disease sick plots are being established to allow screening of the germplasm collection for possible resistance to these diseases.

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Studies of Resistance to Foliar Pathogens

D. J. Nevill*

The training program at ICRISAT gives people the opportunity to work for between 6 months and 2 years in research programs of the Institute. In the groundnut program, there are three postdoctoral fellows who have come from Japan, UK and USA; there are three research scholars working for M.Sc. degrees, from Benin, Ghana and India; finally, this year, there have been in-service trainees from the People's Republic of China, Sudan and Tanzania. This great diversity of workers has three major roles in the program: to gain experience; to familiarize staff members with new techniques; and to carry out basic research which may be outside the usual work of ICRISAT scientists. Since these last two roles are particulary important for postdoctoral fellows, they will be emphasized in this paper.

Research Work

Groundnut rust, *Puccinia arachidis* Speg. and the two leaf spot fungi, *Cercospora arachidicola* Hori and *Cercospondium personatum* (Berk. & Curt.) Deighton, are extremely important pathogens of groundnuts. In the USA, the leaf spot fungi have been successfully controlled by fungicides (Backman et al. 1977); however this approach may not be feasible in less developed countries. The use of disease resistant varieties is an alternative method of control, but in the past it was thought that there was no useful variation in leaf spot resistance within the cultivated species (Abdou et al. 1974; Hammons 1973). However, recent work has demonstrated that such variation does exist (Sowell et al. 1976; Hassan and Beute 1977; Melouk and Banks 1978; Nevill 1979; Subrahmanyam et al. 1980). In this paper, studies into the nature and utilization of this resistance will be described.

Resistance to groundnut rust exists withi n the cultivated species (Mazzani and Hinojosa 1961; McVey 1965; Cook 1972), and at ICRISAT further studies have been carried out to investigate screening methods and the nature of the resistance response. These will also be described here.

The Potential of Disease Resistance

During the last two rainy seasons, the response of 20 groundnut varieties to chemical disease control has been studied. Three fungicides have been used that control rust and leaf spot separately or together. Both diseases appear to cause similar yield losses (Table 1). Reduction in pod yield varied from 20 to 70% and if this level of resistance could be incorporated into a high yielding variety, such as Robut 33-1, then yields of 4 t/ha could be achieved without the use of fungicides.

It must be stressed that these results provide only an indication of the potential of disease resistance, si nee the effects of the chemicals on groundnut development and on the supposedly uncontrolled fungus are not known. This experiment is in progress, and from the results,

Table 1. The response of four varieties to chemical disease control.

Variety	Percentage yield loss caused by: Rust	Leaf spot	Both	Potential yield (t/ha^{-1})
Robut 33-1	27	38	70	4.8
NC Acc 17090	14	17	30	3.4
EC 76446 (292)	15	13	23	2.2
PI 259747	10	18	37	2.0

* International Intern, Groundnut Improvement Program, ICRISAT.

multiple point models of disease development will be derived which should improve crop loss assessment methods.

Laboratory Studies of Leaf Spot Resistance

In the laboratory, a simple detached leaf technique is being used to study disease reactions in detail. Groundnut leaves have abscission layers at the base of the leaflets and the petiole. Excision through the pulvinus stimulates rooting without the application of hormones or specific nutrients if humid, moist conditions are maintained. Healthy leaves have survived for more than 3 months when cultured in moist sterile sand.

To use this technique in screening tests leaves were placed in plastic seed trays with the cut pulvinus buried in a layer of wet sand. The adaxial surfaces of the leaves were inoculated with an aqueous spore suspension and when the leaves were dry, the trays were placed in transparent plastic bags for incubation. This method has been found to provide a screening technique for which little equipment or resources are required, but which reduces enviornmental variability and avoids the confounding effects of multiple infection.

Use of this techniqu e has demonstrated large varietal differences in the expression of *C. personatum* symptoms, particularly in halo formation. Components of resistance to this fungus, when estimated in the laboratory were significantly correlated with field scores of resistance based on a 0-9 scale. The characters — lesion diameter, incubation period, lesion number and defoliation — explained 54% of the variation in the field score when they were included in a multiple regression analysis. This model has been able to rank 90% of varieties in a similar order to the field method. A better fit of the model would be achieved if more characters, such as latent period and sporulation, were included, but these are more difficult to measure on a large number of varieties. Other reasons for the unexplained variation are inadequacies in the assumptions of the regression model and imprecision in the estimates of the field scores.

For a small number of varieties, a complete study of components of the *C. personatum* and *C. arachidicola* disease reactions has been conducted. Resistance was associated with reduced sporulation, longer latent periods and less defoliation, but the success of spores in producing lesions did not differ between varieties. Sporulation from resistant varieties was one-quarter to one-sixth that from susceptible varieties (Fig. 1) and latent periods were increased by 80%. These components have been integrated by means of a computer simulation model (Fig. 2). Using this technique, values of defoliation, leaf damage and spore production are estimated for each day of a simulated growing season. The model predicts that defoliation caused by the leaf spot pathogens can be eliminated by use of the resistance levels that exist within *A. hypogaea.* The computer program is being refined to improve the realism of the model.

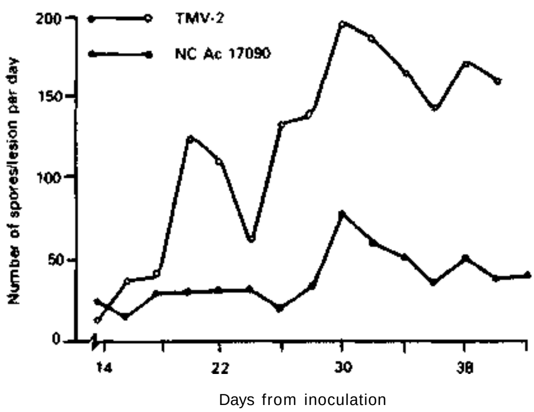

Figure 1. Daily spore production from C. arachidicola *lesions.*

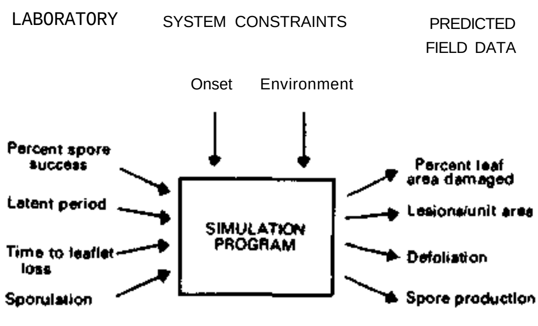

Figure 2. Diagrammatic representation of the simulation model.

Laboratory Studies of Rust Resistance

The detached leaf technique has also been used to study rust resistance. In this case it was found that most of the resistance components which were estimated in the laboratory were not correlated with a field score (0-9 scale). Only one character, i.e., numbers of lesions, gave a significant regression and only 19% of the variation in the field score was explained. It was therefore concluded that only the most resistant and susceptible varieties could be separated reliably by this technique. It is likely that the physiology of interaction between *P. arachidis* and its host is extensively altered after excision of the leaves.

Some basic histological studies are being carried out to investigate the nature of rust resistance in the cultivated species. Events during penetration and early mycelial development are being studied using leaf clearing and staining methods. The mortality of developing rust infections has been estimated using an approach similar to the life-table analysis of human populations and some results are shown in Fig. 3.

The percentage survival of two populations of uredospores on leaves of a resistant and a susceptible variety declined during infection. Despite the occurrence of the highest mortality during penetration, resistance was expressed later, during colony development. Similarly, in studies of immune wild species, *P. arachidis* was able to penetrate through stomata, but in this case development ceased after the formation of a single hypha out of the substomatal vesicle.

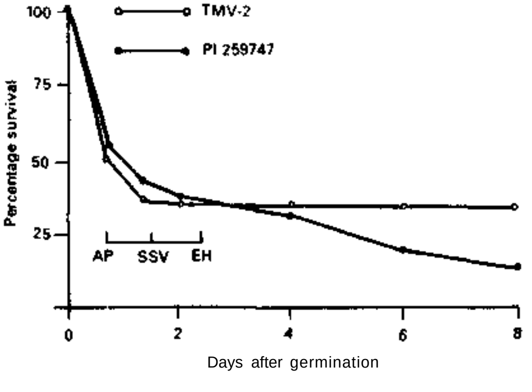

Figure 3. Mortality of P. arachidis *during the infection process (AP, Appressorium formation; SSV, sub-stomatal vesicle formation; EH, the production of an elongating hypha).*

There appear to be differences between species in the different sections of the genus in their ability to penetrate (Table 2). These effects are still being studied, since it may be possible to introduce new types of resistance into the cultivated species, particularly from section Rhizomatosae of the genus.

The Genetic Control of Leaf Spot Resistance

The genetic control of leaf spot resistance is being studied in both field and laboratory experiments. Parents were selected using detached leaf tests in April 1979 and F2 progenies were screened as detached leaves during the post-rainy season of 1979-80. Thus, by using this technique, three generations have been grown and one generation has been tested within one year. If field tests of the selected F3 progenies are successful, the technique should be a useful tool in rapid cycle backcross and recurrent selection breeding methods.

In the F2 progenies, a great range of disease reactions was observed and all components of resistance were inherited in a quantitative manner. Defoliation was controlled by genes with additive action, but for other components, dominance effects were important and resistance was recessive (Fig. 4). From the numbers

Table 2. Percentage survival of groundnut rust during the Infection of three *Arachis* species.

	State of the infection process*				
Species	GT	AP	SSV	EH	CF
A. hypogaea (cv TMV-2)	100	57	35	30	30
A. chacoense	100	50	35	30	0
A. glabrata	100	39	10	8	0

a. GT, germ tube formation (assumed value); AP, appressorium formation over a stoma; SSV, the production of a sub-stomatal vesicle; EH, the production of an elongating hypha; CF, colony formation.

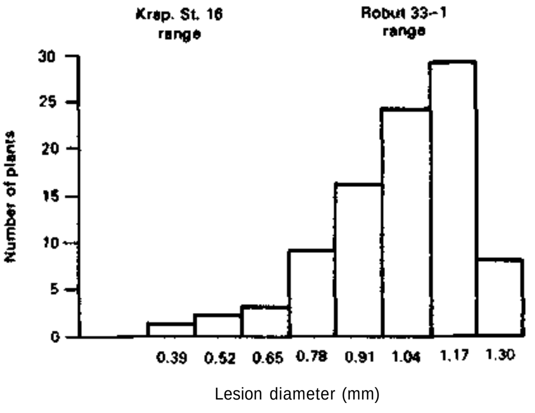

Figure 4. The frequency distribution of an F2 population derived from crossing Robut 33-1 and Krapovickas Strain 16.

of resistant segregates, it is likely that genes at 3 or 4 loci are controlling the disease reaction. The results of these tests are being confirmed in field trials this season.

Furthergenetical studies which involve diallel and line x tester crossing systems, are being conducted in the field. The results of this season's trials should provide a good deal of knowledge about the genetics of leaf spot and rust resistance and also the relationship of this resistance to plant yield.

Conclusion

During this project, a number of new techniques have been developed and demonstrated. In particular, tests of detached leaves have been used to study disease reactions of F2 progenies and computer modelling has been employed to investigate the relationship between field and laboratory results. Fundamental studies of the nature of resistance have been initiated and have provided a necessary basis for the more applied aspects of ICRISAT research. This briefly demonstrates the ways in which a post-doctoral fellowship can contribute to the groundnut research program.

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International Aspects of Groundnut Virus Research

D. V. R. Reddy*

Several virus diseases of groundnut occur in the Semi-Arid Tropics (RAT) (Chohan 1974; Feakin 1973; lizuka et al. 1979; McDonald and Raheja 1980) and some are economically important (Gibbons 1977; lizuka et al. 1979). Peanut mottle virus (PMV) is the most widespread (Reddy et al. 1978) and can cause considerable yield losses (Kuhn and Demski 1975). Other economically important virus diseases have more restricted distributions. For instance, groundnut rosette is important in Africa, south of the Sahara (Gibbons 1977; Gillier 1978; Rossel 1977; Yayock et al. 1976); peanut clump (PCV) in West Africa (Trochain 1931; Bouhot 1967; Germani et al. 1975) and in India (Reddy et al. 1979); bud necrosis (caused by tomato spotted wilt virus-TSWV) in India (Ghanekar et al. 1979); and witches' broom (a disease associated with mycoplasma-like organisms) in Southeast Asia (lizuka, personal communication).

Applied research on plant virus diseases differs from that on fungal and bacterial diseases because of the special nature of viruses. Some important prerequisites to the eventual control of virus diseases are characterization of the causal virus and elucidation of its mode of transmission. Precise virus characterization involves complicated techniques which are constantly being improved as a result of rapid technological advances and increasing interest in the mode of replication of plant viruses.

For effective management of plant virus diseases it is essential that their ecology is understood. The distribution of each disease should be ascertained and yield losses assessed. High priority should be given to screening for host plant resistance and production of resistant cultivars and this depends on close cooperation with scientists in other disciplines. To enable these aims to be achieved it is necessary that simple and effective techniques should be developed for the detection and identification of viruses.

* Principal Virologist, Groundnut Improvement Program, ICRISAT

Problems of Virus Research in the Semi-Arid Tropics (SAT)

Most reports on the occurrence of groundnut virus diseases in the SAT have been based largely upon visual symptoms. However, it is well known that external symptoms can be greatly influenced by such factors as genotype, plant age, environment, and strain of virus present. On the basis of symptoms alone it appears that bud necrosis in India (Ghanekar et al. 1979) has been described under six different names; each being regarded as a new disease by the authors. Again, on the basis of external symptoms, rosette has been reported from India, the Philippines, Indonesia, Australia, Russia and Argentina (Rossel 1977).

For most areas of the SAT, data on the incidence and distribution of groundnut virus diseases are either incomplete or lacking. Causal viruses, with very few exceptions (Bock 1973; Germani et al. 1975; Dubern and Dollet 1978 and 1979) have not been fully characterized. This is true even for groundnut rosette virus which has been under investigation in Africa for almost half a century. Reports on limited characterization of this virus (Okusanya and Watson 1966; Hull and Adams 1968) are yet to be confirmed.

Losses due to diseases have been reliably assessed for only few groundnut virus diseases, including those which have been characterized.

Methods for screening groundnut germplasm for resistance to viruses (and to their vectors) have been developed for only a few diseases, and only in the case of groundnut rosette has there been successful development of resistant cultivars (Gibbons 1977; Gillier 1978; Harkness 1977).

The most important objectives of the ICRISAT program are to characterize the economically important virus diseases in the SAT and to present reliable data on their distribution and interrelationships with similar viruses occurring in other countries.

In order to provide a basis for the control of virus diseases, research should be pursued into: (1) screening for disease resistance in *Arachis hypogaea* and in wild *Arachis* sp; (2) the effect of cultural practices (including date of sowing, spacing and intercropping) on the incidence and spread of disease; and (3) avoiding sources of infection.

Diagnosis of Groundnut Virus Diseases

Various steps involved in the diagnosis of plant virus diseases (Bos 1976) are given in Table 1.

Table 1. Steps in the diagnosis of plant virus diseases*

1. Assessment of economic importance (incidence, distribution, and yield losses).
2. Transmission by grafting, sap inoculation, insects, nematodes, etc.
3. Inoculation to a series of test plants (preferably by mechanical sap inoculation) and back inoculation to a parallel range of test plantsto check possible multiple infection and host range.
4. Identification of a host which consistently produces characteristic symptoms, especially local lesions (diagnostic host).
5. Identification of a systemically infected host which supports high virus concentration (for purification of viruses).
6. Determination of biological properties using local lesion, assay (TIP, LIV and DEP).
7. Examination under electron microscope (leaf dip, thin sections).
8. Testing by serological methods.
9. Development of methods to purify the virus.
10. Determination of physico-chemical properties and electron microscopy of purified virus.
11. Production of antiserum.
12. Testing of serological relationships with similar viruses occurring elsewhere.
13. Fulfillment of Koch's postulates, especially using purified virus.

.. Modified from Bos (1976).

Although it will eventually be necessary to diagnose virus diseases of minor importance, characterization of economically important groundnut virus diseases (bud necrosis, clump and peanut mottle) has to receive top priority.

Sap Inoculation

In initial stages, sap transmission of viruses present in crude groundnut leaf extracts could be achieved by adding reducing agents such as 2-mercaptoethanol to extracting buffers. In addition, maintenance of low temperature throughout the inoculation process, determination of optimum ionic strength and pH of phosphate buffer, and the selection of only young infected leaflets showing certain characteristic symptoms, have facilitated mechanical sap inoculation of all groundnut viruses isolated so far in India.

Diagnostic Hosts

A large number of hosts commonly used in the diagnosis of virus diseases have been secured and are being maintained. From these, diagnostic hosts have been selected for each of the virus diseases characterized at ICRISAT.

Serology

If virus antisera are available, serological techniques (Ball 1974; van Regenmortel 1978) offer effective means of diagnosis. They are rapid and can easily be standardized for the detection of specific viruses. Conventional serological techniques such as tube precipitin, micro-precipitin and precipitin ring tests have been used but have serious limitations for work with groundnut viruses. For instance, they were not successful when used for detection of TSWV in groundnuts because of limitations such as low virus concentration in plant extracts and lack of high titred antisera.

Three other serological techniques that have been used at ICRISAT with considerable success are Ouchterlony's agar gel double-diffusion (AGD); passive haemagglutination (PHA); and enzyme-linked immunosorbent assay (ELISA).

In the AGD test, antigen and antibody are allowed to diffuse into agar. A positive reaction results in the appearance of a thin white band where antigen and antibody meet. The test is easy to perform and requires no specialized equipment (Ball 1974). It can be used to test several samples at the same time. By using the slight modification of incorporating 3,5-diiodosalycilic acid into the agar for dissociating long rod-shaped viruses, the test has been successfully employed to detect PMV and Cowpea mild mottle virus (CMMV) (Table 2).

The PHA test (Ball 1974), one of the most sensitive serological techniques, has been simplified and modified to prevent non-specific agglutination (Rajeswari et al„ in press). Glutaraldehyde-fixed red blood cells, after *treatment* with tannic acid, are coated with antiserum. Antibody sensitized red blood cells are then added to various dilutions of test solutions. The test is performed in lucite plates containing 'U'-shaped wells and in a positive reaction red cells agglutinate, forming a smooth mat with a serrated margin on the bottom of the well. In a negative reaction, red cells form a discrete red ring at the periphery of the well.

The PHA test is extremely sensitive, easy to operate, does not need specialized equipment or reagents, and requires much less antisera than the AGD test. The PHA technique can be used to detect viruses in crude plant extracts. The test has been successful in the detection of TSWV antigens in infected groundnut plants and in the thrips vector. The test has also been successfully used for the detection of other economically important virus diseases in India (Table 2).

Both AGD and PHA techniques were tried for detection of viruses in seeds but without success. The ELISA technique was acquired and successfully adopted for detection of PMV in seed (Reddy et al., in preparation). The ELISA test is by far the most sensitive and specific

Table 2. Characterization of important viral dlseases of groundnut in India.

characterization	Name of the virus			
	TSWV	PCV	PMV	CMMV
1. Serology				
Gel diffusion	?	+	+	+
Haemagglutination	+	+	+	+
ELISA		#	+	*
2. Electron microscopy				
Plant material	+	*	+	#
Purified virus	*	+	+	+
3. Transmission				
Mechanical	+	+	+	+
Vector	+	+	+	?
Seed		?	+	
4. Physicochemical properties				
Sedimentation coefficient	#	#	+	*
M.W. of protein	«	+	+	+
M.W. of nucleic acid	#	*	+	+
5. Host range	+	+	+	+
6. Biological properties				
TIP	+	+	+	+
LIV	+	+	+	+
7. Symptoms				
Groundnut	+	+	+	+
Diagnostic host	+	+	+	+

+ = Positive result, - - Negative result. *= Not performed, ? >> Data Inconclusive serological technique now available for detection of plant viruses (Clark and Adams 1977; Voller et al. 1976). The procedure is simple and rapid. The y-globulins extracted from antisera, are absorbed to welts of a special microtiter plate. Test samples, including crude plant extracts, purified viruses and extracts from seed, are added to the wells. If the test sample contains specific viral antigens, theseare bound tothe y-globulins coated on the inner surface of the well. Thetest samples are washed away and enzyme-conjugated y-globulins are added to the wells. The labelled antibodies bind to the viral antigen already bound to the y-globulins coated on the plastic surface. Finally, a substrate for the enzyme, which was used earlier for conjugating '/-globulins is added to the well. The color change in the substrate is proportional to the amount of enzyme present, which in turn is proportional to the viral antigen concentration.

The two major limitations of ELISA are the need for high titered antisera and specialized reagents and plates for performing the test. Using the ELISA technique, it has been possible to screen nearly 1000 kernels for presence of PMV in two days. It would take nearly one month to field plant seed and score visually for PMV symptoms. A small portion of the cotyledon is adequate for detecting the virus. In addition, PMV could be detected in crude plant extracts d iluted to 1:10000.

Experiments are under way to employ ELISA for the detection of other groundnut viruses and especially for monitoring field collected viruliferous vector populations.

Electron Microscopy

Electron microscopy is an essential technique for the detection and identification of plant viruses. An electron microscope has recently been installed at ICRISAT and facilities are available for fixation, embedding and thin sectioning of plant material. Purified preparations of PCV, PMV and CMMV have been examined. Tomato spotted wilt virus and PMV could be localized in thin sections of infected plant material.

Purification

Purification of plant viruses is essential to produce antisera, for determining physicochemical properties and for electron microscopy. Purification of viruses requires expensive laboratory equipment such as a refrigerated superspeed centrifuge, an ultracentrifuge, a spectrophotometer and a gradient scanner. In addition, expertise is required for virus purification. However, with the aid of a refrigerated superspeed centrifuge it would be possible to partially purify viruses and prepare electron microscope grids for examination at ICRISAT.

Several physicochemical techniques are now available for separating virus particles from the normal constituents of their host cell, and the art of purification is to exploit these techniques so as to produce highly infective virus preparations as free as possible from host material. Groundnut tissue contains an excess of tannins which normally interfere in virus purification. At least one more suitable host has been discovered for each one of the groundnut viruses characterized at ICRISAT for use in virus purification. Various buffers, with specific ionic strength and pH values, have been used successfully to stabilize viruses in the initial purification steps which involve extraction from the leaves, clarification with organic solvent, precipitation with polyethylene glycol (PEG) and subsequent resuspension of PEG precipitates. Further purification has been achieved in rate and quasi-equiiibrium zonal density gradient centrifugation in sucrose solutions.

Purification techniques specific for PMV, PCV and CMMV have been developed to obtain high virus yields and high specific infectivity with no detectable impurities (Table 3). Tomato spotted wilt virus is known to be one of the most difficult viruses to purify, but a purification method developed at ICRISAT should soon be available.

Physicochemical Properties

Specialized skills and experience, and special equipment, are required to characterize viruses by physico-chemical methods. These techniques usually complement the results of electron microscopy and serology but are indispensable in determining relationships among similar viruses and in distinguishing strains. Molecular weight determination of viral proteins and nucleic acids employing polyacrylamide gel electrophoresis (Adesnik 1971; Maizel 1971; Reddy and Black 1973; Reddy and

Table 3. Virus purification methods davalopad at ICRISAT Center.

To obtain:	High virus yields No detectable impurities High specific infectivity	For:	Peanut mottle virus Cowpea mild mottle virus Peanut green mosaic virus Peanut clump virus Tomato spotted wilt virus

MacLeod 1976) has now become an indispensable tool for rapid characterization of viruses.

Chemical characterization has been successfully employed at ICRISAT to distinguish the morphologically identical PMV and peanut green mosaic virus (both belong to the potato virus Y group) and the morphologically similar CMMV which belongs to the Carla Virus group) (Table 2).

General

The important criteria employed in the characterization of groundnut viruses are given in Table 4. A series of occasional papers, describing details of all the steps involved in each of the techniques employed for the diagnosis of groundnut viruses at ICRISAT, is under preparation.

Table 4. Diagnosis of virus diseases.

Identification depends on
Serology
Electron microscopy
Transmission
Physicochemical properties
Host range
Symptomatology

Management of Virus Diseases

With the exception of PCV and CMMV the vectors of all groundnut viruses, characterized at ICRISAT, have been identified (Table 5). Studies on various factors contributing to the multiplication and spread of vectors have provided us with ways and means of managing the diseases. For instance, cultural practices (date of sowing, and plant spacing) have been successfully employed to reduce losses from bud necrosis (TSWV). In addition, identification of

Table 5. Vectors of virus diseases identified at ICRISAT Center.

1. Bud necrosis (Tomato spotted wilt virus)	: *Scirtothrips dorsalis* *Frankliniella schultzei*
2. Peanut mottle	: *Aphis craccivora* *Myzus persicae*
3. Peanut clump	: Nematodes (?)
4. Yellow spot (Tomato spotted wilt virus?)	: *Scirtothrips dorsalis*
5. Peanut green mosaic	: *Aphis gossypii* *Myzus persicae*

vectors and virus-vector relationship have been helpful, in the diagnosis of TSWV and PMV. Large scale methods for screening germplasm have been developed and sources of resistance have been identified for some viruses.

Groundnut Virus Research in the SAT

The techniques described for detection, identification and purification of viruses require elaborate and expensive equipment (Table 6) and availability of highly trained scientific and technical staff. The virus laboratory at ICRISAT and a relatively small number of other laboratories in the SAT are so equipped. It would not be practical to set up such laboratories in all areas of the SAT where research on groundnut viruses is considered desirable. However, the absence of a fully equipped and staffed virus laboratory does not meanthat useful research ongroundnutviruses cannot be undertaken.

Groundnut virologists from ICRISAT, or from other institutions where specialized virus research is being undertaken, could visit different areas of the SAT and in collaboration with

Table 6. Requirements for virology research.

1.	Maintenance and transmission
	*Glass or screenhouse
	*Autoclave
II.	Serology
	*Clinical centrifuge
	*Hot water bath
	Special chemicals, plates
III.	Production of antisera
	*Animal house
	*Rabbits
IV.	Diagnosis
	*Diagnostic hosts
	Chemical characterization
	Electrophoresis apparatus
	•Spectrophotometer
V.	Purification
	•Ref. superspeed centrifuge
	Ultracentrifuge
	Gradient scanner
VI.	Electron microscopy
	Fixing and embedding
	Electron microscope
	Vacuum coating device
	Ultra microtome

* Essential

national scientists carry out surveys to determine the occurrence and distribution of important groundnut virus diseases. The basic technology for such work could readily be prepared at ICRISAT and taken to the survey areas. This would include a supply of seed of diagnostic hosts, antisera for use with PHA and ELISA techniques and fixatives to prepare tissues for eventual electron microscopy.

Antisera can be stored for long periods at low temperature without considerable loss of their titers. Gluteraldehyde-fixed red blood cells can be held at room temperatures for at least a week, without impairing their suitability for sensitization; and if kept at low temperatures they are suitable for use in the PHA test after 3 months of storage.

If it were desired to test seeds or plant tissues for the presence of PMV, the ELISA technique could be employed. At ICRISAT, y-globulins and enzyme labelled y-globulins could be prepared and taken to the laboratory where tests were to be done. These preparations can be kept at room temperature for 10 days without damage and stored at low temperature for over a year.

Where no electron microscope facility is available locally, it would be possible to fix and embed plant tissues for later sectioning and examination at ICRISAT. Where no facilities for fixation and embedding exist, it would be sufficient to infiltrate portions of plant tissues with gluteraldehyde; this process being carried out at reduced atmosphere pressure. Such materials could be shipped to ICRISAT, or another laboratory with electron microscopy facilities.

Problems could arise where an important virus disease was of relatively restricted distribution and where no fully equipped virus laboratory was available to carry out virus purification and production of antisera.

Irrespective of the presence of a similar disease in India, it would not be possible for such work to be carried out at the ICRISAT Center because of plant quarantine laws prohibiting the importation of live viruses. This problem could be solved if virus laboratories in technically advanced countries where groundnuts are not grown could cooperate in purification and antisera production. A number of such laboratories have already shown interest in such cooperation.

Cooperation is also envisaged between virus laboratories in the exchange of antisera, seed of diagnostic hosts, and other materials useful in virus identification. Every effort should be made to expedite publication of research findings and in particular to make available data on new techniques.

An important part of the work of ICRISAT is the collection, recording and dissemination of research data and the provision of specialized training and opportunities for cooperative research. As already mentioned, papers are being prepared on the various techniques used in the groundnut virus research laboratory. Training can be given on these techniques and on other relevant techniques in the associated fields of entomology (identification and control of virus vectors), plant breeding (screening of germplasm and production of resistant cultivars) and cytogenetics (utilization of wild *Arachis* species as sou rces of resistance to virus diseases). It can also be arranged for virologists to make visits of varying duration to ICRISAT to discuss collaborative projects, acquire expertise in specific techniques, or to process their own research materials.

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Groundnut Virus Research at ICRISAT

A. M. Ghanekar*

Several virus diseases of groundnut have been reported in India based on symptoms, host range and biological properties. These properties are now regarded as inadequate to identify a virus. Characterization should be based on serology, electron microscopy, transmission and physico-chemical properties.

Three economically important virus diseases (bud necrosis, clump and peanut mottle) and several virus diseases of minor importance in India have now been fully characterized.

Bud Necrosis Disease

Bud necrosis disease caused by tomato spotted wilt virus (TSWV) has been recognized as one of the most important virus diseases of groundnuts in India (Chohan 1974; Ghanekar et al. 1979). The disease has also been reported on groundnuts in several other countries including Brazil, USA, S. Africa and Australia (Costa 1941; Halliwell and Philley 1974; Klesser 1966; Helms et al. 1961). A clear account of the disease symptoms was given by Reddy et al. (1968).

The causal virus was characterized at ICRISAT (Ghanekar et al. 1979) and the thrips vector chiefly responsible for transmitting the disease was identified (Amin et al. 1978). Bud necrosis has been shown to cause yield losses of up to 50% and occurs in all the major groundnut growing areas of India. The incidence ranges from 5 to 80% in different parts of the country (Chohan 1972; Ghanekar et al. 1979).

Symptoms on Groundnut

The typical disease symptoms on groundnut include chlorotic rings, terminal bud necrosis, severe stunting, proliferation of axillary shoots with deformed leaves and production of discolored and shrivelled kernels.

Diagnostic Hosts

The virus produces chlorotic and necrotic local lesions on *Vigna unguiculata* (cowpea cv C-152) and necrotic local lesions on *Petunia hybrida* (cv Coral Satin) which do not become systemic.

Host Range

The virus was found to have extremely wide natural and experimental host ranges. *Vigna radiata* (cv Hy-45), *Vigna mungo* (cv UPU-1), *Phaseolus vulgaris* (cv Local), *Vicia faba, Lycopersicon esculentum* (cv Pusa Ruby) and *Pisum sativum* were all susceptible to infection by TSWV. In addition a number of weeds commonly encountered in groundnut fields were also susceptible.

Biological Properties

The virus has a thermal inactivation point at 46°C and the longevity in vitro is approximately 5 hours at 25°C. These properties indicated that bud necrosis could be related to tomato spotted wilt virus.

Electron Microscopy

Thin sections of groundnut leaves under the electron microscope showed membrane bound virus particles 70-90 nm in diameter and were associated with the endoplasmic reticulum. These particles resemble those of TSWV.

Serology

Antisera for TSWV obtained from the USA and S. Africa when used in haemagglutination tests clearly revealed the presence of viral antigens in crude bud necrosis infected groundnut extracts.

* Plant Pathologist, Groundnut Improvement Program, ICRISAT.

Transmission

The virus was mechanically sap transmissible from plant extracts prepared in 0.05M potassium phosphate buffer (pH 7.0) containing 0.02M 2-mercaptoethanol added as an antioxidant. It was consistently transmitted by *Frankliniella schultzei* (Trybom) and to a lesser extent by *Scirtothrips dorsalis* Hood. The virus was not transmissible through seed of groundnut (Ghanekar et al. 1979).

Control

Screening for Disease Resistance

So far nearly 7000 germplasm lines of *Arachis hypogaea* have been screened under high natural disease incidence in the field and none showed any marked resistance to the virus. However, the cultivars Robut 33-1 and NC Acc 2575 consistently showed lower than average incidence of the disease under field conditions.

Several wild *Arachis* species have been screened under high natural disease incidence in the field, and also by mechanical sap inoculation in the screenhouse. So far *Arachis chacoense, A. glabrata, Arachis* sp (PI 262848) and *Arachis pusilla* have not become infected in thesetests, butthese results need confirmation.

Cultural Practices

As sources of resistance are still being sought, efforts *are* being concentrated on the development of cultural practices to control the disease.

Experiments on effects of date of sowing, plant spacing and intercropping with pearl millet on disease incidence are giving promising results. Early planting at the onset of the rainy season decreased disease incidence and reduced losses from bud necrosis disease. Planting at high density also reduced disease incidence (Table 1).

Experiments on the effect of intercropping with pearl millet were started recently and preliminary observations show a lower disease incidence in the intercropped situation when compared with the sole crop.

Peanut (Groundnut) Clump Virus

A disease of groundnuts resulting in severely stunted plants with small, dark green leaves was observed in 1977 in crops grown in the sandy soils of Punjab and Gujarat. Most of the infected plantsfailed to produce pods, and even in cases of late infection, losses of up to 60% were recorded. A sap transmissible virus which reproduced the disease symptoms was isolated and is being characterized.

Symptoms on Groundnut

Infected plants are severely stunted with small dark green leaves. The young quadrifoliate leaves show mosaic mottling and chlorotic rings. Roots become dark colored and the outer layers peel off easily.

Table 1. Effect of plant spacing on the incidence of bud necrosis disease (TSWV).

Interrow and Intrarow plant spacing (cm)	Postrainy season 1978--79		Postrainy season 1979--80	
	Disease (%)	Yield (kg/ha)	Disease (%)	Yield (kg/ha)
37.5 x 5.0	10	3493	7	2153
37.5 x 15.0	23	2855	16	1524
75.0 x 5.0	20	2289	9	1570
75.0 x 15.0	40	1745	18	917
150.0 x 5.0	23	1270	11	740
150.0 x 15.0	43	777	21	409

Diagnostic Hosts

Phaseolus vulgaris (cv Local), on which the virus produces veinal necrosis, and *Canavalia ensiformis,* on which discrete necrotic lesions with chlorotic centers are produced, have been identified as diagnostic hosts.

Host Range

The virus has an extremely wide host range and several weeds commonly occurring in groundnut fields are also infected by the virus.

Biological Properties

The thermal inactivation point of the virus is between 60° and 65°C and longevity in vitro is 2-3 days at room temperature.

Purification

Nicotiana hybrid *(N. clevelandii* x *N. glutinosa)* consistently gives high virus concentrations. A method to purify the virus from *crude Nicotiana* hybrid leaf extracts has been successfully devised. Polyethylene glycol precipitates of chloroform treated infected leaf extracts are subjected to density gradient centrifugation in sucrose solutions. Virus obtained from the gradients can be inoculated onto healthy groundnut plants and diagnostic hosts where it produces typical symptoms.

Electron Microscopy

Purified virus preparations, and leaf dips of infected leaves of groundnut and *Nicotiana* hybrid, revealed the presence of rod-shaped virus particles of 200-500 nm in length, and 23-25 nm in width, with a central hollow core.

Serology

Antisera were obtained of strains of the soilborne tobacco rattle and pea early browing viruses which have particle morphology similar to the clump virus. These were tested against crude plant extracts and purified extracts of clump virus but there was no positive reaction.

Transmission

The virus was successfully transmitted by means of mechanical inoculations and grafting.

The following observations suggested that the virus was soilborne and possibly transmitted by nematodes: (1) the disease was restricted to sandy soils; (2) infected plants could be obtained by sowing healthy seeds in soil samples collected from depths of 12-28 cm in infected fields; (3) the disease occurred in patches in the field and reappeared in the same positions in succeeding years; (4) air-dried soil could not reproduce the disease; and (5) nematocide applications to infested soils reduced the incidence and spread of the disease.

Nematodes isolated from infested soils, and inoculated onto healthy plants grown in sterilized soil produced the disease in some recent tests. These results need to be confirmed.

Relationship with Similar Viruses Reported on Groundnuts

Based only on symptoms, Sundararaman (1927) described a similar disease in India, which he named clump.

The symptoms observed also resemble those of clump disease reported from West Africa (Germani et al. 1975). In both cases the disease was soilborne and application of Nemagon reduced the disease (Germani et al. 1973). Both diseases are caused by viruses with similar particle structure (Germani et al. 1975; Thouvenel et al. 1976). However, both viruses have to be tested serologically before the relationship between them can be confirmed.

Control

Nematocide and Fungicide Treatments

In collaboration with the Oilseeds Section of Punjab Agricultural University, the nematocides Nemagon, Carbofuran, Temik and a mixture of the fungicides Bavistin and Blitox, were tested for their effect in controlling the disease. Untreated plots served as controls. The chemicals were applied to the soil 1 week before planting and the susceptible cultivar M-13 was used. Nemagon and Temik were the most effective in reducing the disease incidence and increasing the yield when compared with untreated plots.

Screening for Disease Resistance

Screening was carried out in infected soils of the Punjab where the disease had been recurring for three consecutive years. The plots selected had shown up to 98% incidence of the disease in the previous season. A susceptible cultivar M-13 was sown after every 10 test cultivars. Eight cultivars (M 884-75, C 334-AB-13, NC Acc 17847, NC Acc 17866, NC Acc 17732, NC Acc 17740, NC Acc 17840, and EC 21887) showed no disease symptoms.

Another ten cultivars showed a very low incidence of visibly diseased plants. These cultivars will be retested under field and laboratory conditions before any conclusions on their possible resistance or tolerance can be drawn.

Peanut (Groundnut) Mottle Virus

Peanut mottle virus (PMV) is widespread and has been positively identified in the USA (Kuhn 1965), E. Africa (Bock 1973), Australia (Behncken 1970), Europe (Schmidt et al. 1966), Japan (Inouye 1969), the Philippines (Benigno et al. 1977), South America (Herold et al. 1969), West Malaysia (Geh et al. 1973) and India (Reddy et al. 1978). The disease also appears to be present in China (Gibbons, personal communication). The disease can cause up to 30% loss in yield (Kuhn et al. 1975).

Symptoms on Groundnut

Newly formed leaves show mild mottling and vein clearing, whereas older leaves show upward curling and interveinal depression with occasional dark green islands. Infected plants are not severely stunted and older plants seldom show typical disease symptoms.

Diagnostic Host

The virus produces reddish brown necrotic lesions on inoculated leaves of *Phaseolus vulgaris* (cv Topcrop) which was found to be a good diagnostic host for the virus.

Host Range

The virus has a narrow host range and infects mostly legumes.

Biological Properties

The virus has a thermal inactivation point between 55° and 60°C and longevity in vitro is 48 hours at 25°C.

Purification and Antiserum Production

The virus has been successfully purified employing a method developed at ICRISAT (lizuka et al. in preparation). An antiserum has been produced by injecting purified virus preparations into rabbits.

Electron Microscopy

Purified virus preparations and sections of infected leaves, when observed under the electron microscope, reveal the presence of long, flexuous, rod-shaped particles of 700 nm in length.

Serology

An antiserum obtained from the USA, and one produced at ICRISAT, were reacted with PMV using agar gel diffusion, haemagglutination and Enzyme Linked Immuno Sorbant Assay (ELISA) tests. Positive results were obtained in all tests for PMV.

Transmission

The virus is seed transmitted in a range from 0.1 to 3.5% depending on the groundnut cultivars.

Aphis craccivora and *Myzus persicae* transmit the virus in a stylet-borne (non-persistent) manner.

Control

Screening for Disease Resistance

The natural incidence of PMV is not high enough for meaningful screening of cultivars for resistance in the field. It was therefore necessary to reproduce the disease on a large scale underfield conditions. A spray inoculation technique has been developed in which inoculum is mixed with celite and sprayed through fine nozzles at 50 PSI. About 1000 plants can be inoculated in one hour and about 80% of the plants become infected.

An earlier report indicated that no immunity had been found to peanut mottle virus (Kuhn 1968) in groundnut cultivars from different parts of the world. However, tolerance of some cultivars to PMV where there is no reduction in yield even though plants became infected, was reported (Kuhn et al. 1978). Using the inoculation technique described, about 200 cultivars have been screened sofarand yield losses have been estimated. None of the cultivars tested showed immunity or tolerance to PMV.

Screening Cultivars which do not Transmit the Virus Through the Seed

Diseased plants with infected seeds are the primary sources of inoculum. The secondary spread is by aphids which acquire the virus from plants infected through seeds. It would be desirable to have a cultivar which did not transmit the virus through the seed. Approximately 1000 seeds were obtained from infected plants of a range of cultivars. So far two cultivars, EC 76446 (292) and PI 259747, have not shown any seed transmission. Over 5000 seeds from infected plants of these cultivars will soon be tested under field conditions.

Virus Diseases of Minor Importance

Cowpea mild mottle virus (CMMV) and peanut green mosaic virus (PGMV) have been characterized on the basis of electron microscopy, serology, chemical characteristics and host range. CMMV has been detected occurring naturally in the Punjab, Andhra Pradesh and Uttar Pradesh but the incidence is less than 1%. PGMV has so far been detected only in the Chittoor district of Andhra Pradesh.

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Session 7 — Groundnut Pathology

Discussion

B. S. Gill

Rust was first reported from the Punjab in India and now its incidence is increasing very fast in many parts of the country, but at present there is no rust in the Punjab. Has Dr. Subrahmanyam any explanation for this?

P. Subrahmanyam

It is difficult to explain, but rust was first reported from the greenhouse in the Punjab and not the field. Moreover, in Punjab groundnut is a rainfed crop taken once in a year, whereas in other parts of India groundnuts are grown throughout the year. Therefore, the conditions in the Punjab may not be conducive to rust development.

J. S. Chohan

J. S. Chohan supported the report and elaborated that the infestation has correlation with temperatures that are very high in Punjab and Haryana and not conducive to the development of the pathogen.

S. M. Misari

How soon do the detached leaves form roots and become established? How long do these detached leaves last in this system? Is the resistance of detached leaves reduced? Have you noticed any nodulation on the roots formed from detached leaves?

D. J. Nevill

(1) The rooted leaves can remain in good condition for 2 to 3 months.
(2) No nodulation was observed in the roots in the sterile sand.
(3) No reduction in disease resistance was observed; there was a good correlation between disease rating in the laboratory and in the field.
(4) Roots begin to form after 10 to 14 days of incubation.

M. V. R. Prasad

(1) Do you think that it is equally important to identify the varieties that yield well despite the incidence of leaf spot or rust diseases? Has any work been done in this direction?
(2) I understand that some of the varieties of groundnut observed to be resistant at Hyderabad do not maintain the same degree of resistance at Dharwar. Do you think that the collection of rust material from Dharwar area would enable us to identify some physiological races, about which data are scant at present?

P. Subrahmanyam

(1) 1 agree. Work is in progress along these lines, and the subject was covered by Dr. Nigam yesterday. We now have foliar disease resistant lines that outyield nationally released susceptible cultivars under unprotected conditions but, in most cases, they are outyielded by the susceptible cultivars when grown under a protective fungicide regime.
(2) I agree that we need to study the reactions of the resistant lines at Dharwar as well as in many other locations. Such trials are being carried out and should give good indications of whether physiological races exist.

C. Harkness

Is there any relation between dry seed resistance to A *flavus* and seedling resistance to A *flavus* crown rot?

J. S. Chohan

There does not appear to be any such relationship and they appear to be independent of each other.

P. Subrahmanyam, V. K. Mehan

Aflaroot disease may originate from either seedborne or soilborne inoculum. Resistance to invasion of pods or of seeds by A *flavus* could reduce seedborne inoculum but would not affect soilborne inoculum.

We have found that some cultivars with good dry seed resistance to *A. flavus* colonization also possess measurable resistance to aflaroot and crown rot, J-11 being an example, but there is no evidence of a direct connection between the two kinds of resistance.

A. S. Chahal
What about the dangers of the seedborne nature of *Cylindrocladium* in groundnuts?

M. K. Beute
In Virginia, Dr. Porter suggested the possibility that the pathogen could be seedborne. Seed from infected plants is small and usually will not germinate. In commercial supplies of seeds, such small seeds are rejected. Thus I think that thefungus is not spreading through seeds in the USA and it is not I ikely to spread to India through seeds.

M. A. Ali
(1) Was the fungicide for *Sclerotinia* applied to the soil or foliage?
(2) How does the foliage-applied fungicide control the soilborne pathogen's effect on roots, because the fungal invasion gets replenished from the soil every time it is affected by the chemical?
(3) Why is the use of preemergence herbicide found to be less effective than post-emergence applied herbicide?
(4) How many times did you have to use benomyl as a soil dressing to control *Sclerotinia* blight (to Dr. Smith)?

D. M. Porter
The fungicide was applied as a foliage spray. Foliage systemic fungicides can be washed down to the soil and absorbed into the plant and protect the stem tissues from the pathogen. They are very active. The pathogen cannot be eradicated in this way from the soil, but the systemic fungicide will protect the plant.
Preemergence herbicides were not effective because they do not have a long-term effect.

D. H. Smith
I used benomyl only in a greenhouse experiment. In practice, benomyl is not used as a soil fungicide. It was demonstrated that the fungicide moves upward in the plant if applied to the soil. However, the foliar application did not show any downward movement in the plant. The manufacturer did not feel soil application to be practical in a field situation.

I. S. Sekhon
In the ICRISAT 9-pointfield scale, when defoliation is above 50% a cultivar has to be scored 9. For example, there is a lot of difference between the susceptibility of the two varieties M-13and Faizpur 1-5. But with this scale, both of these varieties had to be scored 9 at least at the time of second scoring?

P. Subrahmanyam
Defoliation is only one among the different parameters accounted for in the 9-point scale. It needsto be taken into account with the other parameters.

D. J. Nevill
Defoliation is a difficult parameter to measure and this is to be considered with other factors such as the season length of the variety. In a short-season cultivar, there will be more defoliation, whereas in a long-season cultivar less defoliation occurs at the same time of scoring.

P. Subrahmanyam
The cultivars mentioned are of different maturity groups. Physiological maturity must be considered.

J. S. Saini
In one of the slides you have shown that with the fungicidal control of leaf spots the yield increase has been of the order of 230% over control. What fungicide was used, at what dosage, and what number of sprays were given?

P. Subrahmanyam
We gave seven sprays of Daconil at the recommended rates at 2-week intervals starting at the initiation of disease development.

P. S. Reddy
It has been reported that the cultivar Robut 33-1 is tolerant to the bud necrosis virus. The same cultivar has been reported to be highly susceptible to thrips, the vector of this disease. Is there any explanation for this peculiar be-

havior of this cultivar, i.e., it is susceptible to the vector but resistant to the disease?

P. W. Amin
Robut 33-1 is susceptible to the virus if it is sap-inoculated. Thrips injure the leaves but virus transmission or multiplication may not be efficient. This is based on our field observations only. We have now initiated laboratory studies to confirm these observations.

V. Ragunathan
To control the soilborne inoculum of *Sclerotinia,* is there any method other than chemical control available that can be practiced by the SAT farmers? For example, organic amendments or calcium enrichment of the soil, etc.?

D. M. Porter
We have looked at different cultural practices like (1) different seed rates, (2) different tillage practices, (3) planting methods (such as turn rows), (4) spacing between the rows etc., but we believe that none of these methods is effective in controlling *Sclerotinia.* We have not tried calcium, but we feel that the most promise lies in the identification of resistant varieties.

V. Ragunathan
Can green manure or any soil amendment control the disease — perhaps calcium?

D. H. Smith
Row orientation has been tried recently to study the effect of the sun and the wind on disease development.

D. R. C. Bakhetia
Intercropping of pearl millet in groundnut decreased the movement of the thrips vector. Did it result in any difference in the disease incidence transmitted by the thrips?

A. M. Ghanekar
This experiment is still in the field and we do not yet have complete data. However, early in the season disease incidence was 20 to 25% in the sole crop but only about 15% in the intercrop situation.

R. W. Gibbons
Would K. Middleton care to comment on the management of TSWV in Australia, particularly on the cultural practices that have helped to reduce the disease in recent years?

K. Middleton
Yes. TSWV is present in Queensland but does not produce the bud necrosis symptoms. We control this virus by management practices, particularly by controlling the alternate weed hosts. But the disease incidence can increase with climatic conditions and under poor management. Weed control is important. There are a large number of alternate hosts. There has been as much as 70 to 80% disease infection, but only in seasons with high weed populations.

C. Raja Reddy
(1) Does the screening technique take into account very high vector pressure and BNV pressure, as the drawback of the common field screening technique quoted in literature is that it does not differentiate between resistance to vector and resistance to the virus.
(2) Variation has been shown to the vector — two biotypes in respect of BNV. Is there any strain variation in BNV?

D. V. R. Reddy
Robut 33-1 and NC Acc 2757 were tested under high disease pressure. Perhaps Dr. Amin can tell us about the vector pressure.

P. W. Amin
The susceptible cultivar TMV-2 showed 70 to 80% disease while Robut 33-1 showed 20 to 50% disease under similar high vector pressure.

D. V. R. Reddy
We have examined virus isolates from different places but did not detect any variation.

M. P. Ghewande
(1) What was the percentage incidence level of BNV under 37.5 x 5 cm and 150 x 15 cm spacings?
(2) If it is the case that closer planting reduced the incidence of BNV, what could be the reason?

(3) In India, row-to-row spacing normally adopted is 30 cm or 45 cm, except in the Saurashtra area of Gujarat where it is 90 cm. Why did you try such a wide spacing as 150 cm?

A. M. Ghanekar

(1) For the cultivar TMV-2 in the 1979 rainy season, the closest plant spacing (37.5 cm x 5 cm) resulted in 48.7% bud necrosis infected plants while the wider spacing (150 cm x 15 cm) gave 94.0% diseased plants.
(2) Closer planting reduced the percentage incidence but not the actual numbers of plants infected on a unit area basis.

R. W. Gibbons

Recommendations are always for narrower row spacings but how often are they followed by the farmers? The same recommendations were madef or rosette control. It is the result of poor extension of research; that needs to be improved. Most farmers do not follow extension work recommendations.

S. H. Patil

The management recommendation to sow early for reducing the incidence of bud necrosis in the rainy season is not practical. In this season, sowing can be done only after the rains have started. Similarly the rabi (post-rainy season) sowing in October is not practicable in India as the fields will not be ready for sowing. You are aware that the rabi groundnut occupies mostly the paddy fallows. Your observations may be of scientific value but not practicable.

D. V. R. Reddy

Early planting in the rainy season means as soon as sufficient rain has fallen. Very often the farmer does not do this.

S. H. Patil

In Maharashtra, delayed plantings in January reduced the disease incidence; we got 30% in December planting and 10% in January plantings.

P. W. Amin

The disease incidence depends on the migration of the thrips rather than early or late plantings. Our results are from Andhra Pradesh, and the thrips invasion may vary from area to area. There is a need to do more trials over more varied ecological zones.

Session 8

Country Reports

Chairman: R. W. Gibbons
Co-Chairman: J. P. Moss

Rapporteurs: A. M. Ghanekar
P. T. C. Nambiar
S. N. Nigam

Groundnut Production, Utilization, Research Problems and Further Research Needs in Australia

K. J. Middleton*

Production

Commercial groundnut production in Australia is centered in two distinct areas in the state of Queensland. Total planting in recent years has been 32 000-36 000 ha with production ranging from 32 000 to 62 000 tonnes. There is no government control over the area planted. An erect, large-seeded Virginia type, known as Virginia Bunch, is planted on 75-80% of this area, and Spanish types are sown on the balance. Two Spanish types are grown— a red-seeded cultivar of uncertain origin, and a pink-seeded type which has been introduced recently to the industry. Approximately two thirds of the crop is grown in the traditional groundnut areas of southern Queensland, while the balance is grown on the Atherton Tableland and adjacent areas in northern Queensland, a region of rapid expansion.

In Australia, groundnut production is highly mechanized, and heavily capitalized. Significant amounts of new technology have been obtained from successful groundnut producing countries, particularly the USA. In some instances this technology has not been directly applicable, and some modification has been necessary. This has been particularly noticeable with harvesting procedures, largely because of the peculiarities of soil types used, and due to the centralized marketing establishment.

Utilization

Groundnut production in Australia is intended for the edible market, either as savory or confectionery items, as peanut butter, or as ingredients in baked biscuits (cookies), etc. Production of oil is incidental to the production of edible kernels. Consumption on the domestic market is slightly less than 30 000 tonnes of edible kernels. Per capita consumption is low, relative to consumption in many other producing countries. Any surplus over local demand is available for export, and substantial sales to New Zealand, Hong Kong, Japan, Korea and the United Kingdom have been made in recent years.

Research Problems

The state-wide average yield of groundnut is also low — approximately 1250 kg/ha; however there are cases of yields exceeding 6000 kg/ha. These low yields, coupled with rising costs of production (notably machinery fuel and pesticides) create the major difficulty in commercial production. Innovative research breakthroughs that will improve yields and reduce the cost of production are urgently needed in the peanut industry.

Low average yields, with occasional high yields, are explained by limitations in the availability of water to the crop. Practically all Australian groundnuts are grown without the benefit of irrigation because significant amounts of suitable water are not available. Average rainfall during the growing season in the southern growing area is 500 mm; variability is high. In the northern area, 1300 mm is normal during the growing season, and this explains the recent increase in production in this area. The cultivars grown exhibit drought tolerance, and this trait must be retained in any cultivar used in the future.

The soils used for most of Australia's groundnut production are friable clays. They

* Plant Pathologist, Department of Primary Industries, J. Bjelke-Petersen Research Station, Kingaroy, Queensland.

have better moisture holding capacity than the sandy soils commonly used for the crop. However, crop yields appear to be insensitive to inputs of technology such as introduced cultivars, nutritional improvement, disease control and tillage innovations, so that the improved yields experienced in some other countries have not occurred in Australia. The occasional high yields referred to above are usually from crops grown on land being returned to cultivation after a period under pasture. This would suggest that the physical state of the soil is limiting production, and together with the limited amount of rainfall, is a factor affecting the supply of available moisture to the peanut plants. Also, there are indications that an interaction exists between soil physical conditions and nutrition, soilborne disease, and harvesting losses. It has been determined that symbiotic nitrogen fixation by the crop is adequate. The complex of soil physical conditions, moisture, nutrition and disease is the subject of a research program commencing within a few weeks, based at the J. Bjelke-Petersen Field Station, at Kingaroy.

Diseases also limit yields and/or increase costs of production. A serious problem undoubtedly associated with drought conditions is the occurrence of aflatoxins in the harvested commodity. Maximum efforts to reduce post-harvest development of aflatoxins have highlighted the importance of preharvest contamination by alfatoxins in seasons when the problem assumes real significance. As such, irrigation or other drought mitigation procedures are not available. It appears that the most effective way to control aflatoxin contamination is by host resistance. A pathologist is currently working to demonstrate the degree of association of aflatoxin accumulation with biotic, climatic, and cultural conditions. Quantification of the importance of these factors will enable a reasonable prediction to be made of the likelihood of serious aflatoxin contamination.

Seedling diseases, especially crown rot and preemergence rot, have been adequately controlled since the introduction of captan-quintozeneseed treatment. However, proposed utilization of aflatoxin contaminated material as seed coupled with some expansion of the groundnut crop onto sandy soil under irrigation, has demonstrated a possible inadequacy of captan-quintozene dust treatment to control seed-borne *Aspergillus flavus.* The recent development of a waterless flowable formulation of organic fungicides will be tested as seed treatments for control of this problem.

The stem, peg and pod rot caused by the soil-inhabiting fungus *Sclerotium rolfsii* is a major cause of reduced yields. This disease can cause losses of 25% or more, and attempts to control the disease with chemical treatments or cultural practices (e.g., deep turning) have been unsuccessful. There is a suggestion that the disease is worse when soil conditions are conducive to moisture stress and low yields. The influence of those soil conditions, which produce poor plant growth and production, onS. *rolfsii* occurrence and severity may provide a clue to control of this disease, possibly by biological means.

Another cause of yield loss and increased cost of disease control is the group of foliage diseases caused by *Cercospora arachidicola, Cercosporidium personatum* and *Puccinia arachidis,* the early and late leaf spots and rust, respectively. The leaf spot diseases have been known for many years, but rust was not known in Australia until 1973 when it was found in north Queensland. It spread south in 1976, and is now present in all areas each year. These three diseases are controlled by protectant fungicides, but the cost of such control is high, particularly where benomyl-tolerant strains of the late leaf spot pathogen occur. Currently, control measures are aimed at optimizing disease control with minimum cost, including reducing the number of applications where possible and improving the efficiency of fungicide applications. The breeding program includes screening germplasm for rust resistance, and will include leaf spot resistance when practicable..

Net (web) blotch, *Sclerotinia* blight, *Cylindrocladium* black rot and *Diplodia* blight are relatively minor diseases, but in isolated cases cause serious losses. Net blotch can be controlled by some fungicides but the relationship between environment and infection needsto be more closely studied to enable growers to adjust applications accordingly. This relationship is being investigated. Chemical control of *Sclerotinia* blight appears possible, but the cost of the practice is not yet known. The effect of soil physical conditions on the ecology of *Diplodia* and *Sclerotinia* should be studied to gain an understanding of disease development and to enable effective control measures to be found.

To date, nematodes have not been a consistent problem in traditional peanut soils, but extension of the industry into lighter soil types may cause problems. Virus diseases have caused little commercial loss to date. The strain of peanut *mottle* virus present throughout the peanut area causes only a slight loss in existing cultivars. Tomato spotted wilt virus seriously affects yields, but adequate weed control provides sufficient protection by minimizing the number of plants infected.

In summary, low yields and high costs of production are features of the Australian groundnut industry, and are consequences of two factors: (1) the unreliability of rainfall in much of Queensland and (2) the high cost of control of crop pests, particularly diseases and weeds.

Future Research Needs

The unreliability of rainfall has forced growers to use a specific soil type, sufficiently friable to allow harvesting, but at the same time providing a degree of drought insurance. The soil type used has resulted in a need for nutritional research, including investigations *of Rhizobium* spp. The soil type being used appears to have developed one or more physical conditions which contribute to low yields, to increased disease development, and to soil erosion. The soil type, and its erosion potential, have stimulated studies of tillage methods. This research involves the development of machinery suitable for production practices without destroying preceding crop residues.

A plant breeding program is also under way to improve yields, as well as to control diseases, while maintaining drought tolerance and market competitiveness. This will produce new cultivars, some of which might be a different botanical type to those currently being used. It might be necessary, therefore, to adopt new machinery capable of handling such cultivars. New machinery inputs will continue as improved pest control using more effective methods of pesticide application are developed. In addition to the control of diseases by breeding for resistance, supplemental disease and weed control measures will continue to be necessary. Insects are not a problem. An integration of agronomy, breeding, soil conservation, engineering and pathology is needed to find answers that will improve yields and minimize production costs. A multidiscipline research team has been formed within the Department of Primary Industries at Kingaroy, and in North Queensland. The potential of groundnut oil as an alternative fuel for compression ignition engines might provide the incentive needed to carry this research through to a successful end.

Groundnut Production, Utilization, Research Problems and Further Research Needs in Bangladesh

M. A. Hamid*

Bangladesh is predominantly an agricultural country and 85% of the population depends on agriculture. There is a need to become self-sufficient in food and to produce sufficient quantities to support agro-based industries, and also to earn foreign exchange.

A recent report (Rahman et al. 1976) indicated that an adult in Bangladesh requires 53 g of protein/day but at present the per day consumption of a man is only 8 g. The annual edible oil requirement at the present supply rate of 1.1 kg/capita per annum is 82 500 metric tons. If the reasonable rate is fixed at 2.2 kg/capita per annum, the annual requirement then becomes 165 000 metric tons, but at present Bangladesh is producing only 54 910 metric tons, mainly from mustard and groundnut. This huge deficit is being met either by importing oil or oilseeds from abroad and thereby using hard-earned foreign exchange.

Production

Bangladesh produces eight types of oilseeds of which mustard, rapeseed, sesame and groundnut are the principal ones. The acreage, production and yield of groundnuts are shown in Table 1. Groundnut produces more than twice theyield of sesame and mustard (Table 2).

Groundnut can be grown throughout the year. Land preparation requirement for groundnut is more or less equal in highland compared with mustard and rapeseed, but in "charlands", (very sandy or sandy loam soils), land preparation is less. Groundnut is not influenced very much by environmental variations. The nitrogenous fertilizer requirement is not great mainly because symbiotic bacteria living in their roots fix atmospheric nitrogen.

Table 1. Groundnut area, production, and yield/acre In Bangladesh.

Year	Area (acres)	Production	Yield/acre
1969-70	80	51	17.5
1970-71	78	46	16.2
1971-72	66	36	15.0
1972-73	57	31	14.9
1973-74	51	28	15.1
1974-75	48	26	14.9
1975-76	55	31	15.5
1976-77	52	23	12.1
1977-78	58	27	12.8

Source: Bangladesh Bureau of Statistics 1979 (Ministry of Agriculture).

Note: Area In thousand acres; production Jn 1000 long tons; yield/acre = maunds/acre; one ton = 27.438 maunds; one maund - 82 lbs -37.25 kg.

The most important point in favor of groundnut cultivation is the utilization of charland where no economic crop can be grown except sweet potato, watermelons and massmelons. The groundnut yield/acre in Bangladesh is one of the lowest in the world (Table 3) but the economic return is more from groundnut than other oilseed crops.

Climate and Soil

Groundnut thrives in high temperatures (25-30℃). The daily water requirement is about 0.21 acre inches which equals 26.1 acre inches for its total need (Arakeri et al. 1967). Water needs are mainly met by rainfall. The areas receiving 42-54 inches of rain are suitable for its cultivation.

Although groundnuts can be grown through-

* Scientific Officer, Institute of Nuclear Agriculture, P.O. Box 4, Mymensingh, Bangladesh.

Table 2. Seed yield and expected oil and protein yields from different oilseed crops in Bangladesh.

Crop	Yield/acre (maunds)	Oil (%)	Protein (%)	Yield/acre (mds)		Yield/acre (mds)
				Oil	Protein	Oil (commercial extractable)
Groundnut	16.0	42.2	26.0	5.50	3.40	4.2
Sesame	6.3	47.0	20.0	4.01	1.26	2.5
Soybean	15.0	22.0	42.0	3.03	6.03	3.0
Rapeseed and mustard	6.1	38.2	27.0	2.31	1.65	2.0

One maund = 82 lbs = 37.25 kg.

Table 3. Yields of groundnut (in shell) in Bangladesh and other countries.

Country	Yield/acre (maunds)
Bangladesh	15.0
Mauritius	47.1
Israel	39.0
Greece	31.4
USA	30.3

Source: Food and Agriculture Organization (FAO) 1974.
One maund - 82 lbs - 37.25 kg.

out the year, their cultivation is more profitable in the rabi season — mid-September to mid-March.

The crop can be grown in all thesoil tracts, but it is mostly grown in charlands, which are available adjacent to the rivers. Such soils are well drained, light colored, sandy to sandy loams with adequate calcium. Dark colored heavy soils stain the hulls which lowers the market value of the crop. The cultivation cost is high in heavy soils and they give a comparatively low yield which may be due to unsatisfactory penetration of the pegs into the soil and the failure of nuts and seeds to develop properly.

Cultivation

Groundnut is a clean tilled crop that needs deep plowed friable soils. Two to three cross plowings followed by two or three harrowings are generally practiced in charlands, but with highlands the number of soil workings may be greater.

Planting Time

A favorable yield and a harvest before the start of the monsoon are obtainable if the winter planting is sown within the first fortnight of November. In summer, the crop is planted in June in highlands with well drained soil.

Fertilizers

Groundnut mainly requires N, K, P, and Ca. Its nitrogen need is comparatively less due to symbiosis with *Rhizobium.* The phosphorus requirement is high as it helps in developing better quality seed with a high oil content. Hong and Van Schuylenbourgh reported the role of K as a maintainor of high quality seed. Calcium has been found to affect the shelling outturn of the seeds — a vital requirement for higher yield. Copper and Boron have a positive response on yield, but their application may not be possible in Bangladesh and it is better to apply organic manure.

Hobbs (1976) reported that groundnuts make a heavy drain on Ca and gypsum is effective to improvetheshelling outturn. Moreover, it helps to reduce the number of pops and empty pods. Khan and Rahman (1968) observed in Bangladesh in *alluvial soil that* the application of N, P and K in a ratio of 20:40:40 lbs/acre produced a high yield and oil content, while Quader and Islam (1964) reported that the application of N, P and K in the ratio of 20:60:60 lbs/acre gave a good yield in red soils.

Seed Rate

Groundnut may be sown with or without shell. Experiments conducted in different countries have indicated that germination is very low if the shells remain with seeds. Plant population/ acre is an important factor for yield of nuts. Khan and Rahman (1968) and Quader and Khaleque (1966) using the variety Dacca-1, found that nut production was maximum with an area of 90 sq. inch/plant — 10 inches x 9 inches and 15 inches x 6 inches. Other workers have concluded that 12-15 inch row width and a 4-6 inch spacing between plants were favorable for high yields.

For spreading types, 20-24 inches between rows and 9-12 inches between plants in a row is favorable. Bunch type groundnuts (mostly grown in Bangladesh) require a spacing of 15 inches between rows and 6 inches between plants in a row, thereby accommodating approximately 69 696 plants/acre. It has been found that 80-90 lbs of unshelled nut will provide the desired plant populations per acre.

Cultural Operations

Groundnut can withstand the average drought conditions in this region but an irrigation at first flowering favors yield. One weeding after 30 days and another at 45-50 days after sowing is generally required. For easy penetration of maximum pegs, a layer of 2-3 inches is generally raised up just before the maximum flowers are going to flush.

Diseases

Cercospora leaf spots and *Sclerotinia* blight are the principal diseases. *Aspergillus flavus* attacks stored seeds and produces aflatoxin. Jalaluddin (1977) reported that Dithane M 45 and copper oxychloride increased yield by 50% and 16%, respectively, when sprayed against fungal flora.

Major Pests

These are hairy caterpillars and subterranean ants. The latter are very serious in highland areas and they cause wilting. Leaf rollers and aphids are also commonly found.

Utilization

Groundnuts are used as roasted nuts, salted nuts, blanched nuts and in making candies, cakes and cookies.

Edible oil is extracted. In 1976, an oil mill was commissioned in the District of Mymensingh. It has a present capacity of 50 metric tons/day from which 15 metric tons of oil/day can be produced. The groundnut oil mill does not run at full capacity throughout the year due to an insufficient supply of groundnut. The oil is used in making soaps.

In charland areas of Bangladesh, groundnut tops are used as hay and silage after the harvest of the nuts.

Research and Research Problems

Research work on oilseeds and pulses was started by the Bangladesh Agricultural Research Institute (BARI) about 1957-58. BARI has recommended two groundnut varieties selected from local and exotic sources. The Institute has also collected some exotic germplasms and had undertaken limited variety and agronomy trials.

The Institute of Nuclear Agriculture (INA) in Mymensingh has conducted groundnut irradiation breeding with the local recommended variety Dacca-1. Some selections of desirable types are now in the Msgeneration. About 40 varieties have been collected from India and they are being studied for adaptability and yield performance.

A little work on the selection of high yielding groundnut lines has been attempted at the Bangladesh Agricultural University.

The Bangladesh Agricultural Research Council (BARC) completed a survey on the position of groundnut production and utilization in Bangladesh in 1976 (Anon. 1976). This report also dealt with socioeconomic conditions in the industry and these findings included: 22% groundnut farmers are old, 48% are middle aged and 30% are young; 67% have had no education and 17% and 13% have received only primary and high school education, respectively; the average farm size was 4.68 acres (range: 0.25-21.50 acres); 98% of the farmers owned their land; 98% procured their seed from themarket; 100% sold their produce in the local market; and the low and medium income group of farmers consisted of 40% and 39%, respectively, while the high income group amounted to 21%.

The study also examined the extent of adoption of the principal farm practices and it found that the use of seed treatment chemicals and fungicides was nil; only 22% of the farmers used manures and fertilizers; 36.7% followed earthing-up practices; 0.16% irrigated their fields and only 4% used insecticides.

Problems of Groundnut Cultivation

Low yield is the main problem which is mainly due to the low genetic potentiality of the cultivars, heavy disease infestations particularly from *Cercospora* leaf spots (both early and late) and *Sclerotinia* blight, insect infestations, low levels of fertilization, no irrigation facilities, inability of the farmers to procure timely and adequate quantities of the required inputs, and farmer ignorance of the extent of damage caused by diseases, insects and inadequate fertilizers.

Further Research Needs

There are many requirements. They include the introduction of adequate germplasm; studies on its adaptation; selection of germplasm and breeding for high seed yield with high oil and protein content; resistance to diseases and insect pests; high N fixing ability and adaptability to varying soils and climatic zones; research to develop suitable inocula; and research on seed viability sothatf armers can keep their own seed for the next planting.

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Groundnut Production, Utilization, Research Problems and Further Research Needs in Burma

U. Win Naing*

Local spreading groundnuts have been sown in Burma since 1880. They are two seeded and three seeded pod types. The seed color is pink. During the year 1925, some exotic spreading groundnuts were introduced into Burma and after five years of selection, the cultivar M-30/38 was produced.

Erect groundnuts named Small Spanish, Big Spanish, Small Japanese, and Big Japanese have been grown in Burma since 1920. Later, more exotic erect groundnuts were introduced into Burma and aftersomeyears of selection SP 121/070 was produced at Magwe Central Farm. Distribution to farmers commenced in 1948 and later it became very popular and spread all over Burma. Some years later, the erect varieties M-9, M-10, M-11 were produced.

Production

The area sown to groundnuts fluctuates (Table 1). The highest acreage sown was in 1973-74 when it was 1 973 470 acres. The lowest was 1132 300 acres during 1966-67. The main causes of the fluctuations are the frequent occurrence of unfruitful rainfall in the groundnut areas and the very high price of seed groundnuts in some years.

Varieties

The following varieties are grown during the rainy and winter seasons:

Rainy Season: (1) Erect Type: SP 121/070, M-9, M-10, M-11, and Small Japanese; (2) Spreading Type:- M-30/38, AH-35, Khaungon Spreading, and local spreading.

Winter Season: Erect Type: SP 121/070, M-9, M-10, and M-11. The line M-9 is a selection from SP 121/070; M-10 was produced from a cross between SP 121/070 and S.550-05; and M-11 is a selection from Shawat 21/6.

The characteristics of varieties grown in Burma are shown in Table 2.

Main Factors Affecting Yield

Over 50% of the total area of groundnut is sown as raincrop, under semi-arid region conditions. The rainfall pattern during the crop growing season favors a fruitful harvest only one year in ten. Sometimes there are 25-40 days between two precipitations.

Winter groundnuts are sown on the fertile riverine sides and islands along the Irrawaddy river. Here the yield rate is 50-100% higherthan rainfed groundnut on upland.

Only a few acres of the total area are fertilized with farmyard manure, urea and triple superphosphate (Table 3).

Utilization

Groundnut oil and sesame oil are the main components used for cooking. Because Burmese oil consumption consists of 70% groundnut oil, there is little increase in production of groundnuts for kitchen consumption.

Research Problems

There are many problems in groundnut cultivation in farmers' fields as well as in the experimental stations of the Agricultural Corporation.

To conduct the appreciable amounts of required experiments, the Agriculturral Corporation with the help of UNDP has increased the numbers of farms as well as research facilities and technicians.

In Burma there are two central experimental stations and five seed farms which are conducting groundnut experiments.

* Agriculture Corporation, Rangoon, Burma.

Table 1. Area and yield of groundnuts in Burma.

Year	Sown acreage	Matured acreage	Yield lb/acre	Yield (25 lb basket)
1975-76	1 693 337	1 633 769	554.5	36 229 428
1976-77	1 507 304	1410 357	661.0	37 289 280
1977-78	1 418 263	1 391 822	735.0	40 946 284
1078-79	1 421 840	1387 911	699.0	38 809 216
1979-80	1 493 507	1 468 073	742.0	43 590 000
1980-81 (Projected)	1 789 046	1 732 994	793.5	55 010 558

Table 2. Characteristics of groundnut varieties grown in Burma.

Variety	Plant type	Life period (days)	Seed color	Pod			Oil (%)	Shelling (%)
				L (mm)	B (mm)	Midway girth(mm)		
SP 121/070	Erect	110	Pink	24.7	10.6	9.5	47	71
M-9	"	110		25.4	10.9	9.6	59	73
M-10	"	110		22.9	10.4	10.0	54	76
M-11	"	110		23.5	13.5	10.0	55	75
M-30/38	Spread	150		21.6	10.2	9.0	49	70
Kyaungon	"	150		23.2	9.9	9.3	49	68
Local spreading	"	170		27.0	13.2	11.2	49	70

The following types of experiments are being conducted on these farms in 1980-81:

1. Varietal yield tests.
2. *Rhizobium* inoculation tests (mainly on CB.756. Australian St.)
3. Lime application and plant types.
4. The effect of levels and carriers of phosphorus.
5. Residual effect of levels and carriers of phosphorus on groundnut grown after the monsoon rice crop and after the monsoon jute crop.
6. Application of gypsum, nitrogen and phosphorus on erect groundnut.
7. Depth of land preparation on erect groundnut.
8. Insecticide effects on groundnut leaf miner.
9. Effect of weedicides on weeds.
10. Effect of trace elements on groundnut yield.

Table 3. Fertilizer usage in Burma (1955—86 to 1979—80, average).

Fertilizer	Amount used (tons)	Raincrop acreage fertilized
Urea	4410	200 000
TSP[a]	2500	120 000
Potash	250	

a. TSP - Triple superphosphate.

Further Research Needs

Varietal Improvement

Presently six nucleus stock of erect types and four nucleus stock of spreading types are maintained. For genetic stock, we have 70 erect varieties and 136 spreading varieties.

Under selection, we have 45 Australian varieties and 15 Japanese varieties, and in hybridization we have six crosses and 101 families.

Maximum yield potential of the present varieties used in cultivation is between 2500-3000 lbs. The varieties should be improved to get the maximum yield potential up to 4000-5000 lbs.

We have very few nucleus stock and genetic stocks. For proper selection and hybridization purposes, more exotic varieties should be introduced.

Cultural Practices

Cultivation in rows is usually practiced in groundnut production. Spacings between row to row and plant to plant are the prime factors. In most areas, 15 inches x 4 inches row x spacing for erect groundnut and an 18 inches x 9 inches row x spacing for spreading groundnut are practiced. Experiments should be conducted regionally to produce proper row x spacings.

Uneven spacing and low seed germination produce poor results from hand drilling seeds in furrows. An improved seed driller, that gives precise depth and distance, should be tested.

Fertilizer Experiments

We have some fertilizer experiments on groundnut at Magwe Central Experimental Farm. The last 3 years' experimental results gave little indication of nitrogen and phosphate fertilizer uptake. A significant nitrogen rate is 25 lbs in combination with 35 lbs of phosphate at Magwe. We still have no significant indication of the effect of gypsum on yield, but plants seem to have a deeper green coloration. Experiments on yield with nitrogen and phosphate fertilizer at different rates should be conducted further in different regions.

Since 1979, *Rhizobium* experiments have been conducted, but we have no significant results. Experiments on yield with different rates of gypsum and experiments with *Rhizobium* strains should befurther conducted.

Groundnut Production, Utilization, Research Problems and Further Research Needs in Malaysia

Halim B. Hamat and Ramli B. Mohd. Noor*

Groundnut {*Arachis hypogaea* L.) is the most extensively grown grain legume in Malaysia. It is grown either as a sole crop in the riverine and rainfed rice areas, or as an intercrop especially in young rubber. It is an important cash crop in this country. However, the hectarage has been stable in the last few years. In 1976, the hectarage was 5794 hectares in sole crop equivalent (Wong 1979). The major groundnut growing states are Kelantan (2658 ha), Trengganu (1299 ha), and Perak (1106 ha).

Groundnut Production Areas

All the Malaysian groundnut crop is grown under rainfed conditions. Generally, the growing areas are:

Riverine Area

This is mainly along the banks of the Kelantan, Trengganu, Perak, and Pahang rivers. The soil is alluvial and its fertility is replenished every year due to the annual flooding during the monsoon season. This is the most intensive cultivated area and it contributes about 60% of the total groundnut production.

Rubber and Oil Palm Area

The groundnut is grown as an intercrop in young rubber and oil palm plantations, and in small holdings. Such production is commonly found in the states of Perak and Selangor.

Single Crop Rainfed Rice Area

Here the groundnut is grown in rotation with rice during the off season when a second crop is not possible due to insufficient water. This is the potential area for the expansion of groundnut cultivation. The areas are found in the states of Kelantan, Trengganu, Kedah, and Pahang and are estimated to be about 150 000 hectares (Wong 1979).

Bris Soil Area

Presently a very insignificant hectarage of groundnut is grown in this area. However, it is another potential growing area where the groundnut can be rotated with tobacco. This area is located along the east coast of Peninsular Malaysia.

Groundnut Growing Seasons

Malaysia has an equatorial-type climate, characterized by humidity above 60%, abundant rainfall (200-300 cm/yr), temperatures ranging between 22°-31°C throughout the year, and daylength of about 12 hours. Generally, two crops of groundnut can be grown per year.

In the East Coast states of Kelantan and Trengganu where 60% of the annual rainfall occurs during the North-East Monsoon (November-March), 26% during the Southwest Monsoon (May-September) and only 14% during the two transition months (April and October) (Dale 1974), the first planting (main) season begins in late January or early February and the crop is harvested in April. The second planting season begins in late May or early June and the crop is harvested in September. Generally the groundnut produced from the first planting season is of better quality than the second season (Anon. 1977).

In the West Coast states of Perak, Selangor and Kedah where 36% of the annual rainfall occurs during the North-East Monsoon, 41% during the South-West Monsoon and 23% during the transition months (Dale 1974), the first

* Groundnut Breeder and Agronomist, respectively, of the Field Crops Branch, MARDI, Malaysia.

planting season begins in April or May and the crop is harvested in July or August. The second planting season begins in September or October and the crop is harvested in January. Generally, the hectarage is greater in the second season because the farmers grow more to cater for the demands of the Chinese festive season which occurs in February. Despite this second season being less suitable for the growing of groundnut than the first season due to higher incidence of diseases, the selling price is higher (Ramli et al. 1976).

Although two crops of groundnut are possible per year in most parts of the country, usually only one crop is feasible if it is grown in rotation with other crops. In the rainfed rice area of the East Coast where it is rotated with rice, the groundnut is usually planted in April or May and thecrop is harvested in August or September. In the Bris soil area where it can be rotated with tobacco, the growing season is also similar to that in the rainfed rice area.

Current Production Practices

A number of cultivars are grown by farmers. In the state of Perak, the most common cultivars are Sungai Siput and Mengelembu, which are mainly marketed as roasted groundnut. In other states, cultivars that originated from Indonesia are commonly grown. Presently MARDI is recommending three cultivars — V13, Matjam and 47-5 — for growing throughout the country. They are of the Spanish bunch type with small/medium two-seeded pods. Farmers usually obtain a yield of 3.0-3.75 metric tons of fresh pod per hectare, though a yield of 6 t/ha has been recorded. The national average yield is 2.2 t/ha and this is among the highest in Asia.

In land preparation, generally either one round of plowing and one round of rotovation, or two rounds of rotovations are practiced. A square planting of 30 cm x 30 cm with two seeds per point giving about 220 000 plants/ha is usually practiced. This requires approximately 90 kg seed/ha. MARDI presently is recommending a row planting of 50 cm x 10 cm with one seed per point giving about 200 000 plants/ha.

Liming using dolomitic limestone at the rate of 1-2 t/ha and fertilizer at rates of 34 kg N, 56 kg P_2O_8 and 56 kg KaO in the forms of sulphate of ammonia, triple superphosphate and muriate of potash, respectively, are usually recommended for most soils. Liming is done during land preparation at two weeks before planting, and fertilizer is applied at planting, in band. However, liming and fertilization are seldom practiced by the farmers especially in the riverine areas. If practiced, there is no standard rate of application. Usually a compound fertilizer is broadcasted immediately after weeding, one month after planting. Hilling is practiced during the weeding operation.

Insect pest and disease control is seldom carried out because the problem is usually not serious. Disease like *Cercospora* leaf spot usually occurs very late in the season and has little effect on the yield. However, if the disease occurs early in the season, it can be effectively controlled with benomyl fungicide.

The groundnut is harvested 90 days after planting for use as roasted groundnuts and about 105 days after planting for use as planting material.

Costs of production and returns from groundnut vary greatly depending on the operations carried out, yield and the current selling price. However, groundnut generally gives a good net return ranging from M$625 to 1000/ha per season (Anon. 1977; Ramli et al. 1976).

Groundnut Usage and Utilization

Most of the Malaysian groundnut production is marketed as fresh, unshelled pods. They are used mostly for roasted groundnuts. Some are used for making cooking oil, oleomargarine, and confectionery. A special technique called the Mengelembu process has been developed for roasting groundnuts. There are about ten factories scattered all over the groundnut producing areas. Factories sometimes obtain advance commitments by providing cash advances and planting materials to selected farmers. Ex-farm groundnut prices vary according to locality, season and nut quality. The roasted groundnuts are mainly consumed locally, but some are exported to other countries.

Research Activity

At present, groundnut research activity is focused on breeding and varietal evaluation, development of cultural and management practices, nutrient requirement study, insect pest, disease and weed control studies.

Breeding and Varietal Evaluation

Virtually all the past work on varietal improvement had been varietal evaluation of foreign cultivars. After many years of evaluation, three cultivars were found to be high yielding. These are V13, Matjam and 47-5 and they arecurrently being recommended to farmers. V13 is a local selection, Matjam originated from Indonesia and 47-5 originated from Senegal. These three cultivars perform well throughout the country.

Recently, a breeding program has been initiated. The breeding materials are evaluated at several locations in the groundnut growing area. This is because the environmental conditions and the problems of each area are different. The objective of the breeding program is to develop high yielding cultivars for specific areas.

To complement this program, germplasm from different ecogeographical regions is being evaluated. Presently there are 256 accessions in our germplasm collection, of which 200 were obtained from ICRISAT. Some of these accessions have been included in advanceyield trials over years and locations. A number of them are being used as parents in the breeding *program.*

Development of Cultural and Management Practices

There was limited work on cultural and management practices carried out in the past. The investigations were mainly on plant spacing/ density and harvesting time studies conducted on well-drained upland soils. Presently groundnut production has expanded to other areas like the riverine, single crop rainfed rice and the Bris soil areas. Since each area offers different ecological environments and production problems, there is a need to develop cultural and management practices suitable for each specific area.

Nutrient Requirement Studies

Some work has been done on the nutrient requirements of groundnut. The present recommended rates of fertilizer application have been based on these findings. Since different soil types and locations differ in their nutrient status, nutrient requirement studies are required over many locations to determine optimum rates for each specific location. Also there is a need to study the inoculation requirements of rhizobium bacteria for successful nodulation so that the beneficial effects of nitrogen fixation by these bacteria can be exploited and thus reduce the costs of nitrogen fertilizer application.

Insect Pest Studies

In recent years, research has been focused on the identification of some of the more important insect pests and their chemical control. Some of the recommended insecticides are not as effective and also there have been reports of field resistance to some of the chemicals by the insect pests. New chemicals, therefore, need to be screened as a stopgap measure. Following the availability of effective insecticides, more research should be devoted to screening for varietal resistance. As part of a long term control program, the role of natural enemies also needs to be investigated.

Disease Studies

Much of the research effort on disease problems over the years has been the identification and diagnosis of the prevalent diseases. Chemical control has been effective for some diseases. However, for many other diseases, appropriate control measures are still lacking or have not been investigated. Perhaps the ideal control measure would be through varietal resistance. However, little has been done to utilize this attribute.

Weed Control Studies

Research on weed control in the past has been conducted on well-drained upland soil. It has been found that a preemergence application of alachlor plus one round of manual weeding at two weeks after planting is adequate for this type of ecological environment. However, information on weed control is lacking for the other groundnut growing areas. Weed surveys need to be carried out to determine the major weed species in these other areas. Traditionally, weeding is done manually. Therefore, research needs to be conducted to determine the right time and frequency to maximize crop yields. Also there is a need to screen other herbicides and todetermine their efficacy to control certain prominent weeds.

Further Research Needs

The above research activities are those currently being given priorities. However, we also recognize other areas where attention is required in order to promote the expansion of groundnut cultivation in the country. One such area that needs immediate attention is mechanization. Except for land preparation, all aspects of groundnut cultivation are done manually. Planting and harvesting are the two most laborious and time consuming operations. In rainfed single crop rice and other low lying areas, waterlogging is a constant problem. To overcome it, the groundnut can be planted on ridge or raised beds. Therefore, there is a need to develop a suitable and practical ridger or bedformer. In addition, fertilizer application and spraying to control weeds, insect pests and diseases can also be mechanized. Attention should be given to mechanizing these operations.

It has been recognized that groundnut cannot be grown alone in an area, continuously. Groundnut cultivation needs to fit into a cropping system with other crops. It should be determined whether groundnut is suitable for cultivation after rice, tobacco and other annual crops. Also, there is a need to know the benefits of intercropping groundnut with other crops, whether they be annual or perennial.

To further promote groundnut cultivation, there is a need to expand its usuage and utilization in the country. The present groundnut hectarage is about to saturate the market for roasted groundnut. There is a need to look for new ways of utilizing groundnut to make other products.

Summary

Groundnut is the most extensively grown grain legume and it is an important cash crop in the country. However, the hectarage has been stable in the last few years. Previously, groundnut was mainly grown in young rubber, oil palm and riverine areas, but now its cultivation has expanded to rainfed single crop rice areas. Also Bris soil regions are another potential groundnut growing areas in the future. Generally, two crops of groundnut can be grown per year throughout the country. However, if grown in rotation with other crops only one crop is possible. Although there are recommendations available for growing the crop many farmers seldom follow the recommended practices due to socioeconomic problems. The crop is mainly used for roasted groundnut.

Research activities being currently emphasized include breeding and varietal evaluation, development of suitable cultural and management practices, nutrient requirement studies, and insect pest, disease and weed control studies. Our overall research objective is to develop technologies to obtain maximum yields for specific growing areas. In order to promote the expansion of groundnut cultivation in the country, further research should include mechanization, cropping systems and groundnut utilization.

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Groundnut Production, Utilization, Research Problems and Further Research Needs in Thailand

Arwooth Na Lampang, Terd Charoenwatana and Dumrong Tiyawalee*

There is no definite record about peanut introduction into Thailand. However, it is believed that peanut was brought into this country by European traders during the Ayuthya period — about three hundred years ago. Peanut is well adapted to tropical climate and at present is cultivated in every part of the country. The Thai people consume nuts in various forms. The area (ha), production (metric tons), and yield (kg/ha) in the past decade are given in Table 1. The figures indicate an insignificant change in production during this period. Table 2 shows peanut production and consumption projected for the next 5 years.

Production

The major growing regions are the North and Central Plains, and the Northeast. In the South, heavy rainfall seems to limit large scale production. Nevertheless, isolated fields of peanut are grown for local consumption, mainly in the young rubber replantations. Figure 1 illustrates peanut production in these four regions. The large hectarage falls between latitudes 13 and 20 degrees North.

Soils suited for growing peanut are generally light to medium texture and well drained.

The Thailand climate is divided into two distinct seasons — dry and wet seasons. The monsoon or rainy season begins in May and lasts till October. This is the critical time for Thai farmers since about 80% of the total arable lands depend mainly on this rainfall. The dry *period covers* the remainder *of* the *year* when crop cultivation, except in a small area, can be undertaken only with irrigation. This area amounts to about 20% of the total cultivated land. Thus peanut is grown in both seasons.

Table 1. Area, production, and yield of peanut (In the pod) during the 10-year period (1969-1978).

Year	Area (000 ha)	Production (000 t)	Yield (kg/ha)
1969	103	124	1206
1970	104	125	1200
1971	114	136	1169
1972	119	153	1288
1973	124	147	1181
1974	130	161	1237
1975	118	147	1206
1976	122	151	1244
1977	103	105	1031
1978	106	127	1206
1979	-	132	-

Source: Office of Agricultural Economic Report 1960, Ministry of Agriculture and Cooperative.

Table 2. Projected peanut production (In the pod) and consumption in the next 5-year period (1980-1984).

Year	(000 t)	(000 t)	(000 t)
1980	150	124	26
1981	159	127	32
1982	173	133	40
1983	187	138	49
1984	203	143	60
Rate	+ 8%	+ 3.7%	+ 23%

Source: Ministry of Commerce, 1980.

* Director, Field Crop Division, Department of Agriculture, Bangkok; Vice Rector, Khon Keen University, Khon Kaen; and Dean, Faculty of Agriculture, Chiangmai University, Chiangmai, Thailand, respectively.

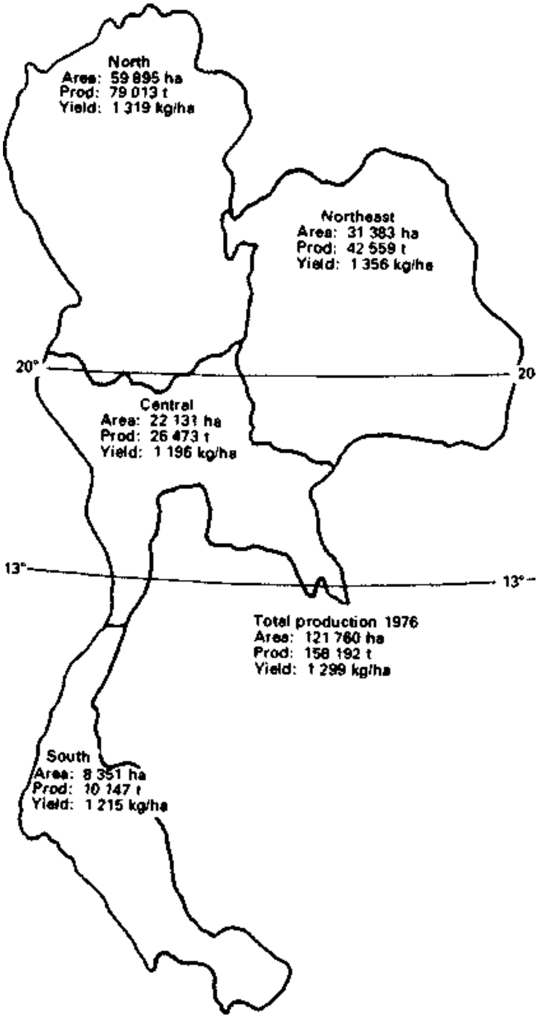


Figure 1. Peanut production divided by regions in the Kingdom of Thailand. Source: Office of Agricultural Economic Report 1978, Ministry of Agriculture and Cooperatives.

In the rainy season, planting is from May-June and harvest is in September and October, while in the dry season, planting is from January - February with harvest in March and April, in paddy fields after rice.

Since there is no specific requirement for types of peanut in the markets, the medium seeded types are generally grown to satisfy a multipurpose demand. Three cultivars have been released to farmers at present. Two of them are Valencia type, S.K. 38, red seed coat, and Lampang, white seed coat, and one cultivar of bunch Virginia, Tainan 9, a white seed coat. They are well received throughout the country. However, the small seeded Spanish type is occasionally seen in certain locations. Attempts to grow large seeded Virginia runners have not been successful due to the longer duration and problems of unfilled pods.

Thai farmers grow peanut as mono or sole crops in the upland during the rainy season, and as mono crop followed by rice in the dry season. A spacing of approximately 30 cm between rows and 20 cm within rows does not permit intercropping. Recently, experiments on intercropping of peanut with other row crops such as cassava, cotton, sugarcane and castor bean appear promising for practical development, based on LER (Land Equivalent Ratio).

Peanut is less vulnerable to serious diseases and insect pests compared with other legumes. Its relatively early maturity, about 110 days, allows it to escape severe attacks of *Cercospora* leaf spot and rust which become serious and widespread late in the rainy season. Seedling, stem and collar rots may occur during the peak of the rainy season, if land is not properly drained. Leaf hoppers, rollers and miners create considerable problems during the dry period. Systemic insecticides are recommended for their control. Since harvesting of both the season crops occurs in the dry periods, the aflatoxin hazard is minimized.

Other factors which make peanut widely adapted in Thailand are its ability to withstand intermittent moisture stress, low soil fertility, low pH and/or soil salinity as well as minimal management. Also it can withstand atmospheric drought for 2-3 weeks and resume growth immediately with good rains.

Most Thai farmers treat peanut as a marginal crop, especially in the rainy season. Hence, yields are low. In contrast, the Thai farmer prefers to grow peanut in the paddy fields, wherever irrigation is available, because of the vigorous growth of the following rice crops, in addition to the extra income from peanut.

Thailand imports considerable amounts of unrefined peanut oil and cake, and exports both shelled and unshelled nuts. Table 3 gives the trade balance during 1975-1979 and Figure 2 shows sharing relationships between the farmer, dealer, shelter and exporter.

Utilization

Peanut utilization in Thailand is relatively similar to that in other countries. There are numerous forms and preparations employed in the processes to obtain the finished products starting with either the whole pod or shelled nuts.

Whole Pod (Unshelled)

BOIL. Fresh pods *from the* fields are *boiled or* steamed, and a small quantity of salt is added as flavoring. The cooked pods are drained out and immediately put on sale as snack. This kind of preparation is simple and popular to street retailers or vendors.

BOIL AND DRY. The above products cannot be kept for a long time. Processors have to dry the cooked pods under sunshine and/or in the oven to reduce the moisture content in the pods to a certain limit. They are packed in airtight plastic bags to prolong their keeping quality. Thailand recently started to export this type of product to neighboring countries. There is a continuously increasing demand.

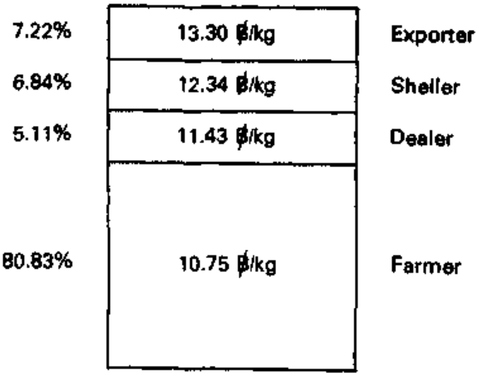
ROASTED PEANUTS. Large and medium pods are sorted out from the dry bulk. Then they are roasted, usually with hot sand. The product is vended directly and/or kept in plastic bags for transportation to other places.

Shelled Nuts

Peanut is generally stored in the pod. At the processing plant, the pods are shelled and nuts are removed from the shells or hulls. The nuts are graded into three classes according to their sizes:

LARGE AND *MEDIUM SEED SIZES. These are* mainly used in the form of whole nuts and they command premium prices. They are prepared for snacks by deep frying, roasting and/or baking and for making confectioneries and desserts.

SMALLANDBROKEN NUTS. These are ground or milled to make peanut meal. The meal is converted into pastes, curries, desserts and several forms of snacks.



Source: Ministry of Commerce 1980.

Figure 2. Shares in peanut exportation (based on 1980 data).

Table 3. Balance of peanut trade during the 5-year period (1975-1979).

Year	Production (dry pod, 000 t)	Import (as pods) (000 t)	Import (as pods) Million β	Dom Consump. (000 t)	Export (as pods) (000 t)	Export (as pods) Million β
1975	142	30	36	133	9	86
1976	151	92	100	140	12	94
1977	105	95	149	82	24	166
1978	127	26	33	92	36	206
1979	131	29	46	117	15	104

Source: Custom Department, Ministry of Finance, 1980.
Note: 1 U.S.S = 20 β

OIL EXTRACTION AND FEED MEAL Due to an increasing demand for edible oils and animal feeds in the past decade, oil extraction industries were established to extract peanut and other edible oils. However, peanut costs considerably more than other sources of oil such as soybean and rice bran. At present, peanuts enter the trade mainly for human consumption in both the domestic and foreign markets as whole nuts.

To a lesser extent, peanut is used in special forms, such as fermented paste and sprouts.

The feed industries used to import peanut cake in large quantities as a substitute for soybean cake. The restriction of aflatoxin imposed in the last few years has led to a considerable reduction of imports.

Research Problems

The Thai government is planning to increase peanut production for both domestic consumption and export. The attention to and investment in this crop is inadequate at present, especially from the research standpoint. There are several constraints to be removed before higher levels of yield can be obtained.

In regard to varietal improvement, thefollowing characters are needed — high, reliable, consistent yields; earliness (i.e., about 90 days) to fit existing cropping patterns; uniform flowering, pod setting and maturity; resistance to major pests and diseases, including Aspergillus *flavus;* and higher shelling percentage.

Research is required on cultural practices and cropping systems to minimize labor and other inputs, obtain higher LER, maintain soil fertility, and to spread the farm labor requirement and thereby reduce peak demand. Small and animal drawn equipment such as the planter, pod digger, pod picker and shelter need to be researched.

Constraints imposed by diseases, insect pests and weeds constitute important problems.

Further Research Needs

Increased research on peanut is urgently needed in order to increase yield per unit area as well as the national product. The goals for further research are:

1. Develop larger seeded varieties with a shorter growing season.
2. Study the peanut cropping system in the rainfed areas, which occupy about four-fifth of arable lands in the Kingdom. Attention must be paid particularly to the Northeast, where soils are relatively infertile and rainfall is erratic.
3. Improve or maintain soil productivity by the application of rock phosphate and other sources of phosphorus (in addition to Item 2).
4. Research on minimizing aflatoxin contamination by means of breeding, cultural practices, storage and detoxification by chemical treatment.

The above goals require a strengthening of research facilities involving (1) staff training in short term and academic programs, (2) coordination at international and national levels with peanut research institutes in the exchange of germplasm, seeds, materials, information and research results, and (3) the establishment of regional yield trials.

Groundnut Production, Utilization, Research Problems and Further Research Needs in Argentina

Jose R. Pietrarelli*

Production

For the past fifty years, groundnut cultivation in Argentina has been concentrated in the central region of Cordoba province and in eight departments located therein. During this period, small areas have been sown in other provinces of the Northeast, Northwest and Argentine Litoral. However, they constitute only 2-3% of the total area of the country with 97-98% of the total sown hectarage being located in C6rdoba.

Since 1970, the average area harvested has been 346 125 hectares per annum with an average annual production of 280 787 metric tons of shelled groundnut, which represents an average annual yield of 811 kg/ha. The sowing record in this past decade was 428 000 hectares in 1977-78. In the 1978-79 season, only 329 000 hectares were cultivated while in 1979-80, only 281 000 hectares were harvested. International markets, lower prices and less demand by the oil industry are expected to cause a further reduction in the area sown to groundnut.

Cordoba Region Production Characteristics

The region is furrowed by the First and Second rivers which run to the northeast, and by the Third river which flows to the southeast.

The soil is generally classified as brown, is deep and is without much impermeable covering. The texture is sandy loam. The alluvials situated in the regions are sandy. Soil organic matter content varies and it averages about 2%. The soils are well supplied with calcium, magnesium and potassium but the levels of nitrogen and phosphorus range from moderate to low. The ground surfaces utilized are mostly level. In a few cases, the slope varies from 1 to 3%. The soil type is such that the land is easily eroded by wind or rain.

The region is semi-arid. Rainfall ranges from 600 to 800 mm annually and falls generally between October and March. There is great variability in the time, amount and rainfall distribution each year which results in yield variations. The coldest month is July, with an average temperature of 9-10°C. The hottest month is January, with an average temperature of 23-24°C. The frost free period is 245 days. Frosts normally occur in May but in some years may commence in April. Because rain falls in the spring and summer seasons when higher temperatures occur, groundnut can be successfully cultivated in the Cordoba region.

Sowing is favored with a spring which is sufficiently humid in order to plant the groundnut in November or the first days of December. The fall-winter period is dry enough to permit harvest and natural drying of the product under good conditions. The areas sown range from 100to 150ha. Minifunds exist which allow a medium extension of 50-100 ha.

The monoculture areas are located on the sides of the Second and Third rivers. The monoculture of groundnut is characterized by a security of cropping.

Agricultural Equipment

In the Cbrdoba region, there is a high degree of mechanization. Equipment is used for tillage, sowing, cultural practices and the application of herbicides and fungicides. The equipment usually consists of plows of 4 or 5 colters, harrow-plows, teeth-harrows, rotary hoes, sowing machines for small and large grain (up

* Agronomist, INTA, Manfredi Research Station, Manfredi, Argentina.

to seven rows), and rowing rakes of lateral discharges, etc.

About 30% of the growers have digger-shaker-windrow machines, and 20% havetillers or peanut combines. Growers who do not possess these last named machines, employ contractors.

Harvest

About 90% of the area cultivated with groundnut is harvested with a digger-shaker-windrower which works from 3 to 5 rows. That same percentage is picked with a peanut combine. The rest of the production is prepared with a stackpole, especially in the monocultural area.

Principal Varieties

The cultivars grown in the Cordoba region belong *to Arachis hypogaea,* subsp *fastigiata* vars *fastigiata* and *vulgaris.* Colorado comun and Blanco Rio Segundo are the most extensively used cultivars (about 50%;. These two varieties were present prior to the commencement of varietal improvement (breeding) at the Manfredi Experimental Station. Their cultivation must be very old. They are perfectly adapted to the ecological conditions of the central region of Cordoba.

Other varieties sown in this area are all products of the Manfredi Experimental Station. Colorado Manfredi was obtained by selection from Colorado comun, and occupies 5% of the planting area. Blanco Manfredi 68 originated from the crossing of a black groundnut (type 4) with a Virginia type line (Fla. 249-40-B3). It occupies 15% of the area. Colorado Irradiado INTA comes from a mutation induced by X-rays in the variety Colorado Manfredi and it occupies 20% of the planted area.

The other varieties — Colorado Correntino INTA (a selection from a population grown in the province of Corrientes), Blanco Asuncion (a selection from a population grown in Paraguay), Manfredi Virginia 3-INTA (a genealogical linefrom North Carolina, USA and Manfredi), Virginia 5-INTA (a product of a selection performed in Florida, USA, and introduced into Argentina in 1964 with the pedigree Fla. 416-2) — occupy the remaining 10% of the groundnut producing area of Cordoba. The last two mentioned varieties have increased in hectarage more than the others.

Utilization

Producers sell their kernels to buyers, who store them, as well as to cooperatives or associations in the region, who in their own time sell the product to industry. In the groundnut region of Cordoba, there are eight oil factories whose primary input material is groundnut. Three years ago, the oil industry absorbed about 75% of the total production.

Research Problems

The greatest percentage of the area is planted with varieties of the subsp *fastigiata.* Problems associated with this type are (a) no seed dormancy with a consequent sprouting risk; (b) fragility of the pegs which causes great yield losses due to the easy separation of pods from the pegs; (c) generally a low fat content; (d) low yield potential; and (e) high susceptibility to leaf spot attacks by *Cercospora arachidicola* and *C. personata.*

Groundnut diseases and insect pests do not yet represent a grave danger, but late attacks of leaf spot are common. Occasionally, when these attacks occur early (early leaf spot) in the vegetative cycle, yield is affected. In the past three years, isolated cases of a scab *(Sphace/oma arachidis)* infection have been found. It appears to show a preference for certain varieties. In Cbrdoba, rust *(Puccinia arachidis)* is not found. Root rot and pod rot, produced by different organisms, are seasonally present under monoculture or during adverse climatic conditions in the maturing period of the pod.

Regarding insect pests, few cases exist of damage by subterranean insects *{Diabrotica speciosa* Germ.), or by the small red spider *(Tetranychus telarius)* which is present especially during long dry periods.

With the present harvesting machines there is a loss of up to 30% of the harvested material. Also the picking and shelling operations simultaneously reduce quality and aggravate the danger of aflatoxin contamination.

Institutions with Research Projects

Since 1944, the Manfredi Experimental Station in Central Cbrdoba province has been responsible for varietal and cultural improvements of groundnut. Other Experimental Stations which like Manfredi are dependent on INTA and which are situated in different provinces, conduct yield testing on different varieties provided by the Manfredi Experimental Station.

The INTA Microbiology Institute in Castelar (province of Buenos Aires) analyzes grades of aflatoxin infection in groundnut samples from growers with fields in Cordoba; they also identify varieties and lines of groundnut with possible resistance to the toxin.

The Botanical Institute of the Northeast in Correntes conducts research on the physiology, cytogenetics and cytotaxonomy of the genus *Arachis.*

Manfredi Experiment Station Research Projects

The station is responsible for the development of new cultivars by selection, intervarietal and interspecific crossing. A collection of about 1500 accessions of *Arachis hypogaea* is maintained. Between 1977-80, another 180 samples were accumulated in the NW of Argentina, Bolivia, Paraguay, Brazil and Peru. All this material is sown each two or three years. There is also a living collection of a wild species of *Arachis* and of interspecific hybrids between A *hypogaea* and A *batizocoi.A. cardenasii* and A *spegazzini.* These last named hybrids were obtained at the North Carolina State University, USA and have been used in interspecific crosses with varieties belonging to the subspecies *fastigiata.*

The station also investigates the improvement of production methodology especially sowing density, row spacing, digging and picking machinery, natural drying, rotations and irrigation.

Research is conducted on diseases that attack the overhead and subterranean parts of the groundnut. These studies include chemical control measures and the evaluation of disease resistance in lines and varieties. Work is also conducted on soil deficiencies and herbicide evaluations.

Further Research Needs

One of the earlier goals was the attainment of a high oil content in new varieties. Now, research is being directed to finding varieties with a kernel of high quality and adequate size for direct consumption, and to meet the demands of the international market.

Groundnut Production, Utilization, Research Problems and Further Research Needs in Brazil

A. S. Pompeu*

Production

Although peanuts are an important source of protein and oil, Brazilian production has been decreasing since 1972. Between 1972 and 1978, the cultivated area declined by 66.8% and production fell by 66% (Table 1). Production decreased due to a reduction in the cultivated area, mainly in the State of Sao Paulo, the leading peanut producer. Changes in state government priorities and a shifting interest among farmers toward more profitable crops, e.g., soybeans, were responsible for this decline.

Sao Paulo State was responsible for 70% of thetotal production in 1978. Two other principal peanut producing states were Parana and Mato Grosso do Sul, which accounted for 15.5% and 7.7% of the Brazilian production, respectively (Table 2).

Peanuts are cultivated twice a year in the *states* of Sao Paulo, Parana and Mato Grosso do Sul, — in the rainy season with sowing starting at the end of August, and in the dry season beginning late January or early February. During 1978, 74.2% of production came from the rainy season crop.

Although the average Brazilian production in 1978 of 1290 kg/ha may be considered low when compared with 2958 kg/ha in the 1978 USA crop, this is not entirely true if the cultivation system adopted in Brazil is considered. Peanuts are planted in small rented areas ranging from 5 to 30 ha using a low level of farm technology.

The northwest of Sao Paulo State is the traditional region of peanut production. However, recently peanut cultivation has expanded toward the northeast region of this state in fields ranging from 300 to 500 ha cultivated during the rainy season by growers who are able to apply a better level of technology. The productivity of these new fields has varied from 2200 to 2500 kg/ha.

Table 1. Brazilian peanut production, harvested area, and yield, 1972—78.

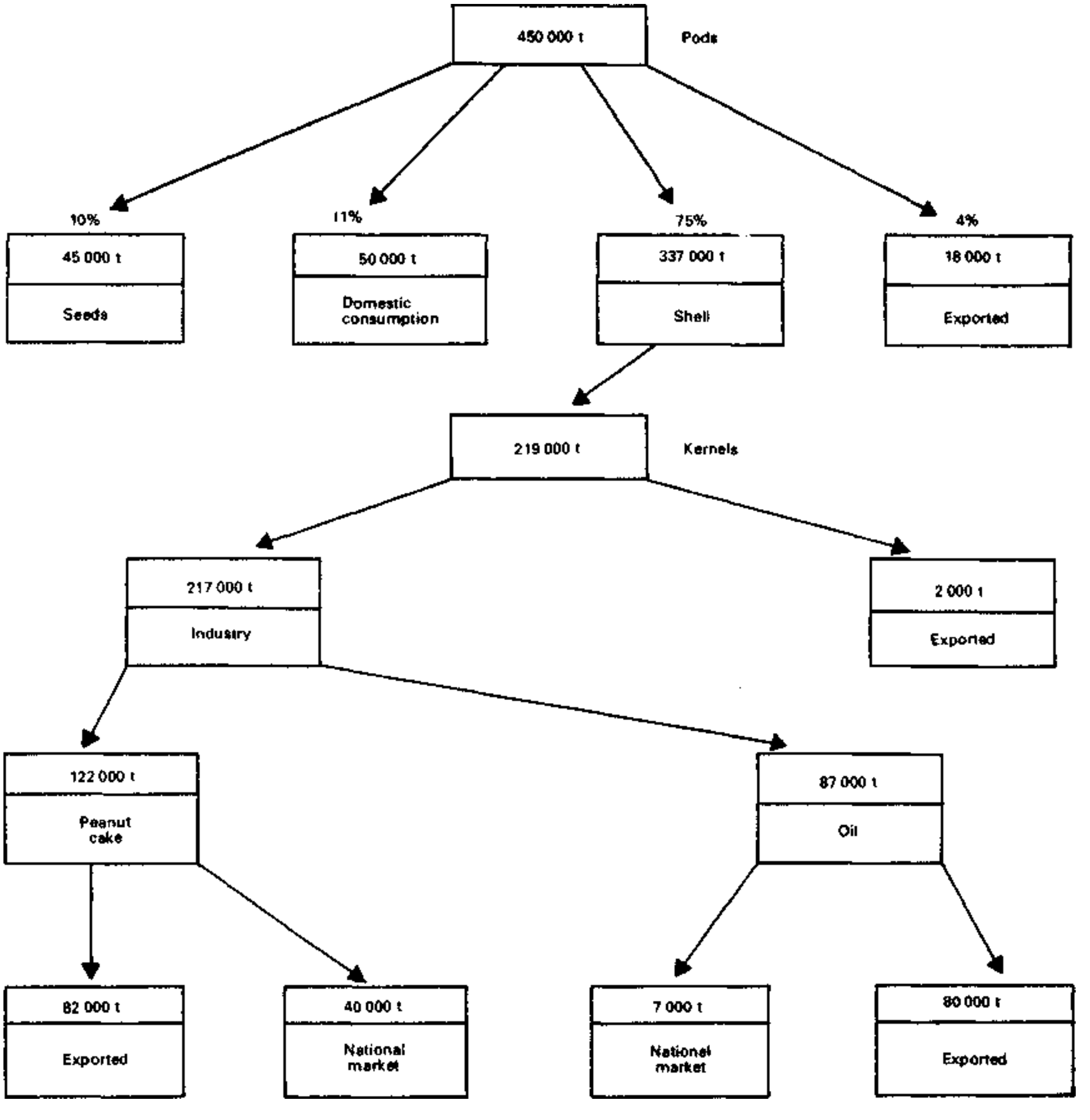
Year	Production (t)	Harvested area (ha)	Yield (kg/ha)
1972	956 200	758 600	1260
1973	589 887	506 083	1166
1974	452 722	373 637	1211
1975	441987	345 095	1280
1976	509 905	371465	1372
1977	320 721	228 747	1402
1978	325 197	252 000	1290

Source: Institute Braslleiro de Geografia e Estetistica (1975, 1976, 1978), Institute de Economla Agrfcola (1972), Food & Agriculture Organization (1978).

Utilization

Distribution and utilization details of the 1979 crop, estimated to be 450 000 metric tons (t) are presented in Figure 1. It was calculated that 10% of the total production was retained by growers for new plantings, 74% went to industries for oil extraction, 11 % was consumed (roasted, salted, candies), and the remaining 5% was exported with and without shell. The refined peanut oil is used in human nutrition. A by-product in the oil refining process is used for making soap. The peanut cake — residue from oil processing — is used for livestock feeding.

* Genetics Department, Instituto Agronomico, P.O. Box 28,13 100 Campinas, S.P., Brazil.



Source: CACEX (1980).

Figure 1. Brazilian peanut production flowchart, 1979.

Research Problems

Although peanuts are produced in at least the following 11 states of Brazil — Sao Paulo, Parana, Mato Grosso do Sul, Rio Grande do Sul, Minas Gerais, Bahia, Goias, Ceara, Sergipe, Paraiba and Santa Catarina — research on this crop has been conducted only in the state of Sao Paulo. In order to increase yield, it is necessary to establish multidisciplinary teams consisting of at least a breeder, phytopathologist, agronomist, and an en-

Table 2. Leading Brazilian peanut producing states, area, and yield in 1972, 1973, 1977, and 1978.

State	Production (metric t)				Area (ha)				Yield (kg/ha)			
	1972	1973	1977	1978	1972	1973	1977	1978	1972	1973	1977	1978
Sao Paulo	645 000	331 392	213 000	227 400	504 000	277 860	144 900	172 400	1280	1193	1469	1319
Parana	155 800	133 664	42 707	50 406	104 200	197 450	33 923	40 266	1495	1244	1258	1252
Mato Grosso	76 800	76 400	42 297	24 948	59 400	87 792	29 258	21 106	1293	1022	1445	1182
Brazil	956 200	589 887	320 721	325 197	758 600	506 083	228 747	252 000	1260	1166	1402	1290

Source: Instituto Brasileiro de Geografia e Estatística (1973, 1978), Instituto de Economia Agricola (1972), Food & Agriculture Organization (1978)

tomologist, at state levels. These teams would determine the limiting factors for peanut production and propose solutions.

In general, the following topics should be taken into account for a research program in Brazil — introduction and evaluation of germplasm in the producing states; identification of the factors affecting yield, e.g., diseases, insects, and their importance; effects of liming, irrigation, fertilization and organic matter on yields; control of the aflatoxin producing fungus *Aspergillus flavus;* determination of the best sowing time within seasons, and best population densities; production systems and crop rotation; and breeding for disease and insect resistance. The *Cercospora* leaf spots caused by *C. arachidicola* and *Cercosporidium personatum* are the important diseases. Among the insects, the thrips, *Enneothrips flavens,* is a serious pest in reducing peanut yield in S. Paulo State.

Further Research Needs

Other peanut research needs should take into account the interaction of peanut x *Rhizobium,* integrated control for peanut pests, breeding for resistance *XoAspergillus flavus,* breeding for earliness, breeding for changing peanut oil composition, and monitoring potentially important diseases such as rust.

Peanut Production, Utilization, Research Problems and Further Research in Venezuela

Bruno Mazzani*

Production

Peanuts were probably grown in Venezuela before the Spanish colonization occurred. Arawak Indians were responsible for spreading peanuts from its southern center of origin to the Caribbean region. Until recently peanuts have been commonly produced on a family scale by small farmers all *over* the country. Modern mechanized production on a large scale commenced only 20 years ago, following successful experiments on peanut adaptation to the ecology of the eastern Llanos region of Venezuela. This region which is characterized by sandy soils of low fertility, has a rainy season of about 1000 mm which is unevenly distributed from May to November. This is followed by a dry season (November-May) with practically no rain at all. The region includes more than a million hectares. The altitude ranges from 70 to 300 m above sea level and the topography is flat or smoothly undulating.

The yield of rainfed peanuts is highly variable, ranging from 700 to 1800 kg/ha (Table 1). Production area figures for the states, expressed as a percentage of the total, are Anzoategui 85.1; Monagas 10.1; Falcon 1.4; Miranda 0.2 and others 3.2. Eastern Llanos, where Anzoategui and Monagas states are located, account for 95.2% of the total area. Irrigated peanuts cover about 25% of the total area. Yields of irrigated peanuts are over 4 t/ha and are less variable than yields of rainfed peanuts. The latter are grown on fields 10-500 ha in size while irrigated peanuts are produced on fields ranging from 50 to 300 ha.

The main cultivars grown are Florunner (irrigated) and Red Starr (rainfed). Seeds of both cultivars are imported from the United States.

* Centra Nacional de Investigaciones Agropecuarlas, HA, Maracay, Venezuela.

Table 1. Peanut production in Venezuela.

Year	Production (metric tons)	Area (hectares)	Yield (kg/ha)
1962	1805	1 924	938
1966	2 254	2 300	980
1970	7 077	9 700	729
1974	27 781	30 701	908
1978	25 833	18 000	1435
1979	27 000 (e)	14 684 (e)	1839

(e) estimated.

The local cultivar 15607 is also grown on a small scale from seed produced in Venezuela. Seed rates are 60-120 kg/ha. Inoculation of seeds is not practiced. One t/ha of lime and one t/ha of fertilizer (6-12-6 or similar) are currently applied to the soil before sowing.

Weeds are controlled by herbicides, applied as pre-emergence or incorporated into the soil before sowing. Weekly applications of fungicides and insecticides afford effective control of diseases and harmful insects. No hand labor is used. Cultural practices from land preparation to harvest combining are mechanized.

Two interesting effects of the introduction of peanut culture to Eastern Llanos are: (Da rapid improvement in soil fertility and texture and (2) the composition of the savannah flora is rapidly changing as a number of new species appear on the peanut fallow. The old species are disappearing from the fallows.

Utilization

Approximately 50% of the crop is processed for oil and residual meal production. The balance is used for direct consumption as roasted peanuts and other confectionery products. Sometimes the haulms of peanut plants are recovered after combining and baled as hay for feed. Its nutritive value is highly regarded.

Research Problems

Current research is performed in several experiment stations directed by the Ministry of Agriculture and universities. The main problems being faced include different aspects of peanut growing such as crop rotations, disease and pest control, chemical weeding, varietal resistance to leaf spots and rust, soil amendments and fertilizers, and seed inoculation.

The results of research on peanuts have been and are being published in a number of papers. Their contents according to the most important aspects give an idea of the research being conducted. The subject matter and the number of papers which have been published for these subjects are: soils and fertilizers, 35, breeding, 23; cultural practices, 14; diseases and pests, 11; experimental techniques, 6; weed control, 10; *Rhizobium* and nodulation, 6; haymaking. 4; yields, 3; harvesting, 2; mechanization, 2; phenology, 1; and analysis and composition, 2.

Between 1960-1979, there have been 119 papers published on peanut culture and improvement.

A collection of approximately 600 cultivars is maintained at two different locations (Maracay and El Tigre).

Further Research Needs

The improvement of yields, the easy availability of land, a support price sustained by the Government and the recent introduction of other crops such as cotton and sorghum for rotation with peanut, are reasons for the probable expansion of peanut growing in the eastern Llanos of Venezuela. This in turn creates an urgent need for more research. The main objectives are reducing the cost of the most expensive practices of peanut production and researching the most important aspects of genetic and agronomic improvement.

Groundnut Production, Utilization, Research Problems and Further Research Needs in Malawi

P. K. Sibale and C. T. Kisyombe*

Malawi is a relatively long and narrow country, which extends some 900 km from North to South and 200 km from East to West. It is positioned along the Great African Rift Valley and the altitude varies considerably from 50 to 3000 m above sea level.

The climate is ideal for groundnut growing in the altitude range of 200-1500 m and only one crop per season is grown during the November-May rainy season.

The problems encountered in production with this smallholder crop, have mainly been of an agronomic nature but foliar and soilborne diseases also play an important role in limiting production.

Research on groundnuts has been carried out since the early fifties so that the farmer now has locally tested research findings to ease most of the problem he encounters.

This report reviews some research and production problems and shows those areas where achievements have been obtained. It also pinpoints problem areas of research which need additional effort in the future.

Production

Table 1 shows the production during the past 10 years (Ministry of Agriculture and Natural Resources). The figures reflect only the groundnut purchases by the Agricultural Development and Marketing Corporation (ADMARC). A lot more groundnuts are sold and consumed locally without reaching ADMARC. Production is expected to rise steeply as a result of directives to extend production of the crop to growers on large estates.

* Senior Groundnut Breeder and Senior Groundnut Pathologist, respectively, Chitedze Agricultural Research Station, P. O. Box 158, Lilongwe, Malawi.

Recommended Cultivars

There are four recommended cultivars — Chalimbana, Mani Pintar, Malimba and RG 1. Each is grown in a range of different areas (Fig. 1).

1. Chalimbana. It is a large seeded confectionery nut recommended for the plateau areas (altitude range 1000-1500 m). This variety forms the basis of the groundnut export trade.
2. Mani Pintar. This medium sized red and white variegated oil nut, is recommended for the lake shore areas (altitude range 500-750 m). It originated from Bolivia, is very adapted to most groundnut growing areas of Malawi and has a comparatively higher yield potential than any of the recommended varieties.
3. Malimba. It is a short season cultivar of the Spanish type and is recommended for the low lying hot areas (altitude range 100-300 m).
4. RG1. A medium sized oil/confectionery nut which is the recommended variety for Thyolo/Mulanje area. It is a locally bred rosette resistant variety.

All the four varieties are susceptible to the major groundnut diseases which limit production, except RG1 variety which is resistant to the groundnut rosette virus.

Utilization

The main uses of groundnuts are confectionery (of which a large part is exported); oil expression with the residual cake being used as cattle feed; local consumption in various forms (boiled, roasted etc); and groundnut hay is fed to animals.

Table 1. Groundnut purchases by ADM ARC (in short tons, 2000 lbs).

Year	Southern region	Central region	Northern region	Total
1969	3 352	35 045	2 458	40 855
1970	3 741	24 219	1 139	29 099
1971	9 500	31000	1 500	42 000
1972	11063	29 588	2 272	42 923
1973	8 228	21828	2 899	32 955
1974	2638	26 863	2 225	31726
1975	1 967	32 895	1303	36 165
1976	1 121	33 248	1 554	35 923
1977	456	18 499	1394	20 349
1978	516	10 439	1313	12 268
1979	1000	21500	1800	24 300[a]

a. Estimated.

Research and Research Problems

The Malawi groundnut improvement program is split into breeding, pathology and agronomy subprograms which reflect the major types of problems encountered in groundnut production. The relationship among the subprograms is close and fully integrated with one coordinator.

The agronomy subprogram has sorted out most of the questions relating to fertilizer use, spacing and plant population, place of groundnuts in rotation, time of planting, harvesting time, and drying procedures etc. Information on all these aspects has been passed to farmers.

Varietal Improvement

In Malawi it has been achieved by the standard methods of introduction, selection, and breeding.

Introduction has been an effective tool as is evidenced by three of the recommended cultivate which have been introduced from abroad — Chalimbana, Mani Pintar and Malimba. This tool will continue to play an important role in the future.

Deliberate breeding is now playing a greater role in our improvement program. The broad objective is to develop high yielding varieties with resistance to the main diseases which limit production. The RG1 variety, for example, is a product of this work.

Considerable effort is also expended to ensure that the product is acceptable to the producer, processor and consumer. Acceptable seed size is an example, and experience has shown that the producer and the local consumer generally are not keen to change to a variety that has kernels markedly smaller than those of the Chalimbana variety.

The following are some of the breeding programs that have been undertaken:

Breeding for Kernel Size and Yield

Tables 2 and 3 present some data on seed size and yield performance respectively for a recently released hybrid (E879/6/4) derived from a cross between Chalimbana and an American variety. This new variety has kernels larger than those of Chalimbana and a similar yield potential.

Breeding for Disease Resistance

Breeding for rosette resistance has been undertaken in the past and the RG1 variety is a rosette resistant product from this program. Kernel size improvement of rosette resistant hybrids has also been undertaken and several such lines are now in advanced yield trials.

Breeding for rust resistance has also been conducted utilizing Tarapoto and the FESR lines as sources of resistance. From our experience, Tarapoto has not been such a useful source of resistance. Better sources have been acquired from the ICRISAT program and these will be further utilized in our breeding programs.

Breeding for *Cercospora* resistance has not been undertaken because of the lack of sources of resistance from the cultivated tetraploid *Arachis* sp. We hope to take advantage of any useful material coming out of ICRISAT's interspecific work.

We have already acquired some lines reputed to carry resistance to aflatoxin, but no work has so far been undertaken mostly due to lack of personnel.

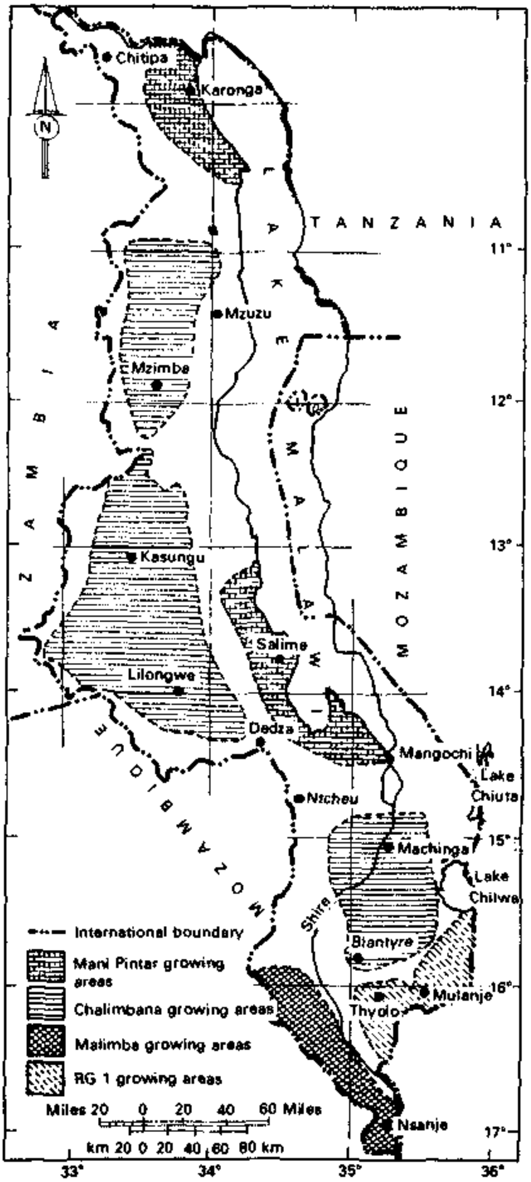


Figure 1. Major areas of groundnut production in Malawi.

The Diallel Selective Mating Program

This is a breeding procedure proposed by Jensen to supplement conventional breeding systems for autogamous crops.

Our program was initiated in 1975 using six selected parents. Wearenowcarrying different composite hybrid populations in various folial generations. A lot of useful variability has been generated using this procedure and there are several lines showing a lot of promise.

Protection from Weeds, Diseases and Pests

Groundnut protection in Malawi involves the control of weeds, disease and pests in that order of decreasing importance.

Weed Problems

Several types of grasses are a problem early in the groundnut growing season—from December to about February. Broadleaved weeds of various types become dominant in groundnuts later in the season from about February to harvest time, which is usually in

Table 2. Seed size of Chalimbana hybrids, 1978—79 Mason (mean weighting of 100 SMK dried to 7.5% moisture content).

	Seed size (g)	
	Treated with Dace-nil 2787	Not treated with Daconll
Chalimbana	135.4	126.7
E8885/1/4A	123.9	117.0
E879/6/4	148.7	132.9
E879/9/2	123.1	116.7
E879/1/2	123.4	112.6
E889/6/4	147.1	126.4

Table 3. Results of yield trials for the 1977-78 to 1979-80 seasons, Chitedze (kg/ha).

	1977-78			1978-79			1979-80		
	a	b	c	a	b	c	a	b	c
Chalimbana (+)	**4141**	**2950**	**71**	**4192**	**2844**	**68**	**3096**	**2100**	**68**
E885/1/4A (+)	**5089**	**3588**	**71**	**2822**	**2074**	**75**	**2089**	**1496**	**72**
E879/1/2 (+)	**4526**	**3134**	**69**	**3948**	**2652**	**67**	**2918**	**1987**	**67**
E879/6/4 (+)	**4941**	**3459**	**70**	**4829**	**3303**	**69**	**2837**	**1989**	**71**
Chalimbana (-)	**4252**	**2918**	**69**	**3407**	**2474**	**73**	**2170**	**1507**	**69**
E885/1/4A(-)	**4326**	**3064**	**71**	**2792**	**1866**	**67**	**1970**	**1437**	**73**
E879/1/1 (-)	**4200**	**2884**	**69**	**3555**	**2578**	**73**	**2185**	**1507**	**69**
E879/6/4 (-)	**4785**	**3321**	**69**	**3577**	**2544**	**71**	**2007**	**1441**	**73**
S.E.	**±207.6**	**±161.1**	**±1.7**	**±310.6**	**±232.0**	**±1.1**	**±153.1**	**±120.1**	**±1.5**
CV	**8%**	**9%**	**4%**	**15%**	**16%**	**3%**	**11%**	**13%**	**4%**

a= Unahelled yield (kg/ha); b - Shelled yield (kg/ha); c - Shelling %;
(+) - Treated with Daconll; (-) - Not treated.

May and June. *Alectra sp* is the only well-known and widespread parasitic weed of groundnut in Malawi.

Handweeding with a traditional hoe is the most effective method of weed control. However, it is a labor demanding and time consuming method.

Chemical weed control with Lasso has been found successful against grasses when the herbicide is applied to the soil after the first rains.

Handpulling is an effective control method for the broadleaved weeds and *Alectra* sp. This method is also labor demanding and time consuming.

Crop rotation has been noted in Malawi to be another good weed control method but it seems to be less effective in many cases.

When early weeding and banking cultivation of the groundnut crop have been done at pegging time, most subsequent weeds are smothered by the vigorous growth of the groundnut crop.

Disease Problems

The virus diseases are rosette and peanut mottle virus (PMV). Important foliar fungal diseases which occur in the medium altitude areas (1000-1500 m elevation) where it is cool, are as follows in order of decreasing importance: pepper spot and leaf scorch, *Leptosphaerulina trifolii* (Rost) Petr.; early leaf spot, *Cercospora arachidicola* Hori.; groundnut rust, *Puccinia arachidis* Speg.; web blotch, *Phoma arachidicola* Marasas, Pauer and Boerema; and late leaf spot, *Cercosporidium personatum* Berk and Curt. Foliar fungal diseases which occur in the low altitude areas (from 200-1000 m elevation above sea level) where it is hot and humid, in order of decreasing importance are: *P. arachidis* Speg., C. *personatum* Berk and Curt, *C.* arachidicola Hori and *L trifolii* (Rost) Petr.

Fusarium wilt caused by *Fusarium oxysporum* is a serious soilborne fungal disease of groundnuts in Malawi. It also causes pod rots usually when groundnuts are harvested late.

The six possible disease control methods are: varietal control, e.g., RG1; early planting; rotation and crop burial; removal of volunteer plants; good crop husbandry; and fungicidal control of foliar fungal diseases.

Pest Problems

Larvae (caterpillars) of leaf-eating insects are commonly found.

The aphid,Aphis craccivora Koch isthevector responsible for transmitting the groundnut rosette virus.

The groundnut jassid *{Empoasca facialis)* is associated with the incidence of the fungal disease caused by *Leptosphaerulina trifolii* (Rost) Petr. (Mercer 1977).

White grubs *(Eulepida mashona)* are larvae of a beetle. These grubs are soilborne pests which cause a wilt of groundnuts by damaging the roots.

Cutworms *(Agrotis* spp) are sometimes a problem, particularly at the seedling stage. To control pests in general it would not appear possible to recommend routine spraying of insecticides in conjunction with fungicides. If serious infestations did occur, the occasional spray would be worthwhile (Mercer 1975).

Pirimiphos — methyl or carbaryl are used to control leaf-eaters on groundnuts when they assume destructive proportions. Dimethoate is used to control aphids in order to reduce their numbers.

Future Research Needs

The major groundnut buyers have indicated a growing demand for the large confectionery nuts and Malawi has to aim at satisfying part of this demand. The best strategy for Malawi would be to ensure that yields per unit area of Chalimbana types are maintained, if not improved.

Research work has shown that Chalimbana has a fairly high yield potential if given good management. However, it is felt that work should be carried out to raise this yield level from a genetic point of view. Recent research work to determine the physiological aspects limiting yield in Malawi groundnut cultivars has given us some insight into the probable limiting factors.

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Groundnut Production, Utilization, Research Problems and Further Research Needs in Mali

D. Soumano*

Groundnuts play an important part in Malian agriculture as one of the principal cash crops. In the early 1960's groundnuts accounted for 38% of the total value of Malian exports. The share of groundnuts in the domestic food economy is sizable.

Production

A large portion of our arable land is suited to groundnut agriculture, principally in the areas within the 500-1400 mm rainfall limits. Within that zone, groundnut production varies according to climate and soil conditions as well as current farming practices.

The principal groundnut production centers in Mali are Kayes, Kenieba, Bafoulabe, Kita, Kolo Kani, Banamba, Koulikoro, Segou, Manicepe, San, and Tominian. All of those centers are serviced by an extension agency that specializes in groundnut agriculture — the Groundnut and Food Crop Extension Service ("L'Operation Arachide et Cultures Vivieres" — OACV). Outside of the territory, groundnuts are considered a minor crop.

Groundnut production has fluctuated considerably over the past 10 years (1969-1979). It fell during the period 1960-1967 with exports plunging from 38 to 16% of the total Malian exportation. The reasons for the production drop were twofold; climatic quirks and outmoded production methods.

Malian agriculture in general is farf rom being freed from the effects of our uncertain climate. All field crop production was considerably set back in Mali during the drought years of 1969-1974. Plantings were futile due to insufficient or totally lacking rainfall. Irregular rainfall often forces the farmer to replant (if he has leftover seed stocks) and the plant stands, representing several replantings, neither develop nor complete maturity in a normal fashion. The yields in such cases are significantly inferior compared to normal yield levels.

Proven agronomic practices are seldom if ever adopted in most of our agricultural regions. Farming is carried out according to traditional practices in which productivity is very poor. Extension services, however, have existed for several years with the aim of extending improved farming techniques which can increase crop yields. Those improved techniques that have been defined by agronomic research include animal traction farming, optimal planting dates and plant densities, seed treatment with fungicides and insecticides, use of chemical fertilizers, use of herbicides, the use of crop rotations which include cash crops, and the careful storage of groundnut harvests.

However, implementation of these agronomic practices has been met with serious difficulties in rural areas. It is forthat reason that our production has little benefited from those methods.

Malian groundnut area, production, and yield in the OACV territory during the past several years are shown in Table 1.

Utilization

Groundnuts are important in the Malian diet. That fact is reflected by the annual per capita groundnut consumption of 15 kg. They are eaten in a variety of ways: fresh, dried and grilled, salted, boiled, ground and served with sugar or honey, ground into paste, and used as a sauce base. The last mentioned use is the most common.

Groundnut hulls are ground and used as fuel in two Malian groundnut refineries; SEPON and SEPAMA. At the village level, groundnut hulls are burned and the ashes are used in local soap and lye production.

* Engineer of Agronomic Research, B.P. 258, Bamako, Mali.

Table 1. Groundnut area, production, and yield.

Year	Area (ha)	Production (tonnes)	Yield (kg/ha)
1967	46 240	23 600	510
1968	48 650	27 855	572
1969	71 630	56 655	790
1970	102 600	68 507	667
1971	92 355	75 185	815
1972	96 000	67 076	698
1973	89 660	68319	761
1974	107 300	110 300	1020
1975	170 455	150 000	1130
1976	164 380	160 440	976
1977	152 100	102 400	673
1978	120 120	100 910	840
1979	112 250	85 000	757

Groundnut plants provide an important forage during the dry season when fresh pasture grazing is no longer available. With the growing use of animal traction the use of groundnuts for forage is gaining importance — an example of the association of crop and animal agriculture.

In the intensive cultivation areas, groundnuts provide a substantial source of income for the farmers. The commercial market is partly exported (by SOMIEX) and partly processed by the two Malian processors SEPOM and SEPAMA. Groundnut processing provides culinary oil, and meal. Groundnut meal is used in animal feed mixtures at the National Large Animal Research Center (CNRZ and the Poultry Center at Sotuba (CAS).

The population of Mali exceeds 6 million and is growing steadily. It is evident that the domestic needs of groundnuts and groundnut byproducts are far from being met. It is for that reason that we look for ways through research to increase groundnut production. Table 2 shows production and end uses of Malian groundnuts.

Research Problems and Future Research Directions

We cannot expect to find clear-cut solutions to problems affecting an increase in groundnut

Table 2. Groundnut production (tonnes) and end uses in the OACV region of Mali.

End uses	1970–71	1971–72	1972–73	1973–74	1974–75	1975–76	1976–77	1977–78
Local consumption	22 447	31 185	25 676	28 119	50 180	79 923	25 679	62 790
Export by SOMIEX	26 877	31 655	31 332	19 983	27 645	43 390	31 121	8 577
Groundnut refineries	17 608	10 385	4 937	14 488	25 834	24 614	108 236	54 433
Confectionary		-	-	-	-	-	326	254
Seed stocks	1 575	1 960	5 131	5 729	6 641	6 073	6 078	6 146
Total	68 507	755 185	67 076	68 319	110 300	150 000	160 440	102 400

production. We must define the parameters and let the solutions evolve over time.

We have outlined the following areas of research concentration in groundnuts:

1. Cultivars. There should be an ongoing search for cultivars adapted to particular rainfall zones and soil types. The principal selection criteria should be yield, flowering cycle in harmony with rainfall cycle, plants adapted to mechanization, disease resistance, and food technology considerations like grain size, oil content, etc.
2. Agronomic techniques. We must identify optimal planting dates; soil preparation methods, plant densities, timing of fertilizer applications, and storage techniques.
3. Chemical fertilizers. We must determine optimal economic returns under intensive cultivation situations.
4. Pesticides. We must find optimal dosages and formulations of fungicides and insecticides.
5. Chemical herbicides. We must find the most economically feasible and agronomically effective formulations.
6. General agronomy. We must accelerate research of rhizobial inoculations and growth regulation.
7. The use of groundnut hay for feed to traction animals.
8. Quality control of groundnut — particularly aflatoxin detection and control.

Additionally we must consider the liaison between our research and the extension of our research. The following play a part in that bridge: the maintenance of foundation seed stocks of released varieties, the quality control of seed increase fields, the measure of quality control for marketing industrial groundnuts, the definition of quality standards for confectionery groundnuts, and quality sampling of exported grain lots.

The above mentioned research themes have already been outlined in our 5 year Malian Research Plan. Already our research structures have addressed themselves to these questions for several years with the following concrete results:

1. The release of five commercial varieties which are already at the farmer level — 28-206, 47-10, 59-127, 55-437, GH-119-20.
2. Optimal soil preparation techniques which consist of plowing in zones above 900 mm rainfall and harrowing operations in areas lower than 900 mm rainfall.
3. The early planting of late maturing varieties with plant spacings of 0.6 x 0.15 m for late varieties and 0.4 x 0.15 m for early varieties.
4. Recommended seed treatment is a mixture of 25% thiram, 25% heptachlor and 25% autraquinone.
5. Chemical fertilizer is recommended at 65 kg/ha superphosphate (21% P_2O_5). This dose is considered economically efficient. Higher doses are now being considered for groundnut-cereal rotations.
6. Different herbicides are now being considered. The most promising herbicide is gerathene (CIBA Geigy) which is already being used at the farmer level.

These research results have been promising and over time they will be defined to fit changing situations.

This summary reports the state of the art of applied groundnut research in Mali and which we find necessary in order to intensify groundnut production. Still and all, we need to further mobilize human and financial resources to achieve our goal.

Groundnut Production, Utilization, Research Problems and Further Research Needs in Mozambique

A. D. Malithano*

Production

Mozambique has a surface area of 79.9 million hectares of which only 18.8% is used for agriculture. Unoccupied land which can be used for agriculture occupies about 52.9 million ha.

In 1969, 155 000 ha of groundnut were estimated to be planted representing 3.5% of the total area under cultivation and making groundnuts the fifth crop in importance in terms of area (Missao de Inquerito Agricola-MIA 1969).

The production suitability of the groundnut areas depends on the rainfall and soil type (Almeida 1968). In the areas that are relatively dry and have an erratic and short duration rainfall, e.g., the southern region with 600-800 mm/yr, early maturing varieties of groundnuts are recommended. In the central and northern regions with 800-1200 mm/yr, late maturing varieties are grown. Areas with heavy clay, black, gray and compact soils were not considered for groundnut production.

Most of the groundnuts are produced in the coastal area, especially in the provinces of Nampula, Inhambane, Zambezia, Maputo and Gaza.

Table 1 summarizes the number of farmers, hectarage and yield in specified years. In 1970, farmer numbers doubled and hectarage increased, butyield was very low. Since then yield has continued to decrease and today there is a critical groundnut shortage.

Yield

The average is very low and ranges from 266 to 521 kg/ha. The main causes are unimproved varieties, traditional production methods, nor use of fertilizers, and diseases. About 99% of the groundnut area is cultivated by the local population on traditional farm units averaging about 0.34 ha.

Varieties

Recommendations for the northern region were Spanish, 48/21, Namarroi and Fumo; for the central region Paulista, White Spanish and Bombay; and for the southern region Natal Common and Valencia, according to Almeida (1968), Sousa (1971) and Milheiro and Rodrigues (1973), respectively. Southern region recommendations based on data obtained from Umbeluzi Agricultural Experimental Station may be invalid as the station soils are not representative of the groundnut growing areas.

The above recommendations were not accompanied by an effective seed multiplication and distribution program. The small farmers planted their own seed resulting in mixtures of early and late maturing types which caused difficulties at harvest and depressed yield.

Crop Husbandry

Improved varieties alone will not make an appreciable increase in yield. If cultural methods were improved, yields could be increased considerably. Therefore, much effort should be made by extension services to improve crop husbandry, but because these services are inadequate and inefficient the problem still continues.

Mixed cropping is practiced and groundnuts are nearly always intercropped with maize, cassava, sorghum, millet and plantation crops such as coconut palm and cashew (Malithano 1979, unpublished; Malithano and van Leeuwen 1980). When interplanted, groundnut density is

* Advisor, Groundnut Improvement Project, University Eduardo Mondlane, Maputo, Mozambique.

Table 1. Groundnut termors, area •own, and production, 1961-1970.

Year	No. of farmers	Area sown (ha)	Production (tonnes)
1961-67	46\1431	155 372	64 777
1968	434 466	126 159	56816
1969	413 583	230 722	80 894
1970	936 338	253 817	55 186

Source: Missao de Inquerto Agrlcola de Mocambique 1968, 1969, and 1970.

very low. It is also low when groundnut is grown as a pure crop (Malithano 1979, unpublished). Thus mixed cropping and low planting density as practiced by farmers in Mozambique adversely affect groundnut yield.

Soil preparation varies from zero tillage to adequate seedbed preparation. The hoe is the main tool for all types of cultivation. Very few farmers use ox-drawn plows. Many groundnut farm units are very small because the farmer cannot prepare a large piece of land before the rains by using a hoe only. Therefore, inadequate land preparation, inefficient farm tools and small farm units minimize the quantity of groundnuts that can be produced.

Late planting, e.g., after the planting rains, is common because the land is not ready for sowing at the beginning of the rains. Milheiro(1962) in northern Mozambique has shown that late planting reduces yield because the number of plants attacked by groundnut rosette virus increases with the delay in planting. When planting was delayed until January, nearly all the plants were attacked by rosette and the yield was very low.

Diseases

Important diseases such as rosette and leaf spot caused by *Cercospora arachidicola* Hori and *Cercosporidium personatum* (Berk. & Curt.) Deighton are endemic to Mozambique and cause great yield losses. Another *important* disease is rust caused by *Puccinia arachidis* Speg. Many other minor diseases also occur.

Fertilizers

They have not been used by small farmers. Experiments carried out at Mocuba and Umbeluzi in northern and southern Mozambique, respectively, did not support their use (Almeida 1968). Most groundnut production soils in southern Mozambique are sandy and very poor in mineral nutrients. Correct use of fertilizers will boost yield.

Natural Hazards

In 1976 and 1977 a large part of the crop in the south was destroyed by the off-season rains which came at harvesting time. Also from 1975-1980, rains have been erratic and unpredictable causing planting delays. Prolonged droughts over the past two seasons have completely damaged the crop in the south.

In many southern areas the consecutive crop failures have caused groundnuts to completely disappear from the local market in the last four years. Many farmers do not have the seed andthisalonewill greatly reduce the area under groundnuts in 1980, with a consequent reduction in total yield.

The Government is very much concerned with this drastic reduction in production because of its effect on the economy and its far-reaching social consequences, especially in the southern region where, as a food crop, its scarcity is keenly felt

Seed Importation

Two varieties, Starr and Tamnut 74 of short vegetative cycle and early maturity were imported by the Government in large quantities in 1977 from USA for multiplication and distribution to farmers in the southern region. In 1979, variety Manipintar was imported from Malawi and the varieties Makulu Red, Mwitunde and Malimba were supplied by the Institute Nacional de Ivestigacao Agronomico (INIA).

Seed Multiplication

It is carried out by the National Seed Company (NSC), administered by the Ministry *of* Agriculture. The Company is a joint venture between the Government of Mozambique and Nordic countries. Its staff are recruited by FAO and the Swedish International Development Authority (SIDA). The multiplication of Starr and Tamnut 74 started in 1978 and that of Manipintar, Makulu

Red, Mwitunde, and Malimba in 1979. State farms are the main centers of multiplication. Some cooperatives, agricultural research stations and training centers are also involved.

Utilization

Most of the produce is consumed as food and only a small percentage is industrialized. For human consumption, groundnuts may be crushed for oil, and to flavor vegetables, meat and fish, or be eaten directly. Woodroff (1973) gives a detailed account of the uses of groundnuts.

Groundnut Oil

Local consumption of groundnut oil as cooking oil is very high. The oil is used in cooking meat, fish, vegetables and rice. Small quantities are also used in seasoning salad.

Food Flavoring

Groundnut flour is added to meat, fish, vegetables, cassava and sweet potatoes after they have been cooked sufficiently. The food is served after it has simmered for some time to allow the groundnut flour to cook.

Groundnut milk is used in chicken, meat and fish curries. The milk is obtained by putting fine groundnut flour in a sieve and mixing with water. The extract is then added to the food.

Groudnut curry sauce is a favorite dish which is prepared by using very fine groundnut powder in a water suspension. It is added to fried tomatoes and onion, allowed to simmer and then served with rice.

Direct Consumption

Fresh boiled groundnuts are widely consumed. They are cooked in the shell and served. To preserve them, the cooked groundnuts are dried in the shell, stored and served as required.

Groundnuts may also be consumed fresh or after drying, but quantities eaten in this way are usually small as they are not very appetizing.

On large farms, laborers were served boiled groundnuts with upsa, a thick maize flour porridge.

Small quantities of groundnuts are consumed roasted either in the shell or as a kernel.

Research Problems

The Institute Nacional de Investigacao Agronomico (INIA), of the Ministry of Agriculture is responsible for and coordinates all agricultural research in Mozambique. Other organizations, outside the Ministry of Agriculture, which are involved in research collaborate with INIA that provides infrastructures such as research stations, farm machinery, transport, fertilizers, insecticides, etc. It is within this framework that the Faculty of Agriculture, University Eduardo Mondlane in Maputo is conducting research on groundnuts. Maputo is located in a very suitable area for groundnut work.

Groundnut is one of the crops that was neglected during the colonial era when very little research was conducted on this crop. The result has been that cultural practices have remained unimproved and very little information is available on varieties adapted to different ecological zones of the country. Adapted, pure varieties for use by farmers do not exist.

Under thesecircumstances it is reasonable to suggest that in Mozambique research must start afresh and should encompass all aspects of production such as variety trials, plant density, date of planting, cultural practices, crop protection, fertilizer requirements and soil types. Acquisition of local and exotic germplasm together with breeding should be an integral part of the research.

Objectives

The objectives of research are the identification of high-yielding varieties adapted to different ecological zones of the country for use by commercial and small farmers, and the improvement of cultural methods. These objectives cannot be realized immediately asthere are many interacting factors requiring both short and long-term solutions.

Short-term Objectives

The most urgent and immediate need is to provide the farmer with seed of groundnuts. This may be achieved by importation of groundnuts with specific agronomic characteristics from those parts of the world that have climatic conditions similar to Mozambique. Already Starr, Tamnut 74, Manipintar, Malimba Mwitunde and Makulu Red have been imported.

The Faculty of Agriculture, University Eduardo Mondlane, has maintained and multiplied some cultivars previously grown in Mozambique and has acquired other exotic varieties from different parts of the world. Most of these cultivars are being evaluated for yield and disease resistance. Those varieties that perform well over years and across sites will be multiplied and distributed to farmers.

Some cultivars in the Faculty collection carry traits such as resistance to rust, rosette and drought.

Surveys have been conducted to study the existing cultural practices used by the small farmers (Malithano 1979, unpublished). This information is useful in order to plan a realistic groundnut improvement program including intercropping.

Long-term Objectives

A major objective is the breeding of high-yielding varieties resistant to diseases and pests, and adapted to the local conditions of crop production. As industrial processing of groundnuts for oil and animal feeding will become increasingly important, there is need to breed and select varieties with a high oil and protein content.

In order to achieve these objectives it is necessary to assemble a large germplasm made up of both local and exotic material. Some of those collections that have specific traits can be used for hybridization in order to incorporate desirable genes in some cultivars with proven performance.

Cultivars and breeding lines have been received from ICRISAT, FAO, USA, and several African countries. A local germplasm expedition took place in Southern Mozambique early in 1980 and another one has been planned for 1981 in collaboration with the International Board for Plant Genetic Resources (IBPGR) to collect groundnuts from the central and northern regions of Mozambique.

Other aspects of research to be studied that affect yield are cropping systems, cultural practices, fertilizer trials, plant density and date of planting.

As Mozambique is endowed with water resources, irrigation of groundnuts will become important and research in this direction should be initiated. Irrigation is particularly important because dryland farming of groundnuts is subject to great variation in yields making it difficult to predict production. In Zimbabwe, irrigation of groundnuts is becoming increasingly popular because of the high yield obtained by farmers (Hutchinson 1980).

In order to remove the drudgery of using a hoe as a tool for all farm operations, a serious study on the mechanization of production to develop simple tools for small farmers is merited. Animal-drawn plows, seed planters and harvesters will facilitate the work of the farmer and will enable him to expand the area under production.

Research is required to identify cultivars that nodulate readily in virgin soils as well as in soils where groundnuts are currently grown. As fertilizer prices continue to rise, nitrogen fixation studies will become increasingly important.

Future Research Needs

There are many problems associated with groundnut research such as lack of trained manpower, research stations not suited to groundnut work, quarantine of exotic accessions, and storage facilities, to mention only a few.

Lack of trained personnel is serious. In order to have an interdisciplinary approach, an agronomist and a plant pathologist are required immediately. Currently, an agronomist is being recruited.

Field assistants and technicians are lacking. ICRISAT has been contacted to train one field assistant and two technicians.

There is a need to identify locations suitable for groundnut work. The choice of Umbeluzi and Ricatia research stations, for instance, was based on needs to conduct research on crops other than groundnuts.

As the importation of exotic germplasm increases so will the dangers of introducing new diseases become more serious. Thus, staff trained in quarantine will be of great value to our future work.

The new introductions will need to be evaluated, documented and stored. At the moment there are no proper storage facilities for either short or long-term storage. There are some funds to buy a cold room for storing breeding stocks, but the equipment has not yet been purchased.

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Groundnut Production, Research and Research Problems in Niger

A. Mounkaila*

Production

Before the 1973 drought, groundnut ranked third in production after millet among the five major crops of Niger (Table 1). Cultivation of groundnut in the pre-1973 years had been encouraged by the presence of a marketing corporation (SONARA), three shelling mills with a capacity of 82 000 tonnes, and three oil refineries for exporting crude oil with a total processing capacity of 105 000 t of shelled groundnuts. This resulted in the area planted increasing from 325 000 to 383 000 ha between 1960-68 and 1969-73.

The 1973 drought and the rosette epidemic in 1975 led to a dramatic decrease in the cultivated area and production (Table 1), with a subsequent failure of the marketing corporation, and the shelling mills and refineries. While the percentage of groundnut in Niger's exports was 45% in 1972, it declined to 24% in 1973, and fell to 5% in 1975.

In 1977 the shelling mills at Dosso and Tchadoua operated at 8.5% and 3.2% of their total capacity, respectively, and the Oil Refineries Society of Niger of Matamey and Siconiger could only use 19% and 9.5% of the processing capacity. The national production provided only 7.4% of the crushing potential of Niger.

To rectify this deteriorating situation, Niger adopted a policy to improve production via two incentives: technical (improved land use, fertilizers, and use of selected seeds) and financial (establishment of finance corporations and increased prices to farmers).

The following production targets (shelled groundnuts) were established: 1979 (80 0001); 1980 (88-0001); 1981 (96 0001), 1982 (106 0001) and 1983 (120 0001). To date, these targets are being achieved.

* Section Arscnide, CNRATarna, BP 240, Maradi, Niger.

Groundnut Research in Niger

Until 1974, research was focused on comparative trials of introduced and promoted varieties, and of cropping techniques.

Since 1975, the National Institute of Agricultural Research of Niger (INRAN) has added other research programs which include foundation seed production, groundnut breeding and improvement through hybridization, and cultivation under irrigated conditions.

Varietal Trials and Irrigated Groundnut Crops

The objective of this program is to identify exotic varieties that are best suited to the cropping conditions in Niger and are superior to the varieties already promoted in the country. This is a very old program which rose in importance in 1976. Since then, more than 200 varieties have been introduced from the neighboring countries (Senegal, Upper Volta, Nigeria, etc.) and the United States.

Each year the best varieties are tested according to thefollowing classes: early varieties (less than 90 days); late varieties (more than 90 days); early rosette-resistant varieties; and late rosette-resistant varieties.

Fertilizer, insecticide, and fungicide trials have accompanied these varietal tests.

Since the objective is to increase groundnut productivity in this arid country, varietal trials were also conducted under irrigated conditions (off-season trials) in order to determine the best varieties and the best period during the year.for growing groundnut. In 1979 the highest yield of 5 t/ha was reached with the variety 796.

Foundation Seed Production

This program was started in 1975 with the objective of providing foundation seed with a

Table 1. Groundnut production in Nigar from 1968 to 1979 (000 tonnas).

Crop	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Millet	733	1035	871	958	919	627	883	581	1019	1130	1123
Sorghum	301	388	230	267	208	126	219	254	286	334	371
Cowpea	74	160	84	72	124	92	133	218	216	207	271
Rice	39	39	37	27	32	46	30	29	29	27	32
Groundnut	270[a]	270[a]	205	257	260	77	129	42	79	90	74

a. Average of production in 1967, 1968, and 1969.

high degree of purity. Modern facilities and equipment are used for conducting the experiments and supplemental irrigation is given to crops when there is deficit rainfall.

Each year seeds of promoted varieties (55-437,47-16,28-206) and introduced varieties such as TS 3-1, are produced in sufficient quantities for supplying material to seed multiplication centers. Yields under these conditions can reach 1000 kg/ha after winnowing. These seeds are produced in an area exceeding 100 ha.

Groundnut Breeding and Improvement

A crossing program was started in 1976 with the objective of producing varieties having the following qualities: productivity, earliness, rosette resistance, rust resistance, and with desirable agronomic and industrial characteristics. The most advanced lines were at the F7 stage in June 1980.

Agricultural Research Problems

As a consequence of the 1973 drought, Niger has given priority to the cultivation of cash crops, and now groundnut ranks only fourth in total tonnes of crop production. This policy does not favor investment in groundnut research.

Although research has made some achievements, there is an inadequacy in the transfer of technology from research stations to farmers' fields. It is a problem causing considerable concern amongst research scientists.

A further problem relates to scientists being isolated from other groundnut workers in respect of inadequate travel, difficulties in publishing scientific findings and also receiving publications from other scientists.

Groundnut Production, Utilization, Research Problems and Further Research Needs in Nigeria

S. M. Misari, C. Harkness and A. M. Fowler*

Production

Groundnut is one of the most popularly cultivated commercial crops in Nigeria with the bulk being grown in the northern states (Figs. 1, 2). The southern states produced only 1% of the total output in 1970-71 (Agboola 1979). The Sudan Savanna Zone (particularly in areas of less than 1016 mm of annual rainfall) has optimum groundnut producing conditions.

Production Statistics

In Nigeria, they can be very misleading and almost invariably underestimated. Production estimates have been based mainly on purchases by the marketing boards (MB), exports from Nigeria and imports of the recipient countries. Such figures underestimate production since primary producers retain unspecified amounts for consumption and for planting in the next season, engage in crude oil processing, sell outside the MB system or smuggle abroad where businessmen take advantage of the price differential between Nigeria and her neighbors. The estimates of groundnut production that is sold to the MBs, for instance, range from 33 to 50% of the total production (Fetuga and Ogunfowora 1976).

A downward trend in groundnut production in Nigeria has been caused by several interrelated factors such as low producer prices, less farm labor due to rural population movements to the cities, the drought years of 1971-73, the unprecedented rosette virus epidemic in 1975, an increasing incidence of rust, and higher prices for guinea corn.

* Entomologist, Plant Breeder and Plant Pathologist respectively, Institute for Agricultural Research, Ahmadu Bellow University, PMB 1044, Zaria, Nigeria.

The fall in groundnut production has continued despite an increase in guaranteed producer price from N 68 per metric ton of kernels in 1966-67 to N350 perm, ton in 1979-80. The purchasing power of N 68 in the mid 1960's is also probably more than that of the current producer price of ft 350. The Central Bank of Nigeria (1974) estimated that while the producers' income for cotton in the Sudan and Sahelian Zones declined from N 12.4 million to N 11.5 million between 1970-71 and 1973-74, thatfor groundnuts went from N19.2 million to N 4.1 million.

These and other factors are enough challenge for Nigerian scientists to look into the problems affecting groundnut production.

Production Areas

Groundnut growing has declined sharply in the old major producing areas north of latitude 12°N. During the 1970's there have been crop failures in many places due to dry weather and other causes.

In the sixties it was generally considered that 33-50% of the national crop came from Kano State. It is very evident now that groundnuts no longer produce well in the northern parts of the state and have more or less gone out of cultivation over extensive areas. A similar situation has arisen in other parts of the Sudan Savanna — Katsina, Daura, Azare, Nguru and Gashua, due basically to less favorable rainfall now than during the sixties and the decades back to the 1920's. As a result of this, the major centers of production of the sixties no longer exist.

In the northern and southern Guinea Savannas, where rainfall is adequate for groundnuts, there are other considerations:

1. Farmers may not regard groundnuts as important and are inexperienced with the crop.
2. The soft sandy soils of the Sudan Savanna

allow easy harvesting even when dry. Heavier soils further south can set hard and make harvesting extremely difficult.

3. Late rain frequently damages harvested groundnuts, and drying can be a problem.

Some changes which could be made to encourage groundnut farmers are mechanization; improved seed; crop protection; fertilizer use; cropping systems, including intercropping; supplementary irrigation on rainfed groundnuts in northern irrigation areas; and change in production areas. There is consider-

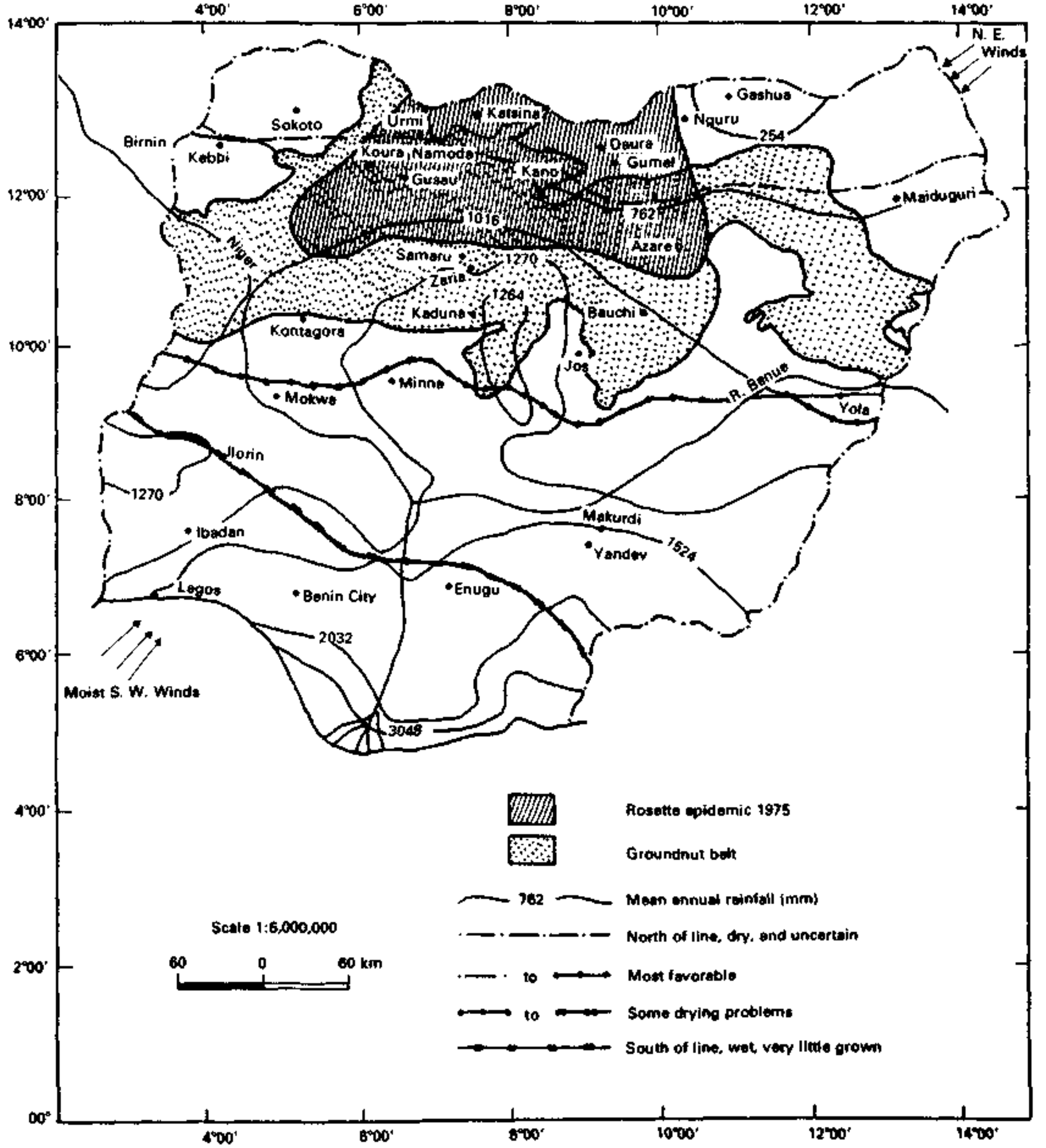

Figure 1. Groundnut producing areas and mean annual rainfall, Nigeria.

able scope for sound extension work in areas where groundnuts have not been traditionally important.

A project was carried out in 1976 and 1977 at Hunkuyi (Zaria), with about 50 farmers who were interested in growing groundnuts. They were provided with advice and seed, fertilizer, and seed dressing. Production varies from about 400 kg/ha pods to 3000 kg/ha. Growers were pleased with the results and with themselves.

Utilization

The groundnut is cultivated for kernels, the oil derived from them, and hay for livestock feed.

The seeds contain about 50% (45-56%)

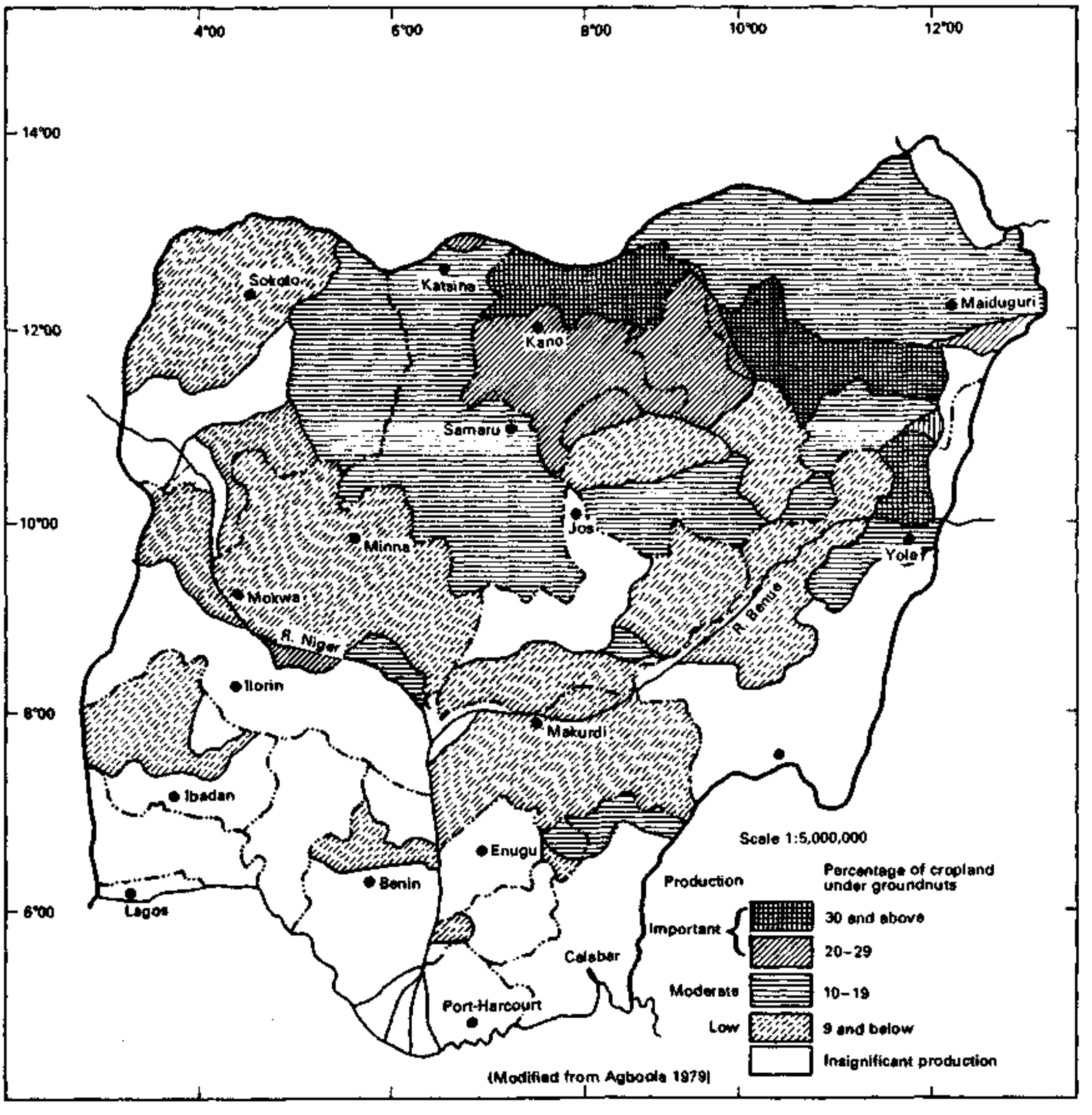

Figure 2. Land use for groundnuts.

non-drying oil and about 30% (25-34%) protein. Because of its very high calorie content, groundnut is one of the most concentrated food products. The importance of groundnuts in the Nigerian diet cannot be underestimated, considering the inadequate protein in such diets.

Five percent (Olayide et al. 1972) of the estimated 58.9 grams of crude protein available per head per day in Nigeria (Abalu 1978) is contributed by groundnuts. Considering that the estimated minimum daily requirement is about 65 g of protein (Olayide et al. 1972), increased groundnut production can help eliminate this protein deficiency.

The groundnut is widely consumed in Nigeria. Oyenuga (1968) has discussed the various uses of groundnut and its by-products. The kernels can be eaten fresh, boiled, dry or roasted. Most are crushed for oil and the residual cake is rich in protein and provides valuable human and livestock food. Groundnut flour can be made by milling the cake and this is used as an ingredient in soups, stews, sauces, sweets, confectioneries, puddings and bakery products.

The most valuable product is the edible oil which comprises 50% of the total kernel. It is used for cooking, especially in northern Nigeria. Other uses are for lighting, a basis of pomade, soaps and cosmetics, salad oil, and in the manufacture of margarine.

The husks find some use as a fertilizer and soi l conditioner. They are also used as litter for livestock and as an absorbent in livestock feed. Industrial uses include production of press board and insulating materials.

The haulms from which the pods have been picked, are a valuable livestock feed in northern Nigeria.

Oyenuga (1968) has summarized most of the possible uses of groundnut (Fig. 3).

Before the petroleum oil boom, groundnut was one of the major sources of revenue and foreign exchange. Most groundnut farmers grow groundnuts in order to sell them for cash to pay their income tax.

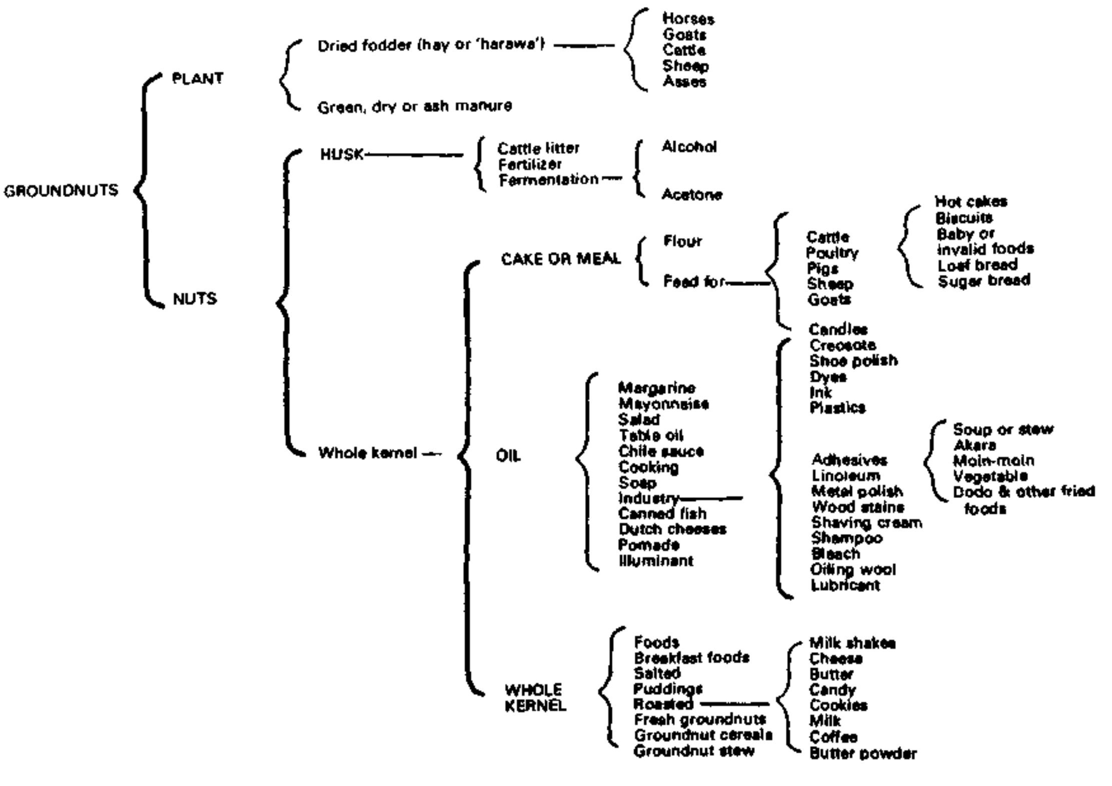

Figure 3. Uses of groundnuts (Oyenuga 1968).

Research Problems

Pests

Groundnut is attacked by invertebrate pests and diseases at all stages of crop development and also during storage. Because groundnuts in the past were considered to be free from any major insect problems (Misari and Raheja 1976), research emphasis was placed only on the rosette virus (GRV) and its vector *Aphis craccivora* Koch. Although GRV is still a major threat to the industry a comprehensive report on pests attacking groundnuts in northern Nigeria (Misari 1975; Misari and Raheja 1976) has revealed the occurrence and diversity of the other major and minor arthropod pests of the crop.

All parts of the plant at all growth stages are subject to attack by pests. There are soil, aerial, postharvest, and storage pests.

Soil Pests

Groundnuts are subject to attack by two major soil pests — millipedes and termites — and three minor pests — white grubs, lepidopterous larvae and nematodes.

Thereare more than five species of millipedes present; the most important is *Peridontopyge spinosissima* Silvestri *(Odontopygidae: Spirostreptida)* (Misari 1975). The estimated yield loss due to millipedes varies from place to place and from year to year (Johnson 1978; Misari 1974; Raheja 1975).The figures range from 1 to 39% but these are an underestimate of the total damage since the very immature pods were not examined in some cases.

Termites constitute one of the most important subterranean pests of groundnuts in Nigeria. Sands (1962 a, b) recorded damage to groundnuts, and the symptoms he described were similar to those found by Perry (1967).

Most of the damage and loss are caused by the ubiquitous small fungus grower *(Macrotermitinae)* belonging to the genus *Microtermes* (Perry 1967; Johnson et al. 1978; Wood et al. 1977). Populations in excess of 4000 termites/M^2 have been recorded in Nigerian agroecosystems (Wood et al. 1977). *M. subhyalinus* Silvestri has been identified as one of the important species (Perry 1967).

Amitermes evuncifer and *Odontotermes* spp are other termites attacking groundnuts in Nigeria.

Unidentified species of lepidopterous larvae (Perry 1967; Johnson 1978) and white grubs (Scarabaeidae) have been observed to attack groundnut but they are important only in localized areas.

To date, nematodes have not been incriminated as economically significant pests on groundnut in Nigeria. Only two species appear to be potentially important. The groundnut-pod nematode, *Pratylenchus brachyurus,* also called the lesion nematode, can kill young seedlings. A species of *Ditylenchus* has also been reported as attacking pods but always at very low incidence. Bos (1977) described a new species called the seed testa nematode, *Aphelenchoides arachidis* (Bos).

Over eleven nematode species have been found associated with groundnuts including *Helicotylenchus dihystera, Scutellonema clathricaudatum, Creconemoides* spp, and *Pratylenchus zea.*

Aerial Pests

Of the more than 70 insect species associated with the groundnut crop in northern Nigeria (Misari and Raheja 1976) only a few are thought to be economically or potentially serious as shoot and foliage pests. These include the cowpea or groundnut aphid, *Aphis craccivora* Koch; several species of cicadellid leafhoppers notably the cotton jassids, *Empoasca dolichi* Paoli and *Jacobiella fascialis* Jac; the groundnut leaf beetles, *Monolepta* spp; and *Luperoides quaternus* Frm; and to a considerable extent flower feeding blister beetles and thrips also becoming more important.

APHIS CRACCIVORA KOCH AND THE ROSETTE VIRUS. This is the most important pest in this category. It is a sap feeder and although a heavy attack can result in wilting and death of the crop especially in hot weather, it is a more serious pest as the vector of the groundnut rosette virus (Zimmerman 1907; Storey and Bottomley 1925).

The groundnut rosette virus disease and its aphid vector, *A. craccivora* have been reported in Nigeria for over 50 years (Harkness 1977). The disease symptoms in Nigeria (Rossel 1977) are similar to those described in other countries but the form of rosette most commonly found in

Nigeria is the "green rosette." Symptoms are variable but a downward and inward rolling of the leaf margins is highly characteristic of the green rosette (Harkness 1977). The chlorotic rosette form is of rare occurrence and is characterized by bright yellow to white interveinal chlorosis, crinkling, twisting and stunting of the foliage and shoots.

In 1957, research work on the aphid/rosette problem began in Mokwa. Here, A' Brook (1964, 1968) showed that early planting and close spacing achieved control of rosette disease. Booker (1963) reported similar findings in Samaru.

The rosette epiphytotic in 1975 was the worst recorded in the history of groundnut production in Nigeria. It destroyed about 0.7 million hectares of groundnuts in the Sudan and northern Guinea Savannas and so revealed the vulnerability of the total crop and the need for resistance (Yayocketal. 1976). Because an estimated 80% of the national groundnut production may come from these zones and nearly all the remainder comes from the southern Guinea Savanna (Harkness et al. 1971), the need for intensive research into the causes and control of the rosette disease cannot be overemphasized.

CAUSES OF THE 1975 ROSETTE EPIDEMIC. It is still not fully understood why the 1975 epidemic occurred (Yayock et al. 1976, 1978; Akinfewa 1978) but some or all of the following factors may have been responsible:

1. Research efforts on rosette-resistant varieties had been concentrated for the riverine areas where rosette consistently caused more significant losses than in the north. While the current recommended resistant varieties (M25.68 and ex-Bambey 69-101) arelong season and most suitable for the riverine areas, those grown in the north are short season and less resistant.
2. Aphid populations and the number of primary rosette infection loci were extraordinarily high in both the epidemic regions of the main groundnut production area in the north and the riverine areas in the south where no epidemics occurred. Since crop seasons in Nigeria are dependent upon the rains which move as a belt up and down with the intertropical discontinuity (ITO), Feakin (1967) postulated that rosette and its vector could move over the groundnut growing areas with the prevailing rain bearing southwest to northeast monsoon winds (Fig. 1). Benoit(1977) has computed the advance of rainy season at various latitudes in northern Nigeria.
3. Earlier widespread groundnut plantings took place in riverine areas together with sporadic plantings in the north. As the rains permitted, early plantings continued in the north so that by mid-May there was a spread of groundnuts of various ages from south to north. This led to an early dispersal of aphids and the virus from south to north. A secondary spread of the virus then overwhelmed thecrop over extensive areas.
4. The mild dry season and early rainfall may have assisted the carry-over of rosette infected groundnuts, especially in the fadama and irrigation areas of the northern groundnut growing areas. The occurrence of abnormally long periods of drought in many areas just after emergence of the groundnut crop enhanced the build-up and dispersal of aphid colonies. This may have led to a zonal build-up of rosette virus reservoirs (Rossel 1977) and a rapid secondary spread of the virus disease.

The role of weather in the epidemiology and population dynamics of the virus and the aphids is being investigated.

APHID AND ROSETTE PROBLEMS IN NIGERIA. Although virus material collected in Nigeria has been studied in England, by Okusanya and Watson (1966) who confirmed its identity as groundnut rosette virus, little is known of the properties of the causal virus or viruses. Hull and Adams (1968) and Okusanya and Watson (1966) found that isolates from East Africa and from Nigeria are sap transmissible.

Their host range and vector studies revealed two components — a symptom inducing component (GRV) being sap transmissible and a symptomless component, being aphid transmissible only. The sap transmissible component was found to be aphid transmitted only when in combination with the symptomless component, and hence the designation of the latter as groundnut rosette assistor virus (GRAV) (Hull and Adams 1968).

It is not known if the two-component nature of this virus plays a significant role in the epidemiology of the disease.

All efforts to find natural off-season hosts (other than groundnuts) of the virus have failed. Since the virus is not seed transmissible, and since the groundnut crop is only of rare occurrence during the dry season, work still continues in search of the carry-over mechanism of the virus from one season to another. Akinfewa (1977) has tentatively identified the rosette vector, A *craccivora* on over 60 wild and cultivated plant species in ten families. About 24 of these species (15 wild and 9 cultivated) belong to the groundnut family *Papilionaceae.*

Since the majority of the wild hosts and groundnut volunteers are found in fadama areas and irrigation sites of the northern states, it appears thatthe hypothesis of a south to north movement of virus/vector complex has to be reviewed.

Recent observations have shown an increasing prevalence of the chlorotic rosette in addition to the usual green rosette. Some virus-vector relationships of the green rosette from Nigeria and the chlorotic rosette from East Africa were studied in England by Okusanya (1965). Her work showed that a Nigerian race of *A. craccivora* transmitted both green and chlorotic rosette, whereas races from Uganda and Kenya, which transmitted chlorotic rosette, failed to transmit green rosette. There has been no report of comparative virus-vector relationships of the symptomatically different types of rosette viruses occurring in Nigeria.

Present studies at the Institute for Agricultural Research, Samaru, Nigeria have indicated that they are both transmitted by *A. craccivora.* An attempt is being made to find out if they are different strains of the same virus and what is the epidemiological significance.

CICADELLID LEAFHOPPERS. These insects are found throughout the cropping season. Their feeding damage can be quite serious and work is in progress to evaluate the losses caused by them.

GROUNDNUTLEAF BEETLES. The adults chew or puncture the leaves but do not cause as much damage as the cicadellid leafhoppers.

BLISTER BEETLES. They are known to cause heavy damage to groundnut flowers; the species involved are *Coryna hermanniea* F.; *Mylabris trifasciata* Thunbs; *Decaptoma affinis* Oliv. and *Epicauta* spp (Misari and Raheja 1976; Raheja and Misari, in press).

Postharvest and storage pests

The decline in groundnut production in Nigeria is greatly amplified by losses incurred at and after harvest, especially in storage. Several insect species are responsible for heavy losses of postharvest groundnuts due mainly to the inadequate storage facilities of farmers and to the ignorance of the government agencies about the need for entomologically sound storage depots. Over 40 storage insect pests have been reported as infesting groundnuts in store (Comes 1964).

The major storage pests are the groundnut seed beetle *(Caryedon serratus* F.); flat grain beetle *(Cryptolestes ferrugineus* Steph.); khapra beetle, *(Trogoderma granarium* Ev.); merchant grain beetle *(Oryzaephilus mercator* Faur.); red rust flour beetle *{Tribolium castaneum* Herbst); confused flour beetle *(Tribolium confusum);* tropical warehouse moth *(Ephestia cautella* Wlk.); rice moth *(Corcyra cephalonica* Staint.); *Aphanus sordidus* F.; and Indian meal moth *(Plodia interpunctella* Hub.).

All told, a groundnut producer experiences 5-35% damage to his crop annually from insect pest attacks in Nigeria. At present, it is economically unrealistic to recommend the routine use of pesticides.

Weeds

They constitute one of the greatest bottlenecks to production (Musa and Kaul 1978). Generally there is about 18-70% (average 50%) loss from weeds recorded in Nigeria.

The parasitic species *Alectra vogelii* Benth. of the family *Scrophulariaceae* is a major threat to groundnut producers. This parasitic flowering plant causes yellowing of the foliage and poor pod set and seed development. It attacks the groundnut root system and taps the host's nutrient energy source through a conspicuous knot which is formed at its point of attachment with the host.

The pest appears to be widespread th roughout the producing areas where its deleterious effect is becoming increasingly recognized. The assessment of yield loss due to this parasite and its control remain to be determined.

Diseases

Severe damage was done to 0.7 million ha by rosette virus in 1975. South of 11½° north latitude, leaf spots cause pod losses of 20-50% everywhere each year. In 1976 peanut rust appeared.

Seedling wilts are serious locally but wilts of older plants have not been so. Pod rots have been significant in some fields at Samaru in some years. No work has yet been done with resistant varieties.

No progress has been made on resistance to aflatoxin. The need is greaterthan before, with a planned expansion of crop in the northern Guinea Savanna. The only large commercial crop bought was in 1972 (half a million m. tons), and this had acceptably low aflatoxin levels. It was a favorable season however, with good drying weather after harvest for most growers.

Rust

The disease is now endemic in the country and has become more damaging each year since it appeared in 1976. So far no significant attack has been recorded north of 11½°N latitude, but south of it there is now widespread and serious damage.

Rust was severe at many sites in 1980 especially in the southern and western areas. It has been observed many times that rust is less severe in late planted crops.

Leaf Spots

Control of the *Mycosphaerella* early and late leaf spots remains a major objective. For most farmers, medium volume spraying is not practical and VLV and ULV techniques are insufficiently researched. Spraying would be required to control rust as well as leaf spots.

The following species have shown resistance in the field: *Arachis chacoense* against *Cercospora arachidicola* (early); and *A. cardenasii* against *Cercosporidium personatum* (late). An un-named species HIK 4.10 (Hammons, Langford and Krapovickas collection), and USDA introduction number PI 338280 have shown some resistance to both leaf spots.

No effective field resistance to leaf spots has been established from crosses made to date. A variety needs resistance to both leaf spots to be satisfactory. Usually both are present at high levels but with great variation in proportion to each other, from spot to spot within the field, between fields, sites and seasons.

It is possible that races of the leaf spots may be present. The leaf spots cause by far the greatest losses of yield which groundnut growers suffer.

Rosette

The groundnut rosette virus disease is by far the most damaging virus disease of the crop in Nigeria. The form of the disease is "Nigerian Green Rosette". "Chlorotic Rosette" also occurs at a low incidence level.

Rosette disease in the past has caused more damage south of latitude 11°N than in the main producing areas which lie north of it.

Losses due to rosette are estimated to be 3% per year from all groundnuts grown in the Sudan and northern Guinea Savanna Zones.

Early planting and close spacing are safeguards against rosette, ft is not always possible to achieve and it is not effective against epidemics like the 1975 outbreak. Rosette resistant varieties are needed to keep the disease in check and insure growers against one of the hazards of the crop.

Effective resistance has long been recognized in collections from Upper Volta, Cote d'Ivoires, Cameroun and other places. It has not been found in Nigeria. The CNRA Bambey, Senegal lines have proved to be highly resistant to the Nigerian Green Rosette and recent screening has shown that lines resistant to green rosette are also resistant to Nigerian chlorotic rosette and vice-versa.

It is not difficult to incorporate rosette resistance into acceptable varieties with a range of season lengths. Recent introductions from the Upper Volta Program (RMP 12, RMP 91) have proved highly resistant and very productive over many sites in the northern and southern Guinea Savannas. No satisfactory rosette resistant lines are at present available in Nigeria and work continues to improve the Upper Volta line KH 14-9A. Rosette resistant, drought material is needed forthe northern areas where the upland crop is at risk from aphids associated with irrigation projects.

Pod Set Failure

The problem of blind or unfilled pods (Yayock 1979) is extensive. In 1978 there were widespread crop failures where vegetative growth was good, but hardly any pods developed.

The causal factor(s) for blind or unfilled pods is not known. Items which have been investigated are insect infestations, disease, late planting and weather. Rainfall, moisture stress, temperature levels and diurnal differences could be involved and linked with nutrient uptake and transport.

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Groundnut Production and Research in Senegal

J. Gautreau and 0. De Pins*

Production

Groundnuts constitute the main cash crop of Senegalese agriculture, with most of the production being turned into peanut oil. They play an important role in the economy of the country, even though during the last few years emphasis has been placed on the development of food crops. They represent between one-third and one-half of the total exports from Senegal.

The groundnut basin covers an area of approximately 3 million hectares of which, on the average, 1.1 million ha are sown with groundnuts every year. During the last two decades the area planted has remained fairly stable, whereas the yields have fluctuated depending on theincidenceof droughtperiods. As a result, crop production has varied greatly (Table 1). The record production in 1975 exceeded 1.4 million metric tons. The 1980 crop season is being compromised by the significantly late arrival of the rains.

The priority aim of the Senegalese Government is to stabilize groundnut production at a maximum limit of 1.2 million metric tons of unshelled groundnuts. This regulation would minimize the fluctuation in metric tons exported, and consequently stabilize the annual income of the producers.

Organizations and Assistance to Farmers

The farmers are grouped into cooperatives which supply them with production inputs and gather products such as groundnuts at the local level.

Several organizations cooperate for aid and development in the rural sector (Sene 1980). Briefly they are:

1. SONAR, a new national organization which supplies the farmers and manages the seed capital.
2. SODEVA, a regional society for rural development, which operates within the groundnut basin. It is in charge of all production activities and provides technical and cooperative assistance for the growers.
3. The CERP centers (multi-purpose center for rural expansion) have an important aid role at the rural community level, in strict cooperation with the regional society for development. They provide the local people with technical services.
4. The National Seed Service created in 1972 produces, controls and looks after the seed capital. Its role is particularly important for groundnuts especially because the annual requirement of recommended seeds is of the order of 100-130 000 t (Lam and Delbosc 1977).

Climate and Soil Conditions

Senegal at the western tip of Africa, is under the influence of the Sahelo-Sudanian climate characterized by a single rainy season, usually short, and interrupted by frequent periods of drought. Lack of water has been the main factor limiting production in a large part of the growing zone for 10-12 years.

The north-south rainfall gradient is very significant: 1000 mm in 5 months in the Casamance and 300 mm in 2.5 months in the north (Mauboussin 1973). Due to the recent years of drought, there has been a disturbing slippage of isohyets towards the south and a shortening of the period of useful rains. The consequences are serious in the northern half of the country, a zone where groundnuts are suffering more and more, often from lack of water.

The groundnut growing soils have a sandy

* Institut Senegalais de Recherches Agricoles (ISRA), National Agronomic Research Center (CNRA), BP 51, Bambey, Senegal.

Table 1. Peanut oil production in Senegal, 1960-1977.

Crop season	Area (000 ha)	Production (00 tons of unshelled peanuts)	Yield (kg/ha)
1960-61	975	890	915
1961-62	1025	995	970
1962-63	1015	915	900
1963-64	1085	950	880
1964-65	1055	1020	965
1965-66	1115	1120	1005
1966-67	1115	855	770
1967-68	1165	1005	865
1968-69	1190	830	695
1969-70	955	790	830
1970-71	1050	585	555
1971-72	1060	990	930
1972-73	1070	570	530
1973-74	1025	675	660
1974-75	1050	980	930
1975-76	1205	1410	1175
1976-77	1345	1210	895
1977-78	1115	520	465
Average	1190	905	830
Standard deviation	93	227	184
CV<%)	7.8	25.1	22.2

Source: Annual DGPA reports quoted by BCEAO informative notes, No. 277, November 1979.

texture (Charreau 1961) with low clay content (4% for the soil called "dior") and a low moisture holding capacity (6-10% on a weight basis) and also a low mineral content.

Agronomy

The 2-year rotation of groundnuts and millet is currently being practiced by most producers. The population growth has brought about a progressive decrease in fallow land in the groundnut basin where the relative role of groundnuts in agriculture has decreased to the benefit of food crops.

The main cultivation operations (planting, hoeing, digging) are performed with small implements drawn by horse or donkey. The use of oxen for traction is expanding, but is still practiced by a minority of growers.

Chemical fertilization is common, but its low average level of application does not properly compensate for the mineral uptake by the crop. The amount of complex NPKS fertilizers used annually varied from 20 000 to 40 000 tonnes, with a maximum dose of 40 kg/ha. Only specially assisted edible peanuts (30 000 t in 1976) are fertilized according to the research recommendation of 150 kg/ha of 8-18-27.

Planting takes place in June or July and the harvest is in October or November, depending on the region. Hand threshing is done on the spot after curing in November or December. After cleaning, the groundnuts are delivered in their pods to the cooperative.

Crop Protection

A combined fungicide-insecticide is generally used on the seeds to protect them from damping off and from predators. Invasions by insects and myriapods during the growing season are transitory and relatively slight, although during

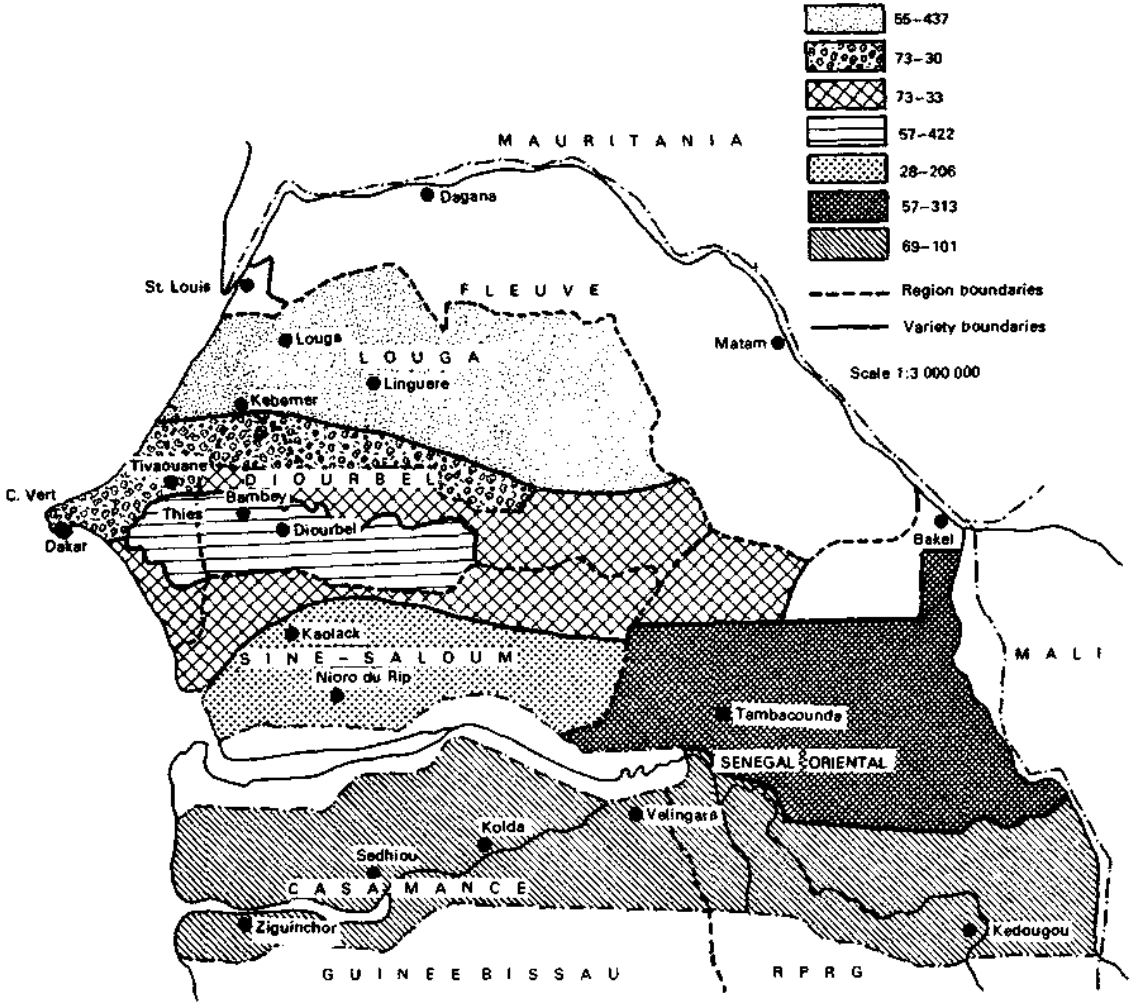

Figure 1. Distribution of groundnut varieties in Senegal.

the last few years significant millipede damage has been observed at emergence time and during the pod formation.

Various groundnut leaf diseases exist. *Cercospora* leaf spot can have a serious impact in the southern part of the country. Groundnut rust appeared in 1978-1979 but with no economic consequences up until now.

The problem of seed contamination by *Aspergillus flavus* has existed for several years. The formation of mycotoxin is encouraged by the more and more frequent periods of drought occurring during the maturing stage. Until resistant varieties become available, Senegal has started a pilot industrial unit for the chemical detoxification of peanut meal, and is experimenting with various electronic screening procedures for seeds.

Varieties

The climatic conditions prevalent in Senegal necessitate the use of varieties adapted to the rainfall constraints. The maturity cycles range from 120 to 130 days in the south, to 90 days at the northern limit of the cultivation zone. Continuous breeding research has enabled the creation of several varieties which are better adapted to the various ecologies (Gautreau 1980). Most of the groundnut varieties cropped in Senegal were recommended by research.

In the south, 69-101 is a Virginia variety resistant to rosette and derived from the 28-106 variety for which the cultivation zone is further north (Fig. 2). In the center, and north-central regions, 73-33 is a new drought resistant variety with a 105-day maturity cycle. It has been released recently (until resistant varieties become available), and will be cultivated on approximately 260 000 ha. The 55-437 variety is a 90-day Spanish commonly grown in the northern part of the basin. Its nondormancy limits its expansion to the south where a new variety with the same cycle, but dormant, is cultivated. The 57-422 variety is a Virginia type with large seeds and a 105-day maturity cycle. Lastly, GH 119-20 of American origin is cultivated for edible peanuts in the Sine-Saloum region.

Groundnut Research and Objectives

The first research in Senegal was conducted in

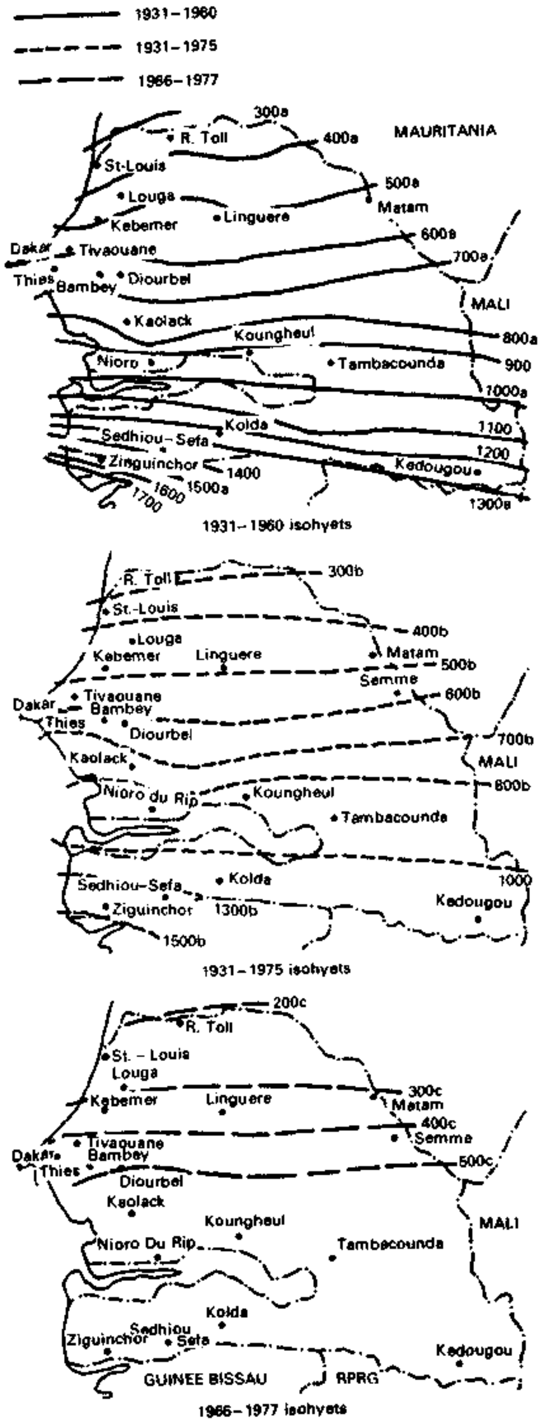

Figure 2. Migration of the isohyets in Senegal from 1931-1977.

the twenties. In 1975, the various organizations which were involved in agricultural research transferred to a national organization — the Senegalese Institute for Agricultural Research (ISRA) under the guidance of the Ministry of Scientific and Technical Research (SERST). Research is carried out in stations all around the country and in the multilocation experimental fields in the farmers' environments.

Groundnut Breading

The breeding objectives of the Senegalese Institute for Agricultural Research (ISRA) are improvement to drought; resistance to rust, leaf spot, and *Aspergillus flavus;* and the creation of edible peanut varieties and peanuts for confectionery use.

Improvement of Groundnut Resistance to Drought

The decrease of rains in the Sahel has caused breeders to create varieties better adapted to drought (47-16, 50-127, 73-33, 55-437) which have shown good performances in dry conditions (Bockelee-Morvan at al. 1974). To do this, the two breeding and physiology divisions of the National Agronomic Research Center (CNRA), in Bambey, collaborate very closely. The two methods being used are shortening of the growing cycles (using the parent "Chico"), and screening lines or varieties with a good tolerance to drought.

In addition to research on better adaptation to drought, different types of improved yield material are being screened (Tables 2,3,4, 5).

Breeding for Resistance to Rust *(Puccinia arachidis* Speg.)

This new program has been designed to counter the threat resulting from the recent appearance of groundnut rust in West Africa. The incidence of this disease in crops varies; it depends on how early the invasion commences.

It has been possible (1) to obtain the main sources of resistance, DHT 200, Tarapoto, Israel line 136, and FESR lines 1-14 promoted by the USDA; (2) to verify in Upper Volta their resistance to the type of rust common in West

Table 2. Variety trial results, Bambey (average yields of poda In kg/ha).

Varieties	Maturity (days)	1975	1976	1977	1978	1979	Average
55-437	90	3125	2530	2125	2250	2200	2445
73-30			2745	2390	2160	1770	2265
73-33	105	3965	2600	2040	2120	2115	2570
57-422		3245	2960	2120	2330	2210	2575

Table 3. Variety trial with yields expressed as a percentage of the best control lines (10 replications/variety = 105 mVvarlety).

Lines	Origin	1977	1978	1979
V37	(28-206 x 48-115) 57-422[2]	112	109	118
V 41	"	118	102	103
V 55	"	115	116	147
V 58	"	114	107	108
V 59	"	108	110	103
V 79	55-437 (48-115 x 28-206)	114	107	100
V 755	55-437 x 57-313	107	100	108

Note: The V 755 variety called 79-2 is likely to replace 57-422 (superior yield of 5% In station experiment*; shelling rate • 1.7%; good seed rate = 5.5%, 100-karnel weight - 60-65g.)

Africa; and (3) start a complete breeding program to transfer these resistant genes to the released varieties.

Recently, a fruitful exchange of plant material with ICRISAT permitted the use of two new parents NC-Acc 17090 and EC 76446 (292) for cross-breeding. It also provided the first segregating generations of 45 families of crossbred varieties for resistance to rust. The screening of these different progenies should start with the 1981 crop season. However, since the disease is still not very prevalent in the country, one

Table 4. Average yield (pods kg/ha) in Bambey of some recent introductions; varietal experiments — 10 replications; 147 m^2 variety.

Introductions	1976	1977	1978	1979	Average
TG 7 (India)			2640	2050	2345
TG8 "		2425	2575	1670	2225
TG 9 "		2425	2615	1585	2210
TG 14 "			2225	1980	2100
Faizpur (India)	2810"	2015	1930	2050	2200
UF 72-101 (USA)	2650*	1880*	2210	1985	2180
UF 73-217 "		1990	2505	2275	2255
Early runner			2215	2175	2195
Comet	1815'	2005[a]	2205	2250	2320
Spanhoma	3010[a]	2490	2115	2110	2430
Spancross		2205[a]	2215	2145	2190
Florunner	2725	1710*	2315	2270	2255
Starr	2890[a]	2400*	1870		2385
Egret			1900	1350	1625
55-437	2665[b]	2125[b]	2105[b]	2130	2255
57-422	2850[b]	2235[d]	2465[c]	2110[b]	2415
73-33	1940[b]	2060[d]	2095[c]	2025*	2280

a. Varietal trial with 4 replications.
b. Average of 2 varietal trials.
c " 3 "
d. " 5 " "

Table B. Average yield (pods kg/ha) of some introductions tested near Louga. Uoltyet = 300 mm; experiments with 7 replications-84 mVvariety.

Varieties	1975	1976	1977	1978	1979	Average
Argentine	560	900	105	920	155	530
Starr	305	885	90	1060	195	510
Spanhoma	525	765	55	900		560
Tifspan	510	885	70	860		580
Spancross	245	940	110	1380	110	560
Comet	350	880	80	1185	105	540
Florispan	385	720	70	1230	130	510
Faizpur			80	945	135	385
Chico		355	35	425	75	220
73-30	340	730	90	1070	150	475
55-437	385	815	95	1180	180	530
Rainfall (mm)	317	289	169	326	223	

foresees that, for the time being, the breeding methods will be limited to laboratory tests in a closed area, such as with the test of inoculation of leaves maintained on Hoagland mediums (Subrahmanyam et al. 1980). For security reasons, it is intended to avoid the use of breeding methods involving artificial contamination in open fields.

Breeding for Varietal Resistance to Leaf Spot *(Cercospora personata)*

Results of experiments carried out in southern Senegal (Casamance) show that this disease can bring about a loss of 30-40% in yield. As of today, there is no effective solution to this disease. The main problem is the lack of genetic variability with regard to this characteristic in the Bambey collection. A search for possible sources of resistance is under way at the present time.

Varietal Resistance to *Aspergillus flavus* Link

Research in this field is extremely important because of the serious consequences for the health of people and animals due to the presence of aflatoxin in the seeds and peanut meal. The economic importance is easily understood since 300 000 tons of peanut meal are exported from Senegal every year which must satisfy the recent norms of the importing countries — less than 50 parts per billion.

The breeding program in Bambey against *A. flavus* is at the F_5 stage. The parents used are those received from the USDA and identified by Mixon and Rogers — PI 337 409 and PI 337 394.

The two selection tests used are (1) inoculation in Petri dishes (Zambettakis et al. 1977) and (2) measuring the aflatoxin content by the Velasco method. A third test based on the measurement of the seed coat permeability to ions has been evaluated for its reliability (Camera 1977). Its first results seem to correlate with those of the artificial inoculation test which is more involved.

The early variety 55-437, cultivated throughout the northern part of the groundnut basin, shows as equally good resistance to *A. flavus* as the two USDA parents used.

The thickness and hardness of the shell as well as an appreciation of the texture of the seed coat are also used (Zambettakis and Bockelee-Morvan 1976; Waliya and Abadie 1978) as criterion of resistance. This research is carried out in collaboration with the Museum of Natural History in Paris.

Creation of Edible Confectionery Varieties

Senegal hopes to achieve more valuable groundnut production by increasing the cultivation of edible and confectionery peanuts for exportation through a favorable and expanding market.

Such varieties must fit the technological norms specified at the level of various channels. Generally one tends to get a well-formed, constricted pod with large and round seeds. A good representative type is GM 119-20 coming from the United States. Variety 756 A is also grown in Senegal. It will soon be replaced by the new 73-27 (GH 119-20 x 756 A) which scores better in grade and productivity.

Certain Spanish varieties such as 55-437, 75-33, and 75-50 (Faizpur) correspond well with the Hand Picked Standard (HPS) norms for the confectionery peanut market.

Agronomy

Long-term studies have been carried out in the CNRA by multi-disciplinary teams in farming techniques, soil management and root-growth systems; crop rotations and farming systems; fertilization and rhizobiology; and agroclimatology.

Bioclimatology studies are particularly needed to evaluate the water requirements of groundnuts (Dancette and Hall 1979).

Crop Protection

Work is being conducted on the screening of the best efficient insecticides to control the main groundnut pests: millipedes *(Odontopygidae),* termites *(Eutermes parvulus),* larvae *(Amsacta moloneyi* and *Spodoptera littoralis),* bugs *(Aphanus sordidus),* and bruchids *(Caryedon fuscus);* selection of active nematocides; screening of active leaf fungicides mainly against rust and *Cercospora* leaf spot; testing of various herbicides; studies on stock protection; and pesticide residue studies.

Postharvest Technology

The main subjects being studied in collaboration with industry and various organizations are: grading of edible and confectionery peanuts; electronic screening of seeds contaminated with *A. flavus;* detoxification of peanut meal with gaseous ammonia; and studies on storage methods, both cold storage or vacuum packs.

Conclusion

Groundnuts have constituted an essential resource of the Senegalese economy for a long time, but the average production for the last 20 years still falls very short of the 1.2 million tonnes optimum levels set by the authorities. This situation is mainly due to more and more frequent years of a significant lack of rainfall and an appreciable delay between the established cultural techniques suggested by research and the more or less improved traditional practices of most of the producers.

Tangible results were obtained due to the activities contributed by the agricultural aid organizations. However, a great deal of work is still necessary. The recent administrative reform should make it easier. On the other hand, it is up to research to prove a renewed dynamism to face new calamities which threaten the income of groundnut producers (drought, rust, *Cercospora* leaf spot, aflatoxin) and to cooperate even more closely with the agricultural aid services.

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Groundnut Production and Research Problems in the Sudan

H. M. Ishag, M. A. Ali and A. B. Ahmadi*

Production

Groundnut is an important cash crop in the Sudan, the largest country in Africa. It provides 7% of the GNP and employs 12% of the population. Sudan is the fourth leading country in groundnut production after India, China, and the United States. Production has increased by a bout 320% since 1965. The three major regions of groundnut production are Gezira and Managil (42%), North Kordofan (17%) and South Darfur (14%). The average pod yield is low, being 600 kg/ha in rainfed areas and 1440 kg/ha in irrigated areas.

There are several distinctive climatic regions. In the north, temperatures are high and rainfall is scanty and irregular, while in the south rainfall is heavy — up to 1400 mm. Soils are classified into four groups (Said and Mustafa 1978) — (a) soils of the central clayplain, (b) sandy soils of western and northern Sudan, (c) desert soils and sands of the northern half of the Sudan, and (d) alluvial and riverine soils along the Nile and its tributaries. The total area suitable for cultivation is about 200 million feddans. There are 16 million feddans under cultivation of which only 4 million are irrigated. (One feddan =1.04 acres = 0.42 ha.)

Crop Management

Rainfed Areas

In sands of the western region of Sudan, the early maturing variety Barberton is sown by hand when the rains start This variety matures in about 100 days. Seed dressing with Aldrex T is practised by most of the farmers. Plant population is low. No fertilizers are used and weeds are controlled by hand. Proper rotations are not followed and shifting cultivation is the normal practice. Crops grown with groundnuts are sesame, roselle *[Hibiscus sabdariffa* L.) and millet.

Irrigated Areas

Groundnut in irrigated areas is normally planted in June in a row spacing of 80 cm with about 30 cm between plant holes and with 1-2 seeds per hole. Different rotations are adopted; in Gezira, a four course rotation (cotton-wheat-groundnuts/sorghum or rice-fallow); in Managil, a three-course (cotton-wheat-groundnuts/sorghum); and in Suki and Rahad, a two-course (cotton-groundnuts). Watering is every 2 weeks, and a light watering is given 7 days before harvest to facilitate pulling of groundnuts as the soils are heavy clay. Tenants normally delay harvest and this causes losses of pods in the soil. In most areas, weeding is carried out by hand, while some government schemes use herbicides.

Past Research Achievements

Agronomy

Disc plowing six inches deep, two passes of disc harrow, or rotovation, followed by levelling and ridging has increased pod yield substantially (Ishag et al. 1980). A single plant at 7.5 cm spacing between plants has resulted in higher yields (Tahir and Misovic 1967). Ishag (1970) found that 15 cm between plants and two seeds per hole significantly outyielded 30 cm spacing. Planting unshelled pods usually results in low yields mainly because of a sparse plant population stand. High pod yield is achieved from early June planting (Ishag 1965). The average seeding rate in irrigated areas is about 30 kg (shelled

* Agricultural Research Corporation, Wad Medani, Sudan.

basis). Recent work (Ishag et al. 1980) showed a marked responseto phosphorus when supplied with the seeds.

Groundnut Breading

Groundnut improvement by selection in Sudan started with the screening of the Tozi collection assembled by A. H. Bunting (1954-55). Tahir (1965) made a few crosses in 1949. The line MH 383, introduced from Nigeria but originally developed in India, was selected for production in the irrigated Vertisols of central Sudan (El Ahmadi 1965-66, 1969-70 and Nur 1976).

Recently, breeding has received more attention and a full time breeder is now in charge of a program aimed at the development of high yielding, early maturing, spreading bunch types adapted to the irrigated Vertisols; selection of early maturing, drought tolerant cultivars for the rainfed sandy soils of western Sudan; selection of large seeded Virginia types for production in northern Sudan; development of genotypes with increased resistance to infection by *Aspergillus flavus* and aflatoxin production; and development of genotypes with high oil content and high kernel yield.

Hybridization work started in 1978. Breeding material is being assembled from the United States and ICRISAT, and close contact with the ICRISAT program will be maintained.

Pests and Diseases

Interest in pests and diseases of groundnuts in the Sudan started in the late sixties when the crop was introduced into the rotation of the Gezira agricultural scheme. The following information has been obtained from old records and recent surveys and research:

Bird, Insect and Rat Pests

According to Ahmed and El Amin (1976), crows *Corvus a/bus* (Mull.) and doves *(Streptopelia decipiens)* may inflict some damage during June and July by picking up unburied or badly buried seeds. This loss usually ends by the first irrigation or rain.

Millipedes (*Julidae)* appear in great numbers at the beginning of rains and they chop the tender parts of the crop at night. During the day, millipedes hide under the shade of trees, loose barks, and in soil cracks and depressions.

Termites *(Microtermes thoracalis)* (S. jost), *Macrotermes bellicosus* (Smeath) and *M. natulenses* (Hak.) cause sporadic damage.

The chaffer grub *(Schizomycha cibrat)* feeds on the subterranean parts of the plant. Sometimes the embedded larvae of an unidentified yellow grub may feed on the inside tissue of the stem and cause wilt.

Thrips, *Caliothrips impurus* (Pr.) and *Caliothrips sudanensis* (Bagn and Cam), usually appear in large numbers in mid August but rarely get serious. Aphids *{Aphis craccivora)* usually attack late sown groundnuts in irrigated areas.

The following minor pests many of which were noted by Clinton (1960) and Ali et al. (1970) in rainfed areas, have been found on groundnuts:

Egyptian leaf worm *(Spodoptera littoralis)* (Boist); leaf roller, *Cosmophila flava* (F); whitefly (*Bemesia tabaci)* (Genn); green bug *(Nezara viridula* (L); stainer bug (Dysdercus spp); American bollworm, *Heliothis armigera* (Hb); and grasshoppers *(Ailopus* spp and *Catantops* spp.).

Field rats *(Mastomys natolensis macrelepsis* (Sund)) occasionally attack seeds before germination.

Diseases

At present there are no serious diseases in groundnuts, yet the following diseases were recorded in different parts of the Sudan by Tar (1955), Ali et. al (1970), El Nur and Ibrahim (1970) and Khalifa (1973):

Cercospora arachidicola (Hori) (early leaf spot) and *Cercosporidium personatum* (Berk and Curt) (late leaf spot) occur late in the season and according to Khalifa (1973) they do not reduce yield significantly.

Rust, *Puccinia arachidis* (Speg), was first recorded by Ali (1978) in both rainfed and irrigated crops in the Sudan. It occurs very late in the season and its effect on yield is not yet assessed.

Crown rot caused by *Aspergillus niger* (Van Tieghem), *Phyllosticta* sp causing leaf spots, and the rosette disease were recorded by Tar (1955) in the early fifties.

A leafmottle caused by a virus disease has been recorded in some parts of the country by Hashim (1975).

Very sporadic wilts have been noted in some fields and the following pathogens were isolated (Ali 1980) from wilting plants: *Macrophomina* sp; *Fusarium* spp; *Rhizoctonia solani* (Kuhn); and a septate nonspore-forming fungus with a fluffy mycelium.

Aspergillus flavus was isolated from a few broken seeds after harvest in the Gezira scheme. A little incidence of aflatoxin, far below the internationally accepted level, was detected in these seeds (El Nur et al. 1970).

Weeds

Many grasses and broadleaved weeds were found to compete with groundnut in its early growth stages. According to Ishag (1971) and Hamdoun (1976), yield could be reduced by 73-80% if the first weeding were delayed more than 4 weeks after planting.

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Groundnut Production, Utilization, Research Problems and Further Research Needs in Tanzania

A. Bolton*

Production

There is a shortage of edible oil in Tanzania due largely to increased domestic consumption and to some extent to increased emphasis on food crops and cash crops. An Oilseeds Research Project was started in 1978 with cooperation from the British Government Overseas Development Administration. It was based in the south of the country but with national responsibilities to deal with sesame, sunflower and groundnut which are the main annual oilseed crops.

The area under annual oilseed crops (groundnut, sesame, sunflower, castor) is difficult to estimate, but the Ministry of Agriculture estimates give a total of about 150 000 hectares of which groundnut accounts for about 100 000 ha. Reliable yield figures are not obtainable but good groundnut farmers may produce about 700 kg/ha with the traditional peasant farmers getting half of this or less.

Mixed cropping is prevalent and groundnuts are nearly always grown in association with other crops. There may be several crops all on the piece of land with more or less random planting of groundnut with cereals (maize or sorghum) etc. It is rare to find fertilizer applied.

Official marketing is carried out by GAPEX (General Agricultural Products for Export) and the proportion of the crop marketed through the organization, as shown in Table 1, is only a fraction of total production. There is considerable domestic consumption by the subsistence farmer, and most of the surplus is sold through unofficial channels at a price well above the official price offered by GAPEX.

The oil mills in Tanzania have a potential demand for 4000 tonnes of groundnut annually (out of a total requirement for all oilseed crops of over 200 0001) but supplies are considerably below this figure, although if the estimate of 100 000 ha under groundnut is anywhere near reliable, the quantity needed by the mills is still only a small fraction of thetotal production. The price offered by GAPEX is at present Shs.4.00/kg (approximately Rs 4) but the unofficial price can be several times higher, particularly in the large urban centers.

Research

A good deal of work has been carried out in the past in Tanzania especially in the years immediately after the second world war when the British Government started a large scale production scheme based at several centers in the country. This scheme was not successful. Since then, work has included a number of variety trials run within the network of research stations administered by the Crop Research Division of the Ministry of Agriculture. Between the 1969- and 74-75 seasons, 28 trials tested 118 entries but the trials were not coordinated and joint analysis has proved impossible.

Many of these entries were collections of local material largely from the north-west area of Tanzania collected by Ukiriguru. The exact origin is not always clear, but they are classified mainly as upright bunch with a fewdescribed as spreading, although none appear to be of purely Virginia or runner habit. In the crops grown by local farmers in the south, a small number of plants of runner habit may be found in the crop.

The Oilseeds Research Project which started in 1978, aimed primarily at breeding and the agronomy of sesame and sunflower. However, in view of the importance of groundnut to the peasant farmer, groundnuts were included with the intention of sorting out the varietal

* Agricultural Research Institute, Nallendele, P.O. Box 509, Mtwara, Tanzania.

position as far as possible, and of conducting agronomic experiments with the more promising entries. Standard varieties in the collection included Natal Common, Sigaro Pink, Red Mwitunde and Makulu Red but the purity of these named entries and of those in the local collection is so doubtful that no single named variety in the country prior to 1978 can be accepted as entirely valid.

During the past two seasons, samples of some named varieties and of breeding material have been received from other countries including the United States and India (ICRISAT), together with some local types from the Lindi and Mtwara Regions in the south of Tanzania. At present they areundergoing multiplication and will be tested in trials as sufficient stocks of seed become available.

Results of yield trials carried out at four sites in 1978-79 are presented in Table 2. Entries identified by numbers are those from the Ukiriguru collection and the indications are that

Table 1. Marketed groundnut production In Tanzania.

Year	Marketed production (tonnes)		Exports (tonnes)		Mtwara Region (%)	Dodoma Region (%)	Tabora Region (%)
	Total[a]	Groundnut	Total[a]	Groundnut			
71-72	30 598	3295	27 686	75			
72-73	30 497	3454	20 733	232	38	35	22
73-74	19 874	1363	9 265	Nil	29	7	46
74-75	16 733	509	9 702	Nil	48	-	5
75-76	15 489	510	2 259	Nil	55	5	-
76-77	14 157	417	3 000	Nil	50	14	-
77-78	17 437	1448	6 669	Nil	61	23	-
78-79 [b]	22 787	2615	—	—	52[b]	2[b]	16*

a. Total Is figure for sesame, castor, sunflower, and groundnut.
b. Purchases to April 1979.

Table 2. Groundnut variety trials 1978-79; kernel yield (kg/ha).

Variety	Nachingwea	Naliendele	Suluti	Mtopwa	Mean
69.62.2.5	1538	1516	1169	1146	1342
70.1.1.1.	1468	1710	1215	955	1337
69.63.2.5	1577	1463	1271	1028	1335
69.17.6	1633	1610	1218	792	1313
69.358.1.4[a]	1596	1450	1208	863	1279
69.29.2	1535	1613	1124	839	1278
69.15.3	1605	1320	1204	756	1221
Natal Common	1227	1315	1277	1007	1207
69.99.1.2.4	1237	1473	1069	940	1180
70.7.3.	1387	1331	1208	748	1169
69.17.1	1345	1505	960	850	1165
Sigaro PinK	1122	623	874	471	773
Mean	1439	1411	1150	866	1217
S.E.	1019	102.0	106.9	116.7	54

a. 68.35a. 1.4 Is Natal Common ex. Ukiriguru.

adequate yields can be obtained under reasonable conditions.

Tables 3 and 4 give results from last season testing at six sites which were much the same as entries in the previous season. The main conclusion is that groundnut can be successfully grown over a fairly wide range of climatic conditions. Next season, 1980-81, some introductions will be tested extensively.

Yields of some introductions are encouraging, e.g., Tifspan did well in a multiplication plot last season. It is hoped to run trials at up to 20 sites to arrive at reliable performance data.

A few agronomy trials were carried out last season. One plant population trial (Table 5) indicated that populations of up to 250 000 plants per hectare gave increasingly higher yields. The difficulty is the large amount of seed required for planting which the peasant farmer does not have available. The variety used last season was one of the local entries.

A similar trial in the 1978-79 season using Sigaro Pink showed that spacing between rows of 60 cm is probably too wide. The present recommendations for crops in southern Tanzania is 50 cm x 10 cm giving 200 000 plants per hectare.

A start was made on intercropping trials with results as in Tables 6 and 7. The aim was to compare rows of cereal, maize or sorghum interspersed with 1, 2, or 3 rows of groundnut. Last season was exceptionally difficult with a pronounced drought for 4 weeks from about 2 weeks after planting. The yields obtained are therefore not unsatisfactory. There was a definite advantage from the intercropping system at one site (Naliendele) but not at the other (Nachingwea). Spacing of sorghum and

Table 4. Groundnut variety trials 1980; kernel yield (kg/ha).

Variety	Nachingwea	Naliendele	Mean
69.63.2.5.	2228	1502	1865
69.1.5	2114	1331	1723
69.29.2	1922	1463	1693
69.99.2.4	2070	1270	1670
69.17.6	1798	1525	1662
69.62.2.1.	1782	1516	1649
Natal Common	1808	1422	1615
69.62.2.5	1742	1429	1586
70.1.1.1.	1968	1196	1582
69.17.2	1772	1301	1537
69.15.3	1854	1218	1536
69.35a. 1.4.	1650	1356	1503
Local	2198	404	1301
69.35.1.	1136	1234	1185
Sigaro pink	1388	576	982
Red Mwitunde	1160	439	800
Mean	1787	1199	1493
S.E.	131.4	67.6	

Table 3. Groundnut variety trials 1979-80; karnal yield (kg/ha).

Variety	Ndengo	Suluti	Utengule	Mtopwa	Mean
69.62.2.5.	903	798	808	1600	1027
69.15.3	1005	584	967	1520	1019
70.1.1.1.	1190	514	696	1600	1000
69.99.1.2.4	935	770	879	1300	971
69.29.2	855	818	866	1140	920
69.63.2.5	880	484	788	1460	903
Natal Common	1013	790	861	-	888
69.35a. 1.4	827	588	467	1560	861
69.17.6.	834	610	867	1120	858
Local	-	280	409	-	345
Mean	938	624	761	1412	
S.E.	76.6	71.6	94.8	-	

Note: Last two replications of the Mtopwa trial were not enalyzed. Data presented above Indicate yield levels attainable. Naliendele and Nachingwea results are shown in Table 4.

groundnut was 50 cm x 10 cm and of maize, 50 cm x 50 cm. These agronomy trials will be continued next year.

Table 8. Groundnut plant populations, Naliendele, 1979-80.

Treatment		
Spacing (cm)	Plants/ha	(kg/ha)
1 60 x 40	41667	1138
4 40 x 40	62 500	1233
2 60 x 20	83 333	1276
5 40 x 20	125 000	1475
3 60 x 10	166 667	1420
6 40 x 10	250 000	1783
		S.E. 53.1

Pests and Diseases

No specific research work was conducted and the following brief notes are records from the main center, Naliendele.

Insects Observed

GROUNDNUT APHID *(APHIS CRACCIVORA).* These were observed giving rise to rosette virus but not in large numbers. The number of plants affected was small. The disease has been reported often in Tanzania but the true effect of the virus on the crop is not known with any certainty.

BEAN WEBWORM *(LAMPROSEMA INDICA).* A little damage was caused.

SPOTTED BORER *(MARUCA TESTULAUS).* These

Tabla 6. Intareropping groundnut/maize, Nachingwaa, 1979-80.

Treatment		LER	Crop value (Sh./ha)
Maize pure			4269
Groundnut pure			6469
Intercropped maize/groundnut	1:1	1.24	6760
Intercropped " "	1:2	0.87	5104
Intercropped " "	1:3	1.04	6075
	S.E.	0.110	546
Mean yield pure stand maize		4270 kg/ha	
groundnut		1617 kg/ha	

Tabla 7. Intercropping groundnut/sorghum, Naliendele, 1979-80.

Treatment		LER	Crop value (Sh./ha)
Sorghum pure			1893
Groundnut pure			2566
intercropped sorghum/groundnut	1:1	1.78	3800
Intercropped " "	2:2	1.81	3750
Intercropped " "	1:3	1.94	4335
	S.E.	0.100	320.9
Mean yield pure stand sorghum		1893 kg/ha	
groundnut		639 kg/ha	

were present in considerable numbers during the two seasons.

AMERICAN BOLLWORM *WEUOTHIS ARMIGERA).* Considerable numbers of these caterpillars were found feeding on the leaves and in 1980 there was noticeable damage after flowering. They were also present on sunflower heads and sorghum in adjacent plots.

COTTON LEAFWORM *(SPODOPTERA UTTORAUS).* Small numbers of the caterpillars were found feeding on the leaves.

TOBACCO WHITEFLY *(BEMISIA TABACI).* This was occasionally found in small numbers sucking the underside of groundnut leaves.

GROUNDNUT HOPPER *(HILDA PATRUELIS).* A few scattered plants were attacked by this insect whose nymphs and adults suck from the base of the plant under the soil surface. Attacked plants wilted and died.

LEAF BEETLE *(CYPONYCHUS* SPP). Some adult beetles were found eating from the leaf surface leaving irregular patterns on the leaves.

FLOWER (POLLEN) BEETLES *(MYLABRIS* SPP AND *CORYNA* SPP). These beetles were common on the groundnut flowers in both seasons.

TERMITES. Nearly always found somewhere.

Diseases Observed

ANGULAR LEAF SPOT *{CERCOSPORA PERSONATA* AND *C. ARACWDICOLA).* This disease was common in plants which had nearly completed flowering. It was therefore not so serious as to call for control measures.

RAPID YELLOWING OF WHOLE PLANT. In the 1980 crop, there was a severe yellowing of plants in most plots around the Institute (but not in the experimental field) and on experimental plants at one subcenter.

The following fungus species were identified from root and stem selections: *Curvularia lunata; Fusarium* spp; and *Botryodiplodia theobromae.*

Root and stem sections showed brown discoloration on the conducting tissues. The pods were also infected.

Groundnut Production, Utilization, Research Problems and Further Research Needs in Zimbabwe

G. L. Hildebrand*

Zimbabwe is situated between 16° and 22°S latitude and varies in altitude from 160 m to 2000 m. Zimbabwe is part of the plateau which traverses the subcontinent of Africa. This central plateau, known as the Highveld extends for some 650 km in a south-west to north-east direction. The rainfall is generally adequate to support a broadly based agricultural industry and the bulk of the country's development is concentrated in this area.

On either side of the central plateau lies the Middleveld where altitudes range from 600 to 1200 m. Below 600 m lies the Lowveld where hot and generally drier conditions prevail. The main cropping area lies between 300-1600 m, although cropping is largely dependent on irrigation below 800 m.

The climate is characterized by definite wet and dry seasons, with the wet season beginning in November and ending in late March. Some climatic data for selected sites at a range of altitudes in Zimbabwe are given in Table 1.

Production

The groundnut crop is small by world standards but is an important source of food in the rural area and surpluses are an important cash earner.

No accurate production figures are available but estimates and sales for the 1978-79 and 1979-80 seasons are given in Table 2. These figures show that more than 90% of groundnut production comes from the rural areas and that this sector retains about 90% of its production for local use. Groundnuts are a controlled product in Zimbabwe and must be sold through the Grain Marketing Board or its agents.

Estimated deliveries to the Board have been of the order of 15 000 to 20 000 tonnes annually in recent years. Before the war in Zimbabwe annual deliveries were about 30 000 tonnesand have now reached 44 000 tonnes.

The irrigated crop that consists of long season varieties grown in the large scale farming area, yields about 50% confectionery nuts of which about 75% are exported. The small-kernelled short season varieties (Spanish and Valencia types), that are grown under dryland conditions in the rural areas, yield about 25% confectionery nuts of which about 60% are exported. Crusher grade accounts for 65% of the dryland crop while about 10% is used for seed.

With peace returningtothecountry, and with it, improved availability of inputs, better communications and transport, and easier marketing, it is estimated that annual deliveries are likely to increase to about 30 000 tonnes in the near future.

A large increase in area planted is unlikely to come about in the foreseeable future and therefore it is doubtful whether further increases in deliveries will occur unless there are significant increases in yield.

Varieties and Production Methods

There are two main types of varieties grown. The long season varieties (mainly of Virginia botanical type), depending on altitude, mature in 140-200 days and are generally only suited to production under irrigation where planting can be carried out before the onset of the rains. These varieties are planted from late-September to mid-October and are harvested from late-March to mid-April. The ability to plant early with irrigation has resulted in the achievement of high yields (Metelerkamp

• Groundnut Breeder, Crop Breeding Institute, Department of Research and Specialist Services, P.O. Box 8100, Causeway, Zimbabwe.

1967). The highest yield achieved to date on a field scale is 9.6 t/ha unshelled.

The short season varieties (Spanish and Valencia botanical types), depending on altitude, mature in 110-150 days and are usually grown under rainfed conditions but have produced promising yields when grown under irrigation in the warmer areas.

Table 1. Some climatic data for selected sites in Zimbabwe (means for 5-month period November—March).

	Meteorological station (with altitude in m)			
	Marandellas 1628	Gatooma 1157	Tuli 765	Triangle 421
Mean max. temperature (°C)	24.4	28.4	30.4	32.2
Mean min. temperature (°C)	14.2	17.0	17.9	19.3
Mean hours sunshine/day	6.5	6.8	7.3	7.3
Mean evaporation/month (mm)	152	175	198	200
Duration of rainy season (days)	135	125	80	105
Rainfall for Nov-Mar (mm)	840	706	394	539
Annual raihfall (mm)	936	776	455	622

Table 2. Groundnut production in Zimbabwe (unshelled groundnuts; Crop Forecast Committee estimates).

Season	Source	Area planted (ha)	Yield (t/ha)	Production (tonnes)	Retention (tonnes)	Deliveries (tonnes)
1978/79	Large-scale farming areas					
	- irrigated	1 500	3.33	5 000		
	- dryland	1400	1.43	2 000		
		2 900		7 000	250	6 750
1978/79	Small-scale farming areas	12 000	0.58	7 000	2 000	5 000
	Rural areas	240 000	0.42	100 000	91 750	8 250
		252 000		107 000	93 750	13 250
	Total	254 900		114 000	94 000	20 000
1979/80	Large-scale farming areas					
	- irrigated	2 200	3.50	7 700		
	- dryland	1400	1.64	2 300		
		3 600		10 000	300	9 700
1979/80	Small-scale farming areas	11 000	0.54	6 000	5 000	1000
	Rural areas	360 000	0.31	110 000	100 700	9 300
		371 000		116 000	105700	10 300
	Total	374 600		126 000	106 000	20 000

Although good yields have been achieved by efficient producers the national average yields are disappointingly low.

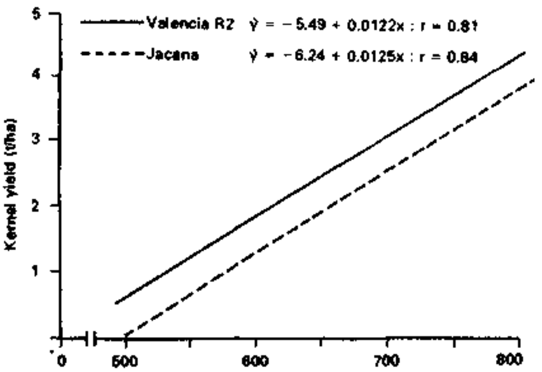
In recent years a close relationship between weather and yield has become evident (Williams, Hildebrand and Tattersfield 1978). The influence of radiation and temperature on final yield is illustrated in Figure 1 for two short season varieties grown in variety trials at Salisbury Research Station over a period of 12 years.

An interaction with environment has also become evident in which Valencia varieties tend to yield more in the cooler, high altitude areas while the Spanish types tend to yield more than Valencia types in the warmer and generally drier areas.

The influence of altitude, and therefore temperature, on the mean yields and gross returns of these two varieties at 11 sites over a number of years is illustrated in Figures 2 and 3.

Research

The bulk of the research effort in the past decade has been placed on variety improvement (Hildebrand 1975a), physiology and growth analysis. This effort has resulted in a number of varieties being made available for commercial production (Department of Research and Specialist Services 1979) and a very significant contribution has been made to the understanding of groundnut growth under varying climatic conditions.



Radiation (22-41 days) + Mean maximum temp. (℃)
(December + February + M8rch)

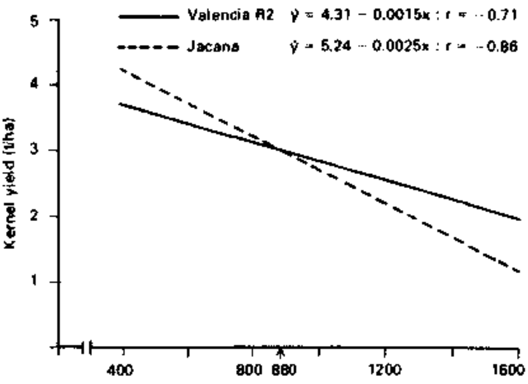
Figure 1. The relation between yield and weather for two groundnut varieties grown at Salisbury Research Station.

Some work on the agronomic aspects of groundnut production was conducted in the sixties and early seventies and has resulted in the basis for recommendations for production in the large scale farming area (Collett 1973). These have also provided principles on which to base recommendations for production in the rural areas. However, certain problems still exist which are limiting yields and for which solutions must be sought. These are dealt with in more detail in the section under Further Research Needs.

Variety Improvement

Long-Season Varieties

Breeding and selection continues to develop



Altitude (m)

Figure 2. The relation between yield and altitude for two groundnut varieties.

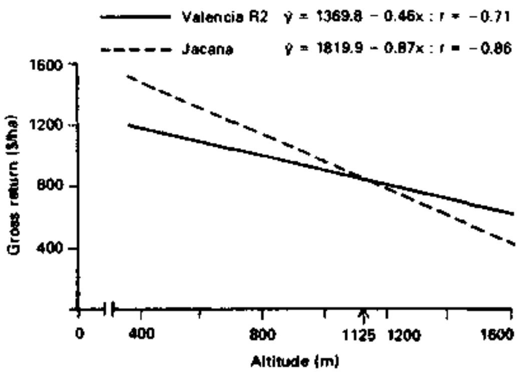


Figure 3. The relation between gross return and altitude for two groundnut varieties.

improved varieties for production under irrigation. Table 1 shows that the irrigated crop, that is largely grown in the large scale farming area, is small but it is nevertheless important as the high yields and good quality nuts produced are a valuable earner of foreign exchange when exported for confectionery. Objectives are to improve yield potential, kernel size and kernel quality. Considerable emphasis has been placed on selection of varieties with a pale pink testa since world markets for red-skinned varieties are limited. This had led to the development of the variety Egret which is now the main variety grown (Hildebrand 1975c). Selection will continue for higher yields, better quality and improved agronomic aspects such as disease and pest resistance, strong peg attachment and acceptable shelling characteristics (Hildebrand and Smartt 1980).

Short-Season Varieties

HIGH ALTITUDE AREAS. Many of the Valencia types collected in the country and introduced from elsewhere are red-skinned. Because of the limited market for red-skinned groundnuts in the confectionery trade, considerable emphasis has been placed on the selection of pink-skinned Valencia varieties or varieties with acceptable testa color that yield well in the high altitude areas.

The red-skinned Valencia R2 was released in 1974 (Department of Research and Specialist Services 1974). This variety was introduced from Dr. W. C. Gregory's South American collection and has given high yields and shows some tolerance to *Cercospora arachidicola.* A number of promising pink Valencias and other varieties which are adapted to the higher altitude areas are in advanced stages of variety testing at this time. Promising results have been shown by locally bred varieties, some arising from infraspecific crosses.

The past season's results indicate tolerance to drought, improved kernel size and quality and the presence of seed dormancy in some of the locally bred selections.

LOW ALTITUDE AREAS. Natal Common has been grown in these areas for many years. It is a small-kemelled Spanish variety with a light pink testa. Considerable effort in the past decade has been placed on the selection of similar varieties with improved yield, kernel size and kernel quality. It was felt that under conditions of limited rainfall, it will be difficult to make significant increases in yield but that superior kernel size and quality could result in greater returns to the producer through better grades and greater value in the confectionery market.

A Spanish type, Jacana, having superior yield, kernel size and market quality, was released in 1975 (Hildebrand 1975b). This variety has, however, recently been withdrawn because of difficulties experienced in shelling.

A number of varieties in advanced stage of testing have shown promise including some already mentioned from locally bred selections which appear to be adapted to a wide range of altitudes.

Dwarf Genotypes

Extreme rank growth has been experienced with long and short season varieties when grown at low altitudes under irrigation. Branches often reach 1.5 m or more in length and represent an apparent waste of photosynthate in producing excess vegetative growth.

Selection for genotypes with short stature has led to encouraging results with lines which have stems of only 0.5-0.8 m in length.

Disease Resistance

Sources of tolerance to *Phoma arachidicola* have been included in crosses and selection from segregating populations and progenies is currently being undertaken.

Some breeding and screening for rust resistance has been carried out. Three of the FESR Fa lines were used as parents in crosses but no major emphasis has been placed on this work as serious rust occurs only in the low altitude areas. It is not likely to become as economically important as the leaf spot diseases.

One source of tolerance to *Cercospora arachidicola* has been used in some crosses. Some fairly promising selections from a cross between this Valencia line and a long season line are in variety trials.

Shelling Ability

The marketing policy in Zimbabwe is to encourage delivery of unshelled pods for centralized shelling by the Grain Marketing Board. There is a specific requirement therefore for varieties that can be suitably shelled since although a small proportion of the crop is marketed, that portion is however valuable, and it must be possible to carry out efficient shelling.

Jacana is one variety which shells very poorly when grown under difficult conditions of harvesting and curing. For this reason routine screening of shelling ability of all varieties entered into variety trials is now carried out using a Dawson Model 3 groundnut shelter (Davidson and Mcintosh 1973). Considerable differences have been noted between varieties but the poor shelling results of Jacana under field scale production has not been found in Jacana grown in variety trials.

Disease Control

Research on the epidemiology of leaf spot and pod rot fungi has been carried out over the past decade (Cole). Leaf spots caused by *Cercospora arachidicola* and *Cercosporidium personatum* are well controlled by the recommended mancozeb/benomyl mixture. Good control has also been achieved with chlorothalonil. *Phoma arachidicola* is more difficult to control with chemicals. It has been found that C. *arachidicola* is antagonistic toward *P. arachidicola* and complete chemical control of *C. arachidicola* results in severe infection by *P. arachidicola.*

Delaying the start of a chemical disease control program, to allow a low level of *C. arachidicola* to develop, generally results in a low and balanced level of both pathogens. Efficient control of foliar diseases results in reduced losses caused by pod rots and pod shedding.

Depressed yields due to chemical disease control have been experienced under conditions of limiting moisture. For this reason spraying of dryland crops is generally not recommended.

Encouraging results have been achieved using spinning disc ULV sprayers and these could be of considerable benefit on irrigation schemes in the rural areas.

Aspergillus flavus appears to occur in significant levels only in those years where a midseason dry spell is experienced during January or February.

Rosette virus is of economic importance only in the rural areas when plant stands are thin.

Physiology and Growth Analysis

A very significant contribution has been made to the understanding of groundnut growth in the past decade (Williams, Wilson and Bate 1976; Williams 1979a, b, c, d, e). This has shown how groundnuts respond to the environment and how different varieties are affected by differences in climate (Williams, Wilson and Bate 1975; Williams and Allison 1978).

Agronomy

Research on plant populations, spacing, and early planting with irrigation have made significant contributions to increased production (Metelerkamp 1967). In additon the work on physiology and growth has contributed towards better agronomic practice, particularly in the irrigated crop.

Mechanization

Investigation into mechanization of groundnut production has resulted in expansion of mechanized harvesting and curing of the irrigated crop plus development of picking and cleaning aids for small scale producers. Investigations into drying methods, including the use of solar energy, have been conducted (Oliver 1978).

Weed Control

Screening of chemicals for, and methods of, weed control have continued and have resulted in chemical weed control recommendations which are widely used in the irrigated crop (Borland 1973 and 1975).

Aflatoxin

During the sixties and early seventies, a survey of the incidence of aflatoxin in the national crop was conducted. This work led to the establishment of a monitoring procedure for aflatoxin for use by the Grain Marketing Board (Du Toit 1971) and established the environmental conditions which would influence the incidence *of Aspergillus flavus* damage in the national crop.

Nutrition

Limited research on nutrition of groundnuts on poor soils in the rural areas has shown large responses to the application of manure, manure and gypsum, and phosphates. Application of phosphate and sulphur are most important. The fertilizer recommendations as made by fertilizer advisory services for large scale farming areas do not apply since the residual fertility in the rural areas is very low. It is felt that groundnuts could play an important part in the improvement of general fertility practices in the rural areas since large applications of nitrogen are not required and the good monetary returns from the groundnut crop are likely to better stand the cost of increased fertilizer application than many other crops.

Responses to *Rhizobium* inoculation have been small since there are naturally occurring *Rhizobia* in most soils.

Further Research Needs

Variety Improvement

This must be continued and expanded with the objective of developing new varieties, particularly for the rural areas, which have: improved yield and quality; drought tolerance; disease and pest resistance; seed dormancy at harvest; reduced vegetative growth for those areas where rank growth occurs; and satisfactory shelling quality when grown under difficult harvesting and curing conditions.

Disease Control

Research should continue with regard to: epidemiology of the economically important diseases; screening of chemical control measures; cost and efficiency of chemical control methods; and feasibility of foliar disease control in the dryland crop.

Pest Control

Hilda patruelis has been a problem in the past in the large scale farming area, particularly in dry seasons. It could well be a problem in the rural areas. Further research on the biology and control of this pest is necessary.

Agronomy

It is generally accepted that the technology for increased groundnut production is available. The greatest need now is for an expansion of the extension effort.

There are, however, certain problem areas the extent of which are not known and it is felt that these should be investigated as early as possible. These problem areas include: (1) methods of facilitating earlier planting. Lack of draught is the greatest limiting factor to being able to plow and plant as early as possible after the first rains. Although it may not facilitate early plowing, water-planting ahead of the rains may enable the producer to best use residual moisture and favorable early season radiation and temperature; (2) the effect of nematodes on groundnut crops is not well known. Some effort should be made to establish if it is in fact a problem.

Nutrition

Further research is needed to provide guidelines for fertilizer applications in the rural areas with particular reference to: basal fertilizer recommendations; the timing of gypsum applications since it is likely that gypsum will be a more important source of sulphur than calcium; and levels of starter nitrogen required and whether benefits would accrue from the use of *Rhizobium* inoculant since groundnut in the rural areas are not, as a rule, inoculated.

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Session 8 — Country Reports

Discussion

P. Subrahmanyam

You mentioned that both rust and leaf spots are important in Malaysia and that you were using benomyl as a fungicide. How are you going to control rust as benomyl will only control leaf spots? Secondly, what is the range of aflatoxins in Malaysian peanuts?

H. B. Hamat

Rust came to Malaysia only recently and so far is not a threatto groundnut cultivation. We are presently controlling leaf spots with benomyl and will have to change fungicides if rust becomes serious. Aflatoxin levels in Malaysian groundnuts have not been determined.

R. P. Reddy

You state that in Malaysia lime is applied at the rate of 1 tonne/ha. What sort of lime do you apply and is it to supply calcium or to change the soil pH?

H. B. Hamat

I am not sure what the source of lime is, but it is to combat the low pH of Malaysian soils, which are very acidic.

R. O. Hammons

You mentioned that peanut is boiled in the shell in Malaysia. In what form is it eaten — as the seeds or the whole fruit? In Bolivia young boiled fruits are eaten whole.

H. B. Hamat

Only the seeds are eaten in Malaysia.

R. W. Gibbons

Do you manufacture your own Ultra Low Volume (ULV) spraying equipment in Australia?

K. Middleton

At present we are importing ULV or CDA (Controlled Droplet Application) equipment from the United Kingdom. But a subsidiary company in the USA is now manufacturing this equipment on a large scale and this should be available on a large scale shortly.

S. M. Misari

The pattern of plants wilting that you showed in one of your slides indicated that the affected areas were scattered through the field, and yet the field showed no obvious depressions. Have you investigated the soil properties, and have you checked for soil pests in these wilted areas?

K. Middleton

We have obtained negative results for soil pests and nematodes in these wilted patches. We feel that these patches are the result of changes in the physical structure of the soils caused by intensive cropping and machine compaction over the years.

J. S. Chohan

You have mentioned that leaf spot and rust are controlled in Venezuela by fungicides. What fungicides do you use, and what costs are involved?

B. Mazzani

The most important disease is leaf spot. Rust is present every year, but only occasionally does it'become serious, say every fifth or sixth year. Benlate is commonly used to control leaf spot, but many sprays are used and it is the most costly of all the inputs. One farmer told me recently that he spent up to US$ 250 per hectare on leaf spot control.

P. J. Dart

I was surprised to hear that you used 1 tonne/ha of a 6:12:6 compound fertilizer on groundnuts in Venezuela. This means that you are applying 60 kg of nitrogen. Do your experiments show the need for so much nitrogen? The implication is that the nodule nitrogen fixing system is not working effectively and would warrant some microbiological research.

B. Mazzani

The soils in the groundnut growing regions are very poor and contain practically no nitrogen. Experiments show that this amount of fertilizer is required, and this question of high fertilizer usage in Venezuela is often asked because it is so unusual.

Vikram Singh

In Venezuela there has been a significant increase in yield, from 700 kg/ha in 1972 to over 1800 kg/ha in 1979. How have these large increases come about?

B. Mazzani

Not all the factors that have contributed to this increase have been analyzed, but I would think thatthe most significant singlefactor has been the increase in the area under irrigation.

A. S. Chahal

Breeding is under way in Brazil for resistance *to Aspergillus flavus* but what about A *nigerl* Is this fungus also a problem?

A. S. Pompeu

Aspergillus niger is at present only a minor problem in Brazil. The most important of all diseases is leaf spot.

K. Middleton

I would like to inform the delegates that besides Brazil, there is an interest in the use of unrefined groundnut oil to power diesel engines at the James Cook University in Townsville, Queensland. Groundnut oil has been used as fuel in a diesel engine, and it proved to be competitive with normal diesel fuel.

J. S. Saini

I would like to ask the speaker from Malawi to comment on weed control in that country. We heard that weeds, particularly grassy weeds, are a real problem there and cause large yield reductions.

C. Kisyombe

Generally, the weed problem is still tackled by most farmers in the traditional way — by using the hand hoe or by hand pulling tall weeds. There has been some success with the "Lasso" brand preemergence herbicide on a research basis, and herbicides will be used by large growers.

T. P. Yadav

The average yields obtained by farmers in Mozambique are very low — around 200 to 500 kg/ha. What are the highest research yields obtained?

A. D. Malithano

During colonial times very little research work was done on groundnuts as it was not a major export crop, so it was largely ignored. The current research program has only just started and our first results gave us yields around 700 to 900 kg/ha; but we are sure we can improve on these figures, particularly if we use supplementary irrigation.

J. S. Chohan

What is the current staffing pattern for groundnut research in Mozambique?

A. D. Malithano

Many scientists left Mozambique after independence in 1975. At present I am the plant breeder, and there is an FAO expert who has to divide his time with several other crops. We hope shortly to recruit an agronomist and a pathologist.

J. S. Chohan

The extension agency in Mali seems to be very effective. Would you care to elaborate on this?

D. Soumano

We have separate extension and research units. Thedetailed data from research findings are handed overto the extension agency. They are well-equipped with extension aids to carry the information to the farmers. Research results are only carried to the farmers via extension workers, never directly.

P. W. Amin

Termites appear to be important pests in Mali. Are they more troublesome as field pests or storage pests? What control measures are used?

D. Soumano

Most of the problems by termites are caused in the field, even before harvest. At present, Furadan is being used to control termites.

Vikram Singh

What are some of the morphological features and/or physiological traits identified by the workers in Senegal that impart drought tolerance or resistance?

J. Gautreau

From our studies morphological characters do not appear to be important. Two cultivars, one drought resistant and the other not, can have very similar morphological characters. We found differences between cultivars when we measured transpiration rate, stomatal resistance, and leaf water potential.

Vikram Singh

In the fungicide trials in Zimbabwe you sometimes got a depression in yield. Can you offer an explanation?

G. Hildebrand

We have not got enough data on this, but we suspect that in dry years the treated plants retain their leaves and lose too much water, whereas the untreated plants have lost some of their leaves due to disease and can withstand the dry conditions.

K. Middleton

We have had similar experiences in Australia. The fungicides we use (chlorothanonil and fentin hydroxide) seem to affect the physiology of the plant even when diseases are not prevalent. They help to delay maturity and the plants may wilt if sufficient water is not available in heavily sprayed plots.

D. V. R. Reddy

Is 'clump' virus economically important in Senegal? Is rosette still important?

J. Gautreau

In Senegal 'clump' is present but in very localized small pockets. It is not economically important as yet but it has a very spectacular effect on the plant.

Rosette is more important in the south of Senegal. A new resistant variety (69-101) has been released, and where it is grown, rosette is no longer a problem.

R. W. Gibbons

The world record commercial yield of over 9 tonnes/ha was achieved a few years ago in Zimbabwe. Under what production practices was this yield obtained?

G. Hildebrand

The yield of 9.6 tonnes/ha was achieved in 1973-74 in a comparatively dry year in the Bulawayo region. The farmer planted early, he followed an irrigation schedule and used benlate and mancozeb for disease control. He did however use about twice the recommended plant rate per hectare but he repeated these yields over the next two seasons with the normal rates of 1.25 to 1.5 million plants/ha. He obtained these yields with the Makulu Red cultivar over an area of 30 acres.

D. R. C. Bakhetia

In one of the slides during the presentation from Nigeria we saw stunted growth in one trial that resulted from the effect of a fungicide. What was the fungicide?

C. Harkness

I would prefer not to disclose the name of the fungicide, which was an experimental formulation. We grew groundnut the next season on the same area and the residual effects were clearly apparent on the plots that had been treated with this chemical.

D. H. Smith

I obtained similar results with an experimental formulation, perhaps the same one. Stunting of the plants was observed in residual peanut crops for 2 years.

W. V. Campbell

I was surprised that so few insects were mentioned as pests in the country reports, except as vectors of virus diseases such as rosette. Are insects not a serious problem or is it because there is a lack of detailed investigations on crop losses or entomologists working in these countries?

S. M. Misari

I think that entomological aspects have been neglected. Very often people look only for the dramatic effects, e.g., a heavy infestation of aphids that are easy to see. If you look carefully, the groundnut plant contains a rich fauna. Over 70 insects have been reported to cause damage to groundnuts in Nigeria; apart from the noninsects such as termites and millipedes, which are also important pests.

C. Harkness

We got an unexplained increase in yield in the 1979 season from insecticide-treated plots in Nigeria. Treated plots gave 2600 kg/ha compared to 1800 kg/ha from untreated plots. We did not determine which pest or pests were involved.

A. S. Pompeu

There are many reports of insect pests on groundnuts in Brazil but very few reports on the actual losses due to pest attack. The major pest in Brazil is Enneothrips *flavens,* which can reduce yields from 10to 100% with an average of 30%.

Vikram Singh

Aphids can cause 40% yield losses in India and the red hairy caterpillar from 35 to 40% yield loss.

K. Middleton

Generally, in Australia there are not serious pest problems. Controlling mites and jassids gives a cosmetic improvement in appearance of the crop rather than a yield improvement. Large losses have been caused by whitegrubs but no effective soil insecticide has yet been approved by the authorities. *Heliothis* can cause up to 35% defoliation without affecting yields.

P. W. Amin

Insect pests are important in West Africa and so are millipedes and termites in Nigeria, Sudan, Upper Volta, and Senegal. Many farmers use insecticides in the Sudan. Storage pests are also important, and they cause quality losses as well as destroying seeds. My second comment is that the entomologists themselves have not done enough on quantifying losses, particularly in financial terms. The first priority must be to obtain more accurate figures.

D. R. C. Bakhetia

Carbofuran 3G at 1 kg a.i./ha and carbofuran 50% WP at 2.5 g a.i./kg seed have been found to be very effective against white grubs in India. Yield increases of between 53 and 144% have been recorded by controlling white grubs.

A. B. Singh

Yield losses due to white grubs and termites vary from season to season and depend upon the soil type and the moisture level. Losses due to white grub may reach 80%.

D. H. Smith

What about the importance of nematodes, which have not been mentioned?

S. M. Misari

A seed coat inhabiting nematode has been recorded in Nigeria. Approximately 11 species of nematode have been reported from groundnuts. Much more work is needed in this area.

R. O. Hammons

Seed lots from Nigeria kept in a cold store at the germplasm center in Georgia were found to be infested with the seed coat nematode mentioned by Dr. Misari. This poses a quarantine problem.

P. Gillier

We get yield increases from applying carbofuran to the soil in Senegal, but so far it has not been determined whether these increases are due to the control of nematodes or other soil inhabitants.

J. Gautreau

In 1975, nemagon-treated plots in Senegal gave yield increases of 39%, and there was also a significant residual effect. Nemagon treatment is difficult and expensive for small-scale farmers.

R. O. Hammons

Five hundred germplasm lines were screened under controlled conditions in Georgia for resistance to the root knot nematode, but no resistance was found.

Session 9

Plenary Session and General Discussion

Chairman: R. W Gibbons

Rapporteurs: D. McDonald
J. P. Moss
D. V. R. Roddy
J. H. Williams

Plenary Session

The Chairman opened this session with the remark that it should be kept as informal as possible and although there were some specific points to be covered, any point could be raised in the general discussion.

The first item on the agenda was the reports from the Chairmen of the sessions, in which they briefly summarized the papers and discussions presented during the respective sessions. Following these reports, there was a general discussion of the major points brought out during the Workshop.

Summary of Session 2 Research Organization and Development

C. Harkness — Chairman

Delegates have been presented with a good picture of groundnut research organization and development in both developed and developing agricultural systems. Dr. Vikram Singh has provided a comprehensive report on the activities of the All India Co-ordinated Research Program for Groundnuts, a large and complex organization. The large numbers of scientists and institutions concerned with research on groundnut problems in India make an organization such as AICORPO a necessity if costly duplication of effort is to be avoided. Dr. Gillier gave an excellent description of the role of IHRO in groundnut research and development with particular reference to West Africa. His comments on seed multiplication are highly relevant and of great value to workers in developing countries. Dr. Hammons talked about groundnut production in Georgia. He described the advances and improvements in farm machinery, weed control, crop protection, supplementary irrigation, and breeding which have together resulted in a high and stable production of groundnuts in Georgia. Dr. Hammons stressed the important part played in this success story by the extension services. There is a great need to improve extension services in developing countries as many useful findings are not getting through to the farmer.

Dr. Jackson's explanation of the Title XII project for cooperative research on groundnuts between USA institutions and research organizations in the developing countries was particularly well received by delegates. The benefits to be obtained by such linkages should be evident to all who have attended the present workshop.

Summary of Session 3 Genetics and Breeding

ft. O. *Hammons — Chairman*

In the initial paper of this session, Dr. V. R. Rao stressed the need for collecting and conserving the world's groundnut genetic resources before further genetic diversity is lost and as crop improvement replaces ancient landraces. Developmental activities will soon result in the irretrievable loss of valuable genes. He traced the scope and present status of ICRISAT's dual efforts in the collection, maintenance, and evaluation of such germplasm and its documentation and distribution. There have been substantial inputs to the germplasm bank from many countries as well as requests for dissemination. Each Workshop participant should have gained the perspective of the special obligation that a groundnut scientist should have to insure that the material already assembled in a particular country should be made available to ICRISAT and to secondary centers.

In discussing documentation. Dr. Rao reported that a descriptive language is under preparation by which evaluations can be computerized to facilitate information retrieval from the catalog. Finally, he pointed to the quarantine constraints that are necessary to minimize the possibility of introducing a new and destructive pest or pathogen into a country during seed transfer.

For improvement of the crop one starts with a portion of the available genetic variation and, through one of the basic techniques used in self-pollinated species, breeds for yield stability by one or more of the procedures outlined by Dr. A. J. Norden. Here considerable interest was shown in the multiline variety concept that has been successfully employed in Florida, USA, to maintain greater genetic diversity in new cultivars than that in the pure lines they replaced.

This report described the successful cooperation among U.S. breeders and the multidisciplinary team effort involved in research and development and introduction of new varieties into agricultural production and use by the consumer.

From a breeding program that has been in continuous progress since 1928 in Florida, our attention was directed by Dr. S. N. Nigam and co-workers to the 4-year-old program at ICRISAT. Here the emphasis is not toward the development and release of the finished variety but, rather, the emphasis has been and is continuing on producing and disseminating suitable breeding material to cooperators in different countries of the SAT. Under the conditions at ICRISAT Center, exceptional numbers of cross-pollinations have been achieved, and very large populations of bulked breeding lines are evaluated in appropriate field designs to provide promising selections for distribution in areas that address many of the major constraints presently limiting production in the SAT.

Summary of Session 4 Cytogenetics and Utilization of Wild Species

V. S. Raman — Chairman

The two papers presented in this session evoked considerable discussion. The major emphasis has been on the analysis and use of wild species that are currently available, and this should be continued and expanded in scope to include newly collected material. The application of D^2 analysis to chromosome arm ratios to increase the knowledge of relationships between wild species to facilitate their utilization is of interest. Aneuploids have received little attention in the past, butthese are of importance and more emphasis is needed, especially on their breeding behavior, because our knowledge of aneuploids in *Arachis* is meager compared with the great advances that have been made in some other crop plants, for example *Triticum* and *Nicotiana.*

The absence of reports on haploids in A *hypogaea* either from twin seedlings or produced by anther culture was noted. These would also be useful in isolating aneuploids.

Another constraint on the utilization of wild species, especially on the production of amphiploids and synthesis of A *hypogaea* from its wild ancestors, is that there is only one species with the B genome, and this limited the range of different amphiploids that could be produced. However, the production of hybrids and hexaploids, their screening for potentially useful characters, especially disease resistance and yield potential, should receive high priority.

The increased knowledge, with the improved techniques and the wider range of germplasm now available, is leading to greater possibilities in the utilization of wild species of *Arachis.*

Summary of Session 5 Crop Nutrition and Agronomy

A. Narayanan — Chairman

The environmental factors responsible for effective nodulation in relation to crop growth need extensive investigations in order to improve the nitrogen nutrition of groundnuts. The influence of fertilizer nitrogen with reference to nodule formation in the seedl ing stage was also stressed. To determine the requirement of nitrogen, a proper balance sheet has to be worked out for various soil types and popular genotypes. It will aid in arriving at an appropriate crop rotation. The utilization of biologically fixed nitrogen by a subsequent crop, especially a cereal in a rotation, is an important area to be considered.

Rhizobial strains are specific for genotype and location, thereby indicating no possibility of having a universally efficient strain for groundnut.

The isogenic nonnodulating lines can be used for quantifying the nitrogen fixed by nodules and the uptake from the soil. It is known that nonnodulating character is genetically controlled, probably by two genes. Evidence is also available to show that genotypes differ in their ability to fix nitrogen.

The mode of inoculation is an important basis for better nodulation. The seed and/or soil treatment(s) with fungicides, pesticides, or herbicides may influence the nodulation and fixation of nitrogen. Application of rhizobial inoculum below the seed, either in the liquid form or with sand, may help to avoid the harmful effects of fungicides used for seed treatment.

Since the soils of the SAT areas are poor in phosphorus the exploitation of mycorrhizal fungi was also stressed.

High partitioning and longer pod filling period are the two important bases for yield improvement under optimum growing conditions. These two criteria, in addition to seedling vigor and rapid canopy development etc., may be used for breeding better genotypes for yield. However, in the SAT regions, the haulms of groundnut are used as cattle feed; thus it becomes an economic yield. Therefore, the physiological bases stressed above may not be applicable for such conditions.

Groundnut is intercropped with various crops including cereals in various parts of the world. This system has proved to be physiologically efficient and economically feasible. Information on the pattern of disease spread in this system is to be gathered for making the system still more efficient.

Summary of Session 6 Groundnut Entomology

W. Reed — Chairman

The Chairman opened the session with the observation that entomology of groundnuts has always been an underrated input. Insect pests causefar greater losses to this crop than is generally realized. The cost of the insecticides poured onto this crop worldwide far exceeds that of the fungicides. In this workshop the entomology session had been allocated one hour, only two papers were presented, and there were relatively few entomologists in the gathering.

The first presentation was by Dr. Campbell, entomologist, and Dr. Wynne, plant breeder, both from North Carolina State University. They described their work on resistance of groundnuts to insects and mites. The results reported were impressive, with substantial resistance to all of the major insect pests of their area having been discovered and subsequently utilized in commercial introductions. Resistance to thrips, leaf hopper, *Heliothis,* and *Diabotrica* was described and illustrated. In addition substantial resistance to the two-spotted mite was reported; this mite being an induced pest following the use of insecticides early in the season. The current work is aimed at increasing the levels of the resistance and combining these with resistance to diseases, which has been developed by pathologists.

Dr. Amin and Dr. Mohammad, entomologists of ICRISAT reported on the current status of their groundnut pest research. Here the initial emphasis has been on the major pests on the ICRISAT farm, i.e., thrips and jassids, with the primary aim of reducing the damage in the research fields and so facilitating the research of the groundnut scientists. The work was structured under three main headings, (1) survey of the pest problems, (2) ecology and biology of the major pests, and (3) screening germplasm for resistance.

Although this program began less than 3 years ago substantial progress was reported. In particular the work on *Frankliniella schultzei,* which is now known to be the major vector of the bud necrosis disease, has already given us a means of reducing this problem in our fields, with early sowing, close planting, and precisely timed insecticide use all contributing to a major reduction of thedisease incidence. Initial results from screening the available germplasm against thrips, jassids, aphids, and termites look promising.

There was limited time for questions and discussion, but it was evident that the representatives from India regard white grubs as the major pest problem. These pests are devastating large areas and are displacing this particularly susceptible crop from several districts. Major questions asked were whether ICRISAT could take up research on these pests and was there any hope of host plant resistance being of any utility against such polyphagous pests.

It was pointed out that white grubs are not common at ICRISAT Center and the initial research has been concentrated upon the locally damaging pests. In future, increased resources may become available and at that time due priority will be given to supplementing the national efforts against this pest, if a suitable site in an endemic white grub area can be made available. The successes reported in locating resistance to *Heliothis,* which is also a polyphagous pest, should encourage us in the search for white grub resistance. Another questioner brought the attention of the meeting to the importance of aphids as pests and vectors of rosette in Africa.

The Chairman had to cut short the discussions because the allocated time had been exceeded. He congratulated the speakers and discussants on their clear and precise contributions. The time limit ensured that the quantity was limited but this was compensated for by high quality. The report by Dr. Campbell, who had dedicated over 20 years to this work, exemplified the need for persistence in host plant resistance research because worthwhile results will only come with continuity. Far too many programs are initiated and then changed or dropped after two or three seasons. The ICRISAT program had made a good, enthusiastic beginning, and it is hoped that an expanding pest management research effort, aimed at practical improvements at the small farmer level, will be built on these firm foundations. There was a clear advantage in cooperation and communication between research programs both nationally and internationally. ICRISAT could derive enormous benefit from the well-established programs at North Carolina and elsewhere. The thrips, jassids, and *Heliothis* methodology and materials developed by Dr. Campbell will be of obvious value to the program being developed at ICRISAT, and it is essential that maximum advantage should be derived. We should not reinvent the wheel in each and every research program.

There is a clear need for an expansion in resources devoted to groundnut entomology research. This need has been recognized, and ICRISAT will be expanding its staffing and resources in this area in the near future.

Summary of Session 7 Groundnut Pathology

J. S. *Chohan — Chairman*

It was strongly felt that diseases (fungal and viral) are causing the greatest constraints *to* groundnut production in the SAT. The researches to date appear to be inadequate in depth regarding the biology, agroecology of the host-pathogen systems and host resistance. In spite of the good work conducted by some institutions/countries in the SAT and particularly at ICRISAT Center, a lot more needs to be done, particularly with respect to screening of germplasm and distribution of the resistant lines to countries in the SAT.

Keeping this in view, although some good germplasm screening methods (epidemiological) have been perfected for some pathogens, more efforts are needed in this direction in the remaining economically important pathogens, especially the soilborne ones and the viruses. Concomitantly, additional laboratory equipment, screen houses, and other associated facilities are required.

After intensification, all these inputs should lead to a major emphasis and breakthrough on the development of stable disease resistance in the not too distant future. It was envisaged that looking at the meager resources at the command of the SAT farmers, regional programs should now be strengthened to achieve the above objectives. Close cooperation with scientists in other disciplines is of paramount importance to develop effective techniques in host-pathogen-environment system(s), and this should be continued.

Summary of Session 8 Country Reports

A. *W. Gibbons and J. P. Moss*
Co-Chalrman

The Chairman opened the session with the observation that this was probably the most important day of the Workshop because the delegates would be hearing about groundnut production, utilization, research problems, and further research needs from 17 countries representing widely different geographical areas, with widely different production methods. These methods ranged from completely mechanized systems to production methods relying almost entirely on hand labor, using simple tools or, at the most, bullock-drawn equipment. The Chairman also remarked that this session was particularly important to the ICRISAT Groundnut Program scientists as they are now at the stage where genetic materials are becoming available for dissemination to other countries, particularly those in the SAT. It was important that the ICRISAT research goals were matching the needs of client countries.

The first session of the day was devoted to Australia and Asia. The Australian groundnut situation was rather unique in that although the production system was highly mechanized there were still serious deficiencies, particularly in the supply of good quality planting seed Only one rainfed crop is grown in a year and drought is a common problem. At present the available planting seed was drawn from the industry and it was often contaminated with *A. flavus.* Aflatoxin is, in fact, a very serious problem and is receiving a lot of attention. In contrast, the Southeast Asian countries of Burma, Malaysia, and Thailand are often able to grow two crops of groundnuts in a season. In Malaysia, groundnuts are often grown under plantation crops. Both Burma and Malaysia have relatively young research programs. In Thailand, the research infrastructure is more advanced and plans have been implemented to increase production over the next 5 years. In general the disease and pest situation in Southeast Asia does not appear to be as serious as it is in India, although the common diseases such as rust and leaf spots are always present. The development of suitable cultivars to fit into the groundnut farming systems, the need for mechanization, and the strengthening of research inputs are important in this region.

The second group of papers covered the main groundnut producing countries of South America — Venezuela, Argentina, and Brazil. The production systems in Venezuela and Argentina are highly mechanized in contrast to Brazil where the production is mainly by small scale farmers. In Brazil, two crops of early maturing groundnuts can be taken in a season. However, there has been a serious decline in groundnut production in Brazil due to competition from soybean. Leaf spots are prevalent throughout the region, but rust is only a threat in Venezuela. In Brazil, the main pest is a species of thrips. Valuable germplasm collections of South American landraces are maintained at Manfredi in Argentina, and wild species are maintained in Sao Paulo, Brazil.

The reports from Africa showed a wide range of variability in production methods, research inputs, and problems. In many West African countries there has been a serious decline in production, mainly due to the succession of droughts, particularly in the Sahelian zone. Nigeria and Senegal have had a long history of successful and continuing research programs. Particularly noteworthy has been the breeding of rosette-resistant cultivars in Senegal, and later in Nigeria, and the breeding of cultivars with drought resistance in Senegal. Thetransfer of technology from research findings to implementation by the farmer, however, remains a problem in many of the African countries. The situation in Sudan, one of the leading groundnut producing countries, is in contrast to that of many of the other countries in Africa as the bulk of the crop is grown under irrigation in the Vertisols of the Wad Medani scheme and yields average about 1440 kg/ha. These irrigated areas are mainly for the production of large-seeded confectionery nuts for export. In the rainfed areas, early maturing cultivars are grown and average yields are around 600 kg/ha. Harvesting, however, is a problem on the heavy Vertisols.Only recently has a fulltime plant breeder been appointed.

The reports from eastern and central Africa also showed some striking contrasts. Malawi and Zimbabwe have a long history of successful plant breeding and disease control programs. Malawi produces a high quality confectionery export crop as well as cultivars for oil crushing to satisfy the internal demands for vegetable cooking oils. Zimbabwe has high input production areas, which receive supplementary irrigation, and low input rainfed areas. Most of the crop is used for local consumption. Both Mozambique and Tanzania wish to increase groundnut production but suffer from a lack of consistent research programs and germplasm. These countries have recently initiated breeding and agronomic research programs, but it will be some time before results are obtained.

In general, the disease and pest situation in Africa is serious. Leaf spots and *Aspergillus flavus* are major pathogens and rosette virus still presents serious problems although, resistant cultivars are available from both West and central Africa. Rust is now present in almost all of the major groundnut growing areas but is not serious at present, probably because only one crop a year is usually grown, and the long dry seasons prevent a continuous inoculum being present. Pests are important — particularly aphids, white grubs, millipedes and thrips. Drought is a major recurring problem and the need for more research effort in this area is important. The yield gap between the potential yields and those actually obtained by the farmer was reported from many countries.

In conclusion the Chairman thanked all the speakers for their excellent presentations and m particular for keeping to the time allotted. The papers stimulated a great deal of useful discussion which was of immense value to the ICRISAT program.

General Discussion

Chairman

The Director General, Dr. L. D. Swindale, charged the delegates in his opening address with the task of evaluating and criticizing the ICRISAT Groundnut Improvement Program and to make suggestions on how it could be improved. We would be pleased to have the views and suggestions of the delegates.

J. S. Chohan

I would suggest that the regional programs should be strengthened and that more emphasis should be put on training.

Chairman

The regional aspects of the Groundnut Improvement Program are being strengthened. In 1981, an outreach program will be started on a regional basis in Central and Eastern Africa, and a similar program is due to commence in West Africa in 1982. Besides this, we are strengthening regional work in India and other countries through the national programs. In India, we are conducting research at stations that have been mutually agreed upon by the Indian Council of Agricultural Research (ICAR) and ICRISAT. We are also increasing our training through the Institute's training program and by giving specialist short-term training through our own program. Our staff give lectures to the trainees, and this year several in-service trainees from Africa and Asia are specializing on groundnut research projects. Besides this, we have research scholars working on M.Sc. theses at ICRISAT. They do their course work at the Andhra Pradesh Agricultural University and their research at ICRISAT. These scholars come from India, Ghana, and Benin. We expect to increase our training activities in the very near future.

J. M. Teri

Has ICRISAT come up with the best methods of advising national programs? I have in mind a system whereby ICRISAT scientists can make extended visits, lasting for 2 weeks or longer, to work in situ with groundnut researchers in the SAT countries. This would be as equally important as the researchers coming to ICRISAT.

Chairman

This is exactly what does happen with ICRISAT research scientists, particularly in the well-established programs. The Groundnut Improvement Program has been in a process of building up its center activities, and staff were still being recruited in 1978 and 1979. We have already made trips to S. America, Africa, Asia, and Australia. These trips will become more frequent and, once the African program has started, we will have ICRISAT scientists actually based in Africa and working on a regional basis. They will visit the national programs in their region as often as possible.

T. P. Yadava
I think that as drought resistance is one of the most important problems in the SAT, this should be extensively worked on at ICRISAT. The economic aspects of groundnut production, particularly in the field of pesticide use, should also be closely studied.

Chairman
Drought resistance will become a major part of the ICRISAT physiology research program. The physiologist only joined just before the workshop and is now recruiting more staff. A great deal of work has been done in this area in Senegal also, and we hope that strong co-operation can be developed between their program and ours.

Similarly the economists at ICRISAT are now going to look at the various economic aspects of groundnut production.

K. S. Labana
I would like to suggest that information relating to the release of cultivars, new agronomic practices, and many aspects of groundnut research should be released through an international newsletter.

Chairman
This is in fact being considered by the ICRISAT groundnut program. International newsletters are already being circulated from the cereal and pulse programs. At the moment, the groundnut research community is well served by 'Peanut Research', which is produced by APRES and with which Dr. Hammons is closely associated. Perhaps he may care to comment?

R. 0. Hammons
The APRES newsletter 'Peanut Research' could be reproduced and circulated globally by ICRISAT. However, the world community of groundnut scientists would welcome and encourage the initiation by ICRISAT of an 'International Groundnut Newsletter'.

Chairman
We will certainly give this very serious consideration.

D. H. Smith
There is a need for a global information retrieval system for groudnuts including a translation service and reprint service.

Chairman
This is also being considered. There is an information system for sorghum and millets at ICRISAT which is being financially supported by the International Development Research Center (IDRC). It is called 'SMIC (Sorghum and Millet Information Center). It would certainly be desirable to have such a system at ICRISAT, but this has been also discussed by other organizations.

R. 0. Hammons
I agree; various international organizations have discussed the need for a computer-based information center for groundnuts. Hopefully, such a system can be worked out.

P. Gillier
In the case of foreign publications, IHRO can, within the limit of their capabilities, furnish all the information from their documentation system.

Chairman
Perhaps Title XII could consider such a request for financing or operating such an international information system?

C. R. Jackson
It could be a possibility, and also I would like to suggest that there should be international meetings of groundnut workers at regular intervals.

J. S. Chohan
As an extension of the idea of publications to be prepared by ICRISAT, it would be valuable to prepare annotated bibliographies, for example, on diseases of groundnut. Preferably these could be prepared for individual diseases when they are of major importance. If scientists had this sort of information they would be better informed and would be more effective in workshops such as this one.

V. Ragunathan
I agree. Several such handbooks have been produced by the sorghum and millet prog-

rams and also by the chickpea program at ICRISAT.

Chairman

We realize the importance of bibliographies and handbooks, particularly those which will be of value to field workers. A start has been made on this already. Two handbooks on aflatoxin procedures have been prepared and, in conjunction with Dr. Hammons, a rust monograph is being prepared that will contain an annotated bibliography.

R. 0. Hammons

Is sufficient work being done on improving preharvest technology? This subject was barely touched upon in this workshop. There appears to be a pressing need for improving the 'desi' plow, the lifting plow, and the small decorticator. If the work has been done, is the information being disseminated?

Chairman

The Farm Machinery Unit of the Farming Systems Research Program at ICRISAT is currently working on the improvement of equipment for the small farmer. This work will include equipment for groundnuts. A great deal of work has also been done to my knowledge in Senegal, Nigeria, Malawi, Botswana, and in India. This information should be gathered together, if it has not already been, and then disseminated.

C. Harkness

Can ICRISATdo more in thefield of agronomic and herbicide research?

Chairman

A certain amount of herbicide work has been done, again by the Farming Systems Research Program, at ICRISAT. However, at the outset of the program the consultants who outlined the groundnut program for ICRISAT stressed that much of the agronomic research needed on groundnuts is very locale specific, and should be done by the national programs. Agronomic work is very much related to local soils and environments. When we commence our outreach programs we will be more closely associated with this type of research.

K. S. Labana

What are the possibilities of ICRISAT conducting international variety trials? The best varieties from each country could be included and this would give us information on their performance over a wide range of environments.

Chairman

The idea is a good one and has been discussed before. One major problem has been the quarantine regulations of some countries. These problems include the import restrictions based on importing seed from certain countries because of the disease situation in the exporting countries. Many countries only allow limited seed to be imported and others will only release material that has been grown from seed to seed. All these restrictions make it difficult to conduct global trials. We do have most of the necessary material in our germplasm collection and this would have to be multiplied first in the recipient country. Perhaps Dr. McCloud would care to comment because he tried to conduct international trials after the 1975 meeting held in Florida.

D. E. McCloud

The International Peanut Program at the University of Florida collected about 33 of the world's outstanding cultivars. These were multiplied in Florida for distribution but funds were not adequate or forthcoming to complete this project.

R. 0. Hammons

The international variety trials concept has been considered again by a panel of scientists during the past year. Under present quarantine constraints it is difficult but the question should remain on future agendas.

As mentioned, one of the problems is the limited amount of seed which can be imported by some countries. This means that with some varieties, which are in fact multilines, it would be difficult to maintain their genetic integrity if only 5 to 10 seeds were allowed to be imported. For example, Florigiant is composited from 8 components and 5 to 10 seeds of this cultivar would not be sufficient.

Chairman

We have circulated a questionnaire prepared by the ICRISAT groundnut scientists which would provide a great deal of information which would be useful for compiling information on most aspects of groundnut production. We would like delegates to consider this questionnaire at length when they return home and make suggestions on how it could be improved. If anyone has had time to read it, we would invite comments now.

J. S. Saini

Under the section on soils I suggest that the nutrient status of the soil may also be included so that it can be correlated with fertilizer response. Rainfall figures should also be given on a monthly basis rather than a seasonal one with the average number of rainy days per month. Average monthly temperatures and relative humidity should also be included.

The Chairman concluded the session by thanking all the people who had helped to organize the workshop and, in particular, the participants who had presented papers and had taken part in the discussions. Professor C. Harkness, Ahmadu Bello University, Nigeria, on behalf of the delegates thanked the Director General of ICRISAT and his staff for inviting them to ICRISAT and giving them the opportunity to take part in the Workshop.

Appendix 1

Poster Session

Poster Session

The following papers appeared in poster sessions or were distributed during the Workshop. Copies can be obtained from the authors.

Groundnut Breeding: Some Considerations

R. Pankaja Reddy and N. G. P. Rao*

National Research Centre, IARI Regional Station
Rajendranagar, Hyderabad 500 030, India
(•Present address- ICRISAT, PMB 1044, IAR, ABU, Samaru, Nigeria).

Abstract

Early maturing bunch type groundnuts have largely been replaced by runner types in many parts of the USA. This subspecific shift has not taken place in India or Africa. Under uncertain rainfall situations in India runners are grown but under the more assured conditions of irrigation bunch forms are grown, which is the reverse of the USA system. The question of whether the subspecific status of rainy and postrainy crops in India should be changed needs investigation. The modern cultivars in the USA are more efficient in partitioning photosynthates to the pods but this does not appear to be happening with Indian cultivars and priority should be given to this by breeders. Through the choice of suitable parents it should prove possible to generate material which is suited to both rainy and postrainy seasons in India. Groundnut also offers scope for fitting into profitable and stable intercropping, relay cropping and sequential cropping systems. This again should be a priority research area.

Groundnut Research at Punjab Agricultural University

Oilseeds Section, Department of Plant Breeding
Punjab Agricultural University
Ludhiana, Punjab 141 004, India

Abstract

Groundnut production has increased rapidly since the crop was first introduced in 1931. Presently the crop occupies 0.13 million hectares with an average yield of about 886 kg lha. About 82% of the crop is grown under rainfed conditions, and groundnuts are rotated with irrigated wheat. Five groundnut cultivars have been released since breeding commenced, and one of these cultivars, M-13, has been released on a national basis. The cultivar M-13, however, is too late in maturity for Punjab conditions, and it has been replaced by new cultivars. The latest cultivar, M-37, was released in 1980, specifically for rainfed conditions. A new package of agronomic practices has been evolved which has substantially increased yields. White grubs, aphids, leaf webbers, termites, and hairy caterpillars are serious insect pests. Considerable research has been conducted on the biology and control of these pests, both by chemicals and by identifying sources of resistance. Of the diseases, collar rot and leaf spots are important and control measures have been recommended.

Clump' virus is a relatively new disease and is causing concern. It appears to be soilborne, and methods of control are being investigated.

Production Problems in Groundnut — Impact of Improved Technology Relating Mainly to Conditions in the Punjab, India

J. S. Saini

Agronomist (Oilseeds), Punjab Agricultural University, Ludhiana, Punjab 141 004, India

Abstract

On the research farm the approved package of practices increased the pod yield by 133%, shelling by 7.5%, total oil yield by 169%, and the haulm yield by 134% over the farmers' local practices. The most important among the production factors were protective irrigation, weed control, harvesting at full maturity and fertilizer application. Omission of these factors from the package of practices reduced the mean pod yield by 33%, 32%, 26%, and 20%, respectively. Control of leaf spots was only important during a high rainfall season. When some of the more important practices were tested in unrep/icated large plots (0.4 ha) on farmers' fields they gave on an average yields of 1730 kglha compared to 1170 kglha obtained from the local methods. This represented a yield increase of 48%. Future research strategies are also discussed to further enhance yields.

Induced Mutants in Peanut *(Arachis hypogaea)*

M. V. R. Prasad and Swamalata Kaul

IARI Regional Station, Rajendranagar,
Hyderabad 500 030, Andhra Pradesh, India.

Abstract

It was envisaged that the use of mutagens was a possible method whereby increased pod production could be achieved with a reduction in plant canopy structure. Seeds of standard Spanish and Virginia cultivars were subjected to a wide range of mutagens such as gamma rays, EMS, and NMU in different doses. In the Spanish cultivars, mutants characterized by a compact canopy frame and short intemodes invariably produced fewer pods. Mutants with a large number of pods did not have compact canopies. A Virginia runner mutant with narrow leaves was developed however from a Spanish cultivar. In addition to the narrow leaf character, there was an increased number of nodules in the deeper areas of the root zone, a reduced susceptibility to leaf spots, an increase in pod number and the seeds were non-dormant. In Virginia types it was possible to develop mutants combining a compact canopy and more pods, as well as high yielding plants without any compaction of the canopy. The useful mutants are being utilized in recombination breeding programs.

The Differentiation and Identification of the Chromosomes and the Embryology of *Arachis* with Reference to Alien Incorporation in Groundnut

U. R. Murty, P. B. Kirti, M. Bharati and N. G. P. Rao

IARI Regional Station
Rajendranagar, Hyderabad 500 030 (A.P.)

Abstract

Triploid interspecific hybrids were produced between 10 varieties of Arachis hypogaea L *and a wild diploid species,* A. chacoense *(PI 276235). The hybrids exhibited varying chiasma frequencies, indicated differences in the pairing ability of the chromosomes in the different groundnut varieties and suggested possibilities of increasing the success of alien incorporation. To enable general cytogenetic studies, and particularly to identify alien addition and substitution races, the twenty pachytene chromosomes of groundnut were identified, described and classified for the first time. The 'A' chromosome was found to correspond to a small chromosome that was completely heterochromatic.*

To fill the gap in our knowledge of seed failure in some Arachis *species, the embryology of a rhizomatous species was studied. Fertilization proceeded slowly and incompletely and seed failure was brought about by a cessation in the endosperm development and by a hyperplastic development of the endothelium. Triploid interspecific hybrids exhibited embryological features suggestive of non-recurrent apomixis.*

Appendix II

Participants

International Groundnut Workshop

Front Row (Sitting) Left to Right	: C. T. Kisyombe, D. Tiyawalee, A. Bolton, S. M. Misari, J. H. Williams, A. B. Mohammad, J. R. Pietrarelli, B. Mazzani, P. T. C. Nambiar, M. V. R. Prasad, P. S. Reddy, R. W. Gibbons, S. N. Nigam, A. M. Ghanekar, D. McDonald, V. K. Mehan, D. E. McCloud.
Second Row (Sitting) Left to Right	: (Miss) N. Fivawo, A. Narayanan, W. V. Campbell, S. L. Dwivedi, V. Ragunathan, P. Subrahmanyam, N. D. Desai, T. P. Yadava, P. K. Sibale, J. S. Chohan, D. C. Sastri, V. R. Rao, J. P. Moss, H. T. Stalker, A. K. Singh, D. H. Smith, V. Singh, D. R. C. Bakhetia, V. V. Modha, (Mrs.) P. Singhal (Interpreter).
Third Row (Standing) Left to Right	: I. S. Campbell, H. B. Hamat, A. B. Singh, V. Arunachalam, V. Ravindranath, G. D. Patil, U. R. Murty, J. S. Saini, A. Nalampang, K. S. Labana, C. R. Reddy, S. V. Jaswal, P. W. Amin, V. S. Raman, N. Rajgopal, M. V. Reddi, M. S. S. Reddy, B. S. Gill, M. A. Ali, S. Thangavelu, J. Kabore, U. Win Naing, A. L. Doto, J. M. Teri.
Rear Row (Standing) Left to Right	: D. Soumano, S. H. Patil, G. L. Hildebrand, A. Mounkaila, J. Gautreau, O. De Pins, J. V. Mertin (Workshop Editor), C. Harkness, A. J. Norden, C. R. Jackson, I. S. Sekhon, R. O. Hammons, A. S. Chahal, P. J. Dart, D. V. R. Reddy, J. C. Wynne, M. K. Beute, M. Porter, K. J. Middleton, D. J. Nevill, A. S. Pompeu, P. Gillier, A. D. Malithano.

Participants

Argentina

J. R. Pietrarelli
INTA, Manfredi Research Station, 5988
Manfredi

Australia

K. J. Middleton
Department of Primary Industries
Bjelke-Petersen Research Station
Kingaroy, Queensland

Brazil

A. S. Pompeu
Instituto Agronomico, CP28
13100 Campinas, S.P.

Burma

U. Win Naing
Agriculture Corporation
Magwe Division
Magwe

France

P. Gillier
Annual Oilcrops Department
IHRO, 11 Square Petrarque
7501L, Paris

Ethiopia

A. Krausz
P.O. Box 30726
Plant Genetic Resources
West German Embassy
Addis Ababa

India

V. Arunachalam
National Fellow
Indian Agricultural Research Institute
Regional Station
Rajendranagar
Hyderabad 500 030

D. R. C. Bakhetia
Entomologist (Oilseeds)
Punjab Agricultural University
Ludhlana 141 004
Punjab

A. S. Chahal
Plant Pathologist (Oilseeds)
Punjab Agricultural University
Ludhiana 141 004
Punjab

J. S. Chohan
Joint Director
Plant Disease Clinic
Communication Center
Punjab Agricultural University
Ludhiana 141 004
Punjab

N. D. Desai
Research Scientist (Oilseeds)
Gujarat Agricultural University
Junagadh 362 001
Gujarat

M. P. Ghewande
Scientist (Plant Pathology)
Directorate of Oilseeds Research
Rajendranagar
Hyderabad 500 030

B. S. Gill
National Fellow
Gujarat Agricultural University
Junagadh 362 001
Gujarat

S. V. Jaiswal
Groundnut Breeder
Punjab Agricultural University
Ludhiana 141 004
Punjab

N. C. Joshi
Director
CPPTI
Rajendranagar
Hyderabad 500 030

K. S. Labana
Senior Oilseeds Breeder
Punjab Agricultural University
Ludhiana 141 004
Punjab

D. P. Misra
Director
National Research Centre for Groundnut (ICAR)
Opp. Timbawadi
Junagadh 362 002

V. V. Modha
Chief Agronomist
The Vanaspati Manufacturers' Association of India
6th Floor, Harilela House
28/32 Mint Road
Bombay 400 001

U. R. Murty
National Fellow
All India Coordinated Sorghum Improvement Project
IARI Station
Rajendranagar
Hyderabad 500 030

A. Narayanan
Professor of Crop Physiology
Andhra Pradesh Agricultural University
Rajendranagar
Hyderabad 500 030

G. D. Patfl
Oilseeds Specialist
MPKV
Jalgaon 425001
Maharashtra

S. H. Patil
Bhabha Atomic Research Centre
Biology & Agriculture Division
Bombay 400 085

M. V. R. Prasad
Geneticist
Indian Agricultural Research Institute
Regional Station
Rajendranagar
Hyderabad 500 030

V. Ragunathan
Deputy Director
CPPTI
Rajendranagar
Hyderabad 500 030

N. Rajagopal
Assistant Oilseeds Specialist
Reg tonal Oilseeds Research Station
Kadirl515 501
Anantapur District, A.P.

V. S. Raman
Professor & Cytogenetlcist (Oilseeds)
Tamil Nadu Agricultural University
Coimbatore 641 003

V. Ravindranath
Plant Pathologist
IARI Regional Station
Rajendranagar
Hyderabad 500 030

C. Raja Reddy
Senior Scientist, Groundnut Breeding
National Agricultural Research Project
S.V. Agricultural College
Tirupati 2

M. S. S. Reddy
Oilseeds Specialist
Andhra Pradesh Agricultural University
Agricultural Research Institute
Rajendranagar
Hyderabad 500 030

M. V. Reddi
Head, Department of Plant Breeding
Cottege of Agriculture
Bapatla

P. S. Reddy
Project Coordinator (Groundnut)
Punjabrao Krishi Vidyapeeth
Akola 444 104
Maharashtra

R. Pankaja Reddy
Groundnut Geneticist
All India Coordinated Sorghum Improvement Project
Rajendranagar
Hyderabad

J. S. Saini
Agronomist (Oilseeds)
Department of Plant Breeding
Punjab Agricultural University
Ludhiana 141 004
Punjab

I. S. Sekhon
Department of Plant Breeding
Punjab Agricultural University
Ludhiana 141 004
Punjab

A. B. Singh
Breeder (Groundnut)
Groundnut Research Station
Mainpuri 206001
Uttar Pradesh

Vikram Singh
Project Director
Directorate of Oilseeds Research
Rajendranagar
Hyderabad 500 030

S. Thangavelu
Breeder (Oilseeds)
Cashew Research Station
Vriddhachalam 606 001
South Arcot District
Tamil Nadu

T. P. Yadava
Project Leader
Department of Plant Breeding
Maryana Agricultural University
Hissar
Haryana 125 004

Malawi

C. T. Kisyombe
Ministry of Agriculture & Natural Resources
Chitedze A.R.S.
P.O. Box 158, Lilongwe

D. E. McCloud
International Programs
University of Florida
Chitedze A.R.S.
P.O. Box 158, Lilongwe

P. K. Sibale
Ministry of Agriculture & Natural Resources
Chitedze A.R.S.
P.O. Box 158, Lilongwe

Malaysia

H. B. Hamat
Field Crop Research Station
Lot 206/94 Sect. 20
Jalan Raja Dewa Hulu
Kota Bham, Kelantan

Mali

D. Soumano
Recherche Agronomique
De Sotuba
B.P. 258
Bamako

Mozambique

A. D. Malithano
Faculty of Agriculture
University of Eduardo Mondlane
C.P. 257, Maputo

Niger

A. Mounkaila
Section Arachide
CNRA/Tarna
B.P. 240, Maradi

NIgaria

C. Harkness
Institute for Agricultural Research
Ahmadu Beilo University
PMB 1044, Zaria

S. M. Misari
Institute for Agricultural Research
Ahmadu Bello University
PMB 1044, Zaria

Senegal

J. Gautreau
Institut Senegalais de Recherches Agricoles
CNRA de Bambey

O. De Pins
Institut Senegalais de Recherches Agricoles
CNRA de Bambey

Sudan

M. A. Ali
Agricultural Research Corporation
Director General's Office
Wad Medani

H. M. Ishag
Agriculture Research Corporation
Gezira Research Station
Wad Medani

Tanzania

A. Bolton
ODA Oilseeds Team
Agricultural Research Institute
P.O. Box 509
Mtwara

A. L. Doto
University of Dar es Salaam
Department of Crop Science
P.O. Box 643
Morogoro

N. Fivawo
Research Division
Ministry of Agriculture
P.O. Box 7091
Dar es Salaam

J. M. Teri
University of Dar es Salaam
Department of Crop Science
P.O. Box 643
Morogoro

Thailand

T. Charoenwatana
Faculty of Agriculture
Khon Kaen University
Khon Kaen

A. Na Lampang
Field Crop Division
Department of Agriculture
Bangkhen, Bangkok

D. Tiyawalee
Faculty of Agriculture
Chiang Mai University
Chiang Mai

USA

M. K. Beute
Department of Plant Pathology
North Carolina State University
Raleigh, NC 27650

W. V. Campbell
Department of Entomology
North Carolina State University
P.O. Box 5215
Raleigh, NC 27650

D. Cummins
Associate Planning Director
Peanut CRSP
Georgia Experiment Station
Experiment, Georgia 30212

R. 0. Hammons
USDA-SEA
Crops Research Unit
Coastal Plain Station
P.O. Box 748
TIfton, Georgia 31793

C. R. Jackson
Planning Director
Peanut CRSP
Georgia Experiment Station
Experiment, Georgia 30212

A. J. Norden
Agronomy Department
University of Florida
Gainesville, Florida 32611

D. *M.* Porter
USDA-SEA
Peanut Research Unit
Tidewater Research Center
Suffolk, Virginia 23437

D. H. Smith
Texas Agriculture Experiment Station
Texas A & M University System
P.O. Box 755
Yoakum, Texas 77995

H. T. Stalker
Department of Crop Science
North Carolina State University
Raleigh, NC 27650

J. C. Wynne
Department of Crop Science
North Carolina State University
Raleigh, NC 27650

Venezuela

B. Mazzani
CENIAP-IIA
AP. Postal 4653
Maracay, 20101

Zimbabwe

C. L. Hildebrand
Crop Breeding Institute
P.O. Box 8100
Causeway

ICRISAT

ADMINSTRATION

L. D. Swindale, Director General
J. S. Kanwar, Director of Research
J. C. Davies, Director for International Cooperation

GROUNDNUT IMPROVEMENTPROG RAM

P. W. Amin, Entomologist
i. S. Campbell, International Intern
P. J. Dart, Principal Microbiologist
S. L. Dwivedi, Plant Breeder

A. M. Ghanekar, Virologist
R. W. Gibbons, Principal Plant Breeder and Program Leader
T. Goto, International Intern
D. McDonald, Principal Plant Pathologist
V. K. Mehan, Plant Pathologist
A. B. Mohammad, Entomologist
J. P. Moss, Principal Cytogeneticist
P. T. C. Nambiar, Microbiologist
D. J. Nevill, International Intern
S. N. Nigam, Plant Breeder
D. V. R. Reddy, Principal Virologist
D. C. Sastri, Cytogeneticist
A. K. Singh, Cytogeneticist
P. Subrahmanyam, Plant Pathologist
J. H. Williams, Principal Physiologist

FARMING SYSTEMS RESEARCH PROGRAM

C. N. Floyd, International Interm
M. S. Reddy, Agronomist
R. W. Willey, Principal Agronomist

GENETIC RESOURCES UNIT

V. R. Rao, Botanist

WORKSHOP EDITOR:

J. V. Mertin, 6 Watson Street, Fullarton 5063, South Australia

FRENCH INTERPRETERS

Mrs. T. N. Raina
M-19 Greater Kailash I
New Delhi, India

Mrs. Pushpa Singhal
Asian African Legal Consultative Committee
27 Ring Road, Lajpat Nagar IV
New Delhi, India

ICR 81-0005

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics

ICRISAT Patancheru P.O.

Andhra Pradesh 502 324, India