Proceedings of the

Fifth Regional Groundnut Workshop for Southern Africa

International Crops Research Institute for the Semi-Arid Tropics

Abstract

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Eighteen scientists representing national programs and agricultural universities in the Southern African Development Coordination Conference (SADCC) region participated in this regional workshop. Angola and Lesotho were the only countries of the region not represented. Also participating were five groundnut scientists from four other African countries (Ethiopia, Kenya, Nigeria, and Uganda), representatives from the Southern African Centre for Cooperation in Agricultural Research and Training (SACCAR) and Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), and 10 ICRISAT delegates. Papers reviewed various aspects of groundnut research, particularly agronomy and physiology. Country reports summarized the state of groundnut research in each country represented. The recommendations made at the Workshop's plenary session provide valuable guidelines for regional project activities.

Resumo

Anais da Quinta conferencia regional de amendoim para a Africa Austral, 9-12 de Marco de 1992, Lilongwe, Malawi. Dezoito cientistas represeniando programas nacionais e univercidades de agricultura de regiao da Conferencia de coordenacao para o descnvolvimento da Africa Austral (SADCC) participaram na Conferencia Regional. Angola e Lesotho sao os unicos paises que nao estiveram representados. Tambem participaram cinco cientistas provenientes de outros peises Africanos (Ethiopia, Kenya, Nigeria e Uganda) representantes provenientes de centro de cooperacao, investigacao e treino para Africa Austral (SACCAR). Deutsche Gesellschaft fur Technische Zusammenarbeil (GTZ) e 10 delegados de ICRISAT. Os artigos reexaniinaram varios aspectos agronomicos e fisiologicos de investigacao de amendoim. Os relatorios sumarizaram o estado de investigacao de amendoim de cada pais representado. As recomendacoes feitas na sessao plenaria da conferencia fornecem indicaoes validas para as actividades dos projectos regionais.

Proceedings of the
Fifth Regional Groundnut Workshop for Southern Africa

9-12 March 1992
Lilongwe, Malawi

Edited by

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and
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ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
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1992

Portuguese Translation

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Introductory Remarks

The Representative of the Southern African Centre for Cooperation in Agricultural Research and Training (SACCAR) and the Technical Desk Officer, German Agency for Technical Cooperation (GTZ), honorable delegates and participants, colleagues, ladies and gentlemen.

It is a great pleasure for me to welcome you to this Fifth Regional Groundnut Workshop for Southern Africa, This biannual workshop has become an important occasion for groundnut scientists from both the **SADCC** region and elsewhere. We have slightly altered the nature of this year's meeting. Whereas the previous workshops were multidisciplinary, this year we have decided to focus on agronomy.

The SADCC / ICRISAT Groundnut Project has been very strong in breeding and pathology since its origin in 1982. The agronomy of groundnut, which is determined by divergent environmental conditions in various agroclimatic zones in southern Africa, was initially undertaken by the national programs.

An overview of the important research results from the SADCC countries over the last 10years was presented by Mr A.Z. Chiteka in November 1991 at the Second International Groundnut Conference at ICRISAT Center, India. During this workshop, delegates from each SADCC country represented will give detailed reports of the cumulative agronomic research results, including those obtained during colonial times, since many of these are still applicable. Soils and climate have not changed to any great extent and very old cultivars are still grown in some countries.

Conventional agricultural research (such as experimentation with plant density, date and depth of sowing, fertilizer requirements, and weeding) has been conducted intensely throughout the region. Do we still need such experiments? I think so, and perhaps on more than a mere maintenance level.

We are all concerned about the catastrophic drought presently afflicting many SADCC countries, especially the southernmost ones. Fortunately, groundnut is less subject to long dry spells than maize, and thus contributes to stability in farm production. Often fairly dry years are the best in terms of yield and quality. This year, however, the drought is particularly severe and all crops are affected.

With regard to research needs, we must put the question whether there are still possibilities of increased yield stability in dry seasons. While breeders select for drought resistance, agronomists can determine optimal plant density for dry years and assess possibilities for increased soil moisture conservation. A modest harvest in a season with catastrophic drought may in some respects be more valuable than a surplus in a good year. Recently, I saw low groundnut populations (40 000 plants ha^{-1}) surviving on sand in Maputo while crops with normal plant density had already collapsed. Both plant density and row distances may be of importance. The difficulty is that if we do not systematically repeat the same type of experiments year after year, we will be unable to cover the variations in weather conditions and assess their influence. The great variability in the weather in southern Africa is a very complicating factor in agronomic research.

Any approach that neglects companion crops in a cropping system are inadequate when it comes to research on fertilizer requirements. Normally, groundnut does not respond to nitrogen fertilizer and responds to phosphates only on phosphorus-deficient soils. It is therefore economically advantageous to concentrate expenditures on the highly responsive maize preceding groundnut in order to secure an immediate return of the expenditures. A full groundnut harvest can then be obtained from a crop which relies entirely on residual phosphorus from the preceding maize crop. Fertilizer experiments must include whole cropping systems to have any relevance for the farmers. Results of fertilizer experiments applicable to farmers* fields can be obtained only if two additional conditions are met.

First, experiments on research stations must be permanent and sites must not be changed for as many years as possible. I have been at Chitedze for little more than 2 years. In a crop succession experiment, maize yields were as high as 11 t ha^{-1} without any fertilizer application. This maize relied on huge quantities of residual fertilizer accumulated in the soil. The question is: how many years will it take to decrease the nutrient availability to approach the levels prevailing in farmers' fields?

Second, annual experiments are recommended to demonstrate fertilizer effects on cereals and groundnut if severe phosphorus deficiency is detected. One does not need to be an expert to observe the widespread nitrogen and phosphorus deficiencies currently affecting farmers' maize fields.

When it comes to prove, demonstrate, or assess the extent of positive residual effects of groundnut on cropping systems, long-term station trials without changing the site or shorter-term experiments on farmers' fields with poor nutrient status are the answer. Groundnut is among the best preceding crops for cereals, equal to cowpea. A maize-groundnut rotation is ideal on lands poor in nitrogen: maize residues poor in nitrogen can decompose during the year of groundnut cultivation without any harm to the groundnut crop. The next year, maize benefits from nitrogen accumulated in the soil after the decomposition of residues, those from the previous maize crop as well as those from the immediately preceding groundnut crop. The difference in maize yields after maize and after groundnut may be substantial.

Agronomy experiments on farmers' fields or on-farm trials are very desirable but expensive and time-consuming. Transport is the most costly item and many visits are necessary to secure a success. Research systems that can barely cope with managing research on stations would fail in on-farm experimentation. It is thus important that we make sure that funding is adequate before initiating on-farm trials.

A final word on experimental policy. Comparisons of cropping systems must always cover a number of years. A small intercropping advantage in one year may be obtained at the expense of decreased productivity in subsequent years. To obtain valid results, intercropping experiments should be repeated on the same site for at least two seasons. Although intercropping and rotation are generally considered to be mutually exclusive alternatives, a combination of both is possible. Intercropping combinations of noncereals, for example, can be grown in rotation with intercropping combinations of nitrogen-deficient cereals.

We may also find slight advantages with regard to disease or pest incidence in intercropping combinations compared with the sole cropping. However, the possibility exists that pests and diseases of a crop mixture can be carried over from one season to the next. Nonetheless, a complete absence of a crop during one or more seasons has often proved to be the most reliable way to prevent carry-over of pests and diseases to subsequent crops.

When concentrating on increasing agricultural production, we should keep in mind the factors that contributed to the eradication of hunger in Europe and even to agricultural overproduction in industrialized countries. These were mainly three.

1. The transition from the medieval three-field cropping system (a winter cereal, a summer cereal, and a fallow season) to an improved three-field rotation system (including a legume crop on the previous fallow) and later to biannual rotations (cereal-noncereal) on good soils.
2. Mineral fertilizer application.
3. Improved cultivars.

Referring to this last point, remember that it is not enough to create excellent new cultivars. We must also get them to the farmers. This task is frequently difficult, particularly with groundnut, a crop with a low multiplication rate. The question of seed multiplication will certainly be an important point of discussion during this workshop.

Population pressure in many areas of the SADCC region places very high cereal requirements on both farmers and governments. Cereal monoculture, often seen as a short-term solution, is fraught with negative effects on sustainable productivity. Price policies therefore sometimes favor this unproductive cropping system. Groundnut, a suitable substitute crop, is, in my view, an essential part of sustainable agriculture in this region.

Thank you for your attention.

G.Schmidt
Team Leader and
Principal Groundnut Agronomist
SADCC/ ICRISAT Groundnut Project

Welcome from ICRISAT

Chairman of the Workshop, the Honorable Deputy Minister of Agriculture, the GTZ Representative, the SACCAR Representative, distinguished guests, ladies and gentlemen.

I welcome you to the Fifth Regional Groundnut Workshop for Southern Africa. Since joining ICRISAT in 1991,1 have been confronted with an apparent outbreak of groundnut workshops. First we had the large Second International Groundnut Workshop at ICRISAT Center in India in November 1991, now we have this workshop in Malawi, and in September we will have the West African Regional Groundnut Workshop in Burkina Faso. The number of workshops being held, and the support being given to them, illustrate the importance of groundnut to many countries of the semi-arid tropics, and the recognition of the importance of ensuring interactions between groundnut researchers.

When the SADCC /ICRISAT Groundnut Project was set up in 1982, it was agreed that workshops should be held every 2 years. The original sponsor, IDRC, is to be commended for its foresight; and the present sponsor, GTZ, is to be congratulated for enabling this interaction between scientists to continue. The Project could not have succeeded without the enthusiastic support of the host country, Malawi, and the cooperation of all concerned national programs. The Project is an excellent example of a genuinely cooperative enterprise and I am convinced that it will go from strength to strength. I wish you all success in your deliberations over the next few days and am sure that you will have a most useful and productive meeting.

J.G. Ryan
Director General
ICRISAT

SACCAR Representative's Address

Mr Chairman, Honorable Deputy Minister of Agriculture Mr F.M. Kangaude, GTZ Representative Dr M. Bosch, Representative of the Director General of ICRISAT Dr D. McDonald, colleagues, ladies and gentlemen.

It is an honor for me to say a few words on behalf of SACCAR at this important regional workshop. For the benefit of those of you from outside the southern African region, allow me to explain the origin and purpose of SACCAR. The Southern African Centre for Cooperation in Agricultural Research and Training was established in 1984 by the member states of SADCC to assist the Government of Botswana to coordinate agricultural research in the region.

SACCAR's activities are classified into two categories, a service function and a coordination function.

Under the service function, SACCAR serves as a secretariat for its Board, which is comprised of the Directors of Research; six Deans of the Faculties of Agriculture, Forestry and Veterinary Medicine; and two Directors of extension programs. The Director of SACCAR serves as Secretary.

SACCAR publishes a newsletter, and in collaboration with the Department of Research and Specialist Services of the Government of Zimbabwe, publishes the SADCC / Zimbabwe Journal of Agricultural Research.

SACCAR awards research and travel grants. Lately, we have become increasingly concerned about the low number of applicants for the research grants. I wish to appeal to our SADCC scientists to make use of this facility, which is also open to social scientists.

SACCAR's coordination function of regional agricultural research involves 15 projects. Nine of these are either ongoing or at various stages of implementation. The other six projects have been developed but not yet funded.

Ongoing projects:

1. **Land and Water Management Research Programme.** Phase I of the project ends in March 1992. Phase II, which still awaits funding, will assume a decentralized structure.
2. **Sorghum and Millet Improvement Programme**
   Donors: GTZ, CIDA, USAID
   Executing Agency: ICRISAT
3. **Grain Legume Improvement Programme**
   a. Bean Improvement Project
      Donor: CIDA
      Executing Agency: CIAT
   b. Cowpea Improvement Project
      Donor: EEC
      Executing Agency: IITA
   c. Groundnut Improvement Project
      Donor: GTZ
      Executing Agency: **ICRISAT**
   d. In-service Training in Research Management
      Donors for Phase I: **USAID, CIDA, ODA**
      Executing Agency: **ISNAR**

e. Agroforestry Research Programme
Donor: CIDA
Executing Agency: ICRAF

f. *SADCC Crops and Forestry Seeds Gene Bank*
Donor Nordic countries
Executing Agencies: Nordic Gene Bank, SADCC
This project is fully staffed by SADCC nationals,

g. *Strengthening Faculties of Agriculture, Forestry and Veterinary Medicine*
This program operates our SADCC / GTZ Postgraduate Training Project. It includes ongoing regional MSc programs at Bunda College (Animal Science), Sokoine University of Agriculture (Land and Water Management), University of Zambia (Crop Science), and the University of Zimbabwe (Agricultural Economics).

Development projects not yet fully funded

1. Collaborative Network for Vegetable Research and Development in SADCC
2. Maize and Wheat Improvement Network
3. Roots and Tiibers Network
4. Research on the Ecology and Biology of the *Conometa* Silkmoth
5. Management of Black Cotton Soils
6. Wool and Mohair Improvement

Together, these programs will enhance the three basic components essential to successful agricultural research: the development and exchange of improved germplasm and technologies with the national programs, human resource development (both long- and short-term), and information exchange.

I now come to our regional groundnut project. The SADCC/ICRISAT Groundnut Project has done very well in germplasm development and short-term training. Recently, the Project has begun to address agronomic problems. A thorny issue, however, is the lack of funds for MSc and PhD training. SACCAR and ICRISAT, the executing agency, will continue to seek funds for this important component. Sustainability of the Project will, after all, be virtually impossible without trained national scientists.

We are also extremely grateful to GTZ for its generous financial support for the Project.

SACCAR has been instructed by the SADCC Council of Ministers to address the question of sustainability of the SADCC regional research by developing mechanisms to sustain them after donor funding has ceased. We will work closely with ICRISAT to accomplish this goal.

I take this opportunity to thank Dr Gerhard Schmidt, who plans to retire shortly after this workshop, for his contributions to the Project during the last 2 years. I refer specifically to his enthusiastic involvement in the creation of the agronomy component of the Project. Although 2 years is a very short period of time for any individual to make an impact in a research program, Dr Schmidt has done just that. I am sure that my colleagues will agree that he is an easy person to work with. Dr Schmidt, we wish you all the best in your retirement.

In conclusion, I would like to convey through you, Honorable Minister, the heartfelt thanks of SACCAR to the Government of Malawi for hosting the SADCC/ICRISAT Groundnut Project and for allowing us to hold this workshop in the beautiful city of Lilongwe. It is always a pleasure to come back to Malawi.

C.T. Nkwanyana
Programmes Officer
SACCAR

GTZ Representative's Address

I am very grateful for this opportunity to convey the cordial greetings of the Management of GTZ, the German Agency for Technical Cooperation, to the participants of this important workshop and the subsequent Steering Committee meeting.

GTZ has had long and very fruitful cooperation with Malawi. All my compatriots who have come back to Germany after several years of service in this country have very agreeable memories. This wonderful country provides an atmosphere conducive to both a rewarding professional career and a pleasant private life.

Since 1982, GTZ has supported the Malawi-based SADCC/ ICRISAT Groundnut Project, which has just entered into a new 3-year phase. GTZ is convinced that the collaboration of all parties involved in the Project-the Project scientists and their Malawian support staff, their colleagues in the SADCC national groundnut programs, the strong backing and resources of ICRISAT Center, and of course SACCAR with its structural support-guarantee a very efficient program. These efforts are beneficial not only to Malawi but to the other SADCC countries.

GTZ follows the progress of the Project with great interest and would like to be as helpful as possible. The Project is a model of cooperation between a number of important parties for whom agricultural development is the common denominator. GTZ looks forward to fruitful interaction with all these parties.

Once more best wishes for the workshop and thank you for your attention.

M. Bosch
Technical Desk Officer
GTZ

Opening Address

Distinguished Guests, Ladies and Gentlemen.

First of all I would like to express my gratitude to His Excellency the Life President, Ngwazi Dr H. Karnuzu Banda, for directing me to open this Fifth Regional Groundnut Workshop for Southern Africa. As you know, His Excellency takes agriculture seriously. He is in fact his own Minister of Agriculture. I am therefore greatly honored and privileged to be given the opportunity to officiate at this opening ceremony of your Workshop on His Excellency's behalf.

On behalf of the Government of the Republic of Malawi, I welcome all the distinguished delegates and guests who have gathered here to discuss and exchange experiences in groundnut research and production. This Workshop will give delegates a unique opportunity to discuss the performance of this crop in southern Africa.

It is pleasing to note that this Workshop is being attended by delegates from eight of the ten SADCC countries: Botswana, Mozambique, Namibia, Swaziland, Tanzania, Zambia, Zimbabwe, and Malawi, the host country. Observer delegates have also come from Ethiopia, Kenya, Nigeria, and Uganda. ICRISAT is represented by scientists based in India, Malawi, and Niger.

Groundnut is one of Malawi's most important export crops and is an important commodity in the confectionery trade. Because Malawi imports substantial amounts of edible oils, we realize the importance of increasing production of oil-rich groundnut in decreasing import requirements. Nutritionally, groundnuts are an excellent source of protein and energy. When grown in rotation with other crops such as maize or tobacco, groundnuts improve soil fertility.

For all these reasons, it has become the policy of the Government of Malawi to increase groundnut production as rapidly as possible. The Ministry of Agriculture is intensifying both research and extension efforts in line with that policy.

Realizing the importance of groundnuts in Malawi and other SADCC countries, the Government agreed in 1982 to host the SADCC/ ICRISAT Groundnut Project, which is based at Chitedze Agricultural Research Station. Malawi also hosts the SADCC/ICRAF Regional Agroforestry Project, which is based at Makoka Research Station. Through these projects and others, Malawi contributes positively to the ideas of SADCC.

The value Malawi attaches to groundnuts is underlined by the fact that since 1982, we have hosted no less than three groundnut workshops. This Workshop is therefore welcome.

The main objective of this Workshop is to review the work during the past decade in the field of groundnut research and development in the SADCC countries. Papers by eminent scientists from within the SADCC Region and elsewhere will be presented on a wide range of topics affecting groundnut production. The workshop will also identify constraints affecting the groundnut industry in the SADCC region and make recommendations to member countries.

This Workshop has been organized by ICRISAT and funded by GTZ as part of activities of the SADCC/ ICRISAT Groundnut Project. On behalf of the Government of Malawi, therefore, I express gratitude to the German Government for funding this important research, and to ICRISAT for executing the Groundnut Project on behalf of southern African countries through SACCAR.

His Excellency the Life President has said many times that no matter what his people may not have, three things at least they must have. These are food, clothing, and houses that do not leak. Our Government is therefore committed to alleviating poverty and malnutrition.

Malawi's overall agricultural strategy, as delineated in the Statement of Development Policies for 1987-1996, is:

- to enhance the social welfare and income of the agricultural community;
- to ensure prosperity and stability of the nation by improving self-sufficiency in food; and
- to expand and diversify export earnings from agricultural produce.

These policy objectives will be achieved by minimizing the deterioration of natural resources, by examining the distribution of agricultural incomes, and by reducing dependence on imports. Malawi is well aware that groundnuts can contribute significantly to the achievement of these objectives.

I am therefore happy that this Workshop has been called to facilitate exchange of scientific information between scientists in the SADCC countries and those from outside the region. Together, you should work to chart the course of groundnut research in the 1990s.

Distinguished delegates, some of you may be visiting Malawi for the first time. I invite you all to visit other parts of our country. We are very friendly people. If you would like to extend your stay, you will find yourselves genuinely welcome, especially by the young. Feel free to talk to any of our people, and to learn about their hopes and aspirations. Wherever you go, you will know that you are among friends.

Mr Chairman, ladies and gentlemen, I wish you every success in your deliberations. I declare this workshop officially open. Thank you.

Hon. F.M. Kangaude, M.P.
Deputy Minister of Agriculture
Government of Malawi

Physiology

Physiological Models and Agronomic Data Applied to Experimental Analysis and Interpretation

B.J. Ndunguru[1], J.H. Williams[2], R.D. Stern[3], and B-R. Ntare[4]

Abstract

Variability in experimental data presents considerable challenge to the analysis of experiments. Physiological models may be useful in this context since they can be used to partition sources of variation into components which can then be used to improve the analysis and interpretation of results. This can be done using data already collected in most experiments (biomass, pod yield, flowering and maturity), so the value of data and knowledge gained from an experiment can be improved without increased costs. The methods and potential benefits of the system are demonstrated using an example from a heat tolerance screening experiment.

Resumo

Modelo fisiologico e dados agronomicos aplicados para analise e interpretaqao de resultados expermentais. Variabilidade nos resultados experimentais apresentam mudengas consideravies para analise dos experimentos. O modelo para proporcionar fontes de variagcao nos componentes que pode se usar para desenvolver a analise e interpretaqao dos resultados. Isto pode ser feito usando dados jd existentes, colectados em muitos experimentos (biomassa, rendimento em vagens, floracao e maturacao), so o valor dos dados e o conhecimento adiquirido dum experimetno pode ser melhorado sem aumentar os custos. Os metodos e o potencial benifico do sistema estao demostrado com exemplo dum ensaio da avaliacao de tolerancia a epoca quente.

Introduction

Variability within data due to site and other causes is a major problem for scientists. To deal with the problem, treatments and experiments are repeated, but results can still be inconclusive. Standard statistical methods exist for dealing with variability and classifying this variation into:

- that which is attributable to experimental treatments;
- that which is associated with systematic or definable site differences (block, or covariate); and
- that which is associated with unsystematic, or unknown causes (error).

These statistical methods then allow the effects of these various contributions to total variation to be evaluated against a measure of the size of variations of unknown origin (the error). The objective of this statistical method is to account for the sources of variation and so diminish the size of the error component. One measure of how well this objective has been achieved is provided by the coefficient of variation (CV%).

Physiologically, yield is the outcome of the effects of environmental and genetic factors. Knowledge of the yield, however, is not as useful as knowledge of the contributions of the determinants of yield to that end product. Recent developments allow the use of agronomic data and crop physiological models to re-

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fine the statistical analysis of experiments and the interpretation of the results. Models can be used to determine the contribution of various components of the crop system to yield, and where the source of variation is understood in the physiological sense, they can be used to refine the analysis and improve the value of the experiment. This technique is demonstrated using the results of a heat tolerance screening experiment conducted at the ICRISAT Sahelian Center (ISC), near Niamey, Niger.

Experimental Background

Droughts are complex situations during which crops may experience various combinations of water, heat, and nutrient stresses as a result of inadequate water supply. Sahelian countries experience high temperatures during the season when groundnuts are grown (Fig.1), and these conditions are aggravated if drought

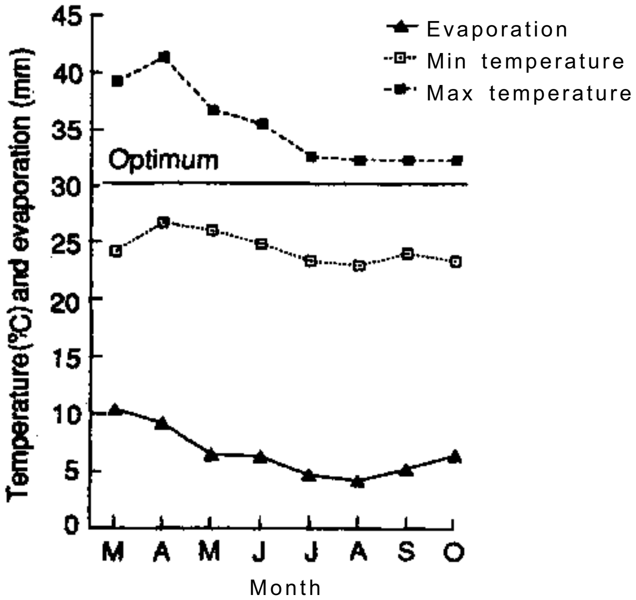

Figure I. 1991 seasonal variation in maximum and minimum temperatures and pan evaporation at Sadore, Niger.

occurs, since plants then cannot dissipate incident energy by evaporation. We have shown that the groundnut varieties adapted to Sahelian conditions all have the ability to yield well during the hot months prior to the onset of rains, and that this ability is due to the adapted varieties' ability to maintain partitioning to pods in above normal temperatures, rather than due to differences in ability to grow in either drought or high temperature conditions (Greenberg et al. 1990). Thus we believe that temperature tolerance is an important component of drought resistance, and a necessary attribute for varieties cultivated in the Sahel. By providing adequate nutrients and water to groundnuts growing in the very hot summer, genotypes with the necessary heat tolerance can be identified without the confounding effects of drought stress. However, groundnut growth at ISC is extremely variable (Subrahmanyam et al. 1991), and obtaining meaningful results can be difficult.

The parameters for simple models of yield determination associated with a measured final product may be estimated for many genotypes without intensive destructive measurements (Williams and Saxena 1991). In the model used the pod yield (Y_{pod}) is defined as:

$$Y_{pod} = C x \, D_{rep} \, x \, p \qquad \text{[Equation 1]}$$

where C = the mean crop growth rate, D_{rep} = the duration of reproductive growth, and p = the partitioning of growth to pods (Duncan et al. 1978).

A second model that has relevance to our problem deals with the determination of biomass production (Monteith 1977):

$$Y_{bio} = I \, x \, e \qquad \text{[Equation 2]}$$

where / = total energy intercepted, and e = the light use efficiency. This model can be converted easily to account for variations in C since:

$$C = Y_{bio} + \quad D_{total} \qquad \text{[Equation 3]}$$

where D_{lotat} = time from sowing to harvest.

Generally, major variations in C are due to / since e is a relatively conservative parameter (Monteith 1990). This model is important to the rationale of the analysis, which suggests that variations in Y_{pod} due to variations in C are largely the result of a factor easily manipulated by managerial techniques. Most differences due to variations in C can therefore be attributed to environmental rather than genotypic effects.

Materials and Methods

The trial was conducted during the dry season of 1991 at the ICRISAT Sahelian Center (13° 29'N, 2° 10'E; 221 m above sea level). Soils are Psammentic Paleustalfs (sandy, siliceous, isohyperthermic) with low pH, low inherent soil fertility, and low organic matter. The trial was laid out as a balanced lattice and 46 kg ha^{-1} P_2O_5 was applied as diamonium phosphate prior to sowing. Plot size was 4 m^2 and seeds were sown on 7 March 1991 at 10 cm spacing along ridges SO cm apart.

The trial used 625 groundnut lines, including some released lines with adaptation to Sahelian conditions. Adequate amounts of water were provided by irrigation so that plants did not experience drought stress during growth. The trial was regularly observed to determine the date at which 50% of the plants in each plot had commenced flowering. At harvest, shoot dry matter, pod yield, and seed yields were measured. To provide the best possible measure of total biomass for groundnuts, one needs to adjust for any defoliation that may have occurred (based on the fractions of stem and leaf without defoliation), and for the higher energy content of the seeds (Duncan et al. 1978). Crop growth rate (C), pod growth rate (R), and the partitioning coefficient *(p)* were estimated for each of the 1875 plots of the experiment using the energy adjusted final biomass, the energy adjusted reproductive yield, and the timing of flowering and maturity (Williams and Saxena 1991). Although growth is known to be a nonlinear function, it is possible to use a linear approximation over the whole crop life, since this will maintain relative differences between treatments/The linear estimation of growth rates using standard growth rate equations was as follows:

$$C = [HWT + (PWT*1.65)]/(T_2) \quad \text{[Equation 4]}$$

and

$$R = (PWT* \ 1.65)I(T_2\text{-}T_1\text{-}X) \quad \text{[Equation 5]}$$

where *HWT* = haulm mass, *PWT* = pod mass, T_2 = days to harvest, T_1 = days to flowering, and *X* = time between flowering and the expansion of the pods (at Sadore this interval is 10 days).

Results and Discussion

Variation in pod yield was very substantial (Table 1). Most genotypes produced pod yields ranging between 0.2 and 0.5 t ha^{-1}, and a few produced more than 1.0t

Table 1. Basic statistics of variables measured in the temperature screening experiment

Variable	Minimum	Mean	Maximum	Distribution
No. of plants emerged	1.00	39.87	99.00	Normal
Days to flower	27.00	32.74	47.00	Normal
Days to harvest	119.0	133.3	148.0	Normal
No. of plants harvested	1.00	24.56	69.00	Normal
Haulm mass (t ha^{-1})	0.008	1.994	11.840	Skew
Pod mass (t ha^{-1})	0.0030	0.5545	4.8200	Skew
Crop growth rate (t ha^{-1} d^{-1})	0.000039	0.007304	0.038800	Skew
Partitioning	0.0260	0.4796	1.4309	Normal
Rep duration (d)	63.00	85.60	104.00	Normal

Table 2. Distribution of sums of squares between factors and covariates in the analysis of variance.

Source	DF	SQRT pod yield	Partition factor	DF	SQRT pod yield with C as covariate
Reps	2	2.144	0.499	2	2,144
Covariate	-	-	-	1	51.700
Cultivars	624	119.318	33.400	623	28.989
Residual	1208	68.810	21.677	1208	17.108
Total	1833	182.477	54.279	1833	182.477
CV (%)		35.5	27.9		17.9

DF = Degrees of freedom.
SQRT = Square root transformed.
C = Crop growth rate.

between 0.4 and 0.6. A negligible percentage partitioned less then 0.2 and there were some that partitioned above 0.8. Several genotypes with low yields were found to have high partitioning. The *p* was only poorly related to plant stand and differences between genotypes have been attributed mostly to genotype effects.

The impact of the use of physiological models in the interpretation of data is provided by examining the effects of selecting on yield alone, compared with that of involving partitioning and yield. The lines can be classified into four groups based on pod yield and partitioning performance (Fig.4).

Group 1 Cultivars with high yield **AND** with a partitioning of above 0.7. For this group the outcome was not influenced by data methodology. This group included cvs 796, 4-2-12-7, 4-4-4-20, 55-437, MF-47, and ICGV 88461. The inclusion of the best available released variety (55-437) in this group provided some measure of confidence in the results.

Group 2 Cultivars with low pod yield **BUT** with high partitioning. These lines would have either been discarded, or required further screening before characterizing them for their heat tolerance. The group included cvs ICG 1141, ICG 2239, ICG 1816, ICG 2149, ICG 2195, ICG 9345, ICG 8620, ICGMS 21, ICG 10736, ICG 1840, ICG 2092, ICG 1338, ICG 1236, ICG 1622, ICG 2058, ICG 1620, and ICG 372.

Group 3 Cultivars with high yield BUT with lower partitioning. The group included cvs ICGV MS 86775, ICG 1697, IITA / IBPGR 42, and ICGV 88427. The majority of the group probably owe their high yield to better radiation interception, and will be retained for further evaluation. The possible existence of genotypes that may have better radiation-use-efficiency justifies further investigation of these lines.

Group 4 Cultivars with low pod yield AND low partitioning. Most of the lines examined came under this group, and there is no justification for further investigation of them.

The extreme genotypes in Group 3 were of interest because they apparently achieved high yields by exploiting mechanisms different from those common to most genotypes. If the high C of these lines is repeatable, our interest in them is in that they had superior growth rates under these adverse conditions and provided the possibility of combining superior p. and *C* under high temperature conditions.

This example of data analysis using physiological models as tools to improve the value of data is one of many potential applications of this approach. There is growing evidence that simple physiological models like those presented here can provide powerful tools to breeders, agronomists, and crop scientists in other disciplines to increase the cost efficiency of research.

Thus, knowledge of the manner in which environmental and treatment factors effect the parameters of these physiological models allows better analysis and interpretation of the results of experiments, and indeed may form the basis for diagnostic interpretation of the results.

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Discussion

Subrahmanyam: You have a large variation in plant population across replications, genotypes, and other treatments* This seems to be the major contributing factor to high coefficients of variation (above 70%). What are the major factors contributing to low plant population? Is it due to low viability of the seed, or is it due to seed/seedling disorders? If these are the major factors, you should be able to manage/control them very easily.

Ndunguru: Our present knowledge indicates that crop growth variability is due to nematodes, peanut clump virus, and Al and Mn toxicities, as well as nutrient imbalance due to low soil pH (about 4.2). Viability of seed was also a source of variation. Efforts have been made to manage crop growth variability. Other studies have been initiated to find ways to interpret data obtained from a crop with variable growth without managing this problem. Both approaches are in progress at 1CRISAT Sahelian Center.

Chiteka: There were varieties with low partitioning and high yield and others with high partitioning and high yield. What was the difference in partitioning?

Ndunguru: We considered a partitioning of 0.7 and above as high, and a partitioning of less than 0.7 as low.

Chiteka: What was the basis for high yield and low partitioning for genotypes with the same crop duration?

Ndunguru: The majority of the variation was attributed to variation in crop growth rate. While the model suggests that variation may diminish with changes in radiation interception, we also want to identify material with tolerance for Al toxicity.

Olorunju: 1. You said your cut-off points were arbitrary, but there must be some factors you considered in grouping your results. What are they? 2. Could you comment on the decision you made to analyze skewed data and the significance of the results that came out of this unusual statistical practice?

Ndunguru: 1. A partitioning of about 0.7 was the cut-off point Pod yield above 1 t ha^{-t} was considered reasonable under our conditions in Niger. 2. Data analysis is based on the assumption that data are symmetrical (he., normally distributed). If the data are skewed then they are transformed. In this case our pod yield data were asymmetrical, but we nevertheless analyzed them, as our aim was to test the model. On transformation, the data became symmetrical, and using the simple grouping technique lines with known drought tolerance got high marks. We would like impress on participants that we deliberately presented these data in various forms to show how much improvement in data analysis and interpretation can be made using these simple models.

Subrahmanyam: Do we have any information on the rates of physiological (natural) defoliation in different botanical groups?

Williams: No. We only have observations that the leaf defoliation is influenced by population and light penetration to the leaves. Widely spaced plants have little defoliation but cloud canopies have substantial defoliation.

Chiteka: At what point do you consider pods to have started forming: pod formation, peg formation, or point of peg entry into the soil?

Williams: The point that you need to fix is when the first pods are expanded. That is the start of significant reproductive growth.

Nageswara Rao: I have a comment regarding calculation of crop growth rate. I believe that we should use days after emergence as the denominator rather than days after sowing. The time to emergence can be affected by differences between genotypes, changes in base temperature, or other factors-all of which can influence the crop growth rate when we are comparing across varieties.

Williams: Perhaps so, but it is more a question of definition. As long as one defines the basis, the values are valid. Changes do not affect the absolute values and should be relatively constant across the treatments.

Freire: 1. Is it possible to use harvest index for probability? 2. How is vegetative growth prior to the beginning of the reproductive stage taken into account in relation to final yield?

Williams: 1. No, harvest index does not take into account the differences in timing. Partitioning is based on rates and therefore defines the efficiencies. 2. It does have some impact on the estimate of the partitioning, but these are absolute rather than relative.

The Potential of Runner Groundnuts to Decrease "Pops" and Increase Yields in Low-Input Farming Systems

U. Hartmond[1], J.H. Williams[2], B. J. Ndunguru[3], and F. Lenz[1]

Abstract

Calcium deficiency is a serious agronomic constraint to pod production on the poor soils (Alfisols) of African groundnut-growing areas. In a series of field experiments at the ICRISAT Sahelian Center in Niger, runner genotypes demonstrated better ability to cope with inadequate Ca supply, producing higher yields, having better pod filling and reduced sensitivity of shelling percentage to increasing pod size across varieties. Breeding for improved yield potential in the runners should be a priority for groundnut breeders concerned with improving productivity in low-input farming systems.

Resumo

Pontencia de variedades postradas de amendoim para *reduzir o estampido das vagens mal* preenchidas e aumentar a produqao nos sistemas de produqao de baixo "input". *A deficiencia do* calcio e urn dos serios limitantes agronomico para a producao de vagens nos solos pobres (Alfisolos) das.zonas de cultura de amendoim em Africa. Noma sirie de experimentos de campo no ICRISAT centro de Sahel em Niger, genotipos postrados mastraram melhor abilidade em fazer frente a seministro inadequado de Calcio, produzindo maior colheita, possuindo melhor preenchimento de vagens e sencitividade reduzida de percentagem de casca para o incremento do tamanho de vagens atravez das variedades. Cruzamentos para o melhoramento do potencial de produqao das variedades postradas deve ser a prioridade para os melhoradores de amendoim relacionado com o melhoramento da productividade em sistemas de campos de producao de pouca conservagdo.

Introduction

In the semi-arid tropics, groundnut pods are often affected by Calcium (Ca^{++}) deficiency because soils often have low Ca++ content, or mobility of this element is limited due to droughts (Cox et al. 1976). Calcium deficiency is a known reason for the failure of seed formation commonly called "pops" (Colwell and Brady 1945). Seed yields and the quality of seeds are reduced drastically by Ca++ deficiency, and the number of empty and immature pods multiplies (Conkerton et al. 1989).

Calcium nutrition is a problem for which there are known genotypic differences in susceptibility. Much attention has been focused on the role of pod size as a factor influencing susceptibility to Ca^{++} deficiencies (Keisling et al. 1982, Kvien et al. 1988). Much less attention has been focused on the role of pod dispersal to limit interpod competition for the element. The better pod distribution of runner groundnuts in the soil makes more than double the soil volume available to individual pods (Hartmond 1991). This effect could be important in influencing Ca++ nutrition. Walker et al. (1976) reported higher yields of a runner

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compared with bunch cultivars at low soil Calcium levels. Despite their widespread use in the intensive groundnut cultivation in the USA, runners are not commonly selected for crop improvement in the semi-arid tropics, perhaps because of their relatively long growth cycle, and disadvantages in hand harvesting.

Breeders have been able to increase the yield potential of groundnuts, primarily by increasing the proportion of assimilates partitioned to the pods (Duncan et al. 1978): These changes have been possible in both runners and bunch types of groundnuts. Much of the production in the USA utilizes runner types with high yield potential (Woodroof 1973, Franke 1982).

The present study evaluated the role of the runner habit as a means of improving pod filling under various calcium supply conditions. Ca^{++} supply was manipulated by combinations of fertilization and irrigation, and the effects of these 'environments' on groundnut varieties of differing habit and pod size were examined.

Materials and Methods

During the rainy and postrainy seasons of 1989 and 1990, field experiments were conducted at ICRISAT Sahelian Center, at Sadore, Niger, in the Sahelian Zone, and at Tara, 300 km south in the Sudanian Zone.

At Sadore, the soils are very variable and belong to the Labucheri Series of the Psammentic Paleustalfs. They have a very low exchange capacity of less than 3 meq 100 g^{-1} of soil and a pH of 5.0 to 5.2. The topsoil is very sandy, with 94% sand and only 3% clay (West et al. 1984). At Tara, the soil is classified as Haplic Acrisol with 90% sand in the topsoil. It has a pH of 3.9 and the exchange capacity is 6 meq 100 g^{-1} (INRAN 1990, Fechter et al. 1991).

The fields chosen for the experiments had been fallow for at least 6 years before the experiments. The grass and bushes were removed manually, and the groundnut seeds sown directly by hand into the soil without further tillage to avoid destruction of the poor soil structure. Plots of 4 x 5 m^2 were arranged in randomized block designs with three (Experiment 1) or five replications. A basal fertilizer of 12 kg N and 30 kg P_2O_5 ha^{-1} as diamonium-phosphate (DAP) was applied before sowing.

Calcium was applied at the pegging stage as gypsum. All fertilizers were distributed by hand onto a 25-cm wide band along the rows. The varieties used were selected to provide a range of growth habits, botanical classes, and pod sizes. The details of the four experiments are summarized below.

Experiment 1 Location: Tara
Varieties: 12 (9 bunch, 3 runner)
Ca^{++} levels: 3 (0, 120, 240 kg ha^{-1})
Drought: No

Experiment 2 Location: Sadore
Varieties: 4 (2 bunch, 2 runner)
Ca^{++} levels: 1 (0 kg ha^{-1})
Drought: No

Experiment 3 Location: Sadore
Varieties: 4 (2 bunch, 2 runner)
Ca^{++} levels: 2 (0, 240 ha^{-1})
Drought: 2 (levels over grain fill)

Experiment 4 Location: Sadore
Varieties: 4 (2 bunch, 2 runner)
Ca^{++} levels: 2 (0, 240 ha-1).
Drought: 2 (levels over grain fill)

Final yield, yield components, and shelling percentage were assessed and the number of empty locules ("pops") was counted separately for one- and two-loculed pods on a 500 g subsample.

Results and Discussion

"Pops" occurred in all experiments. There was considerable variation between experiments, management treatments, and genotypes for this attribute. In all experiments correlation analysis demonstrated that shelling percentage, and percentage of filled locules decreased with increasing pod size, as is shown using the data for experiment 1 (Table 1). Varieties with

Table 1. Correlation coefficients of pod yield, pod volume, shelling percentage, and the number of filled locules (Experiment 1).

	Pod yield	Shelling percentage	Filled locules (%)
Pod volume	0.002	-0.461	-0.385
Filled locules (%)	0.331	0.762	
Shelling percentage	0.328		

r* = 0.195 r ** = 0.254 n = 107

* = $p<0.05$
** = $P<0.01$

smaller pods had fewer "pops" because large size reduces the surface:volume ratio and thus the Ca-uptake ability relative to requirements. This effect was also apparent between the pods with one or two locules.Thus for environments deficient in calcium, and where gypsum is not available, it may be useful to breed for a larger percentage of fruits with only one locule, compensating for the decrease in seed number by greater pod numbers.

To combine results from all experiments stability analysis was used (Finley and Wilkinson 1963). Each treatment level of Ca^{++} and irrigation from the experiments was considered as a separate environment for the analysis.

To compare the shelling percentage of the two morphological groups, all the runner and bunch types were averaged for each 'environment' and plotted against the overall mean shelling percentage in the different environments (Fig.1). The shelling percentage was higher in the runner genotypes than in bunch cultivars in most environments, except in the best environment (i.e., high Ca++ and irrigation levels). The regression lines converged in the best environments and contrasts were more profound in poorer environments. This indicated the better adaptation of runner types to these low Ca++ situations compared with the bunch types, whereas in higher-yielding environments both types filled the pods equally well.

A highly significant negative correlation between pod volume and shelling percentage was detected in all the experiments, a relationship observed by several researchers (Pallas et al. 1977). However, seed size is an important quality criterion in groundnuts, and bigger seed commands higher prices in the market. Since pod size increases the Ca^{++} requirement, and the runner habit decreases this requirement, is there evidence that the runners can better fill pods of a given size than bunch types? The regression of shelling percentage with pod size separately for runner and bunch genotypes (Fig.2) shows that the filling of pods from runners was less sensitive to pod size than was the bunch genotypes, supporting the idea of reduced nutrient competition in the soil due to better pod distribution (Hartmond 1991).

To evaluate the effect of runner or bunch habit on yields, the genotypes were grouped according to morphotypc, and the individual pod yields regressed against the mean yields of the experimental environments (Fig.3). The regression lines presented in Fig. 3 demonstrate that runner varieties yielded comparatively well in otherwise low-yielding environments, but that as the yields increased, reflecting better envi-

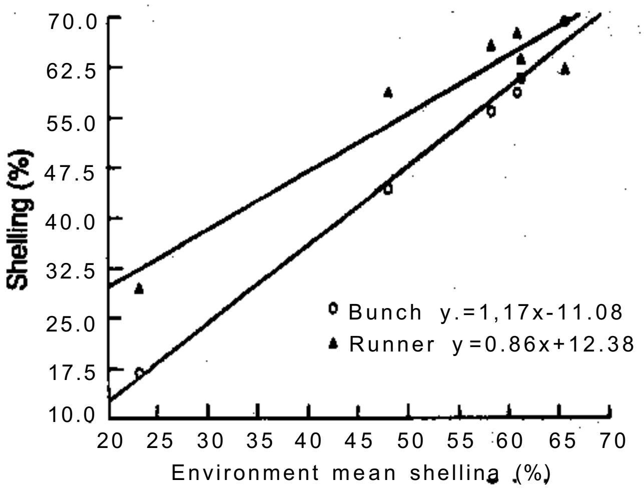

Figure 1. The relationship between shelling percentage of runner and bunch groundnuts in different environments.

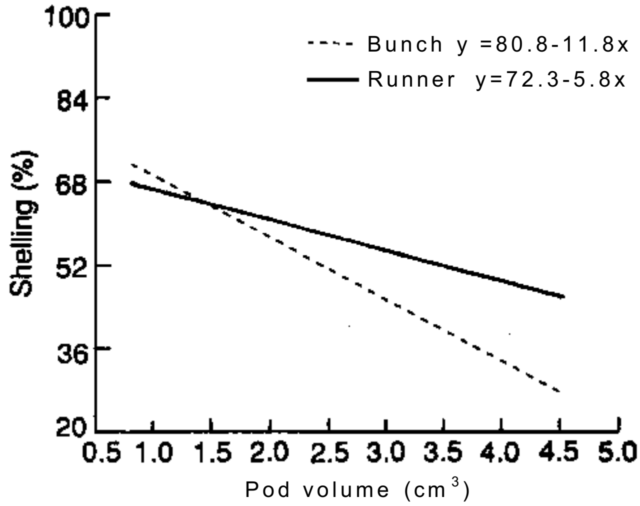

Figure 2. The relationship between shelling percentage and pod size of groundnut varieties with runner and bunch growth habits.

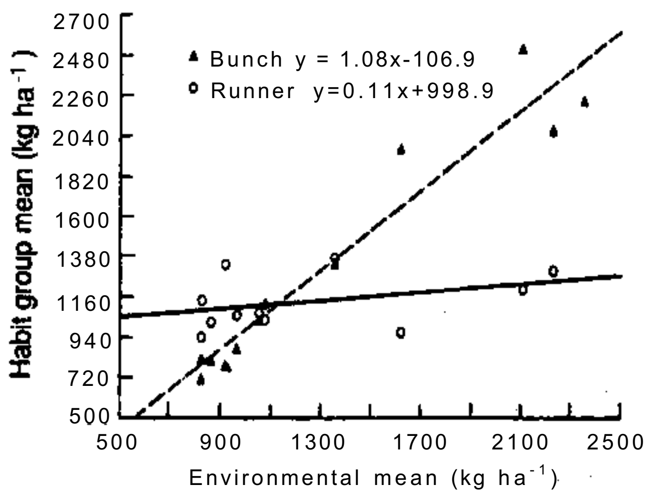

Figure 3. Yield stability of runner and bunch groundnut genotypes in various calcium supply environments.

ronments (Ca, water, and other considerations), then the bunch types outperformed than runners. Perhaps with more improved runner types the cross over would occur at a higher yield.

Many of the pod yields observed in this study are fairly low, but fall within the range of yields reported earlier in these environments (Boote 1983). More importantly, shelling percentage at the lower yield levels was less than normal for many genotypes, but higher for the dispersed pods of the runner types. Therefore, where Ca++ nutrition was probably a factor contributing to the low yields (although the yield potential of runner cultivars was apparently lower than that of the bunch types), the fertility was better realized at low soil fertility, or moisture level. Despite the lower yields in good environments, the high stability of pod-filling of the runners is of great interest because it is likely that the breeder can base corrections of yield potential on low partitioning.

These data show that better filling of pods can be achieved by using genotypes either with small pod size or the runner habit. However, if gypsum is supplied one must anticipate that the most efficient use of limited application would be achieved by the bunch types.

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Discussion

Freire: 1. "Pops" particularly occur on light sandy soils and in drought-prone areas (mainly late-season drought). Runners are normally long-duration groundnuts. How do you see this problem? 2. How did you compute the environmental yield?

Williams: 1. The long duration of runners is still a problem, but have the breeders tried to create a short-duration runner? 2. The environmental means are the treatment means for each combination of calcium and irrigation.

Anders: If you select for a runner type in a marginal environment, would you not then create a situation where the addition offertilizers' might be uneconomical because of the higher value of soil required to raise levels?

Williams: Yes, I agree totally. Inputs are most effective with bunch types. However, for much of Africa, access to these inputs by groundnut producers is unlikely in the near future because of the greater response to fertilizer from other crops. I think that the breeders, through their use of inputs, have biased themselves towards the bunch types.

Syamasonta: If runner groundnuts are less susceptible to "pops" than bunch types, why is MGV 4 (ICGMS 42), a bunch type, less susceptible to "pops" than MGS 2 (M 13), a runner type?

Williams: A number of factors contribute to the occurence of "pops". ICGMS 42 may be better for a number of other reasons. Pod size or calcium uptake efficiency, for example, may be important in deciding the difference. Another possibility is that season length may expose M 13 to more drought than ICGMS 42.

Influence of Soil Type on the Adaptation of Groundnut Genotypes

R.C. Nageswara Rao, L.J. Reddy, and S.N. Nigam[1]

Abstract

Several trials conducted at ICRISAT Center showed that the performance of groundnut on Vertisols was generally poor compared with that on Alfisols. There was a strong soil type x genotype interaction, suggesting specific varietal adaptation for soil type. Physiological studies revealed that while crop growth rates are greater on Alfisols, they are linearly related to those measured on Vertisols (R = 077). However, pod growth rates and partitioning of dry matter to pods showed a strong soil type x genotype interaction, suggesting that the genotypes developed on the Alfisol may maintain relative ranking for total dry matter on Vertisol, but not necessarily for pod yields.

Resumo

Influencia do tipo de solo na adaptacao dos genotipos de amendoim. Muitos ensaisos conduzidos no ICRISAT centro demostraram que o comportamento do amendoim nos vertisolos foi geralmente pobre comparado com dos alfisolos. Houve forte interagao tipo do solo x genotipo. Sugerindo se variedades especificas para adapta-las ao tipo de solo. Estudos fisiologicos revelaram que enquanto as percentagens de crescimento da cultura sao grandes nos alfisolos elas sao linearmente relacionadas para estas medidas nos vertisolos (R = 077). Porem, a percentagem de crescimento de vagens e participacao de materia seca para vagens demostrou forte interagao tipo de solo x genotipo, sugerindo se que os genotipos cultivados nos alfisolos podem manter relativa categoria para materia seca total nos vertisols, mas nao necessariamente para a producao de vagens.

Introduction

Groundnut *(Arachis hypogaea* L.) is an important cash crop grown on a wide range of soils and climates in the semi-arid tropics (Virmani and Piara Singh 1986). In addition to developing genotypes with tolerance for biotic and abiotic stresses, the adaptation of genotypes to varied environments is one of the major problems faced by groundnut improvement programs (Branch and Hildebrand 1989). Soil fertility problems that are likely to be very diverse and location-specific can be overcome to some extent by use of fertilizers and other amendments. However, the inherent physical properties of soil also vary with soil type (El-Swaify and Caldwell 1991), and are particularly important for groundnut, which has a subterranean fruiting habit.

Although some information is available on the effect of various components of the environment, the nature of the limitations imposed by soil conditions to groundnut growth and yield are not clearly understood, mainly because of climatic factors interacting with the performance of genotypes at different sites. It is therefore important to determine whether high-yielding genotypes developed on one soil type are adapted to other soil types.

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Nageswara Rao, R.C., Reddy, L.J., and Nigam, S.N. 1992. Influence of soil type on the adaptation of groundnut genotypes. Pages 15-18 *in* Proceedings of the Fifth Regional Groundnut Workshop for Southern Africa, 9-12 Mar 1992, Lilongwe, Malawi (Nageswara Rao, R.C., and Subruhmanyam, P., cds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

At ICRISAT Center, Alfisols and Vertisols occur in close proximity, thus facilitating the study of crop growth in different soil types but under identical climatic conditions.

Soil Type x Genotype Interaction

Several trials conducted at ICRISAT Center with advanced breeding lines indicated that the performance of groundnut on Vertisols was generally poor compared with that on Alfisols (Table 1). In the trials, the soil type x genotype interaction was significant.

During the 1987 / 88 and 1988 / 89 postrainy seasons, we examined the effect of the two soil types on the growth and yield of four genotypes grown under irrigated and drought-stressed conditions. The four genotypes (ICG 1326, ICGV 87128, ICGV 87160, and ICGV 86635) were subjected to four irrigation regimes.

T_1: Adequate irrigation

T_2: Drought imposed by withholding irrigation during flowering

T_3: Drought imposed by withholding irrigation during pod-set

T_4: Drought imposed by withholding irrigation during pod filling

The three drought regimes (T_2, T_3, and T_4) spanned 25-30 days. Crop growth rates were estimated from plants sampled at 10-day intervals during crop growth.

The pooled data over the two seasons indicate that the total dry matter (TDM) on the Alfisol ranged from 10-12 t ha^{-1} and declined progressively to 6-7 t ha^{-1} as the drought occurred later in the season. However, ICGV 86635 recorded significantly greater TDM on the Alfisol compared with other genotypes in T_1, T_2, and T_3. The mean pod dry matter (PDM) on the Alfisol was 3.5 (±0.5) t ha^{-1} in T_1, and was progressively reduced to 2.0 (±0.5) t ha^{-1} in T_4 with no genotypic variation.

On the Vertisols, the mean TDM was 6.0 (±0.25) t ha^{-1}, although the drought treatments did not significantly affect the dry matter production. However, pod yield ranged from 1.0 to 1.5 t ha^{-1} in T_1 and was reduced to less than 0.5 t ha^{-1} in T_3. ICGV 86635, which had superior pod yield on the Alfisol (more than 3.5 t ha^{-1} in T_1), had the lowest yields on the Vertisol (less than 1 t ha-1), while ICGV 87160 showed superior performance on Vertisols with pod yields about 1.5 (±0.3) t ha^{-1} in T_1. ICGV 87160 was also least influenced by drought.

Table 1. Mean pod yield (t ha^{-1}) of groundnut genotypes from breeding trials grown on Alfisols and Vertisols at ICRISAT Center during the 1987/88, 1988/89, and 1990/91 postrainy seasons (values within brackets indicate the percentage coefficient of variation).

Season	No. of entries	Pod yield (t ha^{-1}) Alfisol	Pod yield (t ha^{-1}) Vertisol	Soil x genotype (F value)
1987/88	4	3.39 ±0.122 (11.6)	1.29 ±0.131 (10.2)	4.86**
1988/89	16	3.81 ±0.154 (7.0)	1.48 ±0.127 (14.9)	6.83**
	25	3.17 ± 0.225 (12.3)	1.06 ±0.148 (24.3)	3.07**
	4	2.02 ±0.092 (15.7)	0.61 ±0.083 (19.1)	8.21**
1990/91	25	3.49 ± 0.178 (8.9)	1.56 ±0.169 (18.8)	4.95**
	16	2.49 ± 0.152 (10.6)	0.81 ±0.144 (30.9)	2.97**
	16	2.52 ±0.212 (14.6)	0.76 ±0.101 (23.0)	3.17**

** $p < 0.01$.

Table 2. The mean crop growth rate (CGR), mean pod growth rate (PGR), and partitioning of dry matter to pods *(p)* of four groundnut genotypes grown on Alfisol and Vertisol at ICRISAT Center during the 1987/88 and 1988/89 postrainy seasons.

		Alfisol			Vertisol		
Treatment	Genotype	CGR ($g\ m^{-2}\ d^{-1}$)	PGR	P	CGR ($g\ m^{-2}\ d^{-1}$)	PGR	P (%)
Control	ICG 1326	13.9	11.2	80	9.2	4.7	54
	ICGV 87128	11.5	9.6	83	8.7	4.7	56
	ICGV 87160	12.1	9.0	75	8.7	5.2	60
	ICGV 86635	16.1	10.9	67	10.9	4.5	43
Early drought							
	ICG 1326	12.9	8.7	66	8.0	3.8	48
	ICGV 87128	10.9	8.1	73	8.6	4.4	56
	ICGV 87160	12.5	9.2	61	9.1	4.5	50
	ICGV 86635	13.8	8.1	58	8.2	3.5	42
Mid-season drought							
	ICG 1326	10.0	7.0	70	6.6	2.6	43
	ICGV 87128	10.1	7.7	76	3.5	2.3	48
	ICGV 87160	9.8	7.2	73	6.8	3.7	55
	ICGV 86635	10.1	7.5	74	6.0	2.5	47
Terminal drought							
	ICG 1326	8.9	6.1	73	5.7	4.0	58
	ICGV 87128	8.1	5.3	65	5.6	3.3	58
	ICGV 87160	8.1	5.1	64	7.0	4,2	61
	ICGV 86635	9.7	6.3	65	7.2	2.9	43
SE		±0.024	±0.011	±2.3	±0.014	±0.091	±2.3

The crop growth rates (CGRs) on the Alfisol were 40% greater than on the Vertisol in T_1 (Table 2). On both soils, the CGRs declined the later the drought occurred in the season. Drought during the pod-filling phase (T_4) reduced PGRs by about 45% on the Alfisol, while the reduction in PGRs on the Vertisol in a similar treatment was only 22%. However, the pod-set phase (T_3) appeared more critical for drought on the Vertisol, where the PGRs declined by more than 40%. Partitioning of dry matter to pods *(p)* was significantly less on the Vertisol, although some genotypes were able to maintain *p* on both the soils.

The correlation of growth rates between the two soil types indicated that the CGR on Alfisol was positively correlated (R = 0.77**) with the CGR on Vertisol, but there was no such relationship for PGR (R = 0.52) and p (R = 0.38) between the two soil types.

These results imply that high-yielding genotypes developed on Alfisols may maintain relative ranking for total dry matter on Vertisols, but not for pod yields. However, it appears that productivity of groundnut can be improved on Vertisols by developing varieties with specific adaptation to this particular soil type.

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Discussion

Ndunguru: Could you expand your work to include climate? Since you have data on both regional and international trials, this would enable us to see how your proposal fits into various agroclimatic zones. Basically, this entails analyzing the data in retrospect

Nageswara Rao: I agree that the results could be expanded. With the GIS system recently installed at ICRISAT Center, we can now analyze international trials and look at the adaptation of genotypes to varied environments with a totally new perspective.

Nigam: The only problem is that we are not getting prompt feedback on information from the international trials that we send to African countries.

Syamasonta: Don't you think it would have been better to include both Virginia and Spanish types in the experiment to obtain more complete varietal information?

Nageswara Rao: In the trials presented, we included only Spanish types. We have not yet included Virginia bunches or runners, although we hope to include them in future work.

Olorunju: Our choice of varieties for different ecological zones has thus far been based on climate, rainfall, etc, without considering the effects of soil. Is it possible that when we introduce the soil factor we may end up with information that contradicts previous findings? Is the soil factor much more important than the other climatic conditions combined?

Nageswara Rao: Soil is an important factor for the adaptation of a crop like groundnut with subterranean fruiting habit. The problem of adaptation becomes important when the breeding program occurs on one type of soil and genotypes are evaluated on other soil types. What I am stressing in my paper is that apart from climatic factors, specific adaptation to soil types should also be considered where applicable.

Freire: Selection for specific adaptation is commonly accepted. But why spend time and money on selection for Vertisols if other crops like soybean or sunflower might be higher yielding, better adapted, and more economically valuable?

Nageswara Rao: Growing other crops in hostile soil environments is one of the options. However, changing of crops at the farmer's level involves considerable time and introduces significant socioeconomic considerations. Specific adaptation of genotypes of the crops already growing in a given environment should therefore be considered.

Chiteka: Specific adaptation creates a problem with seed availability. What information is there concerning soil type distribution across different zones in India and how is this incorporated into the testing sites?

Nageswara Rao: If one is hoping for improvement in yield of groundnut, specific adaptation of cultivars should be considered. In India, the groundnut-growing area is divided into six agroecological zones based on agroclimatic and soil factors. The national trials at the preliminary level are common throughout these zones. Subsequently, however, only entries that perform well are promoted to the advanced trials. The national evaluation system considers both specific and general adaptation, and varieties are released zonewise and nationwide. Scope exists to improve the present system in the light of specific adaptation of cultivars.

Anders: In what season did you conduct these trials and how much importance do you give to soil x season interactions?

Nageswara Rao: All results presented in this paper were obtained during the postrainy seson. We have not yet examined soil x season interactions.

Country Reports

Performance of Elite Groundnut Varieties in Ethiopia

Adugna Wakjira[1]

Abstract

This paper reviews the performance of elite varieties of groundnut in Ethiopia under three agroclimatic conditions to determine the potential of growing the crop in the country. Current production status, constraints, and breeding objectives are examined. Released and recommended varieties are indicated and future crop improvement plans discussed.

Resumo

Compartamento de algumas variedades de elite de amendoim na Etiopia. Este artigo faz revisao ao comportamento de algumas variedades de elite de amendoim na Etiopia em tres zonas agroclimatologicas para determinar o potential do crescimento da cultura no pais. Estado actual da producao, limitacoes, objectivos e desenvolvimento de novas plantas sao examinados. Variedades recomendadas e libertadas sao indicadas tambem; os pianos do melhoramento futuro da cultura sao tambem descutidos neste artigo.

Introduction

Groundnut *(Arachis hypogaea* L.) has been grown by small farmers in Ethiopia since the early 1920s (Yebio Woldemariam 1983), particularly in the northern and eastern parts of the country. The low-lying regions (less than 1600 m above sea level) in the southern and western provinces (Welega, Illubabor, Gojam, and Gamu Gofa) are also potentially suitable for groundnut cultivation. These regions are high-rainfall areas, receiving over 600 mm during the growing seasons.

The current total production area of groundnut in Ethiopia is 40 000 ha, with an average productivity of 1.25 t ha (Table 1). Both area and productivity have been increasing until 1987 when drought and pricing policies affected agricultural production.

Groundnut is a multipurpose crop in Ethiopia. Roasted seeds are directly consumed and crushed seeds are added to various types of dishes, thus providing a good source of proteins and fats. In the East, high quality edible oil is extracted from groundnut and cakes are made from the remaining cake as a valuable foodstuff. Shells are also used for fuel and as organic fertilizer in many regions.

Table 1. Area, production, and average pod yield of groundnut in Ethiopia, 1979-88.

	1979-81	1986	1987	1988
Area ('000 ha)	33	46	40	40
Production ('000 t)	27	53	50	50
Yield (t ha^{-1})	0.83	1.15	1.25	1.25

Besides its superior food value, groundnut provides a source of cash for resource-poor farmers. As

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Wakjira, Adugna. 1992. Performance of elite groundnut varieties in Ethiopia. Pages 21-24 in Proceedings of the Fifth Regional Groundnut Workshop for Southern Africa, 9-12 Mar 1992, Lilongwe, Malawi (Nageswara Rao, R.C., and Subrahmanyam, P., eds.J. Pataneheru,A.P, 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

an export crop, groundnut earns badly needed foreign currency for the country-over US$ 2 million in 1989 (Adugna 1991).

In areas where cereals (primarily maize and sorghum) are cultivated, groundnut is a suitable rotation crop that contributes to sustainable agriculture by maintaining soil fertility and breaking pest and disease cycles.

Since 1976, four varieties have been released. These are Shulamith (1976), Nc 4X (1986), Nc 343 (1986), and ICG 7794 (1988). Crop duration of these varieties ranges from 130 to 160 days. Their yields are 5.0-7.0 t ha^{-1} under irrigation and 2.3-5.01 ha^{-1} under rainfed conditions.

Production constraints of groundnut in Ethiopia include drought stress, poor cultural practices, insufficient supplies of improved seeds, insect pests (particularly termites and boll worms), and leaf spot diseases. Inadequate extension services, the lack of farm tools and implements, and poor incentives have also contributed to poor crop productivity.

Crop improvement work was initiated in the mid-1960s to overcome these problems, with the major emphasis on the identification of high-yielding, widely adaptable varieties for the major growing areas. Present breeding objectives are directed towards developing new cultivars with higher yield, more oil content, better shelling percentage, and yield stability over seasons and across locations. Short-duration varieties for dry and short-season areas are also desirable, while varieties with resistance to early and late leaf spot are needed in the high rainfall regions in western Ethiopia.

Materials and Methods

Field experiments were conducted in three agroecological regions: irrigated, high-rainfall, and low-rainfall areas. Through these experiments, Ethiopian scientists have endeavored, since 1972, to idenr tify varieties with better performance than the local landraces. The environmental conditions under which the varieties were tested are summarized in Table 2. Completely randomized block designs with four replications were used. Before the 1980s, improved varieties were introduced from the USA; since then, they have come from ICRISAT.

Experiments were sown between June and July. Most farm operations (sowing, cultivating, weeding, and harvesting) were done manually. The exceptions were plowing and disking, which were done with tractors. Single seeds were sown in 2-4 cm deep holes, spaced 10 cm apart. Row spacing was 60-80 cm. In most cases, neither fertilizers nor chemicals were applied. In the irrigated sites, 10-12 cm water were applied at intervals of 2-3 weeks, depending on the weather conditions.

Results and Discussion

Irrigated areas

Pod yield at the four irrigated locations ranged from 3.5 to 6.5 t ha^{-1} (Table 3). The yields at the irrigated locations where cotton is grown commercially by state farms were very impressive-sometimes as high

Table 2. Summary of environmental conditions of groundnut testing sites in Ethiopia.

	Locations												
	Abobo	Asossa	Didessa	Fincha	Beles	Tedelle	Melka werer	Ten-daho	Gode	Arba Minch	Babile	Bisi-dimo	Meiso
Altitude (m)	530	1550	1200	1530	1200	1670	750	380	315	1400	1650	1450	1600
Temperature (* C)													
Maximum	35	30	30	28	30	26	38	40	40	33	29	32	30
Minimum	18	14	15	13	13	11	18	20	25	16	14	15	15
Annual rainfall (mm)	600-900	800-1000	900-1300	600-1000	800-1000	900-1300	300-400 + Irrig.	80-200 + Irrig.	200-300 + Irrig,	250-350 + Irrig.	450-600	400-500	300-500
Soil type	clay loam	clay	sandy loam	sandy clay	clay loam	clay	silty clay loam	sandy loam	clay loam	clay loam	sandy clay	sandy clay	Vertisol

Table 3. Mean dry pod yields of elite groundnut genotypes in irrigated locations of Ethiopia, 1972-80.

Locations	Yield (t ha-^{1})	Genotypes
Melkawerer (Eastern Rift Valley)	6.0---6.5	Shulamith, Virginia bunch, Nc-2
Tcndaho (Northeastern Rift Valley)	3.7-4.7	Virginia bunch, MN 383, Congo
Gode (Eastern, Wabi-Shebele Basin)	3.5--4.2	Abadir, Dire Dawa, Nc-2
Arba Minch (Southern Rift Valley)	5.0-5.4	Bamby, Nc-5, AK 11

as 8.0 t ha^{-1} (Yebio et.al. 1986) on experimental plots. On the larger plots, at least half of this amount can be realized, mostly from the large-seeded Virginia bunch types that are usually better yielders than the valencia/spanish types.

In spite of these high yields, however, the state farms did not adopt the groundnut cultivation, mainly because of policy issues, high labor costs, and lack of proper machinery for shelling, sowing, cultivation, and harvesting operations. Nevertheless, if proper agricultural policy prevails for the private farms and small-scale farmers in these irrigated zones, groundnut can undoubtedly become profitable and serve as an alternative crop in rotation with cotton.

High rainfall areas

Pod yields in the high rainfall areas ranged from 1.7 t ha--^{1} at Asossa to 5.3 t ha^{-1} at Didessa (Table 4). The relatively low yield at Asossa was attributed to high incidence of termites and damage by wild animals.

All these elite varieties were Virginia types (ssp *hypogaea),* and while ICG 2518 and ICG 2519 were runner types, the rest were bunch types. ICG 7794 had superior performance across the three locations and was licensed for release in 1988 under the name Roba. All these three varieties (ICG 2518, ICG 2519, and ICG 7794) were introduced from ICRISAT in 1982.

Low Rainfall Areas

Babile and Bisidimo sites in eastern Ethiopia, with marginal rainfall, represent the main groundnut-growing regions of Ethiopia. Similar varietal performance was recorded at Kobo and Humera in northern Ethiopia (Adugna 1991).

At Babile and Bisidimo, ICG 2518 and ICG 7794 yielded on par with local controls, while ICG 273 yielded significantly lower than the local controls at these locations. However, at Meiso, ICRISAT lines showed superior performance compared with the local controls (Table 4).

The First International Trials

Four of 36 ICRISAT varieties gave excellent pod yields at four locations, exceeding the local control (Nc-4X) by 28 to 85% over the 3 years of test's. At the irrigated site of Melkawerer, ICGS 69 yielded nearly as much as the control. ICGS 63 and ICGS 65 performed well at Babile and Meiso (low-rainfall sites) and also had higher oil percentages (Table 5), These genotypes are in the process of release to farmers.

Table 4. Mean pod yield (t ha^{-1}) of some elite groundnut varieties at high and low rainfall locations in Ethiopia, 1985-90.

	High rainfall locations					Low rainfall locations		
Varieties	Didessa	Fincha	Abobo	Beles	Asossa	Babile	Bisidimo	Meiso
ICG 273	-	-	-	..	-	1.7	1.5	1.1
ICG 2518	-	-.	-	-	-	2.4	2.1	1.0
ICG 2519	5.3	4.0	3.3	2.6	2.5			
ICG 7794	4.5	3.6	3.9	2.9	1.7	2.6	2.4	1.1
Manipintar	4.2	3.7	3.2	3.9	2.8			
Code 02						2.8	2.7	0.5
Nc 4x (control)	4.8	3.4	2.9	2.6	1.8	2.4	2.6	0.9

Table 5. Mean yield and other desirable agronomic characters of the top performed varieties of the some ICRISAT-introduced genotypes In Ethiopia, 1988-90.

Locations	Varieties	Yield (t ha-[1])	Percentage over control	Oil (%)	Shelling (%)	Duration (days)
Melkawerer	ICGS 69	6.2	1.2	47	64	133
Tedelle	ICGS 84	4.4	28	48	-	152
Abobo	ICGS 62	3.4	66	48	58	152
Babile	ICGS 63	2.9	51	53	66	141
Meiso	ICGS 65	1.4	85	51	56	146

Future Research

The future groundnut improvement program in Ethiopia will focus on five main points.

- Development of high-yielding, short-duration, and drought-tolerant varieties, especially for dry areas.
- Screening for varieties for resistance to early and late leaf spot for high rainfall locations.
- Strengthening extension capability to disseminate the available production technologies.
- Further collaborative research with ICRISAT.
- Consolidation of the breeding program by addressing labor and material needs.

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Discussion

Syamasonta: 1. How long is the growing season in Ethiopia? 2. What is the altitude of the growing areas? 3. What types of groundnut are grown: Virginia or Spanish?

Adugna Wakjira: 1. About 6 months: May to October. 2. Below 1600 m above mean sea level. 3. The Virginia types are most commonly grown,

Olorunju: 1. How serious is the disease problem in your high rainfall regions? 2. Not much was said about short-duration varieties: do you grow any for the drought areas?

Adugna Wakjira: 1. Both early and late leaf spots are constraints in the high rainfall areas. A study done during the mid-1980s showed a yield loss of about 30% due to these diseases. 2. So far the released cultivars, as well as local landraces, are long-duration Virginia types. ICG 273, with a duration of 100-115 days, however, is in the pipeline.

Groundnut Production and Research in Eastern Kenya

J.W. Kimwaki and J.W. Irungu[1]

Abstract

Groundnut (Arachis hypogaea L.) cultivation in Kenya has remained low despite its suitable agroecological zones for production of the crop. In the eastern part of the country, seed yields of 0.50-129 t ha^{-1} were recorded between 1984 and 1990. Potentialfor expansion ofcultivation in this region is high. The production system and regional constraints are described in this paper. A varietal adaptation trial was conducted by the Kenya Agricultural Research Institute (KARI) at Embu Centre in March 1991. Forty-two improved ICRISAT groundnut varieties and a local cultivar were sown in a replicated trial. Analysis of the results indicated significant differences among varieties for yield and other characteristics. Yields of up to 2.6 t ha^{-1} were achieved. Future research aimed at improving the yield and quality ofgroundnut in the region are outlined.

Resumo

Produqao e investigacao de amendoim na Kenya oriental. O cultivo de amendoim (Arachis hypogoae L.) em Kenya tern sido permanentemente baixo apesar das suas zonas agroclimatologicas serem favordveis. Na porte oriental do pais rendimentos de amendoim de 0.50 a 1.2 t ha'[1] foram registadas entre 1984 e 1990. O potencial para a expansao da area de cultivo e alto. Os sistemas de produqao e os factores limintantes estao descritos neste artigo. Um ensaio de adaptacao de variedadesfoi conduzido pelo Instituto de investigacao agronomica de Kenya (KARI) no centra de Embu em 1991. Quarenta e duas variedades de amendoim melhoradas de ICRISAT e uma variedade localforam semeadas num ensaio em repeticoes. a analise dos resesultados mostrou uma diferenca significativa entre as variedades em rendimento e outras caracteristicas. Rendimentos ate 2.6 t ha^{-1} foram atingidas. Futuras investigacoes com vista a aumentar o rendimanto e melhorar a qualidade do amendoim estao delineadas.

Introduction

Groundnut cultivation in Kenya is small compared with that of other crops. Most of the produce is used locally for confectionery, but the potential for oil extraction is high. If this potential could be fully exploited, the country would be relieved of the heavy import costs presently incurred for vegetable oil. It is estimated that the country is spending in excess of Ksh 2 billion annually to import vegetable oil. The quantity imported represents about 80% of the national requirement (Ministry of Agriculture 1988).

Apart from its use as an oilseed, groundnut is also beneficial to the farmers when rotated with cereals in dry and irrigated farming systems, as it contributes to soil enrichment and nitrogen economy. Also, the dried or fresh haulms and oilcake are good animal fodder and concentrate (Singh and Rutto 1991).

Groundnut production is mainly concentrated in warm, humid areas, particularly along the coastal and lake regions (Western and Nyanza Provinces). There are, however, scattered pockets of production in the Rift Valley and Eastern Provinces.

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Kimwaki, J.W., and Irungu, J.W. 1992. Groundnut production and research in eastern Kenya. Pages 25-28 in Proceedings of the Firth Regional Groundnut Workshop for Southern Africa. 9-12 Mar 1992. Lilongwe, Malawi (Nageswara Rao, R.C., and Subrahramanyam. P.. eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute tor the Semi-Arid Tropics.

In the Western, Nyaza, and Rift Valley Provinces, groundnut is mostly grown below 1500 m above mean sea level (msl) with annual mean temperatures of 21-24'C. On the coast, the crop is grown at much lower altitudes (less than 400 m), with temperatures of 24-27 C.

Production Practices in Eastern Kenya

In the eastern region, groundnut is mainly grown in the marginal cotton zone (LM4) and the lower midland livestock-millet zone (LM5) of Meru District. These zones are found between 710 and 1280 m above msl with a mean annual temperature of 21-24°C and a mean annual rainfall of 1000 mm for LM4 and 800 mm for LM5. Rainfall occurs during the October-December period (long rains) and the March-May period (short rains).

The crop is mainly grown in small holdings between 0.5 and 1.0 ha, usually in pure stands, but some farmers intercrop it with crops like maize *(Zea mays),* sorghum *(Sorghum bicolor),* cassava (*Manihot esculenta),* sunflower *(Helianthus annus),* or cotton *(Gossypium hirsutum).* It is grown during both the long and short rains. It is sown in October and harvested in February in the long-rain season; and during the short-rain season it is sown in March and harvested in July. Single-plowing is done in the month preceding the sowing.

Farmers grow their own seeds of local varieties (e.g., Ex-Meru) to which they apply no fertilizer at sowing time. The crop is sown in rows, 1-2 seeds per hill at a spacing of 45 x 7 cm. A few farmers spray foliar fertilizer twice a season. Hand hoes are used for weeding two to three times each season. Harvesting, threshing, and shelling are done manually. The local variety has seed yields ranging between 0.5 and 1.29 t ha^{-1} and seed size of about 45 gm 100-seed mass. The produce is sold at Ksh 7 kg^{-1} to stores in Meru town, about 50 km from the farms.

The most common diseases are leaf spot *(Cercospora arachidicola)* and root rot; while cutworms, bollworms, termites, and squirrels are the major pests.

Production Constraints

- Seed acquisition is a major constraint to production because there are no groundnut seed agents in the country. Improved cultivars that would probably be higher-yielding and resistant to diseases and pests are unknown.
- Because the local variety takes 5 months to mature* it always suffers when drought occurs.
- The tillage method used in this region (plowing with oxen) limits the cultivated area to small manageable plots.
- There is general lack of knowledge of appropriate technologies among the farmers.
- Labor-intensive manual farm and postharvest operations limit the area under cultivation.
- The marketing infrastructure for the crop is inadequate. Farmers must transport their produce long distances on public transport. The low production could be a major cause of this problem. Also, the prices offered for the produce are quite discouraging to the growers.

Present Research Focus and Preliminary Varietal Trials

The area under cultivation is presently estimated at 1080 ha (Ministry of Agriculture 1990) and considerable scope to extend it exists. Our research focus is to extend this area and to maximize production. The strategy is to identify potential areas in both traditional and new zones and to introduce improved varieties best adapted for the specific agroecological zones. Potential areas in LM4 and LM5 zones of Embu district have been identified in close collaboration with ICRISAT, our major source of germplasm.

To initiate the work, a preliminary varietal trial including 42 ICRISAT groundnut varieties and one local cultivar was conducted at KARI's Regional Research Centre, Embu, in March 1991. Embu is situated at latitude 0° 30' S and longitude 37° 27'E in the upper midland subhumid zone, the main coffee zone (Jaetzold and Schmidt 1983). It stands at 1470 m above msl with a mean annual maximum temperature of 26^0C and a minimum of 14°C

The area has bimodal rainfall with annual average rainfall of 1081 mm. The rainy seasons occur from March to May (long rains) and from October to December (short rains). The average rainfall during the long rains is 340 mm, and that of the short rains is 240 mm. The soils of the area are well drained, very deep, dark reddish brown, friable clay, and classified as Eutric Nitosols.

The 43 entries were sown in a randomized complete block design on 27 Mar 1991. Two replications

Table 1. **Performance of ICRISAT groundnut varieties at the Regional Research Centre, Embu, 1991.**

Entry	Variety	Seed yield (t ha^{-1})	Shelling (%)	100-seed mass (g)	Disease incidence[1] (%)
1	ICGV-SM 86708	0.93	59	104	29.0
2	ICGV-SM 86720	1.38	53	86.5	7,5
3	ICGV-SM 86725	0.71	63	95	28.0
4	ICGV-SM 86734	1.01	50	79.5	18.0
5	ICGV-SM 86737	0.54	44	74.0	12.0
6	ICGV-SM 86743	0.30	44	66	25.0
7	ICGV-SM 87723	1.22	49	75	13.0
8	ICGV-SM 87798	0.82	54	74	19.0
9	ICGV-SM 87805	1.41	54	80.5	8.0
10	Control Ex-Meru	1.85	67	44.5	6.0
11	ICGV-SM 88710	0.67	46	63	11.0
12	ICGV-SM 88711	0.37	56	67.5	20.0
13	ICGV-SM 86584	1.01	64	77	12.0
14	ICGV-SM 86726	0.37	53	74.5	17.0
15	ICGV-SM 88701	0.26	48	71.5	20.0
16	ICGV-SM 88737	0.75	47	67.0	5.0
17	ICGV-SM 88757	0.32	58	80.5	16.0
18	ICGV-SM 89742	1.40	57	85.5	22.0
19	ICGV-SM 89744	0.93	62	81.0	2.0
20	ICGV-SM 89749	0.40	58	75.5	19.0
21	ICGV-SM 89778	0.69	39	82.0	16.0
22	ICGV-SM 284	1.10	39	51.5	19.0
23	ICGV-SM 285	2.02	56	52.0	13.0
24	ICGV-SM 286	1.57	44	59.0	12.0
25	ICGV-SM 550	1.98	49	91.5	1.5
26	ICGV-SM 554	1.01	38	79.5	0.7
27	ICGV-SM 83005	1.38	57	75.5	2.0
28	ICGV-SM 83011	1.52	55	67.0	1.5
29	ICGV-SM 83030	0.55	56	62.5	0.7
30	ICGV-SM 85038	1.28	55	96.0	2.0
31	ICGV-SM 86051	2.38	61	88.5	1.5
32	ICGV-SM 85048	1.53	56	62.5	7,0
33	ICGV-SM 85055	0.48	47	82.5	12.0
34	ICGV-SM 86004	1.97	50	75.5	8.0
35	ICGV-SM 86022	1.64	44	76.5	19.0
36	ICGV-SM 86068	1.60	51	61.5	0.7
37	ICGV-SM 87019	0.53	62	80.5	4.0
38	ICGV-SM 87039	2.13	61	61.5	4.0
39	ICGV-SM 87050	0.69	49	52.5	16.0
40	ICGV-SM 87053	0.53	70	55.5	19.0
41	ICGV-SM 87064	2.62	70	58.5	17.0
42	ICGV-SM 87082	0.84	59	62.5	21.0
43	ICGV-SM 86061	0.85	58	75.0	*7.0*
Trial mean		1.10	53.8	72.8	
SE		±0.42	±6.9	± 5.7	
CV (%)		53.8	18.1	11.1	

1. Sclerotinia blight.

were made to determine the best adapted varieties for eastern Kenya, Each plot had two rows of 34 plants spaced at 15 cm intarow and 40 cm interrow. Triple Super Phosphate fertilizer (100 kg ha^{-1}) was used at sowing, and hand weeding was done twice.

Significant yield differences *(P<0.05)* were recorded among varieties with ICGV-SM 87064 (Spanish type) yielding the highest (Table 1). This variety's yield, though not significantly different from that of the local variety (Ex-Meru), was 41% higher. Spanish varieties generally performed better than other types with six among the 10 highest in yield. Among Valencia types, ICGV-SM 285 and ICGV-SM 550 performed well. Hundred-seed mass differed significantly (P<0.05) among the varieties. ICGV-SM 86708 weighed 104 g, while the local variety weighed the least (44.5 g).

There was high incidence of *Sclerotinia* blight in this trial, resulting in low plant stand at harvest and low yields in most entries. Excessively wet conditions persisted during harvesting, resulting in harvest delays and reduced yields. Yields in this trial, however, indicated that production of more than 2.6 t ha^{-1} can be achieved with improved varieties and good management.

Twenty entries were retained for further evaluation.

Future Research Programs

Introduction of improved varieties will be continued. Varietal adaptation trials will be conducted in several sites of the potential agroecological zones.

Most agronomic recommendations are general and were developed elsewhere in the country. The program will therefore be geared towards developing efficient low-input agronomic packages specific to different agroecological zones. These will then be disseminated to farmers through extension officers and other appropriate channels.

Lack of certified seed is a major constraint of production in Kenya. A sound seed multiplication program will therefore be initiated to ensure availability of good quality seed at the right time and place.

As previously indicated, groundnut production in the region is undertaken by resource-poor farmers who use hoes and other hand implements for farm operations, harvesting, and shelling. Joint efforts with the engineering department of the Ministry of Agriculture will help to improve farm tools to ease the farmers' work. This will improve the efficiency of production and reduce cost of production.

Periodic surveys for production constraints will be conducted to help identify farmers' problems. Research should then be directed to remove these constraints, increase productivity, and sustain production.

When production increases, the marketing structure will improve as the buying agents will have the courage to go out to the fields and collect the produce themselves. There is, however, need for increased prices in order to stimulate interest among growers to increase production.

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Discussion

Chiteka: In Zimbabwe, sclerotinia blight presents problems during very wet seasons and on irrigated crops. What is the rainfall in the areas of Kenya where sclerotinia is a problem?

Kimwaki: The region receives an average of 1081 mm $year^{1}$ and about 240 mm during the short rainy season. This amount of rainfall is quite high, hence the development sclerotinia blight.

Groundnut Agronomy Research in Malawi: Past Achievements and Future Priorities

N.E. Nyirenda[1], T.J. Cusack[2], and V.W. Saka[3]

Abstract

Since the 1940s, groundnut agronomy research in Malawi has determined the appropriate types and levels of a wide range of cultural practices intended for smallholders with recommended cultivars. These findings, where appropriate, have become standard farm practice. They have been incorporated into the national extension handbook and used by agricultural administrators to set credit guidelines and other policies. Groundnuts are currently ranked fourth in national commodity research importance, with an estimated priority weighting of 9% of total research resources. This weighting compares with an actual resource usage of 7%. Agronomy is given a weighting of 20% of the total resources used in groundnuts research, compared with 14% actual usage. Within ground* nut agronomy, the highest priority research category is the evaluation of breeders' varieties for yield adaptation and "pops".

Resumo

Investigaqao agronomica de amendoim em Malawi Anteriores sucessos e prioridades de investigacao. Desde 1940 a investigacao agronomica de amendoim em Malawi tern determinado niveis apropriados e uma vasta gama de praticas culturais recomendaveis para os pequenos agricultores. Estes resultados eram apropriados, comecaram a ser uma pratica padrao (standard) para estes agricultores. Tern sido incorporado no manual national de extensao e usado pelos administradores de agricultura para trassar linhas de creditos em outros lugares. O amendoim aumentou quatro vezes a sua prioridade na investigaqao com urn peso prioritdrio estimado em 9% do total dos recursos. Este peso compara se com 7% do uso actual dos recursos. Agronomia e dado um peso de 20% do total dos recursos usados na investigacao de amendoim comparado com 14% do uso actual. Dentro de agronomia de amendoim, a mais alta categoria de prioridade de investigacao e a avaliacao das variedades reproductoras para adaptacao e consistencia de vagens.

Introduction

Groundnuts are important for smallholder agriculture and for the national diet in Malawi. They contribute significantly to dietary requirements in most parts of the country and provide more than 25% of all smallholder cash income. Groundnut accounts for approximately half of Malawi's supply of edible oils and is its fourth most important export crop. National policy objectives are to increase groundnut production, mainly through increases in yield. It is felt that increased output will:

- reduce import requirements for edible oils;
- increase exports of confectionery nuts;
- improve the quality of smallholder diets; and
- significantly improve smallholder cash income.

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Groundnut production, however, has declined from 80 000 t shelled nuts equivalent in the mid-1980s to 20 000 t at present, due primarily to seed shortages and the erosion of profitability of groundnuts compared with other principal crops. Nonetheless, groundnut research has recorded significant achievements, and continues to enjoy high priority within the overall agricultural research program.

The material presented in this report is taken from a research planning exercise presently being implemented by the Groundnuts Commodity Research Team. The results of this exercise will be written up as an "Action Plan" in late 1992. The material for the achievements section of this report was obtained primarily from recent Annual Research Reports by the Groundnut Commodity Team (Groundnut Commodity Team 1991), while the priorities section is based primarily on a comprehensive departmental report which established research priorities and proposed resource allocations to research for 1991-95 (Department of Agricultural Research 1991).

Achievements

Groundnut research in Malawi is currently conducted by a multidisciplinary research team called the Groundnuts Commodity Research Team, based at Chitedze Agricultural Research Station. The team consists of one pathologist, two breeders, and two agronomists. This core team undertakes its own research, and simultaneously cooperates with other research teams investigating aspects such as adaptation, farm machinery, economics, and farming systems research.

Overall constraints to groundnut production in Malawi are:

- use of low-yielding varieties;
- a narrow germplasm base;
- inferior cultural techniques;
- the prevalence of early leaf spot and rosette diseases (Subrahmanyam 1983); and
- extended dry spells within the growing season.

Agronomists are charged with the development of appropriate cultural practices for groundnut cultivars in the major groundnut-growing areas of Malawi. Nine agronomic research thrusts (listed below) have been incorporated into the Extension Handbook (Department of Agriculture 1991). Farmers have widely adopted the applicable technologies, many of which have become standard farming practices throughout the country.

1. Crop rotations

Low soil nitrogen is a major limiting factor in most soils. When groundnut follows a well-fertilized maize or tobacco crop, it benefits from the residual nitrogen fertilizer (Brown 1965).

On deep ferruginous soils, groundnuts tend to suffer less setback than unfertilized maize or tobacco, when sown after a plowed-out Rhodes grass ley.

On higher ferallitic soils with marked sulphur and nitrogen deficiency, application of gypsum increases groundnut yields; otherwise, groundnuts should be sown after a crop of maize or tobacco that has had a moderate dressing of sulphate of ammonia or single superphosphate.

The maximum safe frequency of a cropping system that includes groundnut in a rotation was found to be 1 year in 3 at Chitedze.

2. Fertilizers

The elimination of "pops" through soil fertility changes has not yet been found possible; however, on ferallitic soils, both gypsum and calcitic limes, either incorporated into the soil before sowing or applied at the pegging stage, have resulted in some reduction in "pops", and in increased shelling percentage and seed yield.

Preliminary results show that incorporation of potassium sulphate into the soil at sowing can increase shelling percentage by up to 10%.

Although yield responses to fertilizers were substantial in some cases, responses to potassium sulphate, sulphate of ammonia, urea, and phosphorus were generally low and inconsistent (Brown 1965).

3. Plant configuration and population

Under good management conditions, optimal plant population was 60 000-90 000 plants ha^{-1} for all recommended varieties at 90 cm between ridges, and a population of 111 000 plants ha^{-1} at 60 cm between ridges. The exception was the variety Malimba, which had an optimal population of 120 000-140 000 plants ha^{-1} at 90 cm between ridges,

Sowing a single seed per hill results in slightly lower yield than sowing two seeds per hill (Brown 1965); however, no significant difference in yield was obtained for the variety Chalimbana using one or two seeds per hill (on one or two rows per ridge at either 70 cm or 90 cm between ridges.

Although 60 and 75 cm distances between ridges produced superior quality seeds from both runner and semi-bunch groundnuts-as opposed to 90 cm-the optimal configuration for farmers is 90 cm combined with interplant spacing of 15 cm (10 cm for Malimba) and one seed per hill. The 90 cm spacing, rather than 60 cm or 75 cm, is chosen for convenience to farmers since most use the 90 cm ridge spacing for their maize.

4. Time of sowing

The optimal time for sowing cultivars in Malawi is at the onset of the rains, or as soon as possible thereafter. For example, using Chalimbana, late sowing (i.e., 1-3 weeks after the onset of the rains) resulted in 20-50% yield losses.

5. Weed control

The critical period at which Chalimabana yield and quality is affected by weed competition is 30-50 days after emergence (Chiyembekeza and Sibale 1986). This period coincides with peak flowering and pod-set.

Initial weeding is better if done not more than 5 weeks after sowing. For all the recommended groundnut varieties in Malawi, the critical weeding time falls 35-45 days after crop emergence.

Studies at Chitedze have shown that by 45 days after emergence of groundnuts, almost all the major weeds (Nicandra spp, Elensine indica, and Commelina spp) tend to outgrow the groundnut crop and restrict the canopy. Yield losses of 40% resulted were recorded when weeding was delayed by 35 days for variety Chalimbana, by 32% for Mani Pintar, by 20% for Mawanga, and by 45% for Malimba. Malimba was the most sensitive to weed competition.

6. Diseases

Fungicide applications to control leaf spots and rust were effective, particularly in high altitude areas; however, use of these fungicides by farmers was rare due to the high prices prevailing between 1986 and 1991 (Mwenda and Cusack 1987 and 1988, Kisyombe 1987).

Cultural practices such as early sowing, close spacing, and maintenance of optimal plant stand reduced the incidence of rosette disease. RGI, a rosette-resistant cultivar developed in Malawi, was successfully established as a recommended variety in rosette-susceptible areas.

7. Harvesting

Under adequate rainfall over a 4-month period, Red Valencia must be lifted at 90-100 days for optimal yield, after which sprouting in the pod and damage to the pegs occurred. With dormant varieties such as Mwitunde, date of lifting is not so critical, although at least 130 days growth should be allowed and the plants must be lifted before the stems turn black at about 160 days.

In the hotter and drier climates of the medium and lower altitude areas, nondormant short-duration varieties can mature in about 120 days, and must soon thereafter be lifted before the stems die and the pegs become weak, resulting in significant yield loss. Similarly, long-duration dormant varieties are best left for 140-150 days before lifting.

8. Labor requirements

It is estimated that an average hand-cultivated crop (hoed twice and weeded once), yielding 0.8 t ha^{-1} shelled nuts, requires 80-100 person days of labor (from land-clearing to delivering unshelled nuts to a store).

On a per task basis, using 1 person day, 0.04 ha can be sown, 0.04-0.06 ha can be hoe-weeded, 0.04-0.08 ha can be hand-pulled of large weeds, 0.06 ha can be hoe-lifted, 22.7-27.3 kg unshelled nuts can be hand-stripped, 45.5 kg nuts can be shelled using a hand-operated shelling machine, and 4.5 kg shelled nuts can be hand-shelled (Brown 1965),

9. Intercropping

Groundnut yields are reduced by 56-70% compared with sole crop yields when groundnuts are mixed with maize. The taller maize crop develops more rapidly and maintains a competitive advantage over the slower-growing and shorter groundnut crop. The maize itself does not suffer any yield loss.

In groundnut/maize intercropping, Mani Pintar outyields Chalimbana, RG1, SAC 58, and Malimba (Edje 1981).

Priorities

Groundnuts are presently ranked fourth in national commodity research importance behind maize, roots and tubers, and livestock, but ahead of other grain legumes and cotton (Department of Agricultural Research 1991). In terms of use of resources, as a proportion of total research resources, groundnut is given a weighting of 9%, 2% less than the present allocation to groundnuts (7%). Actual resource allocations to groundnuts have varied between 5 and 10% in recent years, and it is expected that current allocations will increase to almost 10% following the return of three professionals in late 1992 (after training abroad).

Within the groundnut commodity research team, overall priorities have been indicated (Department of Agricultural Research 1991) (Table 1), The groundnut team is responsible for research in breeding, agronomy, and plant protection, which together are given a weighting of 60%, with breeding being given the largest individual research area weighting. The other research disciplines are given 40% of the total weighting. In terms of total resources used, breeding presently attracts 50% of all funding, with agronomy in second place with 14%. Other research areas appear to be similarly underfunded. However, the pattern of resource allocation corresponds to the established priorities.

Table 1: Research priorities and resource use for groundnut.[1]

Research area	Priority weighting (%)	Actual 1990/91 weighting (%)	1990/91 total resources used (Kwacha)
Breeding	30	50	262 006
Agronomy	20	14	74 859
Plant protection	10	7	37 429
Irrigation/drainage	5	7	36 707
Farm machinery	10	9	45 908
Agroforestry	5	1	4 601
Adaptive research	10	3	14 867
Crop storage	1	1	3 270
Soils	3	4	22 691
Socioeconomics/statistics	5	3	16 990
Food science/ postharvest	1	1	3270
Total	100	100	522 598

1. This table excludes resources used to provide direct services to farmers through extension, such as implementation of the smallholder groundnut seed production scheme.

Within groundnut agronomy, preliminary estimates of research priorities were ranked in accordance with the expected extent that a given proposal, if successfully researched, would result in production increases by farmers (see Department of Agricultural Research 1991, Section 2, for a details of the ranking criteria). The core activity of evaluating breeders' varieties for yield adaptation and resistance to "pops" is given highest priority, and the detailed review of past fertilizer work, intercropping, and rotation are given intermediate priority. It should be noted that these are preliminary indicators of research importance which will be modified during the writing of the Action Plan.

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Discussion

Williams: I'm concerned about the retention of 90 cm ridges. This must result in yield limited by light interception. Can't this system be modified to allow higher population to increase yield? What about growing on the flat, or making furrows at 90 cm rather than ridges, or having two rows per ridge? Ideally, radiation interception should be complete either at flowering or shortly after that stage.

Nyirenda: Past research on variety Chalimbana showed that sowing on one or two rows per ridge of either 0.68 m or 0.91 m distance between ridges results in yields that are not significantly different.

Singa: Ridge sowing in Malawi is a blanket recommendation to conserve soil. In practice, farmers find it easier to sow on ridges when rotating crops, as most crops (e.g., maize) do well at 90 cm spacing. Mechanization makes this job easier. Recent research has made specific recommendations as to where flat sowing should be done, depending on the slope.

Chiteka: Why is the variety Mawanga difficult to store under farmers' conditions?

Cusack: Farmers responded that Mawanga was difficult to store because of its high oil content.

Groundnut Production and Research in Namibia

D.J.M. Marais[1]

Abstract

Namibia is a dry country with a national rainfall average of less than 380 mm year^{-1} Associated with this low rainfall is an average annual evaporation rate of 2300 mm and a daily rate of 15 mm during the groundnut-growing season. A majority of groundnut production is located in the North-east of the country where rainfall averages more than 500 mm year^{-1} Cultivation is conducted primarily by commercial farmers. A small amount of groundnut is grown in irrigated areas such as the Kardap Scheme in the South. Maize (23 000 ha) and millet (more than 5000 ha) are Namibia's primary crops. Approximately 4500 ha of groundnut are grown. This paper describes the production inputs and agronomic practices used by farmers.

Resumo

Namibia: investigacao e produqao de amendoim. Namibia e urn pais seco com media anual de precipitaqao inferior a 380 mm. Associado a esta baixa principitaqdo tern uma media anual de evaporaqdo de 2300 mm e uma midia didria de evaporacao de 15 mm durante o periodo de crescimento, a maior produqdo de amendoim e feita no nordeste do pais onde a precipitaqao media 4 superior a 500 mm por ano. O cultivo de amendoimm ifeito por agricultores comerciais. Pequena quantidade de amendoim 4 cultivada nas zonas de regadios como kardap scheme no sul. Milho (2300 ha) e maxoeira mais que (5000 ha) sao culturas primdrias de Namibia. Amendoim 4 cultivada numa area de 4500 ha aproximadamonte. Este artigo descreve os "inputs" de producao e as praticas agrondmicas dos agricultores.

Production

In Namibia, groundnut is mainly produced be commercial farmers. Seed is not produced in the country, with most farmers obtaining seed from South Africa.

Soil preparation

Before sowing, the soil is plowed to a depth of 20-25 cm in order to bury debris from the previous crop (generally maize). After plowing, the seedbed is prepared Normally, no fertilizer is applied because groundnut is sown following maize, which receives substantial fertilizer inputs. Sowing is done between 20 November and 15 December.

Plant population

Average plant density is 150 000 plants ha^{-1}. Plants are sown in 90-cm rows with approximately 7.5 cm between plants.

Weed and pest control

Weeds are controlled both chemically and manually. Although chemicals are usually employed to control

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Marais, D.J.M. 1992. Groundnut production and research in Namibia. Pages 35-37 *in* Proceedings of the Fifth Regional Groundnut Workshop for Southern Africa, 9-12 Mar 1992, Lilongwe, Malawi (Nageswara Rao, R.C., and Subrahmanyam, P., eds.). Patanoheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

pests and diseases, primarily on commercial farms, smallholder farmers rely on crop rotations to reduce pests and diseases to tolerable levels.

Harvesting

Groundnut is generally harvested manually, with pod yields averaging 0.8-0.9 t ha^{-1}

Constraints

There are five main constraints to groundnut production in Namibia.

1. Low rainfall.
2. The preference of maize production over that of groundnut.
3. Smallholders' access to seed is restricted because of underdeveloped extension services in many rural areas.
4. Acid soils.
5. Draft animals are often weak at the start of the growing season (attributed to long dry season), which results in delayed land preparation and sowing.

Research

1990/91 growing season

The Regional Groundnut Variety Trials were sown at Mahanene and Mthomst Research Stations. All genotypes sown were Spanish types. Sowing details are shown in Table 1.

Table 1. Groundnut trials sown at two sites in Namibia, 1990/91.

	Mahanene	Mthomst
Altitude	1100 m	1500 m
Sowing date	17 Jan	8 Jan
Spacing: row	7.5 cm	90 cm
Spacing: plants	20 cm	20 cm
Rain before sowing	25 mm	122 mm
Rain after sowing	384 mm	165 mm

1991/92 season

Two trials were sown at Mahanene and Mthomst Research Stations.

1. 1991/92 SADCC Regional Variety Trial
2. Fourth International Early Groundnut Variety Trial

An additional trial was sown at Mahanene Research Station. This trial consisted of 18 segregating populations from crosses bred for short duration (harvest at 85 days) and dormancy.

In addition, 12 cultivars from South Africa were sown at Sonop Research Station, northeast of Grootfontein in the middle of the groundnut production area.

Future Research

Because Namibia is a country where drought stress is common, it is important that agricultural researchers focus on this constraint. Three basic activities are envisioned in future groundnut work in Namibia.

1. Plant population trials.
2. Crop rotation trials with 1 fallow year for conservation of moisture and 2 years of sole cropping groundnuts, then maize. The idea is to increase residual moisture.
3. Development of cultivars with drought tolerance.

It is important to undertake farming systems research to help smallholder farmers increase their management skills. Although production by smallholders is presently very low, through the introduction of improved methods and management techniques it is possible to increase groundnut production in Namibia by 100%.

Discussion

Nageswara Rao: 1. What is the extent of acid soils in Namibia? 2. Is there any ongoing research on acid soils? 3. Are groundnuts grown on acid soils now? 4. If not, what are the crops now being sown on the acid soils?

Marais: 1. Mainly in the northeastern area in sandy soils with high rainfall. 2. No such research is being done at present, although it is planned in future. 3. No. 4. Millets.

Cusack: 1. What is the difference between "commercial" and "small" farmers? 2. What are the constraints to small farmers in trying to increase groundnut production? Specifically, why haven't the large increases in production enjoyed by commercial farmers been shared by the small farmers?

Marais: 1. Commercial farmers cultivate groundnut purely as a cash crop. Small farmers grow it for their own consumption first, and then as a cash crop. 2. The main constraint is the extreme distance from the farm to markets. Because groundnut is still grown as a subsistence crop by the small farmers, and is therefore consumed at home, large production increases have not yet occurred. The first step is to improve management.

Olorunju: 1. What is the proportion of small farmers to commercial farmers in Namibia? 2. Groundnut is grown once in 3 years. In the year that the crop is sown, do the farmers ignore the maize crop, i.e., do they use a rotation system?

Marais: 1. The overall smal:commercial farmer figure is 10:1, but in groundnut production the figure is 1:1. 2. The farmers don't ignore the maize crop, they sow groundnut and maize in rotation,

Ndunguru: From your presentation, it appears that the constraints in Namibia are very similar to the ones in the Sahel. Resources permitting, I suggest Namibian participation in the Regional Workshop at "Quagadougou, 14-17 September 1992, as well as the development of linkages between ICRISAT Sahelian Center and Namibia.

Groundnut Breeding in Nigeria; Past and Present Achievements

RE, Olorunju and S.M. Misari[1]

Abstract

This paper discusses the groundnut breeding efforts in Nigeria, where the crop is a major staple food as well as a cash crop. It covers the history of groundnut cultivation in that country from 1928 to the present, describes the breeding achievements, and suggests the nature of future work.

Resumo

Reproduqao de amendoim na Nigeria exitos do passado e do presente. Este artigo discute os esforcos na reproducao de amendoim em Nigeria, onde esta cultura 6 alimento bdsico assin como cultura comerical. Cobre a historia de cultivo de amendoim neste pais desde 1928 ate ao presente, descreve os exitos da producao e a natureza dofuturo trabalho.

Introduction

Groundnut (Arachis hypogaea L.) is an important crop in Nigeria as it constitutes a principal source of protein and dietary oil for both subsistance farmers and urban dwellers. It also provides a significant source of cash income through sale of seeds, groundnut cake, dietary oil, and haulms. In Nigeria, 0.8-1.2 million ha are sown to groundnut each year with yields ranging from 0.8 to 2.5 t ha^{-1}.

Between 1956 and 1967, groundnut products, including cake and oil, accounted for some 70% of total Nigerian export earnings, making it the country's most valuable single export crop. The drought years of the early 1970s, the unprecedented epidemic of groundnut rosette in 1975, and the increasing prevalence of rust disease combined with infection by leaf spot diseases that occur every year resulted in the considerable decline of groundnut production after 1967 (Alabi et al. 1990). The focus of research since then has therefore been on crop improvement. This paper reviews the breeding work that has been done and highlights current breeding activities, achievements, and future prospects.

Breeding Objectives and Program

The breeding program in Nigeria dates as far back as 1928 (Harkness 1977), Long-term and short-term breeding objectives include developing genotypes that have the following attributes:

- high yield with good agronomic characteristics;
- different season lengths for the various ecological zones;
- drought tolerance for the Sahelian and Sudanian Zones;
- high nutritional quality; and
- pest and disease resistance.

Crosses were made in Nigeria using introductions from America, Asia, and Africa. These crosses were followed by single plant selections during the early segregating generations and by bulk selections in advanced generations. Material emanating from these crosses plus introductions were tested for yield, quality disease resistance, and other traits such as crop duration and seed dormancy. Promising lines from preliminary trials were tested in advanced trials from

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which selections were made for state trials in order to determine their performance under the various ecological zones of the country.

Research Activities in the First 6 Decades

Breeding work in the first 4 decades focused on introductions and selection as well as hybridization and evaluation of the material for productivity, disease resistance, and adaptability. The emphasis during the next 2 decades was concentrated on disease resistance and drought tolerance. The genetic material / base population was therefore widened by introducing material from other countries in West Africa, America, and Asia*

This resulted in the release of rosette-resistant varieties such as M25.68 and M554.76, as well as introductions such as RMP 12, RMP 91 and 69-101 to the farmers. Among the exotic lines, 55-437 (ExDakar) was found to be drought-tolerant but susceptible to rosette. All these recommended varieties were suitable for the Northern Guinean and Guinean Zones where the rainy season lasts for 190 days or more with a total annual rainfall of 1000-1650 mm. The traditional commercial groundnut-producing areas (Sahelian and Sudanian Zones and the northern half of the Northern Guinean Zone) still need short-season, rosette-resistant varieties.

Current Breeding Activities (1986 to the present)

Inheritance of resistance, mechanisms of resistance to rosette, and epidemiology have become the major focuses since 1986 because it was apparent that all available rosette resistant varieties were long duration and little information was available on the disease.

A disease resistance study was conducted by the Institute for Agricultural Research, Zaria, in collaboration with the University of Georgia, USAID Peanut Collaboration Research Support Program (Peanut GRSP), and the Institute for Viniskrankheiten de Pflanzen, Braunschweight, Germany. Crosses were made between resistant and susceptible selections on short-, medium-, and long-duration varieties. Selections followed in the early segregating generations were screened using the procedure described by Bock and Nigam (1988). Results of this work have been reported by Olorunju et al. (1991 and 1992).

The problem of drought is difficult. The Institute for Agricultural Research, Zaria, recently obtained material from ICRISAT Center, India, with which it hopes to develop a solution to the problem. This work will involve strong collaboration with ICRISAT Sahelian Center, Niger, which has the facilities and expertise to conduct the work.

Future Prospects

- The release of a number of medium- to long-duration (more than 120 days), rosette-resistant varieties with yields ranging from 2.0 to 2.5 t ha^{-1}.
- Establishment of a reliable groundnut rosette screening project.
- Greater understanding of the groundnut rosette viruses to ensure the adoption of preventive and control measures.
- Establishment of a strong collaboration with other scientific programs such as Peanut CRSP and ICRISAT.

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Discussion

Subrahmanyam: I am surprised to know that the variety 55-437 was listed under rosette-resistant lines in the Peanut Disease Compenendium published by the American Phytopathology Society. In fact, it is a well-known standard susceptible control in rosette resistance screening experiments in West Africa. It must be a typographical error and the editors must be informed. What is the percentage of disease incidence on a control cultivar in your rosette nursery?

Olorunju: The disease incidence so far has been 100% for the infector rows, except for the first year when we had 80% infection due to the rainfall pattern which interfered with aphid populations.

Singa: In spite of your conducting screening work for rosette resistance on several groundnut varieties, why was the released variety found susceptible?

Olorunju: The variety was identified as a result of general field observation as resistant. At that time, a reliable screening procedure had not developed **or** adopted in Nigeria. The procedure currently used, adopted from ICRISAT in 1988, has been effective and reliable.

Banda: How successful were you in the greenhouse experiments involving mechanical transmission of groundnut rosette virus conducted to corroborate field experiment results?

Olorunju: The results obtained from the greenhouse were similar to the field results. Disease progress and severity followed the same pattern as in the field experiments.

Anders: How successful have you been in incorporating disease resistance into commercially acceptable lines?

Olorunju: RMP 12, RMP 91, and M 55476 are available and grown commercially. They are acceptable to farmers, but these varieties are still unsuitable for the traditional groundnut-producing areas of Nigeria becuase they are long-duration varieties and these areas need short-duration (less than 110 days) varieties.

Mayeux: KH 149A and KH 241D are two short-duration groundnut varieties with resistance to groundnut rosette disease. These varieties could be evaluated in areas where the growing season is short.

A Review of Groundnut Production and Research in Swaziland

V.M. Mkhonta and Z.1. Mamba[1]

Abstract

Groundnut production in Swaziland has been declining due to decreasing hectarage during the 1970s and 1980s. Some progress has been made with the re-establishment of the National Groundnut Research Programme, which has not operated for 10 years. Virginia and short-duration varieties have shown promise, and in view of current changes in climatic patterns, these varieties could be what the country needs to boost its groundnut production.

Resumo

Revisao da investigacao e produqao de amendoim na Swaziland. A producao de amendoim tern declinado na Swaziland por causa da reducao de area do seu cultivo durante os anos 70 e 1980. Alguns progressos tern se alcansado com o restabelecimento do programa nacional de investigacao que nao tern estado a funcionar a 10 anos. As variedades do ciclo curto e Virginia tern se mostrado promissoras e em vista as corentes mudancas climaticas, estas variedades podem serem as que o pais necessita para exibir a sua producao de amendoim.

Introduction

Groundnut *(Arachis hypogaea* L.) production in Swaziland is mainly limited to Swazi Nation land, which accounts for 60% of the total hectarage. Groundnuts are grown in all four agroecological regions of the country, but most of the cultivation occurs in the Middle Veld. There has been a steady decline in the production of groundnuts in the country from 3000 t in the early 1970s to less than 500 t in the early 1980s. This has been due mainly to a decrease in hectarage under groundnuts (Rao and Masina 1991).

Progress in Groundnut Research

A series of variety trials conducted since 1988 has included Spanish, Valencia, and Virginia types, as well as drought-resistant and short-duration varieties. This paper will only cover the progress made on two trials, the Virginia and the Short-Duration Variety Trials.

Virginia Variety Trial

This trial was conducted at Malkerns and Luve Research Stations during the 1989/90 and 1990/91 seasons. Fifteen varieties were tested in the first season and seven in the second season. These were selected on the basis of their yield potential and tolerance for rust and late leaf spot. In 1989/90, each plot consisted of four rows, each 4 m long. In 1990/91, the plots likewise consisted of four rows, but their length was increased to 6 m. Rows were spaced 60 cm apart in both years, while the intra-row spacing was 10 cm in 1989/90 and 15 cm in 1990/91.

Basal fertilizer was applied at a rate of 25 kg N, 38 kg P, and 25 kg K ha^{-1}. Manual weeding was done three times and ridging was done before the first

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flower appeared. Data were collected from the two center rows.

The final plant stand and seed yield is presented in Table 1. There were no significant differences in plant stand at Malkerns in either season. At Luve, groundnut varieties ICGV-SM 86715 and ICGV-SM 85718 produced lower plant populations compared with the other varieties in 1989/90, while in 1990/91 ICGV-SM 86715 had a lower plant population than the control, Mani Pintar. Generally low plant populations were experienced at Malkerns due to poor drainage.

Seed yield differences between varieties were significant at both sites in both seasons. ICGV-SM 86715 produced the highest yield at both sites in 1989/90. ICGV-SM 83708 resulted in a higher seed yield than the other varieties at Malkerns in 1990/91. At Luve, in 1990/91, ICGV-SM 86720 produced a higher seed yield than-all the other varieties except ICGV-SM 86704 and ICGV-SM 83708.

Short-Duration Variety Trial

This trial was conducted at Malkerns and Nhlangano in 1989/90 and 1990/91. Twenty-five varieties were tested in 1989/90 and eight in 1990/91. Each plot consisted of 4 rows, each 6 m long and spaced 60 cm apart. The plants were spaced 10 cm apart. Basal fertilizer was applied at a rate of 25 kg N, 38 kg P ha, and 25 kg K ha-^{1}. Manual weeding was performed three times during the season.

Results are presented in Table 2. Final plant stand differences between varieties were significant in both

Table 1. Plant stand and seed yield of Virginia Variety Trial.

	Malkerns				Luve			
	Plant stand (plot^{1})		Seed yield (t ha-^{1})		Plant stand (plot-^{1})		Seed yield (t ha^{1})	
Variety	89/90	90/91	89/90	90/91	89/90	90/91	89/90	90/91
ICGV SM 86715	36	23	1.10	1.05	49	28	1.40	0.00
ICGV SM 86720	38	26	0.54	0.92	61	44	1.31	1.43
ICGV SM 86704	40	23	0.56	0.85	65	42	0.98	1.09
ICGV SM 83708	41	35	0.86	1.25	61	42	0.80	0.92
ICGVSM 85718	37	29	0.86	0.85	50	38	0.85	0.61
Mani Pintar	38	35	1.03	0.68	66	53	0.68	0.47
ICGV SM 86719	42	22	1.01	0.48	61	46	0.58	0.44
Trial Mean	39	28	0.85	0.88	59	42	0.93	0.90
SE	-	-	±0.45	±0.31	± 9	±18	± 0.52	±0.59
CV (%)	14	26	35	24	10	27	37	56

Table 2, Plant stand and seed yield of short-duration varieties, 1989/90 and 1990/91.

	Malkerns				Nhlangano			
	Plant stand (plot^{-1})		Seed yield (t ha-^{1})		Plant stand (plot-^{1})		Seed yield (t ha $^{-1}$)	
Variety	89/90	90/91	89/90	90/91	89/90	90/91	89/90	90/91
ICGV SM 86016	75	53	0.50	0.90	60	50	0.37	0.49
ICGV SM 86105	73	44	0.47	0.69	54	36	0.33	0.48
ICGV SM 86117	71	32	0.43	0.64	62	34	0.54	0.46
ICGV SM 86015	78	22	0.39	0.48	78	42	0.55	0.46
ICGV SM 86063	83	27	0.38	0.73	56	37	0.43	0.65
ICGV SM 86017	78	36	0.36	0.78	60	70	0.53	0.64
ICGV SM 86103	76	37	0.34	0.50	66	34	0.34	0.59
Natal Common	71	32	0.30	0.80	59	53	0.51	0.46
ICGV SM 86092	78	36	0.19	0.72	67	47	0.62	0.72
Trial mean	77	36	0.37	0.69	62	45	0.48	0.55
SE	±9	±11	±0.17	±0.36	±15	±13	±0.23	-
CV (%)	8	22	31	36	17	20	32	32

seasons. ICGV-SM 86063 had a higher plant population than Natal Common or ICGV-SM 86117 at Malkerns in 1989/90. In Nhlangano, ICGV-SM 86015 produced a higher plant population than Natal Common, ICGV-SM 86017, ICGV-SM 86063, ICGV-SM 86105, and ICGV-SM 86016 during 1989/90. Plant stand was low in Nhlangano due to a nutsedge weed problem. In 1990/91, ICGV-SM 86016 had a high plant stand at Nhlangano and Malkerns. Seed yield differences between varieties were significant in both seasons at Malkerns and Nhlangano. ICGV-SM 86092 produced a lower seed yield than ICGV-SM 86063, ICGV-SM 86015, ICGV-SM 86117, ICGV-SM 86105, and ICGV-SM 86016 at Malkerns in 1989/90. During the same season in Nhlangano, ICGV-SM 86092 produced a higher seed yield than ICGV-SM 86105. In 1990/91, ICGV-SM 86016 had a higher seed yield than ICGV-SM 86063 at Malkerns. ICGV-SM 86103, ICGV-SM 86016, and ICGV-SM 86063 will be tested on-farm in 1992/93.

Achievements

1. The National Groundnut Research Programme, which had not functioned since 1972, was re-established, and has been able to conduct multilocation testing. The re-establishment of this program was made possible through the efforts of the SADCC/ICRISAT Groundnut Project.
2. An informal survey on food grain legume crops was conducted in 1991. Farmers' problems with groundnut production were identified.
3. Several groundnut varieties from the Virginia, Spanish, drought-tolerant, and short-duration types have been found promising for adaptation to our climatic conditions. Some of these varieties will be at the prerelease stage during the 1992/93 season.

Future Plans

1. Continue participating fully in the SADCC/ICRISAT Groundnut Project.
2. Conduct a verification survey on groundnuts. It is hoped that the SADCC / ICRISAT Groundnut Project will assist in funding this activity.
3. Start an on-farm research program on groundnuts. However, groundnut seed is more difficult to multiply than beans or cowpeas. Both technical and financial assistance will be necessary.
4. Advise the national program to expand its groundnut research to include cultural practices and other agronomic aspects in addition to varietal screening. There is a need to request additional Government funding since groundnut cultivation is labor-intensive.

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Discussion

Bosch: Could you tell us something about the results of your informal survey conducted in 1991?

Mkhonta: We found that in most cases farmers do not apply fertilizers. Even if they do, the amounts are negligible. Farmers weed twice by hand, and the second weeding is done while ridging. They do not apply any pesticides.

Olorunju: How would you rank the crop in Swaziland: is it a major crop, i.e., among the priority crops?

Mkhonta: Groundnuts are not a major crop. The staple food crop is maize, which covers more than 70% of the cultivated land area. Groundnuts rank below beans and are given little attention. They are more important in certain areas such as the low veld.

A Review of Groundnut Agronomy in Tanzania: Current Status and Existing Gaps

K.P. Sibuga[1], E.M. Kafiriti[2], and F.F. Mwenda[3]

Abstract

This paper examines past and present agronomic research on groundnut in Tanzania. The discussion covers time of sowing and harvesting, seed bed types, plant population, weed management, response to fertilizers, and intercropping. Future strategies for agronomic studies on groundnut are suggested.

Resumo

Revisao agronomica de amendoim na Tanzania: estado actual e lacunas existentes. Este artigo examina o presente e o passado da Investigacao agronomica de amendoim na Tanzania. A discussao abarga epoca de sementeira e colheita, metodos de sementeira, densidade de plantas, controlo das ervas daninhas, adubacao e consorciacao. Estratigias futuras para estudos agronomicos no amendoim sao sugeridas.

Introduction

Groundnut is one of several oilseeds produced in Tanzania, the others being sunflower, sesame, coconut, cottonseed, soybean, and castor. However, edible oil production is dominated by cottonseed and sunflower. Groundnut is mainly used as a food crop and consumed directly (MALD 1989). Groundnut oil processing is therefore only an alternative end use.

Groundnut production is undertaken mainly by smallholders who intercrop it with a cereal (sorghum, millet, maize), a legume (pigeonpea), or cassava.

Although the principal means of groundnut cultivation in Tanzania is the hand hoe, animal power and tractors are also used. In Dodoma (Central zone), 90% of the groundnut area is hand cultivated. The main inputs are labor and seed. Most farmers use no chemical fertilizers, although it is reported that small quantities of TSP are often used and that farmyard manure is applied where draft power is utilized (MALD 1989).

Since the inception of groundnut research in Tanzania in the early 1940s, the main thrust has been on varietal improvement. Research on groundnuts is currently based at Naliendele (National Oilseeds Research Programme) and Morogoro (Pulses and Groundnut Improvement Project, Sokoine University of Agriculture).

This paper reviews past and present agronomic research and highlights the major tasks ahead The groundnut agronomy program has two main objectives.

- To identify the best cultural practices (e.g., spacing, time of sowing, and fertilizer application and maintenance) for different varieties of groundnut.
- To investigate the role of groundnut in local farming practices and to recommend improved practices for groundnut in these systems.

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Time of Sowing and Harvesting

Adverse weather conditions, particularly unreliable rainfall (Nigam 1984, Preston et al. 1985) have long been recognized as partially responsible for the current low average yield of 0.60 t dry pods ha^{-1}, compared with the world average of 0.99 t ha^{-1}. Much of the groundnut-growing area receives an average 500-800 mm rainfall per annum. Since groundnut in Tanzania is grown entirely under rainfed conditions, rainfall intensity and distribution are important factors which can influence sowing dates and yields. Erratic and poorly distributed rainfall resulting in frequent dry spells is common in Tanzania. Rweyemamu and Mushi (1989), reported that drought conditions soon after sowing led to poor crop establishment and reduced yields.

In an experiment to evaluate the performance of seven groundnut lines sown at four different dates at seven-day intervals, Sibuga et al. (1990) reported that the groundnuts sown first received more than 60% of the total rainfall within the first 5 weeks of growth (i.e., up to early pod formation). The pod filling was poor if moisture was limited during the later period of growth. Furthermore, a 21-day delay in sowing reduced seed yields by an average of 52% in one year and 75% in another. Early sowing, which allowed plants to receive most of the rain, was also associated with high leaf area index (LAI).

Trials were conducted at two sites in southern Tanzania during the 1982/83 season to compare the performance of Red Mwitunde (Virginia type, long-duration) and Natal Common (spanish type, short-duration) at five sowing dates. Sowing date effects on seed yield were significant at both sites. The yield of Red Mwitunde fell after the first sowing, whereas that of Natal Common was maintained in the second sowing.

The main conclusions from these trials are that large yield losses can be attributed to delayed sowing and that the effect is more significant with long-duration varieties (Virginia types) than with short-duration varieties (Spanish types).

Timely sowing enables the crop to mature when the weather is favorable for lifting (i.e., at the end of the rainy season). Timely sowing, however, is likely to be a constraint to most farmers due to labor competition between groundnut and other food crops. The farmers' need to sow staple food crops as early as possible in the rainy season implies that timely sowing of groundnut may not get due attention.

Kafiriti (1990), attempting to determine appropriate timing for lifting of groundnuts using Nyota (a short-duration Spanish cultivar lacking seed dormancy) and Red Mwitunde (a long-duration Virginia cultivar with strong seed dormancy) over two seasons and two sites in southern Tanzania, reported that:

- there was a steady decline of seed yield as lifting was delayed, and that the loss in yield was ascribed to factors other than sprouting (e.g., increased attacks from termites, rodents, and crows, especially for the long-duration cultivar); and
- at the maximum period of delay in harvesting (i.e., 28 days after physiological maturity), yield losses for Nyota averaged 24% and for Red Mwitunde 77%.

Regardless of the difference in yield losses, it was concluded that timely harvesting is important for both dormant and nondormant cultivars, particularly under moist conditions which increase both pod rot and incidence of *Aspergillus flavus* with subsequent aflatoxin contamination (Mixon 1980).

Seed Bed Types

Farmers sow groundnuts on flat seedbeds, on the tops of ridges, or on the lower sides of ridges (hereafter referred to as furrows) for various reasons.

Using two Spanish genotypes and three plant populations (333 333-400 000 plants ha^{-1}), at Morogoro, Likango and Tarimo (1986) reported that genotypic response to seedbed type was similar, with both types giving highest yields on the flat seedbed (average 0.72 t ha^{-1}); and that yields from ridge and furrow sowing were comparable (average 0.59 t ha^{-1}).

In a separate study over a 2-year period combining seedbed types (flat, ridge, and furrow) and four spanish genotypes, Rweyemamu and Boma (1990) reported that although seedbed types did not significantly affect seed oil content, the lowest yields were recorded when groundnuts were sown on ridges during the drier year (307 mm) and in furrows during the wetter year (about 23% more rainfall). Yield reduction in the latter was enhanced by a drought spell during the podding and seed-filling stages which reduced podding and seed size. Weiss (1983) contends that ridges enhance soil desiccation while furrows conserve moisture. Results suggest the use of either flat or furrow seedbeds for groundnut production.

Plant Population

Suboptimal plant population is one of the constraints to improving groundnut yields (Bolton 1980, Taylor 1985). In southern Tanzania, Bolton reported higher hields at 40 cm row spacing than with 60 cm spacing. In another study conducted at Morogoro in which row spacing was maintained at 50 cm, Rweyemamu and Mushi (1989) similarly reported a higher yield at 10 cm (200 000 plants ha-') than at 40 cm (50 000 plants ha^{-1}) spacing. In this study, plants formed more pegs and pods and gave higher kernel yields per plant at lower populations. The overall yield advantage at the higher plant populations was apparently a consequence of higher plant stand at harvest.

On the other hand, Government researchers, at Morogoro in the mid-1980s reported highest seed yields with a plant population of 400 000 ha^{-1}, as opposed to the current recommendation of 200 000 plants ha^{-1}, regardless of whether sowing was done on flat seedbeds, on ridges, or in furrows. Another Government study at Morogoro in 1990 similarly recorded highest seed yields of 1.3 t ha^{-1} at 500 000 plants ha^{-1} (5 x 40 cm). This plant population also gave the highest 100-seed mass on average. In these studies, increases in population were accompanied by decreases in shelling percentage. This finding contradicts the results of Enyi (1977).

When combining plant population with defoliation to duplicate the adverse effects of foliar diseases and insects (Tarimo and Mkesele 1987) within the range of 100 000-440 000 plants ha^{-1}, seed yield increased significantly with increase in plant population. Furthermore, increasing the defoliation intensity (from 0 to 100%, carried out after flowering) within any plant population reduced yield, but the effects were less severe at the higher plant population levels. These workers suggested that plant populations could be manipulated to minimize the adverse effects of insects and diseases.

Trials on plant population in southern Tanzania compared the local variety (mixed runner and spreading bunch) with a spreading bunch (Red Mwitunde) and an upright bunch (Natal Common) at populations from 50 000 to 250 000 plants ha-'. Results from two seasons (1981/82 and 1982/83) showed highly significant differences between varieties, and while the overall response to population was small, there were significant differences between varietal responses. As population increased, the yield of the local variety declined slightly, the yield of Red Mwitunde remained constant, and the yield of Natal Common increased linearly. The main conclusions from these trials are twofold.

- High populations are not required for spreading bunch and locals. Optimal results can be obtained from a range of 150 000-200 000 plants ha^{-1}.
- Upright bunch varieties need high populations from 200 000 plants ha^{-1} for optimum results.

Due to the high price of seed, however it is likely that smallholders would prefer lower plant densities to obtain maximum yield per ha.

Weed Management

Groundnut farmers use the hand hoe for most land operations, including weed control. However, the subterranean nature of pods makes groundnut weeding a delicate and labor-intensive activity, often leading to suboptimal weed control. In Tanzania, little work has been done on weed management, even though studies from other areas (Omran 1961, Drennan and Jennings 1977) indicate yield losses due to weeds as a major problem for small farmers.

In a field experiment over 2 years at Morogoro using three Spanish genotypes, Sibuga et al. (1989) reported that lengthening the period of weed infestation (predominantly broadleaf type-- 69% and 83% in the 2 study years) increased weed dry mass at the expense of seed yield. Genotypes did not exhibit any significant difference in weed suppression, but weeding within the first 6 weeks-either once at 4 weeks after emergence (WAE) or once at 6 WAE, or twice at 2 WAE and 4 WAE-had no deleterious effects on yield and resulted in very little subsequent weed growth. On the other hand, weed infestation beyond the first 6 weeks reduced yields significantly (by 46-55%) in the 2 years of study. In one of the years when moisture was most limiting, weeds thrived better than groundnuts, manifesting their greater efficiency than groundnuts in utilizing resources.

Response to Fertilizers

Fertilizers are rarely used by groundnut farmers in Tanzania, partly because the crop is regarded as a second or third crop when allocating resources, and also because groundnuts seem to thrive better than many other crops without fertilization. In addition, there is a lack of information on appropriate nutrient requirements under Tanzanian conditions.

Based on results from the work of Taylor (1985) in southern Tanzania, good response of groundnuts to phosphorus (P) fertilizer was obtained with up to 22 kg P ha^{-1}, a slight response to farmyard manure, and no significant evidence of response to Ca. At Morogoro in 1990, researchers recorded seed yield increases following the application of P either as triple superphosphate (TSP-20% P) or as Minjingu rock phosphate (MRP--14.8% P). The application of MRP at 75 kg P_2O_5 resulted in yield levels and oil content of seed, comparable to the application of 50 kg P_2O_5 as TSP. Based on these results, these workers suggested a replacement of TSP by MRP in areas with acidic soils, low available P, and low exchangeable calcium (Ca). MRP undergoes considerable dissolution in acidic soils, thus releasing both P and Ca, which constitute the greatest proportion of elements in the rock (Mnkeni et al. 1989).

Intercropping Studies

Intercropping research has been sporadic in the past. However, evidence now exists for yield advantages of intercropping groundnut with several crops. In the late 1950s and early 1960s, trials conducted at Ilonga and other places showed good yield advantages for intercropping systems compared with sole crops when groundnut was grown with maize, sorghum, cassava, or castor.

For example, Evans (1960) obtained yield advantages ranging from 9 to 54% from five groundnut/maize intercropping experiments conducted at two locations during 1957 and 1958. In 1980/81, studies involving a single row arrangement experiment with groundnut/sorghum intercropping showed significant advantage (an average of 43% over sole crop), but a significant yield disadvantage involving groundnut/maize (-9%). In 1981/82 and 1982/83, three groundnut genotypes at two densities and two sowing dates were intercropped in alternate 50-cm rows with cassava at Nalien dele Research Institute. Sole crop plots were not included, but results indicated that cassava yields were not affected by intercropping; groundnut could therefore be considered to be a bonus to cassava yields. However, Government officials reported that when early-sown groundnuts were intercropped with late-planted cassava, the yield of groundnuts was seriously affected, but the yields of cassava were reduced to less than 20% of the sote crop.

At Morogoro, Rwamugira and Massawe (1990) compared single alternate rows of groundnut and maize (1:1) and single rows of maize alternating with paired groundnut rows (1:2) to sole crops. They reported that yields of maize and groundnuts were reduced by this intercropping system. For maize, the significant yield reduction in sole cropping (6.2 t ha^{-1}) to intercropping (4.2 t ha^{-1}) was attributed to reduced plant population in the latter, since other yield components (cobs $plant^{-1}$ and 100 seed-mass) were not affected. For groundnut, the main crop in the study, the yields of four genotypes were not significantly different, although yield was reduced in one of them (Natal Common) by 59% in single alternate rows and 43% in paired alternate rows. This suggests differential performance under intercropping. However, all intercropping combinations gave an LER greater than 1, indicating enhanced productivity in this system and that paired alternate rows gave a higher average advantage (29%) than single alternate rows (5%).

Studies at three sites in southern and eastern Tanzania in 1991 similarly indicated that the 1:2 (sorghum:groundnut) combination was more productive. At each site, the short-duration variety (Nyota) consistently gave the highest level of yield advantage (up to 62%) compared with the long-duration (Red Mwitunde), which only attained a 4% yield advantage.

In combination with cassava, results thus far obtained are inconsistent (Kafiriti 1991), with the short-duration genotypes giving higher intercropping advantage in one season and the long-duration genotypes in another.

Conclusion

Results available so far indicate that although some work has been done on various aspects of groundnut agronomy, many of the results are only available in annual reports with limited circulation and accessibility. The need for more coordination is evident in order to identify and prioritize the missing links. Such a strategy could ensure that each of the identified problems is given due attention and researched conclusively.

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Discussion

Chiteka: You have identified two key problems in Tanzania as low rainfall and poor distribution. You have also stated that optimal plant population is about 200 000 plants ha^{-1}. Your experiments indicated that populations of 500 000 plants ha^{-1} would give higher yields. Given the unreliability of rainfall, however, it seems unlikely that such a high population would be feasible for smallholder farmers. You have said that a future research need is to develop cultivars tolerant of drought, and then to determine the mechanisms that provide drought tolerance in those cultivars. Research has shown that no single criterion can be employed to determine or identify drought-resistant materials in the field. How do you propose to solve this problem?

Sibuga: We plan to follow the example of similar research at ICRISAT Center. Dr Nageswara Rao, could you summarize this work?

Nageswara Rao: At ICRISAT Center, the investigation of mechanisms of drought tolerance has received serious attention for several years. We have developed screening techniques to identify genotypes with greater water use efficiency using either carbon-isotope discrimination or leaf thickness techniques. We plan to use the models presented at this workshop by Dr Williams to estimate growth rates and partitioning of dry matter to pods to select genotypes with greater partitioning efficiency. Apart from water use efficiency, we also are making efforts to identify genotypes with efficient root systems and ability to recover rapidly under intermittent drought conditions.

Ndunguru: Was the Minjinju Rock Phosphate partially acidulated or naturally occuring?

Sibuga: Naturally occuring.

Adungna Wakjira: It is difficult to advise a farmer on series of cultural practices to obtain higher yields. Have you conducted studies to determine yield-limiting factors or the relative contributions of cultural practices to yield?

Adungna Wakjira: It is difficult to advise a farmer on series of cultural practices to obtain higher yields. Have you conducted studies to determine yield-limiting factors or the relative contributions of cultural practices to yield?

Sibuga: What we have presented is the ideal scenario for achieving maximum yields. Rarely can farmers follow all the recommendations. Also, we have not done any specific studies to determine yield losses if the package of recommendations is not fully implemented. It is therefore difficult to quantify the contribution of each cultural practice to total yield. Such trials require controlled conditions to obtain meaningful results.

Nageswara Rao: I wish to know about the commercial importance of groundnuts in Tanzania. The true value of inputs (such as the high seed rate recommended by some researchers) to increase yield depend on the cash value returned to farmers.

Sibuga: In Tanzania, because groundnuts are grown on only about 5% of the total area under food crops, they are not as important as crops like coffee or cotton. However, the price of groundnut in the unofficial market can be as high as twice that of maize. Therefore, even though groundnut is not cultivated as a commercial crop for export, it is widely used at the household level either in cooking or as confectionery. Its market value is thus assured; furthermore, the high unofficial price makes groundnut production attractive.

Groundnut Production and Research in Zambia

M.B. Syamasonta[1]

Abstract

The importance of groundnut (Arachis hypogaea L.) in Zambia; research results of Zambia's national groundnut improvement program; and the progress made in cultivar development, agronomy, and plant protection during the 1982-92 period are outlined. Future strategies of the national research program are also discussed.

Resumo

Investigaqao e producao de amendoim na Zambia. A importancia de amendoim (Arachis hypogaea L.) para a Zambia. Resultados da investigaqao do programa national da Zambia para o melhoramento de amendoim, progressofeito no desenvolvimento da cultura, agronomia e proteccao das plantas durante o periodo de 1982-92. Sao tratados neste artigo. Estrategias futuras do programa national de investigacao sao descutidos.

Introduction

Groundnut production in Zambia is small by world standards. However, it is an important food crop in both rural and urban areas. It provides cheap plant protein to low-income groups and is a substantial cash earner. Groundnut is also a good crop for rotation with cereals. Above all, it has a potential for export, and could earn the country much needed foreign exchange.

Despite the importance of this crop in Zambia, there are numerous production constraints. As a result of these constraints, low yields are obtained from year to year. Hence, research work on groundnut is designed to address these problems in order to maximize plant productivity and production in general.

Production and Adaptation

Although accurate figures are unavailable, estimates of production during the 1980-88 period indicate that annual production ranges from 9 372 to 116 558 t. About 75% of this production is grown on the central plateau of Eastern Province. The crop consists mainly of the Virginia types belonging to the sub-species hypogaea. Depending upon the length of the rainy season, cultivars and landraces mature in 140-160 days.

In the high-rainfall areas of Northern, Northwestern, and Copperbelt provinces (1100-1400 mm), which have acid leached soils associated with 'pops' problems, local landraces of the Virginia type are grown. Production from these areas contributes about 3% to total annual national production.

Short-duration Spanish types belonging to the subspecies fastigiata that mature in 100-120 days are grown in the drier conditions prevailing in the southern and western part of the country (less than 900 mm rainfall). Although the genotypes grown in these areas have good yields under favorable growing conditions, seed size is small. These provinces contribute about 22% to total annual national production (Sandhu et al. 1988).

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Crop Improvement

A hybridization program was initiated in the 1982/83 season. Single plant selection for desirable characters from the segregating populations was done in the F_5 generation. At this point, a reasonable degree of homozygosity is expected to have been achieved. The selected plants are progeny-tested, and promising lines placed in preliminary yield evaluation trials. Locally bred materials are also supplemented with early-generation single seed bulks from ICRISAT (Malawi and India). Production of breeders' seed for all released genotypes is a regular activity of the program.

Agronomy

Prior to the final release of selected genotypes, both on-farm and on-station evaluations of prereleased genotypes are undertaken. The genotypes are also investigated to determine the most productive spacing and response to different levels of fertilizers and spray regimes of fungicides and insecticides. In addition, intercropping trials including maize, sorghum, cotton, sunflower, and pigeonpea in various intercrop row arrangements are studied.

Pathology

Early leaf spot (Cercospora aruchidicola), late leaf spot (Phaeosariopsis personata), rust *(Puccinia arachiclis),* and rosette are the major foliar diseases affecting groundnut in Zambia. Other disease problems are aflatoxin contamination *(Aspergillus flavus),* aflaroot, and the viral diseases streak necrosis and bud necrosis. Genotypes which show tolerance for the major diseases are further evaluated in a foliar diseases nursery where conditions conducive to spread of the diseases are artificially created by using spreader rows. Promising lines are utilized in the breeding program.

Entomology

Soil insects (termites, white grubs, and wire worms) and sucking pests (aphids and jassids) cause economic damage to groundnut. Experiments are being conducted to determine the extent of the avoidable losses due to these pests. A number of groundnut genotypes have been screened for resistance to sucking and soil pests on both on-station and on-farm locations. Short-term measures for insect control, involving applications of carbofuran, chlorpyriphos, and neem leaf extracts have been explored.

Research Results

Following a 10-year (1982-92) multidisciplinary intensive research project on groundnut, three cultivars-Comet, MGS 2 (M 13), and MGV 4 have been released.

Comet, a Spanish bunch groundnut cultivar was released for growing on the light textured soils of Southern and Western Provinces, which receive scant rains over a short growing season. Maturing in 110-116 days, Comet has high yield potential (1-1.5 t ha^{-l})i thin shells, and attractive small seeds. Comet is susceptible to early leaf spot (Sandhu et al. 1988).

A long-duration Virginia runner cultivar introduced from India, MGS 2 (M 13), was released for medium-rainfall areas. MGS 2 matures in 135-145 days. It has high yield potential (1.5-3.5 t ha^{-1}), acceptable seed qualities, and tolerance for early leaf spot (Sandhu et al. 1988).

MGV 4, another Virginia bunch cultivar, selected by the SADCC / ICRISAT Groundnut Project, was released for use in the medium-rainfall areas. So far, this cultivar has shown the highest yield potential in Zambia (2.5-3.5 t ha^{-1}), and is well adapted to stress conditions. It matures within 125-135 days and has thin shells and large attractive seeds.

MGS 3, another Virginia bunch type, was selected by Zimbabwe's groundnut improvement program and is in the prerelease stage, undergoing on-farm testing. It is doing well in Eastern and Central Provinces (Syamasonta 1990).

Results from the on-farm trials showed that the three new cultivars (MGS 2, MGV 4, and MGS 3) have significantly outyielded Chalimbana by 20-30% under farmers' conditions. The most productive spacing for the 3 cultivars was 75 cm between rows and 10 cm within rows.

Sowing of MGS 2 on 24 November (compared with the usual sowing date of 8 December) resulted in a 38% yield gain, while sowing the same cultivar on 22 December resulted in a 24% yield reduction. One-hand weeding at 45 days after sowing (DAS) increased seed yield by 9%, while two weedings at 20 and 45 DAS increased seed yield by 25% over no weeding.

Intercropping of maize with groundnut offered an advantage of 20% seed yield over sole cropping. This system required only 50% the labor of sole cropping both crops (Reddy et al. 1988).

Development of cultivars resistant to leaf spots is a long-term, economical way to control these diseases. Screening for leaf spot resistance resulted in the identification of SAC 58, Gambia Bunch, C 177/5/1, ICGMS 54, ICG 7884, and ICG 2271 as tolerant of early leaf spot. Gambia Bunch D had high yield potential and could be released to farmers. However, the rest had poor seed characteristics and are being used as parents in the hybridization program.

Experiments on short-term control measures have yielded interesting results. For example, one application of cither Labilite (3 g L^{-1} water), Bravo (3 mL L^{-1} water), or Benlate (0.5 kg L^{-1} water) effectively controlled leaf spots. The sprays should be applied at 75 DAS. These fungicide sprays resulted in 20% seed yield increases (Kannaiyan and Haciwa 1990).

Groundnut genotypes ICG 2271, ICG 2306, ICG 5041, ICG 5045, and ICG 7237 have been found resistant to most groundnut pests, including leaf hoppers (Sithanantham et al. 1990).

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Discussion

Chiteka: You staled that groundnuts intercropped with maize yielded 20% more than the same variety grown as a sole crop. How do you explain this?

Syamasonta: This may depend on the spacing between rows of groundnut and maize. A full explanation may be possible after further experimentation.

Freire: In Mozambique, we got similar results with groundnut/maize intercropping during the 1990/91 season, with groundnut yielding more intercropped with maize than as a sole crop. However, the results seem to be quite unpredictable, and probably depend on the quantity and distribution of the groundnut component.

Nyirenda: If Chalimbana grown in the intercrop with maize gave higher yield than that variety as a sole crop, I would like to know the actual yields of groundnut in both cropping systems. Also, what was the yield of maize in each cropping system?

Syamasonta: The data of this particular trial will be sent to you in due course.

Schmidt: The fact that groundnut yields were increased by 20% in the intercrop over sole cultivation is interesting. Did groundnut plants replace maize plants or were they added to the maize population?

Kanenga: We sowed alternating rows of maize and groundnut.

Schmidt: Normally, maize competes strongly with groundnut. The result is increased maize and decreased groundnut yield,

Kafiriti: What was the distance between rows of the same crop?

Kanenga: Seventy-five cm.

Sttbrahmanyam: What are the future plans for chemical control of leaf spots in Zambia? Do you have any conclusion from the work on the number of fungicide applications?

Syamasonta: The future plan concerning chemical control of leaf spots is to conduct experiments in farmers' fields. Right now little work is done outside the research stations. The spray regime trial is in progress, but this season's results may not be representative due to drought.

Agronomy Research on Groundnut in Zimbabwe: A Review

B. Mpofu[1]

Abstract

This paper discusses the agronomic constraints limiting groundnut production in Zimbabwe. It reviews past agronomy research aimed at improving yields and outlines the country's future research trends.

Resumo

Investigacao agronomic a de amendoim em Zambia: revisao. Este artigo descute os principals factores agronomicos que tern limitado a producao de amendoim na Zambia. Faz revisdo a investigacao agronomica anterior com vista a aumentar os rendimentos e definir os futuros trilhos de investigacao no pais.

Introduction

In Zimbabwe, groundnuts are grown by commercial and communal area farmers. Between 1956 and 1976, sales from communal areas to the Grain Marketing Board averaged 19 000 t shelled nuts $year^{-1}$ (Shumba 1983). Between 1977 and 1985, the area sown to groundnuts in the commual sector declined 51% while productivity dropped 45% (Dendere 1987). In 1989, sales from this sector totalled 1700 t. This diminishing groundnut production has contributed to malnutrition in most communal areas.

Production Constraints

Drought is the single most important constraint to groundnut production in Zimbabwe (Chiteka 1985). Another factor is the inherent low fertility of the sandy soils that predominate in most communal areas (Mashiringwani 1983). Lack of draft power results in delayed sowing and reduced yield (Shumba 1983).

Furthermore, groundnut has a higher labor requirement with respect to sowing, weeding, and harvesting than maize, the staple crop, which receives higher priority.

Research

Agronomy research on groundnut conducted in the 1960s and early 1970s formed the basis for the currently recommended cultural practices. Research on plant population, spacing, and early sowing with irrigation were significant contributions to production (Metelerkamp 1967).

Nutrition

Small yield benefits were obtained in a fertility trial by applying 5 t manure. A 21% yield increase was obtained with the application of 46 kg ha^{-1} P_2O_5, and a 27% increase with an application of 200 kg ha^{-1} gypsum. Field trials to investigate the response of groundnuts cultivated at different levels of phosphate and lime to inoculation with various strains or rhizobia did not show any significant yield difference be-

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tween either strains or phosphate levels. However, application of lime at 500-800 kg ha^{-1} significantly increased groundnut yields.

Sowing date trials

Two trials were conducted on farmers' fields to compare the performances of short-season cultivars sown during November and December. The first trial was sown with the first rains and the second 4 weeks later. Delayed sowing reduced yields at all sites and yield was further constrained by drought.

Plant population

A comparison of two plant populations, 250 000 and 350 000 plants ha^{-1} was conducted using short-season cultivars on farms in four different agroecological zones during the 1983/84 and 1984/85 seasons. In both seasons the two populations showed no significant yield differences.

Sowing method

A yield trial was conducted to compare the effect of sowing groundnuts on beds with sowing on flat ground. Results were inconclusive. Another trial compared yields of groundnuts sown in disced land with yields obtained from plowing on clayey soils. Higher yields were obtained from plowed land.

Cropping systems

Groundnut was a component crop in experiments with intercropping and rotational cropping systems. Work was conducted by the Agronomy Institute for five seasons. One trial studied the effect of row proportion and plant density on the productivity of maize/groundnut and sunflower/groundnut intercropping systems. A pattern of one row of maize or sunflower to two rows of groundnut was the most productive, and a population pressure of 133% was found beneficial to the maize/groundnut combination.

In another trial, groundnut yield was reduced by 33% when intercropped with pigeonpea, indicating the need for a higher proportion of groundnut than the 4:1 groundnut:pigeonpea ratio used during the trial* A rotation trial conducted to monitor the productivity of four systems of maize/groundnut over a 4-year period showed that both maize and groundnut benefitted from a simple 2-year rotation.

Weed research

In 1983/84, two trials were conducted to investigate long-term effects of herbicide on groundnut following maize treated with pre-emergence herbicides in sandy soils. In one experiment, groundnuts were sown 1 year after maize. In the second experiment, groundnuts were sown 2 years after maize. The herbicides applied to the maize were atrazine, prometon, and a metolachlonterbuthylazine mixture. These treatments were compared with an untreated control. No significant yield differences were observed between treatments during the three seasons in either experiment.

Further Research Needs

- Further research is needed to provide guidelines for fertilizer application in communal areas. Residual fertility studies warrant detailed investigation as a basis for fertilizer recommendations in rotations that include groundnut.
- Research on *Rhizobium* inoculation must be continued.
- The possibility of sowing groundnut on minimally tilled land should be investigated. Reduced tillage would reduce demand for draft power.
- Since reduced tillage is associated with heavy weed infestation, herbicide research aimed at minimizing the cost of application (e.g., broadcasting granular herbicides) is recommended.
- Studies on labor-saving implements are needed. The Farming Systems Research Unit must continue to adapt, develop, and test production technologies and systems generated by the various institutes involved in groundnut agronomy research.

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Discussion

Williams: ICRISAT had a rhizobium program which we terminated because, with one exception, we found no positive responses that transferred from the glasshouse to the field. This lack of transferability was due to the fact that fixation per unit light was no different under a range of circumstances. In field conditions, total radiation was the limiting factor. The one exception was the case of Nc 92 rhizobium which gave very good yield response on an alkaline Vertisol. The bacteria apparently worked by modifying iron nutrition rather than nitrogen fixation.

Freire: 1. What are the yields of groundnut in communal areas? 2. What is your view of the economics of herbicide technology related to the high risk, low yield cropping systems of the communal areas? 3. We also undertook rhizobium research with negative results.

Mpofu: 1. Less than 1 t. 2. At the moment, we are encouraging farmers to use herbicides for maize, which they consider more important than groundnut. This should release labor for weeding groundnuts. 3. Initially, several trials were conducted in pots under glasshouse conditions and positive results were obtained.

Singa: What implements were used that led to the conclusion that reduced tillage required less draft power? What were the draft power requirement differences between full and reduced tillage?

Mpofu: Work on reduced tillage in groundnuts has not yet been initiated. In maize production, where reduced tillage is fairly widely practiced, farmers use herbicides to kill weeds, then open a furrow with a tine before sowing.

Location-Specific Research

Yield and Quality of Groundnut Hay from a Commercial Crop in Zimbabwe

Z.A. Chiteka[1]

Abstract

Three long-duration groundnut cultivars were grown in two tests during the 1989/90 and 1990/91 seasons to determine the yield and quality of hay. Hay yields ranged from 4.6 to 6.8 t ha^{-1} and percentage of crude protein (CP) ranged from 9.8 to 20.3%. Yield and quality of hay harvested declined from a maximum at 120-160 days after sowing (DAS). Harvesting at about 150 DAS maximized pod yield with an acceptable CP percentage.

Resumo

Rendimento e qualidade do feno dos restolhos da cultura de amendoim de cultivares comerciais de longo ciclo, no Highueld em Zambia. Tres cultivares de amendoim de longo ciclo foram testadas na campanha agricola de 1989/90 e 1990/91 para determinar o seu rendimento e qualidade do feno. O rendimento do feno oxilou de 4.6 a 6.8 t ha^{-1} e a percentagem de proteina bruta oxilou entre 9.8 a 20.3%. O rendimento e a qualidade do feno baixou ao maximo entre 120-160 dias depots da sementeira. Colheita aos 150 dias depots da sementeira deu um rendimento mdximo de vagens com uma percentagem aceitavel de proteina bruta.

Introduction

Groundnut is widely grown in Zimbabwe (Hildebrand 1980, Chiteka 1984). The crop is a rich source of oil (46-63%) and CP ranges from 25 to 30% (Knauft et al. 1987). Groundnuts are an important food as well as a cash crop with surplus produce marketed to generate foreign exchange. Groundnut tops are used as an important stockfeed in Zimbabwe.

During the dry months (May-October), grass is unpalatable and very low in protein. This reduces the feed intake and results in a loss of body weight. Supplementary feeding is therefore necessary during this period to prevent loss of body weight in ruminants raised largely on veld. The loss of body weight reduces fertility and conception rates, thereby reducing animal productivity.

Although groundnut is primarily grown for grain in Zimbabwe, substantial amounts of high-quality hay can be also be obtained from the crop. The area sown to groundnuts in communal areas of Zimbabwe is estimated at 180 000 ha. This could provide a cheap source of protein which could be used for supplementary feeding of cattle. The quality and quantity of hay harvested from a commercial crop depends on the timeliness of harvesting and the method of curing of the hay. The objectives of the research reported here were:

- to quantify the yield of groundnut tops obtained from a long-season groundnut crop; and
- to determine the crude protein level of the groundnut tops obtained at the time of lifting.

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Chiteka, Z.A. 1992. Yield and quality of groundnut hay from a commercial crop in Zimbabwe. Pages 63-65 *in* Proceedings of the Fifth Regional Groundnut Workshop for Southern Africa, 9-12 Mar 1992, Lilongwe, Malawi (Nageswara Rao, R.C., and Subrahmanyam, P., eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics,

Materials and Methods

Three long-season commercial cultivars, Flamingo, Makulu Red and Egret, were grown during the 1989/90 and 1990/91 seasons at Harare Research Station. The trials were sown on 18 Oct 1989 and 15 Oct 1990. Standard cultural practices were followed but the crop was not sprayed to control leafspot diseases. Supplementary irrigation was applied to ensure an adequate moisture supply throughout the growing period. In both seasons, randomized complete block design was used, each with four replicates.

Each plot consisted of 20 rows spaced at 45 cm and seeds spaced at 15 cm within the rows. At 9-day intervals, starting from 120 DAS, one plot consisting of two rows 240 cm long was harvested in the traditional way and both the pods and hay were air-dried to 10% moisture. The mass of hay and pods was determined in each case. A sample of hay was drawn from each plot for determination of the CP using the Keldhal Method.

Results and Discussion

There were no significant differences in hay yield among cultivars at all harvest dates at Harare Research Station (Table 1). The mass of hay harvested from 120 to 140 days generally increased, and after 140 days hay yield decreased. This is largely due to translocation of nutrients to the pods and the rapid loss of foliage due to foliar diseases. Since the primary objective of cultivating the crop is for improved seed yield, it is not desirable to lift the crop before 140 DAS as this results in reduced seed yields.

Table 1. Yield of hay in t ha[1] for three groundnut cultivars harvested at five different stages during the 1989/90 season at Harare Research Station.

	Harvest date (DAS)				
Cultivar	120	132	141	150	160
Flamingo	6.1	6.4	6.6	3.2	5.3
Makulu Red	5.4	5.6	6.5	5.7	4.7
Egret	5.5	6.3	6.5	5.7	5.2
Mean	5.7	6.1	6.5	5.9	5.0
SE	±0.5	±0.2	± 0.7	± 0.5	± 0.2
CV (%)	17.9	7.8	23.0	7.8	17.0

The mean CP percentage dropped from 19.7% at 120 DAS to 11.0% at 160 DAS (Table 2). This is also due to the loss of leaves since foliage carries a higher CP percentage than the stems. Harvesting at about 150 DAS would achieve both high seed yield and acceptable quality. The timing of harvesting depends on altitude, season quality, and the incidence of defoliation on the crop.

Table 2. CP percentage in hay for three long-duration groundnut cultivars harvested at five different dates during the 1989/90 season at Harare Research Station.

	Harvest date (DAS)				
Cultivar	120	132	141	150	160
Flamingo	19.4	18.4	14.8	14.0	12.6
Makulu Red	19.4	18.4	13.6	13.7	9.8
Egret	20,3	18.0	15.6	14.3	13.0
Mean	19.7	18.3	14.7	14.0	11.8
SE	±0.4	±0.6	±0.7	±0.6	±0.9
CV (%)	4.3	7.1	9.2	8.2	14.9

Pod yield increased from 4.9 t ha^{-1} at 120 DAS to 5.41 ha^{-1} at 140 DAS (Table 3). There were no significant differences *(P < 0.05)* in pod yield among cultivars at all harvest dates. All varieties had similar pod yield at harvest time.

Table 3. Pod yield (t ha^{-1}) for three groundnut cultivars harvested at three different dates during the 1990/91 season at Harare Research Station.

	Harvest date (DAS)		
Cultivar	120	140	150
Flamingo	3.7	4.6	4.3
Makulu Red	5.4	6.3	4.5
Egret	5.7	5.6	5.1
Mean	4.9	5.4	4.6
SE	±0.4	±0.4	±0.7
CV (%)	16.7	15.5	26.5

Conclusion

Yield of groundnut hay of up to 5 t ha^{-1} can be achieved when the crop is lifted at the right time. Delayed harvesting causes a reduction in harvestable hay yield after physiological maturity. CP levels of 12% or higher can be achieved at harvest time. CP of the harvestable hay also decreases with delayed harvesting.

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Discussion

Sibuga: The use of groundnut hay for animal feed could lead to problems due to pesticide residue.

McDonald: Problems could be especially significant if fungicides such as triphenyl are used. For most commonly used fungicides, a period of 3-4 weeks after the last spray is sufficient for decomposition of active ingredients. This is particularly the case when rain falls after the last spray is given.

Sibuga: You informed us that you did not spray your experiments with pesticides. But the commercial farmers do. To make the study complete, you should include fungicide spraying and then determine residues in the hay so that the farmers can be assured of the safety of their animals, which are eventually consumed by people.

McDonald: Chemicals like chlorothalonil do not have much residual effect.

Subrahmanyam: Mancozeb, chlorothalonil, and benomyl break down rapidly and there is no danger of any mammalian toxicity if there is enough time between harvest and feeding.

Schmidt: What kind of storage do you propose for groundnut hay? In Malawi haulms are destroyed completely by termites within 2 weeks if left on the soil surface.

Chiteka: Farmers using groundnut hay for their animals do not leave it in the field. They generally collect it as soon as possible and keep it in bundles or in piles under some form of shelter.

Freire: 1. What is the quality of the pods at 120 days if the pod yield is reasonably high? 2. Is there an earlier harvesting time with lower pod/seed yield and higher hay yield that can have better economics than the harvesting of grain alone?

Chiteka: 1. At 120 days the pods are not yet filled and shelling percentage is very low. This would not be the appropriate time to harvest long-duration groundnuts because the seeds are small, irregular, and shrivelled. 2. We have not harvested earlier in our experiments, but I would expect the hay yield to be higher than that reported in this research. There would invariably be a very low pod and seed yield at that date of harvesting.

Nageswara **Rao:** I am told that the commercial yield of groundnut in Zimbabwe is about 10 t ha^{-1} and that groundnut farmers have 10-t clubs. The yield data you have presented, however, shows that the commercial yields ranged from 4 to 5 t. How do you explain this?

Chiteka: The yields reported in the range of 9 t ha^{-1} in 1980 were from one specific area where record yields were achieved. The average farmer's yield is 5-7 t ha^{-1} of pods; but some farmers, using very high management, can achieve yields of over 8 t ha^{-1} of pods.

"Pops" Screeing in Groundnut

M.B. Syamasonta[1]

Abstract

One hundred eighty groundnut genotypes were screened for acid soil tolerance at Misamfu Regional Research Station, Zambia. Results of two seasons showed significant differences among test entries for seed yield, shelling percentage, and "pops" percentage. Coefficients of variation were 19.6% for "pops" percentage, 34.9% for shelling percentage, and 703% for seed yield. "Pops" percentage was negatively and significantly correlated to seed yield, shelling, and 100-seed mass, while seed yield was positively and significantly correlated to 100-seed mass and number of pods per plant. Broad sense heritability estimates were moderate for seed yield (43%), 100 seed-mass (40%), and number of pods per plant (35%). However, the broad sense heritability estimates were low for "pops" percentage (7%) and shelling percentage (9%).

Resumo

Observaqoes e avaliqao sobre estampido de vagens de amendoim (Vagens mal preenchidas). Cento e oito genotipos de amendoim foram testados d tolerancia a accidez na Estaqad de investigacao regional de Misamfu. Resultados das duas epocas demostraram diferenqas significativas a produqao de sementes, percentagem de casca e percentagem de estampido de vagens mal preenchidas em todos os testes reializados. O coeficiente de variacao foi moderado a alto para a percentagem de estampido com (19.6%) a percentagem de casca foi (34.9%), e a produqao de sementes (17.3%). A percentagem de estampido de vagens foi negativamente e significativamente corelacionada para produqao de sementes, casca para o peso de 100 sementes e o numero de vagens por planta. O sentido amplo da heritabilidade estimada foi moderada para a produqao de semente com (43%), para a produqao de 100 sementes (40%) e para o numero de vagens por planta (35%). Com tudo o sentido amplo de heritabilidade estimada foi baixo para a percentagem de estampido (7%) e percentagem de casca com (9%).

Introduction

In the high rainfall areas of Zambia, groundnut is a common crop in village gardens. It is an important food crop, particularly for subsistance farmers. Large-seeded varieties with relatively low oil content and pink testa color are desirable. The crop is often consumed after being cooked in shells, and Zambians prefer a floury consistency to a hard and oily one. Roasting plays a secondary role, while the surplus is sold at local markets.

Soils in the region are highly leached due to heavy rains (900-1500 mm $year^{-1}$), resulting in soil Ca deficiency and acidity. On such acid soils, groundnut requires Ca application to give high quality nuts and maximum seed yield (Walker and Kersling 1978). Severe Ca deficiency in the soil results in seed abortion, commonly known as "pops'*, while moderate

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deficiency results in poor seed filling, reducing germination capacity (Cox and Reid 1964, Sullivan et al. 1974).

While the application of gypsum has often given erratic results under Zambian conditions, the application of lime has consistently given positive results and is consequently recommended. Despite this recommendation, the farmers who live in the "pops"-prone areas are unable to obtain lime due to its scarcity, high price, and transportation problems.

The objective of this study was therefore to screen groundnut genotypes for tolerance for "pops" formation. Selected cultivars should have acceptable agronomic and seed characteristics. Such cultivars would give reasonable seed yield on leached soils without liming.

Materials and Methods

During the 1988/89 cropping season, a "pops" screening groundnut experiment was conducted at Misamfu Regional Research Station. The experiment included 180 groundnut genotypes with varied phenology, involving both local and exotic material. The trial, sown on 15 Dec 1988, was conducted as a randomized complete block design (RCBD) with three replications/Seeds were sown 10 cm apart on ridges prepared at 75-cm intervals. The pH of the soil at the trial site was 4.5 at sowing.

In 1989/90, 58 entries selected from the previous year for their low "pops" percentage and high yield potential were evaluated on the same site. An RCBD with three replications was again used. Soil pH was 4.2 and the trial was sown on 5 Dec 1989. In both seasons, data on yield and yield components were recorded.

Results and Discussion

There were significant differences among genotypes for seed yield and shelling percentage in both years. Low yields were observed in the second year. Significant seedling mortality occurred within 3 weeks after sowing. The low shelling percentage (mean = 27%) and the high "pops" percentage (mean = 72%) were the main effects of soil acidity in the second year (Table 1). Sarmezey (1978) reported similar results.

Table 1. Performance of selected groundnut genotypes on acid soils, Misamfu Regional Research Station, 1988/89 and 1988/90 seasons.

	Seed yield (t ha"[1])		Shelling percentage		"Pops" (%)	
Cultivar	1988/89	1989/90	88/89	89/90	88/89	89/90
Comet	0.52	0.58	65	51	49	44
C 16/10/11	0.53	0.54	50	41	62	60
ICG-1152	0.82	0.48	70	67	8	48
ICG 9096	0.58	0.42	55	39	43	72
ICG 3243	0.57	0.40	54	55	86	30
ICG 9097	0.55	0.37	60	41	36	48
ICG 777	0.55	0.34	70	37	26	42
ICGMS 36	0.53	0.33	40	36	65	78
Gambia Bunch D	0.51	0.33	42	36	63	78
Ch. 83/74	0.48	0.31	58	27	56	74
Robut 33-1	0.50	0.29	36	43	79	34
ICGV-SM 86068	0.43	0.27	28	31	80	48
Makulu Brown[1]	0.23	0.11	43	41	212	60
Copperbelt runner (C)	0.16	0.16	44	27	46	92
Mean[2]	0.39	0.18	41.6	27.4	63.6	71.5
SE	±0.02	±0.02	±3.8	±5.8	± 5.2	± 8.1
CV (%)	10.6	70.3	15.7	34.9	7.3	19.6

1. Control.
2. Means are for 180 entries for 1988/89 and 58 entries for 1989/90.

Table 2. Correlation coefficients among yield components of groundnut cultlvars grown on acid soils.

	Seed yield	"Pops" (%)	Shelling percentage	100-seed mass	No. pods plant'[1]
Seed yield	1.00	-0.57*	0.67*	0.40*	0.56*
"Pops" (%)	-	1.00	-0.77*	-0.58*	0.18
Shelling percentage	-	-	1.00	0.29	-0.74*
100-seed mass	-	-	-	LOO	-0.35
No. pods plant $^{-1}$	-	-	-	-	1.00

* *P* < 0.05.

Variation among genotypes for yield was particularly pronounced during the first year at Misamfu. Positive and significant correlations were observed between seed yield and 100-seed mass and between seed yield and number of pods per plant (Table 2). These results confirmed previous observations that yield is reduced when "pops" incidence increases, while the number of pods per plant increases or remains unchanged. The findings of previous researchers (Chiow et al. 1983, Dholoria et al. 1972, Coffelt and Hammond 1974, and Lin 1954) are also corroborated by the results.

Broad sense heritability estimates were moderate for seed yield (43%), 100-seed mass (40%), and number of pods per plant (35%). However, low estimates were obtained for "pops" (7%) and shelling percentage (9%).

Conclusions

- Environmental factors play a more important role in "pops" formation than do genetic factors as indicated by low heritability for "pops" percentage. Selection for "pops" tolerance will require many cycles and large populations.
- The screening method resulted in the identification of entry ICG 1152 as having a reasonable level of tolerance for "pops" formation. This genotype has also shown high yield potential (0.5-0.8 t ha^{-1} without fertilizer).
- Further studies on this subject should include physiology, genetics, and nutrition.

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Discussion

Nigam: 1. You said that when a plant 'realizes' it has empty pods, it produces more pods-so what is your problem? The plant is already trying to solve its own problem. 2. Why should the negative correlation between "pops" percentage and seed yield worry you? This only means that by selecting for high seed yield, you can reduce "pops" percentage. 3, The low heritability for "pops'' percentage is due to variation in soil pH in the field. If you improve the uniformity of low soil pH, the h^2 estimates will increase.

Syamasonta: 1. What worries me here is that the formed pods may be empty. 2. The negative correlation does not worry me because selecting for high yield would lower "pops" percentage. 3. I agree with you, but this subject requires further study.

Williams: Would you care to comment on the difference in your results and those that I presented in my paper? I suggested that some simple considerations such as pod size and dispersal may be effective.

Syamasonta: The fact that small-seeded cultivars are more tolerant to "pops" formation is well documented, but farmers prefer medium to large nuts. The dispersal of pods in runner types will be further investigated.

Olorunju: What components did you use to calculate your h^2 estimates?

Syamasonta: Broad sense heritability estimates were calculated from components of variance.

Regional Screening of Groundnut Germplasm for Late Leaf Spot and Rust Resistance in Swaziland

D.M. Earnshaw and Y.P. Rao[1]

Abstract

During 1990 / 91, 22 groundnut germplasm lines were tested for late leaf spot resistance, and an equal number of lines were tested for rust resistance in Swaziland under a regional cooperative program. Nineteen of the 22 lines tested for late leaf spot resistance reacted as susceptible to highly susceptible, the disease scores ranging from 6 to 9. However, entries NC Ac 17132, PI 476164, and PI 476168 showed some tolerencefor late leaf spot. Screening for rust resistance was inconclusive because of interference from late leaf spot, a much faster spreading disease under the prevailing conditions. It is suggested that in all future screening programs, attempts be made to avoid undesired disease problems.

Resumo

ObservaqoeSy avaliaqao da resistencia de germoplasma de amendoim a mancha da folha e ferrugem na Swaziland. Em 1990 / 92, 22 linhas de germoplasma de amendoim foram testadas sobre a resistencia a mancha da folha e simultaneamente um numero igual de linlias da mesma foi testada sobre a resistencia a ferrugem na Swaziland. Dezanove das 22 linlias testadas sobre resistencia a mancha tardia da folha reagiram como susceptiveis a altamente susceptiveis o registo da doenca oxilou de 6 a 9 - Porem, NCAC 17132, PI 476164 e PI 476168 mostraram uma certa tolerancia a. mancha tardia da folha. Observacoes a resistencia a ferrugem foram inclusos por causa da interferencia da mancha tardia da folha, uma doenga que se espalha rapidamente nas condicoes prevalescentes. Sugere se que em todos os programas de avaliaqao no futuro tentativas devem serfeitas para evitar o problema indesejado.

Introduction

Swaziland was chosen for regional screening of groundnut germplasm for resistance to late leaf spot *(Phaeoisariopsis personata)* and rust *(Puccinia arachidis).* Results of the 1989/90 screening were presented at the Second Regional Groundnut Plant Protection Group Tour in February-March 1991. In 1990/91, 22 lines were tested for late leaf spot resistance and an equal number for rust resistance. The results obtained are reported in this paper.

Experimental Details

Two rows for each test line, each row 4 m long, were sown at spacings of 45 cm between rows and 10 cm within rows. After each test line, a row of Natal Common was sown as a disease spreader. The spreader row was sown 2 weeks prior to sowing the test lines. Malimba was sown as a local control. The plot received a compound NPK fertilizer 2:3:2(22) at 0.30 t ha-^{1}. Weeding was done regularly. The season (November to April) recorded a total rainfall of over 1000

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mm, most of it falling between December and March. Using a modified ICRISAT 9-point field disease scale, late leaf spot and rust intensities were recorded at maximum disease development-approximately 2 weeks prior to harvesting. Other diseases of importance were also recorded. Crop protection measures included one spraying with dimethoate at (3 mL L^{-1} water concentration) to control a severe attack of thrips.

Results

In the late leaf spot experiment, 19 of the 22 lines tested gave scores ranging from 6 to 9 (Table 1). Only 3 lines, NC Ac 17132, PI 476164, and PI 476168, showed tolerance for the disease. Most of the lines also developed moderate levels of early leaf spot (Cercospora arachidicola) and a low intensity of rust (Pseudomonas solanacearum). Isolated cases of bacterial wilt were also recorded in some lines (EC 76446 (292), PI 350680, PI 259747, PI 270806, PI 341879, and PI 405132). With regard to rust screening, the disease scores obtained were generally very low (Table 2). Late leaf spot was, however, the most dominant disease in this experiment as well, severely affecting almost all lines.

Conclusions

Seasons with total rainfall of over 1000 mm and an average maximum temperature of 26.9'C and a mini-

Table 1. Screening of groundnut germplasm for resistance to late leaf spot disease.

		Disease scores[1]		
Germplasm entry	Identity	Late leaf spot	Early leaf spot	Rust
ICG 1707	NC Ac 17132	4	3	1
ICG 1710	NC Ac 17135	7	3	1
ICG 2716	EC 76446 (292)	6	4	1
ICG 4747	PI 259747	8	3	1
ICG 6022	NC Ac 927	7	4	1
ICG 6330	PI 270806	9	4	1
ICG 6340	PI 350806	7	4	1
ICG 7013	NC Ac 17133 - RF	6	3	1
ICG 7621	NC.Ac 17718	8	4	2
ICG 7881	PI 215696	7	3	1
ICG 7884	PI 341879	6	4	1
ICG 7888	PI 393516	7	5	2
ICG 7897	PI 405132	8	7	1
ICG 10029	PI 476164	8	6	3
ICG 10035	PI 476172	8	3	2
ICG 10891	PI 476018	9	7	1
ICG 10920	PI 476152	9	5	3
ICG 10931	PI 476164	4	5	2
ICG 10936	PI 476168	5	4	4
ICG 10951	PI 476178	7	3	2
ICG 10975	PI 476195	8	3	4
ICG 11485	PI 393530	9	4	-
Susceptible controls				
ICO 221	TMV 2	9	5	-
ICG 799	Robut 33-1	9	6	-
	Malimba	9	5	-

1. Diseases scored on a 9-point scale where I = no disease present, 9 = 80-100% leaf area damaged.

Table 2. Screening of groundnut germplasm for resistance to rust.

		Disease scores		
Germplasm entry	Identity	Rust	Late leaf spot	Early leaf spot
ICG 1697	NC Ac 17090	1	7	5
ICG 1710	NC Ac 17135	1	6	4
ICG 4746	PI 298115	1	8	6
ICG 6284	NC Ac 17500	1	6	4
ICG 6330	PI 270806	1	5	5
ICG 6340	PI 350680	1	7	5
ICG 7340	WCG 182 198/66	4	7	4
ICG 7883	PI 315608	1	9	6
ICG 7888	PI 393516	1	5	5
ICG 7890	PI 393526	1	6	6
ICG 7893	PI 393531	1	8	4
ICG 9294	58-295	3	8	4
ICG 10030 A	PI 476166	1	9	3
ICG 10031	PI 476168	1	9	4
ICG 10042	PI 476177	1	9	4
ICG 10052	PI 476182	1	8	5
ICG 10053	PI 476183	1	9	4
ICG 10061	PI 476186	2	9	4
ICG 10068	PI 476192	1	9	5
ICG 10939	PI 476172	1	8	5
ICG 10978	PI 476197	1	9	4
ICG 11285	PI 476165	1	8	5
Susceptible control cultivars				
ICG 221	TMV 2	1	9	6
ICG 799	Robut 33-1	1	9	4
-	Malimba	-	9	6

1. Diseases scored on a 9-point scale where 1 = no disease present, 9 = 80-100% leaf area damaged.

mum of 15.9.C were generally conducive to development of foliar diseases.

Late leaf spot, as expected, dominated the scene, and affected severely most of the lines in both late leaf spot and rust screening. While leaf spot screening was successful, rust screening was less so because of interference from late leaf spot. The high incidence of late leaf spot may have prevented rust from establishing to its fullest potential. It is therefore essential to control such unwanted diseases in nurseries where resistance to specific diseases are being sought. According to P. Subrahmanyam of the SADCC/ICRISAT Groundnut Project, Malawi (personal communication), carbendazim to control leaf spot and tridemorph to control rust can be sprayed. But such fungicides, which are not locally available, must be supplied along with seeds.

Discussion

Nigam: While genotype PI 270806 has a score of 9 for late leaf spot in Table 1, it shows a score of 5 for the same disease in Table 2. Were these two experiments conducted at the same location during the same season? If so, what are the reasons for this difference?

Earnshaw: Yes, they were grown at the same place and during the same season. But since we did not inoculate the plants with the pathogens for even distribution of the disease, I think the disease was not evenly distributed.

Ndunguru: What were the yields like in this trial?

Earnshaw: We were not interested in yields-the experiments were focused on disease resistance.

Subrahmanyam: International Groundnut Late Leaf Spot Disease Nursery (IGLDN) and International Groundnut Rust Disease Nursery (IGRDN) trials should be conducted in locations where the disease is severe and where the interference from other diseases is low. This can be achieved by selecting the experimental sites carefully. If it is not possible to do that under natural disease pressure, you should try to create this situation artificially by inoculating the infector rows with rust and late leaf spot, as described in the logbooks supplied to you. The interference of other diseases can be minimized be spraying carbendazim or tridemorph in your trials. In fact, if you artificially inoculate the infector rows you will minimize the interference of other diseases to a greater extent.

Freire: Natal Common is widely cultivated. Why didn't you use it as a control?

Earnshaw: We used it as a disease spreader since it is very susceptible.

Banda: How were you able to score for leaf spots using ICRISAT's 9-point scale without going into detailed leaf-by-leaf assessment?

Earnshaw: Since early leaf spot comes very early in the season in Swaziland-usually it is the first disease to occur-it is not difficult to score. Using ICRISATs 9-point scale, we look at the general severity of the disease per test line. But with late leaf spot and rust, I would agree that it is quite difficult.

Effect of Sowing Time on Groundnut Yield in Botswana

A. Mayeux[1]

Abstract

Spanish groundnut genotype 55-437 was sown under minfed conditions at different dates to evaluate the effect of sowing time on reproductive and yield components. Sowing date did not effect the time of first flower appearance, but subsequent flowering was highly dependent on rainfall distribution. Early (November) and mid (December) sowing dates produced well-developedplants, while late (January/ February) sown crops were stunted with poorly filled pods. The early-sown crop matured when there was a high probability of rain and the risk of seed germination was high. Groundnut efficiently exploited soil moisture and abundant rainfall led to high haulm yield with a smaller increase in pod yield. In two seasons, a December sowing gave the best yield and the highest seed quality.

Resumo

Efeito da ipoca da sementeira no rendimento de amendoim em Botswana. O genotipo Spanish 55-437 foi semeado na estagdo chuovosa em diferentes datas de sementeira para avaliar a data efectiva da sementeira, producao e rendimento dos componentes. A data da sementeira ndo afectou o tempo do inicio da floracao mas subsequentemente a floragdo esteve altamente dependente da distribuigao das chuvas. Sementeiras nos principios de Novemebro e meiados de Deiembro produziram plantas hem desenvolvidas enquanto que as sementeiras tardias de Janeiro e Fevreiro as plantas estiveram atrofiados e com pobre preenchimento de vagens. A cultura semeada cedo atinguiu a maturacao quando havia fortes probabilidades de chuvas e o risco de germinacao de amendoim era maior O amendoim explorou efectivamente a humidade, a abundacia de chuvas induziu o maior crescimento da parte aerea pouco aumento de produgdo de vagens entre as duas epocas, as sementaireas de Deiembro deram melhores rendimentos e semente de alta qualidade.

Introduction

Because sorghum and maize have priority over groundnut under the current farming system in Botswana, groundnut does not always receive the required attention. For example, sowing could be done between November and February, depending on the interest of the farmers in this crop. In view of the seed and labor costs, the purpose of this trial was to study the effects of sowing dates on yields and encourage farmers to sow groundnut at the right time.

Materials and Methods

In a 2-year experiment at Sebele Research Station, three sowing periods were studied in the first year and four in the second year.

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Mayeux, S. 1992, Effect of sowing time on groundnut yield in botswana. Pages 75-79 *in* Proceedings of the Fifth Regional Groundnut Workshop for Southern Africa, 9-12 Mar 1992, Lilongwe, Malawi (Nageswara Rao, R.C., and Subrahmanyam, P., eds,). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

- Beginning of the rainy season (mid-November); early sowing-ES
- 1 month later (mid-December): mid sowing-MS
- 2 months later (mid-January): late sowing-LS
- 3 months later (mid-February): very late sowing-VLS

The trial was conducted on sandy soil marked by a compact ferruginous zone, varying in thickness, about 1 m below the surface. A randomized complete block design with three replications was used on plots of six rows, each 6 m long. Seed of Spanish cultivar 55-437 was sown manually in rows spaced 75 cm apart, with 10-12 cm spacings along each row. Seed was protected by a fungicide/insecticide mixture (captan and malathion). Fertilizer in the form of 0.2 t ha^{-1} of single superphosphate (10.5% P) and 0.1 t ha^{-1} of limestone ammonium nitrate (28% N) were applied. Weeds were controlled by manual hoeing. The water potential of the soil was monitored using a neutron probe calibrated at 10, 25,40, 55, 60,75, 85,100, 115, and 130 cm with aluminum access tubes (45 mm diameter) placed in the middle of each plot. Two plants were uprooted every 10 days to monitor development of various vegetative growth and reproductive organs. Leaf area was measured by planimetry. Flowering was monitored each day on two tagged plants plot-'.

Results and Discussion

Climatic conditions

Temperatures were normal with a mean maximum of 30°C from November to February, falling to 25°C in April. The minimum temperature throughout the season ranged from 18°C to 20°C, but fell to 8°C in May. Daily pan evaporation ranged between 4 and 8 mm. Total rainfall was 471.1 mm in 1989/90 (October-May) and 571.1 mm in 1990 / 91 (October-March).

Vegetative growth and flowering

Flowering began 30 days after sowing (DAS) for all four dates (Fig.1). Flowering intensity was the same for the first few days, and then rapidly became dependent on rainfall. Figure 1 shows the significant variations of rainfall pattern during the flowering period. Since 90% of pod production is determined by the flowers produced in the first 3 weeks, the total number of flowers produced after 20 days was 73 for (ES), 128 for (MS), 124 for (LS), and 74 for (VLS). The longer flowering period of ES allowed a longer podding period but the later pods were of poor quality (see harvest analysis).

During the 1990/91 season, leaf production followed a similar pattern for ES and MS until the 70th day after sowing. However, ES retained almost all its leaves until harvesting at the end of March, while MS was severely defoliated after the abrupt end of the rainy season. The LS and VLS plants remained stunted, with a maximum leaf area index of 1.5 (compared with 4.3 for ES).

Development of pegs, pods, and seeds

In the 1989/90 season, with no water stress after sowing, sowing date did not significantly affect appearance of the first pegs, which occurred around the 35th day after sowing. However, number of pegs $plant^{-1}$ produced in the first 3 weeks increased from 8 for ES to 37 and 36 for MS and LS. During the 1990/91 season, drought stress in December delayed peg appearance. Low relative humidity in December (57% at 0800 compared with 73% for January) was probably responsible for reduced flower fertility in the ES. The number of pods and seeds followed the same pattern. In the late sowing, peg production was similar to MS because of good soil moisture; however, the number of pods declined dramatically due to unfavorable environmental conditions.

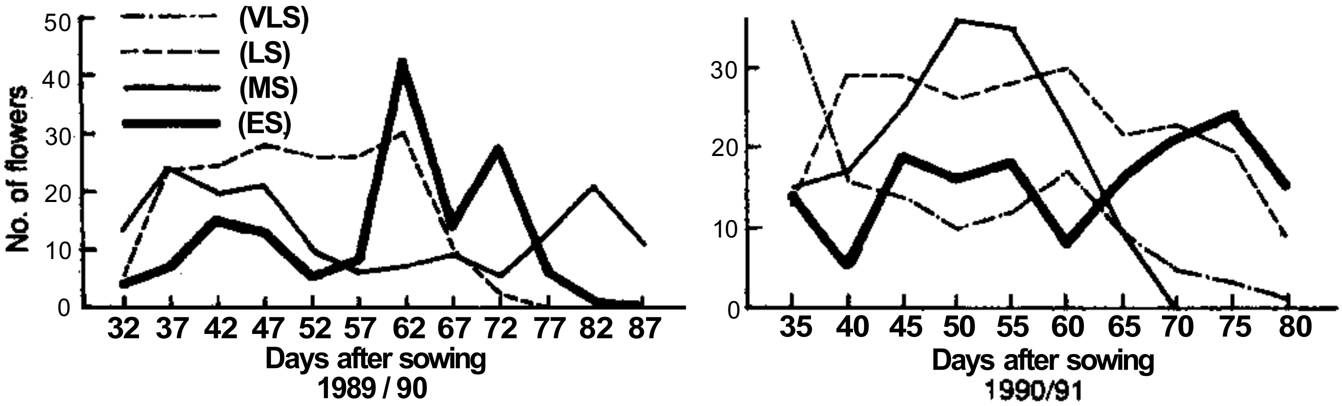

Figure 1. Effects of sowing dates on flowering of groundnut (55-437), Sebele Research Station, Botswana, 1989/91.

Table .1. Effect of sowing dates on the distribution of dry matter in stems, leaves, and pods (expressed as percentage of total plant mass), In groundnut 55-437 over two seasons at Sebele Research Station, Botswana.

		Total dry mass (g)		Distribution of dry mass (%)					
				Stems		Leaves		Pods	
DAS	Sowing date	1	2	1	2	1	2	1	2
30	ES	1.5	1.4	20.0	36.8	53.3	63.2	0.0	0.0
	MS	4.6	1.7	30.4	35.9	59.8	64.1	0.0	0.0
	LS	3.0	1.4	30.0	34.3	63.3	65.7	0.0	0.0
	VLS	2.0	-	25.0	-	60.0	-	.0.0	-
60	ES	19.4	11.7	47.9	42.9	45.1	53.7	1.2	3.4
	MS	51.9	20.8	32.4	28.7	39.1	43.3	22.2	28.0
	LS	13.2	16.9	32.6	26.6	55.3	65.1	2.3	8.3
	VLS	11.4	-	21.1	-	71.9	—	2.6	-
90	ES	54.1	20.7	31.4	34.3	32.3	48.3	31.1	17.4
	MS	51.5	31.1	37.9	25.7	40.4	38.6	34.6	35,7
	LS	37.1	20.8	34.5	28.4	30.7	48.1	27.0	23.6
	VLP	12.5	-	37.6	-	42.4	-	11.2	-
120	ES	98.1	46.3	35.7	23.8	29.9	33.0	30.3	43.2
	MS	67.6	47.6	29,6	18.7	8.1	28.8	57.7	52.5
	LS	23.2	24.7	29.7	30.8	18.1	35.2	47.0	34.0
	VLS	14.7	-	38.8	-	40.8	-	13.6	-

1 = 1990/91, 2 = 1989/90.

Table 2. Yields of groundnut (55-437) over two seasons at Sebele Research Station, Botswana.

Sowing dates	Final stand ('000 ha-1)	Haulm yield (t ha-1)	Pod yield (t ha-1)	Mixed seed yield (t ha-1)	1st grade seed yield (kg ha-1)
ES	95.4	5.62	1.41	0.90	615
MS	91.5	3.10	1.37	0.93	734
LS	91.2	2.18	0.75	0.50	339
VLS	91.8	1.70	0.15	0.11	89
Mean	92.5	3.15	0.92	0.61	444
CV (%)	5.2	11.3	9.4	12.5	19.9

Changes with time in stem, leaf, and pod mass

Rainfall plays a major role in plant development. Table 1 shows dry matter partitioning between stems, leaves, and pods as a percentage of total dry mass production. Defoliation 1 month before harvesting in MS was very severe, following an early end to the rainy season. Leaf mass represented 18.4% of total plant mass of the plant compared with 31.0% for ES. At harvest, the ES plants reached a mean height of 53.3 cm, compared with 37.5 cm for MS, 28.5 cm for LS, and 18.2 cm for VLS. Pod mass at harvest was 36.7% for ES and 55.1 for MS.

The comparison between the two seasons was similar, with well-developed plants (dry mass) for November (ES) and December (MS), and a very significant reduction in development in January (LS) and February (VLS).

Yield

The effect of rainfall was greater on vegetative development than on reproductive organ development. The ES plants, which were harvested in mid-March before the end of the rainy season, had a fair amount of haulm yield, which explains their higher yields when compared with the other sowing dates, The LS suffered from drought and thus accelerated plant defoliation.

Differences in pod yield were highly significant between sowing dates. Pod yields decreased significantly between the early sowing date (1.41 t ha-[1]) and the very late sowing date (0.15 t ha"[1]).

A comparison of the November and December sowings showed almost no difference in pods ha-[1] (Table 2). However, an extended flowering period for the early sowing (Fig.1) led to pod production over a longer period. The later pods did not reach full maturity because the plants were harvested early while soil moisture was high to prevent germination of the first mature seeds. As a result, the last pods to form were not fully mature, resulting in the reduced shelling percentage of quality seed from 45.1 for the November ES to 53.7 for the December MS (Table 3). in terms of quality seed production ha*[1], the mass difference is 119 kg, the equivalent of US$ 61 (as of April 1991). The percentage of poorly filled pods ("pops") in ES was significantly higher than in MS due to the extended pod formation period.

Table 3. Harvest quality of groundnut (55-437) over two seasons at Sebele Research Station, Botswana.

Sowing dates	100-pod mass (g)	Shelling percentage[1] A	Shelling percentage[1] B	100-seed mass (g)	"Pops"[2]
ES	49.2	63.6	45.1	21.2	18.0
MS	54.6	67.8	53.7	23.2	11.6
LS	44.9	64.2	43.2	18.2	15.7
VLS[3]	40.4	60.5	46.1	19.0	22.9
Mean	47.3	64.0	47.0	20.4	17.1
CV(%)	11.4	5.6	12.7	9.0	49.0

1. A = mixed seeds, B = good seeds.
2. Measured as percentage of aborted seeds.
3. Only 1990/91.

Water consumption

Abundant rainfall at ES in 1990/91 resulted in almost 100% increase in haulm yield and 50% increase in pod yield for the Spanish type genotype (Table4) .Water use efficiency, expressed as mm of water consumed (evapo-transpiration) per kg of pod, assuming that no water drains to below the 130 cm zone, was similar for the two seasons with an average of 3.5 kg mm-[1]. A root system study showed that groundnut is quite a flexible plant with regard to soil water, and is capable of effectively exploiting soil moisture by very quickly extending its root system.

Conclusions

Analyses of the advantages and disadvantages of each sowing date are summarized below.

Early sowing (ES)

- Due to the low probability of rain in October to build up soil moisture reserves, ES can suffer very quickly if rainfall is low.
- Minimum temperatures are sometimes low at this time of year, and this delays seedling emergence.
- Flowering period is long, leading to a range of pod maturity, then an increase of immature pods mixed with mature pods at harvest.
- Plants reach maturity when the probability of rain is still high, posing harvesting and drying problems. Losses attributable to seed germination can be high.

Intermediate sowing (MS)

- Soil water reserves are assumed to be adequate for the plants to withstand slight water deficits.

Table 4. Water-use efficiency on a groundnut crop (55-437) sown at different times.

Sowing date	Rainfall (mm)		Yields: Pod (t ha-[1])		Yields: Haulm (t ha[-1])		Water use efficiency: Pod (kg mm-[1])		Water use efficiency: Haulm (kg mm-[1])	
	89/90	90/91	89/90	90/91	89/90	90/91	89/90	90/91	89/90	90/91
ES	275.8	486.3	1.13	1.69	3.82	7.43	3.2	3.8	10.8	16.7
MS	177.8	355.9	1.44	1.31	3.42	2.78	5.7	3.4	13,5	7.2
LS	222.3	283.9	0.66	0.85	2.46	1.87	2.5	22	9.4	4.9
VLS		222.4		0.15		0.17		0.5		5.7

- Higher temperatures favor development throughout the growth cycle.
- Harvesting is completed during a period with a low probability of rain. This facilitates drying, and harvests are of high quality.

Late sowing (LS)

- The crop is always sown under good conditions, since soil water reserves are high.
- Flowering and peg formation are also good, but the well-developed plants can rapidly suffer from drought stress due to the erratic rainfall at the end of the season.
- The low temperatures at the end of the cycle reduce plant metabolic activity, resulting in small, poorly filled pods.
- The early sowings from January and February are susceptible to infestation by aphids (rosette vector), that are more numerous at this time of year.

These results indicate that sowing groundnut in Botswana during mid-December results in optimal pod yield and seed quality.

Discussion

Olorunju: What time of the year is sorghum sown in Botswana? Since there does not appear to be any clash in sowing dates, is it possible to advise farmers to sow groundnut before sorghum?

Mayeux: Sorghum, as a staple crop in Botswana, is always sown first, usually between mid-November and mid-December, depending on the rainy season. Since sorghum and groundnut have similar growing cycles (120 days), selection of a short-duration groundnut could be a solution.

Ndunguru: Cattle play a more important role in the economy of Botswana than food crops. What is the potential of growing long-duration groundnut for fodder, particularly during the long dry season when pastures may be in short supply?

Mayeux: There are 3 million head of cattle in Botswana. Growing long-duration groundnut for fodder will not have a significant impact and would be very uneconomical because grazing land is so important. However, we encourage farmers to use groundnut haulm to feed draft animals before the cropping season.

Williams: Have you considered the possibility of mixing groundnut varieties? In West Africa, especially with cowpea and groundnut, we find much greater stability from mixed maturities relative to pure varieties.

Mayeux: If farmers sow in late December, there is no opportunity to sow mixed varieties. Mixed varieties should be sown in October, but since priority is given to sorghum, we have had little success with this idea.

Kefi: To improve groundnut production, the whole farming system should be examined to determine the leverage points through which the productivity can best be achieved.

Response of Groundnut Varieties to Drought Stress at Namulonge Research Station

C M. Busolo-Bulafu[1]

Abstract

Groundnut (Arachis hypogaea L.) is a very important legume crop in Ugandan agriculture. It is well accepted for cultivation and consumption. The general trend is to increase productivity in all crops, including groundnuts. However, one of the factors responsible for lowering this productivity is drought. Preliminary observations have shown that some lines are highly tolerant of drought stress.

Resumo

Resposta de algumas varidades de amendoim a "stress" provcado pela seca na Estaqao Agraria de Namlonge. Amendoim (Arachis hypogaea L.) e uma leguminosa de maior importancia na agricultura de Uganda. O seu cultivo e consumo tern boa aceitacao. A tendencia genral e aumentar a productividade de todas as culturas incluindo amendoim porem, O factor responsavel pela baixa productividade e a seca. Observacoes preliminares tern mostrado que algumas linhas sao altamente to/erantes ao "stress" originado pela seca.

Introduction

Because agriculture is the backbone of Uganda's economy, there is a tendency to emphasize increases in crop productivity per unit area of land. However, some abiotic factors such as drought lower the potential productivity by interfering with the growth and development of the crops.

Drought is one of the main constraints to the production of groundnut, the second most widely grown grain legume in Uganda. Besides its direct effect in reducing groundnut yields, drought discourages farmers from alleviating effects of other constraints such as diseases, pests, and nutrient stresses through managerial practices. One way to increase and stabilize groundnut yields is to moderate the impact of drought stress by using tolerant cultivars. Another way is to match cultivars to specific agroecological zones.

Uganda has two growing seasons. Dry spells at the beginning and end of each season are common. However, potentially damaging dry spells also occur at any time during the growing seasons. Damage to groundnut in particular depends on time of occurence and duration of the drought spell. In the final analysis, recovery of a cultivar and return to active growth and development, after exposure to varying periods of drought, may be more important than drought avoidance or drought tolerance. Although reliable estimates of average crop losses due to drought are lacking in Uganda, total (100%) losses of the crop have been observed in some areas.

Most of the farmers growing groundnuts in Uganda are peasants of limited means. These farmers

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Busolo-Bulafu, CM., 1992. Response of groundnut varieties to drought stress at Namulonge research station. Pages 81-82 *in* Proceedings of the Fifth Regional Groundnut Workshop for Southern Africa, 9-12 Mar 1992, Lilongwe, Malawi (Nageswara Rao, R.C., and Subrahmanyam, P., cds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics,

are aware that late sowing results in low yields, but lack of farm power and erratic rainfall often force them to sow late. Some farmers give priority to other staple food crops.

Although the Groundnut Improvement Programme at Namulonge Research Station has not yet conducted a full-fledged study on groundnut response to drought, several useful observations have been made on materials under evaluation and screening for other parameters. This paper reports the preliminary observations on the drought responses of 10 cultivars.

Materials and Methods

Ten varieties were evaluated at Namulonge Research Station under rainfed conditions. No irrigation treatments were applied. The experimental design used was the randomized complete block design with five replications. Each plot consisted of six rows, each 5 m long with 0.6 m distance between rows. The trials were conducted during the two rainy seasons in 1991 (March-July and September-December). Observations were made on the ability of genotypes to recover and return to active growth after exposure to varying periods under drought stress.

Results and Discussion

The observations were made following mid-season droughts in a number of seasons, leading to adverse effects on the trials. Despite severe drought, however, a few varieties consistently gave better yields, indicating better drought tolerance than others. These varieties recovered more quickly after drought stress than the drought-susceptible varieties. The lines identified as highly tolerant are long-duration types (120-130 days). RMP-12 was one of the best yielders.

Unfortunately, little information is available on the extent of yield loss due to drought in Uganda. It is therefore desirable to conduct more detailed investigations involving drought simulation studies in order to establish the yield losses caused mainly by mid-season droughts. Research efforts should also put more emphasis on the development of drought-tolerant varieties since this is a natural hazard which cannot be easily controlled. Drought not only causes loss of yield, but deterioration in quality because it predisposes the groundnut pods to infection by *Aspergillus* sp.

Discussion

Mayeux: You mentioned your preliminary observations were made from return to active growth. Can you make any other observations, such as flowering (time, intensity), which is more important in relation to drought and gives a better understanding of plant's ability?

Busolo-Bulafo: Drought can occur at anytime during the growing period of the crop. If the spell occurs just after flowering, the flowering will be retarded; but if moisture returns, the rate of resumption of flowering will differ with the varieties, resulting in different yields.

Nageswara Rao: 1. What were the lowest and highest yield levels recorded in your trial? 2. You mentioned that long-duration genotypes yielded well in your experiments. Did you include genotypes with varied duration in your trials?

Busolo-Bulafo: 1. Yields ranged between 0.79 and 2.50 t ha^{-1}, while the average was 1.15 t ha^{-1}. 2. The series we are evaluating now consists mainly of long-duration varieties (120-130 days).

Olorunju: In your trials, RMP 12 yielded 2.50 t ha^{-1} under stress conditions. You said under rainfall (adequate conditions), it yields 3.50 t ha^{-1}. Is that the normal yield in farmers' fields for this variety or does it only reflect experimental conditions?

Busolo-Bulafo: RMP 12 is a new variety and has not yet been released to farmers. We hope to release it in the near future since the evaluation is an advanced stage. The average yield is 1.20 t ha^{-1} in the trials, while the national average is 0.80 t ha^{-1}.

Bosch: What methodology did you use for simulation of drought?

Busolo-Bulafo: We did not use any simulation/The trials were grown under rainfed conditions. However, we intend to conduct more detailed trials where drought simulation will be used.

Production Methods and Farming Systems

Groundnut in the Farming System: A Case Study in Salima Agricultural Development Division, Malawi

T.J. Cusack and N.E. Nyirenda[1]

Abstract

The principal crops grown in the Chinguluwe area of Salima Agricultural Development Division are cotton, maize, and groundnut. Both the area sown to groundnut and the proportion of the groundnut area planted to the recommended cultivar Mawanga are declining. Farmers indicate that these trends are due to the relatively low profitability of groundnuts, the lack of availability of Mawanga seed, and the superior drought resistance of alternative groundnut varieties. These findings suggest that future research be directed specifically towards cultivar adaptability and on-farm seed storage.

Resumo

Amendoim nos sistemas de producao: um caso em estudo na divisaos de desenvolvionento de agricultura em Salima, Malawi. As principals culturas praticadas na divisao de agricultura de Salima em Chingulwe sao: algodao, milho e amendoim. Tanto a area semeada de amendoim assim bem como a porporcao da area semeada com o cultivar recomendado de amendoim estdo declinando. Os agricultores indicaram que esta tendencia deve-se relativamente a baixa rentabilidade de amendoim, falta de semente de mawanga (variedade recomendada), falta de variedades alternativas e tolerantes a seca. Estas informacoes sugerem que as futuras investigacoes devem serem dirigidas especificamente a adaptabilidade de cultivares e armazenamente de semento no campo dos agricultores.

Introduction and Method

The lakeshore area of Malawi is historically an important groundnut-producing area. In order to ensure that on-station and on-farm groundnut research is undertaken on those topics having highest potential impact on lakeshore smallholders, a research planning exercise is presently being undertaken by the Chitedze-based Groundnut Commodity Team. As part of this exercise, researchers undertook a brief survey of groundnut-growing farmers during the 1991/92 season, and reviewed earlier survey results over the past 5 years (Mwenda and Cusack 1988, Mwenda 1992), for smallholders in the Chinguluwe area of Salima Agricultural Development Division (ADD). Surveyed farmers were more commercially oriented than average. Because of their membership in farmers' clubs, they had access to credit, their farms were above average size, and a large proportion owned their own draft animals. Farmer survey data were supplemented by interviews with extension staff and by data published by national scientists.

The primary objectives of the study were to identify constraints to groundnut production, and to identify research activities which could address these constraints. Of particular concern was the national

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Cusack, T.J., and Nyirenda, N.E., 1992. Groundnuts in the farming system: a case study in Salima Agricultural Development Division, Malawi. Pages 85-87 *in* Proceedings of the Fifth Regional Groundnut Workshop for Southern Africa, 9—12 Mar 1992. Lilongwe. Malawi (Nageswara Rao, R.C, and Subrahmanyam, P.. eds.). Patancheru, A.P. 502 324. India: International Crops Research Institute for the Semi-Arid Tropics.

decline in groundnut production over the past several years. Output during the 1984-87 period averaged 80 000 t shelled nuts, compared with an average of only 20 0001 during the 1988-91 period (Ministry of Agriculture 1991), This trend was reflected by the declining levels of output at the Salima ADD (Salima Agricultural Development Division 1991).

Results

Production changes

Total area of cultivation per sampled farmer ranged from 1.2 ha to 5.4 ha, compared with an average farm size for the area of 1.2 ha. Substantial changes have occurred in the importance of various crops between 1986/87 and 1990/91. The proportion of the farm (considering only the three principal crops: maize, cotton, and groundnut) sown to maize has remained constant at approximately 40%, but there has been a substantial shift away from maize composite cultivars to maize hybrids, with strong interest in the variety MH 18; respondents indicate that the poor drought tolerance of the composites and the availability of credit for hybrids were the main determining factors. Of the total maize area, the proportion of maize landraces has remained at approximately 40%, with hybrids recently replacing almost all of the composites.

The area sown to cotton, expressed as a proportion of the area of principal crops per farm, has grown from 41% in 1986/87 to 52% in 1990/91, reflecting an equivalent reduction of the area devoted to groundnut. Farmers expect that cotton will suffer only a 10-20% decrease in yields under the 1991/92 drought conditions.

The area sown to groundnut has declined from an average of 20% of the sown area of farms in 1986/87 to only 8% in 1990/91. For those farmers who continue to grow groundnut for cash sale as well as for home consumption, the typical area sown to groundnut has declined from 0.8 ha in 1986/87 to 0.4 ha in 1990/91. The areas devoted to the various groundnut cultivars have also changed on commercialized farms. Whereas approximately 90% of groundnut sown during the 1986/87 season were Mawanga, a high proportion of the total area (approximately 70%) is now sown to cultivars other than Mawanga. More land is sown to Chalimbana than to Mawanga, and the local cultivars Kalisere and Mani Pintar are also popular. In addition, Malimba is gaining in popularity, although it is not clear how the seed was introduced, having been previously released only for the Lower Shire Valley area. Farmers in the silty-loam areas of Chinguluwe expect significant yields only from Malimba this season, whereas farmers in sandy-loam areas expect significant yields from all cultivars.

Reasons for production changes

Main reasons given by farmers for these changes in groundnut production were the removal of Mawanga seed from the credit system due to lack of supply, the removal of the Mawanga seed program from Chinguluwe (members of this program received substantially higher output prices with no additional inputs needed), and lower levels of profitability for groundnut than for cotton. Some farmers were finding it difficult to store Mawanga as sowing material, although there was some evidence to indicate that farmers who stored Mawanga seed in *nkhokwe* (bamboo storage sheds) were less successful than those who stored material in sacks in the house.

Despite the well-recognized yield advantage of Mawanga, it was considered too oily to make a successful relish, and yields fluctuated under erratic rainfall conditions. Chalimbana is grown mainly for its taste, and is clearly the preferred cultivar for home consumption. Although farmers reported that Chalimbana yields are usually less than 50% those of Mawanga, the seed is easy to store. Kalisere is similar to Chalimbana, with somewhat smaller yields. It has slightly superior drought tolerance but is less tasty as a relish. It is usually used where Chalimbana is unavailable. Malimba is renowned for its maintenance of yield under severe drought conditions, and farmers reported that they would like to include it as perhaps 10% of an ideal groundnut cultivar portfolio which would also include 70% Mawanga and 20% Chalimbana. Malimba is considered intermediate in taste and yield, and is easy to store, with some farmers suggesting that Malimba can in some seasons be sown twice within the same season. Some farmers also observed that Mawanga is more prone to termite attack than other cultivars, and therefore plant population at harvest tends to be low.

Farmers indicated that they preferred a rotation of maize/cotton/groundnut, but due to the small areas devoted to groundnut, cotton is usually rotated with either of maize or groundnut. The sequence of sowing is often cotton (dry sown), followed by maize and then groundnut, or maize followed by groundnut and cotton. The groundnut haulms are valued for livestock feed, but are not sold if the farmer does not own livestock. Shells are thrown away. Farmers often save three 35-kg bags of unshelled nuts for domestic consumption and two bags for seed. The remainder is sold to private traders [1991 prices were K 40-45 (US$ 10-12) bag^{-1}], or at higher prices to farmers for seed.

Cotton is valued for its high profitability and its ability to yield effectively even under the most adverse conditions. Maize is considered essential for the domestic provision of staple food, and is moderately profitable when hybrids are used as cash crops. Farmers are frequently reluctant to sow groundnut because of its low profitability and because of low yields during drought years (40% of years). However, it is valued for home consumption as relish, for cash income, for fertility enhancement, and for the crop's ability (according to one farmer) to substantially reduce *Striga* incidence in succeeding maize.

Conclusions

From farmer responses, groundnut production in Chinguluwe appears to be constrained by:

- a lack of seed of the recommended cultivar, Mawanga;
- low levels of profitability of groundnut compared with the other principal crops; and
- low levels of yields of established cultivars in low rainfall years.

Additional extension efforts to promote more effective domestic seed storage methods, backed up by an on-farm trial, could help to reverse the decline in area sown to the highly productive cultivar Mawanga. It is unlikely, however, that farmers will be able to obtain substantial Mawanga seed materials from outside sources (on credit or otherwise) in the foreseeable future. At the same time, prices recently received by farmers for unshelled nuts sold to private traders are up to twice that offered by the Agricultural Development and Marketing Corporation, so a review of the relative profitability of groundnut is needed.

This study has raised a number of questions about the suitability of established cultivars for conditions found in Chinguluwe. Researchers should review past results tor variety/agronomy trials on the lakeshore, Phalombe, and the Lower Shire areas, using these as a basis for designing on-farm trials in Chinguluwe. Malimba, Mawanga, and cultivars such as CG 7 should be used in these trials.

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Discussion

Freire: 1. What is the origin of the local cultivars? 2. If groundnut prices have doubled, why is the crop less profitable?

Cusack: 1. Local cultivars originated from introductions made by extension/research workers in previous decades. The original introductions are generally recognizable as separate cultivars in farmers' fields today. Farmers often maintain separate stocks and sowings of these cultivars. 2. Private traders have recently been allowed to purchase groundnuts from farmers, and prices received by farmers have correspondingly increased substantially. Potential profitability is therefore increasing at present, reversing the decline in profitability during the 1980s.

Anders: Why did you select the top 25% of commercial producers: does the remaining 75% not make an impact on production? Does this group have any contact with the commercial sector? Is there a movement of technology from this top 25% to the other 75%?

Cusack: The sampling frame was "farmers who were members of farmer clubs", because these clubs have extension contacts and are capable of swiftly responding to production incentives. The remaining 75% of farmers are difficult for researchers to work with, but do significantly impact production. Movement of technology from the top 25% to the other 75% is slow and informal, but is nevertheless quite effective with some technologies.

Investigations of Cultivation Systems and Cultural Methods of Weed Control

D.D. Singa[1]

Abstract

Research on the mechanized cultivation of groundnut, as with other high-priority crops in Malawi, is now biased towards smallholder farmers. The smallholders produce the bulk of the crop in the country with hand cultivation practices, which usually limit production to subsistence levels. Land holdings are generally small, and there is increasing need to conserve the country's foreign reserves by minimizing importation of tractors and petroleum products. This paper reports recent efforts to seek improved groundnut production techniques using human and animal draft power.

Resumo

Investigacao nas tecnicas de cultivo: practicas culturais de controlo de infestantes. Investigacao no cultivo mecanizado de amendoim assim como culturas prioritarias no Malawi e agora baseado em pequenos agricultores, os pequenos agricultores produzem o grosso da producao no pais com praticas de cultivo manual as quais limitam a producao para o nivel de subsistencia. Possuidores de terras sao geralmente poucos e ha necessidade de conservar as reservas do pais (Divisa) atravez da diminuicao das importacoes de tractores e derivados de petroleo. Este artigo reporta esforcos recentes na busca de tecnicas melhoradas de producao de amendoim usando a tracao animal c humana.

Introduction

The Government of Malawi, faced with the need to increase both land and labor productivity while conserving the country's foreign reserves through the minimization of machinery and oil importation, encourages the use of animal and human power.

Over the past 3 years, a highly promising multipurpose tool frame capable of accepting a wide range of attachments has been developed, tested, and manufactured. Attachments are currently available for ridging and lifting. The tool frame has gained increasing popularity with farmers, and as farm machinery extension services are introduced in all Agricultural Development Divisions (ADDs) along with credit systems, more farmers should be able to own the equipment. Work on a planter, a cultivating tine, a weeding sweep, and a clod crusher is under way.

A farmer is able to save about 35% of the cost of single implements when he buys tool-frame with plowing and ridging attachments. The phenomenon gives a chance to low income farmers to own the implements.

Malawi is now self-sufficient in the manufacture of all ox-drawn implements. The problems of ownership and lack of high adoption of farm machinery technologies are due to external forces beyond the control of the farm machinery team and are not examined in this paper.

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Singa, D.D. 1992. Investigations of cultivation systems and cultural methods of weed control. Pages 89-92 *in* Proceedings of the Fifth Regional Groundnut Workshop for Southern Africa, 9-12 Mar 1992. Lilongwe, Malawi (Nageswara Rao, R.C.. and Subrahmanyam. P., eds.). Patancheru. A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Cultural Methods

Trials in weed control and crop response from alternative cultivation systems and subsequent weeding methods using ox-drawn equipment on groundnut were conducted from 1981 to 1985 at Chitedze and Chitala Research Stations (Table 1). The mechanized systems were based on combinations of methods using existing equipment and others which had become available with the introduction of the multipurpose toolframe. Planters and lifters were developed between 1982 and 1985 as a continuation of investigations conducted from 1968 to 1970.

In each treatment in the Chitedze and Chitala treatments (Table 1), sowing was done by hand. Three plants were sown at each station spaced at 90x90 cm. Hand weeding was done at 3 and 6 weeks after sowing. While no direct measurement of weed intensity was recorded, the total labor hours spent weeding indicated the overall importance of this task. Fertilizer and pest control procedures followed standard recommended applications.

Ox-drawn Planters

Investigations were made into the operations of four types of ox-drawn planters in 1969 and 1970. Two were the proposed attachments to the National Institute of Agricultural Engineering's wheeled, two-row, tool carrier which itself proved to be inappropriate. The third one, known as 'Safin.' was manufactured by the Agrimal Company. It was recommended for sowing maize and soybean and featured a special plate to provide adequate seed rate. However, it proved unsuitable for groundnut due to high seed damage and low seed rates. The fourth planter, part of a pedestrian-operated toolbar package specifically designed for maize, was not recommended.

A promising double-row ridge planter, an additional attachment to the new multipurpose toolbar, was designed and developed by FMU between 1982 and 1985. This planter sows on two ridges per run and sows one seed every 30 cm, 3-5 cm deep. The planter consists of two drive wheels that move inside the furrow, two hoppers and seed plates, an opener, and a cover. The final stage of development has been reached and two manufacturers have been identified (Agrimal and Lilongwe Sheet Metal).

Field Trial Results

- Tine cultivation provides less residual weed control. Deep-tine cultivators have greater draft requirements than plows.
- Although ridging requires extra labor, substantial labor can be saved with ridge sowing, especially when the sowing is done in straight lines. This

Table 1. Cultural methods of cultivation and weed control, Chitedze and Chitala Research Stations, 1981-85.

Treatment and category	Primary and secondary cultivation	Weeding method
1. Flat	Moldboard plow and harrow	Hand (control) as recommended to farmers[1]
2. Flat	Mold board plow and harrow	3x250 mm sweeps
3. Rat	Moldboard plow and harrow	5x150 mm sweeps
4. Flat/ridge[2]	Moldboard plow and harrow	Ridger
5. Flat/ridge[2]	Moldboard plow and harrow	Ridger combine with 2x 150 mm sweeps
6. Flat	Winged deep tine and leading tines[3]	Hand (control) as recommended to farmers[1]
7. Flat	Winged deep tine and leading tines[3]	3x250 mm sweeps
8. Flat	Winged deep tine and leading tines[3]	5x150 mm sweeps
9. Flat/ridge[2]	Winged deep tine and leading tines[3]	Ridger
10. Flat/ridge[2]	Winged deep tine and leading tines[3]	Ridger combined with 2x150 mm sweeps
11. Flat/ridge	Moldboard plow and harrow and ridge	Hand (control) as recommended to farmers[1]
12. Ridge	Moldboard plow and harrow and ridge	Ridger
13. Ridge	Moldboard plow harrow and farmers	Ridger combined with 2x150 mm sweeps.

1. Method did not include ox-drawn lifting (as did all other methods).
2. Ridges were built as the season progressed.
3. Winged deep tines were used at a maximum of 300 mm depth with the leading tines at 150 mm deep and spaced at 450 mm. Seed was sown in line with the deep tine.

facilitates weeding with animal drawn-implements.

- Weeding with cultivators (tines and sweeps) is only effective when the soil has average moisture and weeds are small.
- If soil is well plowed, insignificant yield differences are obtained whether sowing is done on ridges or on flat ground.
- Ridger weeding on flat-sown crops provides good banking systems and saves labor.
- Only two weedings are required.
- Groundnut lifting using animal-drawn implements is easier when the crop is grown on ridges. Performance of crops sown on flat ground deteriorated over 3 years of trials. Poor pegging was observed under such conditions.

Lifting

Trials during the 1968/69 and 1969/70 seasons on blades and shares for lifting groundnuts indicated that a curved 600-mm blade was the most suitable. Such a blade penetrates the ridge effectively with minimal draft requirement. Flat blades were recommended because they can be reversed, thereby halving sharpening time.

Another reversible leaf-shaped share was found useful as a dual-purpose ridgebreaker/groundnut lifter. In 1975, a design was completed for a single-purpose groundnut lifter using a curved blade. Although 50 were made for evaluation and extension purposes, large-scale commercial manufacture did not result.

A completely suitable groundnut lifting tool was developed by FMU in 1992. This lifter features circular legs, which enable the lifted groundnut haulms to slip off easily during the operation. The tool has been recommended by the Government and is being manufactured by Agrimal as an attachment to the multipurpose tool frame.

Concluding Recommendations

1. Where residual weed control and proper soil tilth are required, a plow should be used instead of deep tine (or chisel plow).
2. Deep tines and front tines can only be used where drainage is required and weeds are not a problem in land preparation (old field with no resulting weeds). Strong animals should be used as the implement requires considerable power.
3. Although sowing on ridges is faster, the initial ridge-making requires considerable labor. It is recommended that ridging be done where slopes will encourage erosion. Otherwise, flat sowing on well-plowed land is preferable since it is labor-saving.
4. Weeding using a ridger on a flat-sown crop grown in straight lines is recommended due to the resulting banking situation. It is also labor-saving.
5. Weeding with cultivator saves time but this should only be done when weeds are small and soil is not too wet.
6. Minimal tillage can only be practiced safely for 3 years. Thereafter, complete plowing should be done. During the 3 years, all recommended inputs should be applied; else the crop will be affected more adversely during the final 2 years than during the one under normal tillage.

Observations of ox-drawn planter development indicate that farmers without access to the multipurpose tool frame can efficiently use the Agrimal-manufactured Safim planter. Meanwhile, those with access to the tool frame should soon be able to avail of the new planter attachment. For groundnut lifting, the only efficient and inexpensive lifter is the tool frame attachment currently manufactured by Agrimal on order from farmers. The ADDs can place orders for the attachments (as well as all other Agrimal implements) on behalf of their farmers at wholesale prices.

Discussion

Mkhonta: Which weeding methods are the farmers currently using?

Singa: Mostly hand weeding (with hand hoes). A few (about 10%) use ridger weeding.

Williams: How much of the groundnut crop is buried during the growing season by ridging to control weeds?

Singa: Not much. For bunch varieties, three weedings can be done; for runner varieties two ridge-weedings are sufficient.

Nigam: You mentioned 90 cm row-to-row spacing for groundnut. When I was here, the Malawi national program had decided to recommend 60 cm row-to-row spacing for groundnut. Has it been changed back to 90 cm?

Singa: No, the national program also recommends 60 cm spacing. But many farmers find it difficult to adopt this spacing because of the various crop combinations they sow. These combinations often require 90 cm row-to-row spacing. Farmers find switching from 90 cm to 60 cm or vice versa difficult. However, in the case of 60 cm row-to-row spacing, by reducing the yield size, animal traction can be used for effective breeding

Anders: What is the minimal farm size required by a farmer to invest into animal tool carriers and how many farmers have sufficient land to use animal tool carriers?

Singa: A minimum of 2 ha, although smallholders are encouraged to pool their resources. Pooling, however, is a long-term strategy. In northern Malawi, over 50% of the farmers have sufficient land; in the central region, about 20%; and in the southern region, about 10%.

Sibuga: The information you have presented with regard to the multipurpose tool frame for ridging, sowing, and weeding is very interesting, especially in view of increasing labor shortages. Is it possible for ICRISAT to take a leading role in assisting national programs to adopt such tools? Can someone from ICRISAT please comment?

McDonald: ICRISAT is not doing active research on the mechanization of groundnut production. However, we are collecting all available information on machinery-manual, animal draft, and mechanization-and will be glad to make this information available on request to researchers worldwide. Much work has been done in the past in many countries and there is good scope for moving information and equipment between countries.

Effects of Improved Technology on Groundnut Yield and Probable Adoption Implications for the Farmer

K. Kanenga[1]

Abstract

Poor crop husbandry is one of the most important constraints to increasing groundnut yields in Zambia. The study reported here was undertaken at Msekera Regional Research Station to establish the benefits from the incremental adoption of improved technologies into traditional systems. Early sowing, improved seed, optimal weeding, improved plant density, and disease management practices were evaluated in a full factorial design. After 2 years, the data showed that by using all improved technologies there was a 176% yield increase over the traditional system. Early sowing alone resulted in a 94% increase, while early sowing combined with optimal plant density resulted in a 200% increase. These data indicated that significant yield increases are possible with minimal management changes.

Resumo

Efeito de tecnologias melhoradas sobre o rendimento de amendoim e possiveis implicacoes da sua adopqao pelos agricultores. O fraco conhecimento de tecnicas culturais e um dos mats importante factor limitante para o aumento do rendimento de amendoim na Zambia. Os estudos aqui apresentados foram conduzidos na Estacao regional de Investigacao de Msekera para estabelecer os beneficios da adopcao das tecnologias melhoradas no sistema tradicional. Sementeiras na epoca propria, sementes melhoradas, optimas sachas, densidade de planta mellorada e pratica de controlo de doengas foram avaliadas num desenho factorial completo. Depots de dois anos os resultados mostraram que usando todas as tecnologias melhoradas houve urn aumento de rendimento de 176% em relagdo ao sistema tradicianal. So a sementeira na ipoca propria resultou man aumento de produgao em 94%, em quanto que sementeira na ipoca propria combinado com optima densidade de plantas resultou num aumento de produgao de 200%. Os resultados indicaram que um significativo aumento de produgao e posssivel com pequenas mudangas no maneio.

Introduction

One of the most significant constraints to increased groundnut productivity under low-input agriculture is the low level of crop management. This is made worse when cultivars that demand high management crop husbandry are introduced. It has been observed that while research yields could be as high as 1-3 t ha^{-1} under rainfed conditions, farmers' yields are often as low as 0.5 t ha^{-1}. Optimal agricultural production requires timely, effective use of interrelated and interdependent factors (land preparation, sowing date, optimal plant density, etc.).

According to a report of the Eastern Province Agriculture Project in legume research, 90% of groundnut farmers would adopt the improved technology. However, the actual adoption rate is still undocumented. If only 15% of the total area under maize, the

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region's staple food, were farmed with modern production techniques, the adoption rate of groundnut would be about 7% (Reddy 1989). Zambia's Department of Agriculture (1989) attributed this low figure to the restricted availability of new seed, which is directly related to the low multiplication rate of groundnut.

In the tropics, most food production is undertaken on marginal land by small-scale farmers with limited resources and poor access to credit for purchasing inputs. Irrigation and fertilizer-two essential inputs for the production of new high-yielding varieties, are not easily available to these farmers. Improved technology has not therefore been readily adopted. Researchers must consequently take a new look at the practicality of generating improved technology.

This study was conducted with two aims: first, to measure the potential benefits of adoption of improved technology; and second, to establish the most effective cultural practices available.

Materials and Methods

The study site was located at the Msekera Regional Research Station, Chipata, in Zambia's Eastern Province (elevation 1024 m). Rainfall averages 887-1014 mm. Soils are Acrisols, They are moderately deep, dark reddish brown, moderately to strongly leached, moderately permeable, well-drained clayey soils with sandy loam topsoil and low nutrient holding capacity and pH ranging from 4.5 to 5.6.

The data presented were derived from a 2-year study. In the first year, the experiment consisted of five treatments.

1. Recommended plant density: 88 888 plants ha^{-1} vs farmers' practice (44 444 plants ha^{-1})-
2. Weeding frequency: two weedings at 35 and 45 days after sowing (DAS) vs one weeding at 45 DAS.
3. Protection against leaf spot: one fungicide spray at 75 DAS vs no protection.
4. Sowing date; early sowing with the first effective rains vs late sowing (around 15 Nov).
5. Improved seed.

This gave a total of 32 treatment combinations. In the second year, however, the leaf spot protection was dropped, resulting in four treatments, a total of 16 treatment combinations. The experiment was therefore initially a 2 x 5 factorial, and later a 2 x 4 factorial. In both cases the treatments were arranged in a randomized complete block design with two replications.

Each plot comprised 5 rows of 5 m long with 75 x 30 cm spacing for low density and 75 x 15 cm for recommended density. Gross plot area was 3.75 x 5 m (18.75 m^2), and the net plot area, the three center rows, was 2.25 x 4.5 m (10.125 m^2).

Seeds were sown on ridges at 5 cm depth with one seed sown per station. Before ridging, 150 kg ha^{-1} 'D' compound (N:P:K:S 10:20:10:10) fertilizer was broadcast as a blanket treatment. Captasan M 125 g 50 kg^{-1} seed was applied as a seed dressing to the improved seed, while the farmers' seed was not treated.

In the first season (1986), early sowing was conducted on 15 December and late sowing on 25 December. In the second season (1987), early sowing was done on 4 December and late sowing on 27 December. Harvesting in 1986 was done on 22 April for the early-sown crop and on 12 May for the late-sown crop. In 1987, harvesting was done on 30 April for the early-sown crop and on 21 May for the late-sown crop.

Observations included days to 50% flowering, a stand count at both emergence and harvest, assessment of disease and pest incidence, number of pods plant'1, pod yield $plot^{-1}$, shelling percentage, and 100-seed mass. Before any weights were taken, seed had to be dried as much as possible to reach the standard of 7% moisture content.

The data were finally subjected to statistical analysis using MSTATC with factor option of RCBD 5 and 4 factors.

Results and Discussion

Table 1 presents the 2-year results. Significant yield benefits were observed from the adoption of improved technology as opposed to farmers' practices (203% in 1986 and 149% in 1987).

Individual cultural practices contributed differently to yield. Early sowing alone gave a 94% yield advantage (average of 2 years) over control. Leaf spot protection, weeding frequency, and optimal density, on the other hand, had no significant effect in isolation.

Application of two factors was, however, significant. Plant density with early sowing, for example, gave a 168% advantage. Leaf spot protection with early sowing gave 156%, improved seed plus early sowing 145%, optimal plant density plus leaf spot protection 138%, early sowing plus two weedings

Table 1. Groundnut yield response (t ha^{-1}) to the adoption of different cultural practices, Msekera Research Station, Zambia.

Treatments	1987 Yield (t ha^{-1})	Increase over control (%)	1988 Yield (t ha^{-1})	Increase over control (%)	Mean increase (%)
1. Control	0.46	-	0.86	-	-
2. A	0.67	45	0.68	-21	12
3. AB	1.03	124	1.15	34	79
4. AC	0.86	87	0.70	-18	34
5. AD	0.68	48	-	-	-
6. AE	1.21	163	1.96	128	145
7. ABC	0.99	115	1.13	32	73
8. ABD	0.81	76	-	-	-
9. ABE	1.39	203	2.13	149	176
10. ABCD	1.06	131	-	-	-
11. ABCE	1.21	165	2.02	136	150
12. ABCDE	1.39	203	-	-	-
13. ABDE	1.95	323	-	-	-
14. ACD	0.84	82	-	-	-
15. ACE	0.88	90	1.20	133	111
16. ACDE	1.42	208	-	-	-
17. ADE	1.33	189	-	-	-
18. B	0.69	51	1.01	18	34
19. BC	0.80	74	2.00	133	103
20. BD	1.09	138	-	-	-
21. BE	1.43	210	1.94	126	168
22. BCD	0.87	88	-	-	-
23. BCE	1.44	214	1.97	130	172
24. BDE	1.58	243	-	-	-
25. BCDE	1.38	200	-	-	-
26. C	0.67	45	0.74	-13	-13
27. CD	0.95	106	-	-	-
28. CE	1.02	122	1.85	115	118
29. CDE	1.25	171	-	-	-
30. D	0.68	45	-	-	-
31. DE	1.18	156	-	-	-
32. E	0.94	103	1.59	86	94
Mean	1.07	-	1.43	-	-
SE	±0.1	-	±0.1	-	-
CV (%)	19	-	14	-	-

Control = Farmers' practices.
A = Improved seed.
B = Recommended plant density.
C = Two weedings.
D = Leaf spot protection.
E = Early sowing.

118%, and two weedings with leaf spot protection 106%.

A combination of three factors was even more significant. Combining optimal plant density, leaf spot protection, and early sowing, for example, gave a 243% yield advantage. Optimal density/two weedings/early sowing, two weedings/leaf spot protection/early sowing, and improved seed/optimal density/early sowing all gave a 172% advantage.

Combining four or five factors gave substantial yield increments, averaging 200% over the control.

There is little justification for this number of factors, however, since the yield advantage was not significantly different from some of the treatments with only two or three factors. This finding suggests that certain factors are more effective than others. Early sowing, optimal density, and two weedings (in that order) proved the most effective because they were expressed with just two or three factors. Improved seed and leaf spot control, on the other hand, proved effective only with more than three factors.

As mentioned earlier, farmers' labor conditions and credit facilities rarely permit them to adopt agronomic packages. With this problem in mind, this study has attempted to show that by applying minimal combinations of techniques, farmers can increase yield even if they cannot afford costly inputs. Optimal plant density combined with early sowing, for example, gave a yield advantage of 168%.

Conclusions

1. Adoption of improved technology improved groundnut yield 176% over the control.
2. The most effective and consistent single factor was early sowing, which gave a 94% yield increase. When combined with optimal plant density, it gave a 174% yield increase over the control.
3. Rather than adopting the whole package (all factors), which is rarely feasible for resource-poor farmers, the farmer can concentrate on the most practical factors.
4. Firm recommendations will be possible after further on-farm research.

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Discussion

Banda: Were genotypic responses to various treatments taken into consideration? For example, Malimba responds much more to early leaf spot control than ICGMS 42?

Kanenga: No. Only variety Chalimbana was tested in these experiments. Other varieties will of course respond differently.

Mpofu: 1. What were the timings of the two weedings? 2. Can you explain why you did not get a positive response to the two weedings?

Kanenga: 1. Thirty and 45 DAS. 2. According to earlier findings, groundnut suffers most from weed competition before 45 DAS. Since the one weeding was also done within this limit, neither one weeding nor two weedings expressed themselves significantly in terms of yield.

Freire: It seems that your improved seed gave unsatisfactory results. However, experiments with plant density and early sowing have shown encouraging results. Are you going to test all the factors on on-farm trials or are you going to select only some of them?

Kanenga: Given the nature of on-farm research, we must endeavor to suggest crop improvement that do not require inputs. Therefore not all factors are tested. In fact, after the second year of testing, we have already dropped leaf spot protection.

Chiteka: Why was there no response to control of leaf spot?

Kanenga: It is true that there was no response to control when we used a single factor, but in combination with other factors there was.

Effects of Cultural Practices on Diseases of Groundnut

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Abstract

The relative value of the application of cultural practices in the control of groundnut diseases is discussed in this paper. The emphasis is regional, targeting the southern African region. The cultural practices examined are various cropping techniques, time of sowing, plant density f removal of volunteer plants and groundkeepers, inoculation, and the application of fertilizers and pesticides. The principal diseases covered are leafspots, rust, web blotch, pod rot, rosette, and aflatoxin.

Resumo

Efeito das praticas culturais sobre doencas de amendoim. Este artigo discute o valor relativo da aplicacao das praticas culturais no controlo de doencas de amendoim. A enfase e regional a barcando a Africa Austral. As praticas culturais descutidas sao varias tecnicas de cultivo tais como: epoca da sementeira, densidade de plantas, controlo de ervas daninha, culturas de cobertura, inoculacao, aplicacao de fertilizantes e pestecidas. As principals doencas cobertas sao: mancha da folha, ferrugem, "Web blotch" podridadao da raiz c vagens, roseta e aflotoxina.

Introduction

Diseases are generally regarded as major constraints to groundnut production in the SADCC region. Many fungal, viral, nematodal, and bacterial diseases of groundnut have been reported in the region, but only a few of them are economically important on a regional basis. Several workers have investigated the effects of various cultural practices on diseases of groundnut. In this paper the effects of cultural practices on the incidence and severity of diseases of groundnut, with particular emphasis on economically important diseases, are briefly reviewed.

Leaf Spots

Early leaf spot (Cercospora arachidicola Hori) is the most destructive disease of groundnut in the region (Hildebrand and Bock 1990). Losses of 50% in potential yield are sustained annually over wide areas in the region (Bock 1989). Late leaf spot *(Phaeoisariopsis personata)* occurs sporadically in some countries, mainly in low altitude areas, but is economically important in lakeshore areas of Malawi, coastal southern Tanzania, southern Mozambique, Swaziland, and parts of Zambia.

Crop rotation provides partial control of leaf spots (Hemingway 1954, Rothwell 1962, Mughogho 1969, Kucharek 1975). In Malawi, the effects of crop rotation on early leaf spot were spectacular. The disease onset was very early (before flowering), and the disease progress was most rapid in plots where one groundnut crop followed another, resulting in a rapid increase in area under the disease progress curve

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(AUDPC). However, in groundnut following either maize or pasture, disease development was slow and less severe, and the AUDPC was low (Subrahmanyam 1991).

Both leaf spot pathogens perpetuate from season to season in infected crop debris. Burial of crop residues with a moldboard plow delays disease onset. Removal of volunteer groundnut plants and groundkeepers may reduce the primary sources of inoculum (McDonald et ah 1985).

Delayed sowing increases the severity of leaf spots and reduces yields in Tanzania (Simons 198,5, Lyimo and Kangalawe 1991) and in Malawi (Subrahmanyam 1991). However, in Zambia, the severity of leaf spots was higher in early-sown (late November to early December) than in late-sown (late December) groundnut (Kannaiyan et al. 1989).

Disease severity of groundnuts intercropped with maize, pigeonpea, sorghum, sunflower, or cotton was not markedly different from that of sole groundnut crops in Zambia (Kannaiyan et al. 1989). Subrahmanyam et al. (1983) also reported no differences in severity of late leaf spots between groundnuts intercropped with pearl millet or sorghum and that of sole groundnut crops in India. In Malawi, the effects of intercropping groundnut with maize or pigeonpea on disease severity were investigated at two locations. The severity of early leaf spot was not markedly different between sole and intercropped groundnuts at Chitedze. However, at Makoka, the severity of early leaf spot and rust was lower on intercropped groundnut than on sole crop (Subrahmanyam 1991). Mukiibi (1982) reported low disease severity in groundnuts intercropped with bean than in sole groundnuts in Uganda. In Tanzania, however, the disease severity was higher in intercropped groundnuts than in sole groundnuts (Lyimo and Kangalawe 1991). Mpiri (1991) reported an interaction of groundnut genotypes and the ratio of crop components in intercropping on the severity of leaf spots in Tanzania.

Plant densities ranging from 44 000 to 222 000 plants ha^{-1} showed no marked effects on leaf spot severity in Zambia (Kannaiyan et al. 1989). However, Farrell et al. (1967) reported an inverse relationship between in-row spacing of plants and intensity of leaf spots in Malawi.

Late leaf spot was less severe in cultivar mixtures than in the individual components in Tanzania. Cultivar mixtures suffered less from late leaf spot and yielded higher than the individual cultivar in pure stands (Lyimo and Kangalawe 1991).

Rust

Rust *(Puccinia arachidis)* occurs sporadically in several countries of the region, mainly in low-altitude areas (Cole 1987), but is economically important in the lakeshore and southern areas of Malawi, coastal southern Tanzania, southern Mozambique, Swaziland, and Zambia.

The groundnut rust pathogen is short-lived (less than 1 month) in infected crop debris. A clear break in time between successive groundnut crops to reduce or eliminate viable inoculum is recommended (Subrahmanyam and McDonald 1983). In the SADCC region, groundnut is grown mainly during the rainy season, and the possibility of P. *arachidis* survival during the off-season is very remote. However, care should be taken to prevent perpetuation on off-season seed multiplication crops. Volunteer groundnut plants and groundkeepers should be eradicated to eliminate the primary sources of inoculum (Subrahmanyam and McDonald 1983).

Web Blotch

Web blotch *(Didymella arachidicola)* occurs in a number of countries, but is important only in Zimbabwe, where it occurs mainly on long-season crops (Cole 1981), and in Swaziland (Rao and Masina 1987).

The web blotch pathogen can survive in infected crop residues, or on volunteer groundnut plants. Pycnidia and pseudothecia develop on fallen leaves in the field, and provide initial inoculum to infect subsequent groundnut crops. Crop rotation and eradication of infected crop debris and volunteer groundnut plants may be useful in eliminating the primary sources of inoculum. Although groundnut is the only known natural host, the pathogen can also infect several other legumes, such as soybean, sweet clover, and hairy vetch (Philley 1975).

Pod Rot

Pod rot of groundnut is caused by a variety of soil-borne fungi *(Rhizoctonia solani, Macrophomina phaseolina, Sclerotium rolfsii, Pythiuni* spp, and *Fusarium* spp) commonly occur in all countries in the region. However, they are considered economically important only in Zimbabwe.

Traditional crop rotation was ineffective in controlling pod rots. However, in Malawi, fields where groundnut had been grown for several years in succession had significantly more pod rots caused by 5. *rolfsii* and R. *solani* than did rotated or fallowed fields. Cultivation in well-drained soil reduces pod rots. Delayed harvesting increases pod rot and reduces pod quality in Malawi (Subrahmanyam 1983) and in Zambia (Kelly 1985). Mercer (1978) showed that control of leaf spots reduced the incidence of pod rots in Malawi. Application of high rates of gypsum (1.12-2.24 t ha^{*1}) at early pegging is effective in controlling pod rot in the USA (Bell and Sumner 1984). Pods may be predisposed to infection by *R. solani* and other microorganisms because of calcium deficiency or imbalances of calcium, potassium, and magnesium (Bell and Sumner 1984). Application of potassium sulphate or magnesium sulphate to groundnut at flowering stage increases pod rot (Beute 1984).

Seedling Diseases

Seedling diseases caused by several seed and soil-borne fungi *(Aspergillus niger , R. solani, M. phaseo-Una, Rhizopus* spp, *Pythium* spp, and *Fusarium* spp) are widespread and important in most countries of the region. These diseases can be very effectively and economically controlled by seed dressing with fungicides combined with certain cultural practices. Only high quality seed should be used for sowing. Deep sowing of seed should be avoided as etiolated seedlings are more susceptible to infection. Deep plowing of fields and crop rotation reduce the incidence of seedling diseases.

Groundnut Rosette

Rosette is one of the major constraints to groundnut production in the region (Nigam and Bock 1985). Although disease epidemics are sporadic, yield losses approach 100% whenever the disease occurs in epidemic proportions. The pathogen is transmitted by aphids *(Aphis craccivora).*

Several researchers have conclusively demonstrated that groundnut rosette can be effectively reduced when groundnut is sown early in the season and at high population densities (Guillemin 1952, Jameson and Thomas 1954, Sauger et al. 1954, Smartt 1961, Booker 1963, A'Brook 1964, Gibbons et aL 1966, Davies 1976, Farrell 1976a and 1976b). Although Bock (1987) observed aphids at crop emergence, early sowing will avoid peak periods of aphid flight activity, resulting in low disease incidence (Farrell 1976a, 1976b). This observation is supported by recent research in the SADCC region. In Zambia, late-sown groundnuts with poor plant stand showed higher rosette incidence (36-85%) than the earlier-sown crops with full stand (2-6%) (Sandhu et al. 1985). Subrahmanyam (1983) reported that the disease incidence was higher (97.3%) in late-sown (mid-January) groundnut than in early-sown (early December) groundnut (22.1%) in Malawi. Aphids were more severe in low plant populations (222 000 plants ha^{-1}) than in high plant populations (333 000 plants ha^{-1}) in Mozambique (Ramanaiah et al. 1989).

Eradication of volunteer groundnut plants and groundkeepers was recommended for preventing the perpetuation of virus inoculum during the off-season (Reddy 1984). However, Bock (1989) found no evidence of pathogen survival on volunteers during the dry season in the SADCC region.

Intercropping groundnuts with beans decreased rosette incidence in Malawi (Farrell 1976b) and Uganda (Mukiibi 1982), and similar effects were found when groundnut was intercropped with maize in the present Central African Republic (Guillemin 1952). In Zimbabwe, groundnut rosette has been virtually eliminated in commercial farming areas by the use of improved cultural practices such as removal of volunteer groundnut plants, early sowing, maintaining optimum plant stands, nutrition, and insecticide applications (Cole 1985).

Aflatoxin

Contamination of groundnut with aflatoxin, the secondary toxic metabolites produced by fungi of the *Aspergillus flavus* group, is a serious quality problem in the SADCC region (Cole 1991). *A. flavus* may invade groundnut seeds before harvest, during postharvest drying, and during storage if seeds are rewetted. Preharvest aflatoxin contamination is important under drought-prone conditions, while postharvest contamination is significant under wet and humid conditions (Mehan 1987).

A considerable amount of information has been assembled in the region and elsewhere on the influence of environmental factors, crop production, and produce handling procedures on seed invasion and aflatoxin contamination (McDonald 1989). Invasion of seeds by *A. flavus* and aflatoxin contamination can be minimized by:

- crop rotation;
- prevention of drought stress by supplemental irrigation during the 4-5 weeks of the crop season;
- avoiding mechanical crop damage, particularly during cultivation, harvesting, and subsequent storage;
- harvesting at optimum maturity;
- drying pods to a safe moisture level (8%); and
- storage of produce at low temperature, low humidity, and insect-free conditions.

It is important to tailor these recommendations to fit the particular conditions in each country in the region. Farmers should be apprised of these simple but effective cultural practices to reduce aflatoxin contamination of their crops.

Conclusions

The effects of cultural practices on diseases of groundnut, particularly rosette and leaf spots, have been exhaustively studied.

It has been conclusively demonstrated that early sowing at optimal plant densities can reduce the incidence of groundnut rosette; hence the successful adoption of this practice by the commercial farming sector in the region. However, over much of the region, early planting at high plant densities may not be possible because of the sowing sequence and differential crop priority, labor constraints, or because of nonavailability of good quality seed and seed dressing chemicals. In addition, early sowing in some areas of the region may result in harvesting the crop during the wet season, leading to severe aflatoxin contamination.

Crop rotation reduces the severity of several fungal, bacterial, and nematodal groundnut diseases. This simple cultural practice can pay high dividends in crop productivity. Unfortunately, crop rotation may not be feasible to many smallholders. It is nonetheless important that farmers be informed about the value of adopting these beneficial cultural practices, thus minimizing crop losses due to diseases while improving the quality of produce by minimizing aflatoxin contamination.

Although cultural practices may provide only partial control of diseases, they can be used effectively as one component of an integrated disease management strategy, thus lessening the risk of disease severity and minimizing the impact of disease on yield.

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Discussion

Schmidt: You mentioned crop rotation as an effective measure against aflatoxin contamination. However, this contamination is not limited to groundnut but occurs on cereals as well. What kind of rotation do you propose? Or does the aflatoxin problem occur, as with maize, only during storage?

Subrahmanyam: As a matter of fact, maize-groundnut rotation proved effective in reducing aflatoxin contamination in groundnut. This is because groundnut infection takes place in the soil, whereas maize infection is air-borne.

Nageswara Rao: What are the reasons for reduction in area under the disease progress curve (AUDPC) when groundnut is rotated with cereals like maize?

Subrahmanyam: The disease onset is delayed and less severe when groundnut in grown in rotation with maize, resulting in low AUDPC.

Syamasonta: Is there any difference between burning and burying the crop remains in controlling leaf spot?

Subrahmanyam: Deep burial of infected crop residue is probably the best means of reducing the severity of leaf spots.

Ndunguru: When pathologists assess the importance of a disease they measure yield losses. But when it comes to screening for disease resistances, yield figures are not presented. I am pleading that yields be recorded as well for three reasons: (1) potential yields should be recorded, (2) some national programs have no breeders so measuring yields is doubly important, and (3) some resistant lines may be negatively correlated with high yield and they may retain these negative aspects in the crossing activities.

Subrahmanyam: 1. Yield potential of disease-resistant lines is determined. 2. Yes, I agree. 3. Yes, it is true with some of the foliar disease-resistant germplasm lines. However, the populations originating from crosses between resistant and susceptible genotypes have good levels of resistance and yield because they are carefully selected for these two characters.

Ndunguru: The incidence of groundnut rosette is increased with low plant population and decreased with intercropping when the groundnut population is also low. Do you see a conflict in these two findings?

Subrahmanyam: No. The component cereal crops may be acting as a barrier for the vectors.

Olorunju: Our work corroborates this. Aphids are attracted to brown color (ground color). Intercropping discourages aphids by covering the ground. I have another question: what is the prospect of cultural practices in disease control when you consider the problems faced by most groundnut farmers (e.g., which crop to prioritize?). Most farmers grow maize or millet before groundnut, thus sowing late and exposing the crop to disease (leaf spot, rosette).

Subrahmanyam: I agree with your comments. Even though cultural practices provide only partial disease control, they should be considered as integral components of integrated disease management strategies.

A Model for On-farm Research to Improve Groundnut Production

D. McDonald, C.L.L. Gowda, and D.G. Faris[1]

Abstract

The dramatic increases in rice and wheat production during the Green Revolution era were mostly from highly productive, irrigated, homogenous lands (core areas) cultivated by farmers with adequate resources. However, the success could not be duplicated in the less productive, heterogenous, rainfed areas (hinterlands). The main reason was that the technology developed at well-endowed research stations could not be replicated in the diverse ecological conditions of the hinterlands. A concept of decentralized research strategy coupled with farmer involvement and use of indigenous practices to develop and adapt technologies suited to the needs of the resource-poor farmers has evolved in the 1980s. This paper describes the farmer-participatory, on-farm adaptive research currently undertaken by ICR1SAT to help increase groundnut, chickpea, and pigeonpea production in South and Southeast Asia.

Resumo

Modelo de investigcao no campo do agricultor para aumentar o rendimento de amendoim. O dramatico aumento de producao de arroz e trigo durante a era da revolugdo verde era proveniente de regadios altamente productivos des agricultores com recursos adequados. Porem o sucesso nao podia ser duplicado nas dreas heterogenias de baixa productividade, quentes e dependentes de chuvas. A razao fundamental foi de ter se desenvolvido investigagdo destas tecnologias em estagoes bem definidas que nao se podia repetir em diversas zonas ecologicas de areas quentes. Um conceito estratigico de descentralizagao de investigagdo associando o envolvimento do agricultor, uso de praticas indigenas e adaptor tecnologias adequadas as necessidades do agricultor pobre em recursos foi levado a cabo em 1980. Este artigo descreve a participacao dos agricultores nos ensaios de investigagdo de adaptabilidade no campo dos agricutores actualemente levados a cabo pelo ICRISAT para ajudar a elevar o rendimento de amendoim, grao de bico e feijao boer no suie sudueste da Asia.

Introduction

High-yielding varieties of rice and wheat were responsible for the Green Revolution of the 1960s and 1970s. However, the dramatic yields from the improved semi-dwarf and fertilizer-responsive varieties came largely from 'core areas' of highly fertile and uniform land cultivated by farmers with adequate resources. The 'top-down' approach to transfer of technology was successful in the well-endowed, productive, and homogenous core areas because well-to-do farmers were able to simulate research station conditions. Duplicating the results of the Green Revolution, unfortunately, proved extremely difficult in the less-favored areas usually referred to as 'hinterlands'. Technology adoption was slow or nonexistent in these areas, which were more diverse, less productive, and poorer (Rambo and Sajise 1985).

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McDonald, D., Gowda, C.L.L., and Paris, D.G. 1992. A Model for On-farm Research to Improve Groundnut Production. Pages 105-110 *in* Proceedings of the Fifth Regional Groundnut Workshop for Southern Africa, 9-12 Mar 1992, Lilongwe, Malawi (Nageswara Rao, R.C., and Subrahmanyam, P., eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Technology packages are generally inapplicable to the diverse situations of the semi-arid tropics. Each area requires a system of site-specific management practices. Scientists are obliged to offer a 'basket' of technology options from which the farmers can choose those most suitable and affordable to improve and stabilize their yields. Research and development should therefore be decentralized to enable development of site-specific technologies to serve the resource-poor farmer of the hinterlands.

Over the last decade there has been a shift from the top-down approach to transfer of technology to the bottom-up, farmer-first approach (Chambers et al. 1989), indicating an apparent reversal of roles in agricultural research. However, a more realistic view is that both experts (scientists) and local people (farmers) have unique areas of expertise which collectively can provide a better basis for development than either can achieve alone (Raintree and Hoskins 1988). Since many farmers experiment, advantage should be taken of their technical knowledge and experimental abilities in planning on-site systems research. Farmer evaluation of technical alternatives is particularly useful in the identification of relevant issues and in the adaptation of technologies to specific local circumstances (Fujisaka 1989). Hence the concept of farmer participation should contribute to development and adoption of technologies suitable to particular locations or zones.

ICRISAT's Transfer of Technology Project in India

Groundnut oil is a major cooking oil in India. In 1987, edible oil imports to India totalled US$ 6.5 million. The Government of India established a Technology Mission on Oilseeds, and invited ICRISAT to assist Government efforts to increase production, thereby reducing the need to import vegetable oils.

The average yield of groundnut in India is about 0.8 t ha^{-1} in the rainy season, and 1.7 t ha^{-1} in the postrainy season (for irrigated crops). Under non-stress situations in experiment stations, ICRISAT scientists reported yields of 4-6 t ha^{-1}. In collaboration with national program scientists, ICRISAT researchers tested improved production technologies in farmers' fields. Working with extension staff and farmers, the technology was modified and adapted to suit different areas. The improved technology practices included use of improved varieties and better crop management. In farmers' field trials over a 3-year period, use of one improved variety gave a 32% yield increase, use of improved crop management gave a 25% increase, and use of an improved variety with improved crop management gave a 50-150% increase/The improved packages are now being disseminated by state governments and farmers' cooperatives.

Asian Grain Legumes On-farm Research Project

The impact of ICRISAT's technology transfer activities in India was so successful in India that the Institute felt that extending these activities to other Asian countries would be advantageous. The United Nations Development Programme (UNDP) agreed to provide funds to organize a meeting to determine the interest of national programs in such a project.

The Asian Grain Legumes On-farm Research (AGLOR) Planning Meeting was held at ICRISAT Center in November 1989. Representatives of five countries (Indonesia, Myanmar, Nepal, Sri Lanka, and Vietnam) met with invited consultants and ICRISAT scientists. Country representatives expressed interest in participating in an on-farm research project, and prepared draft plans for such activities in each country. ICRISAT prepared a research proposal based on these drafts and submitted it to the UNDP for funding. The project was approved by UNDP, as a component of its UNDP-FAO/RAS/89/040 Project, to support adaptive on-farm research on ICRISAT mandate legumes in Indonesia, Nepal, Sri Lanka, and Vietnam (Gowda and Faris 1991).

The main objectives of the project are:

- to assist the national agricultural research systems (NARSs) to assemble information from research and extension sources within the project countries and the region that could be used to generate production technologies;
- to generate and test crop production technology under research station and farmers' field situations;
- to modify the most effective production technologies to suit real farm situations; and
- to enhance the adaptive research capabilities and interest of the NARSs in legumes production.

The project activities are described here to provide an example of one way in which an on-farm adaptive research project can be organized. We follow a four-stage approach.

1. Identify constraints.
2. Find suitable technologies or solutions.
3. Evaluate solutions in single-factor or multifactor diagnostic experiments at research stations and farmers' fields.
4. Formulate a basket of technology options for the farmers.

Diagnostic Surveys

The target areas for on-farm research were chosen by the national program administrators based on the area cropped, potential for improvement, and other factors that could eventually facilitate adoption of improved technologies. Diagnostic surveys (Table 1), using rapid rural appraisal methods, were then conducted in the target areas by multidisciplinary teams of scientists from the NARSs and ICRISAT. The survey teams included agronomists, breeders, entomologists, economists, pathologists, and soil scientists.

The teams visited target areas and discussed the project with farmers and village leaders. Interviews with farmers were conducted informally. Each team member had a check list of questions designed to provide an understanding of local agronomic and crop management practices to help identify the causes of low yield. Plans for on-farm and supportive back-up research to address the farmer-perceived production constraints were then prepared. Suggestions were made to concerned Government authorities to consider how to alleviate the socioeconomic constraints faced by farmers. Survey team members prepared experimental plans for addressing the biotic and abiotic constraints.

Planning Meetings

Planning meetings were held in each project country, usually after the diagnostic surveys. These meetings involved survey team members, national program administrators, extension staff, and research scientists. Participants reviewed existing information and documented available technology and current ideas to provide solutions. The farmer-identified constraints (Table 2) were matched with the available solutions and technology options, and plans were prepared for both on-farm research and supportive back-up work in research stations. Most of the on-farm trials planned were single- or two-factor diagnostic experiments.

Table 1. List of single-factor diagnostic treatments for groundnut on-farm research in Nepal.

	Treatment	Purpose
Seed dressing fungicide	Thiram:Vitavax® (50:50) 3g kg^{-1} seed just before sowing	To determine if seedling diseases are a constraint
Seed dressing insecticide	Chloropyriphos (12.5 mL kg^{-1} seed)	To determine if soil insects (white grubs) reduce plant stand
Rhizobium	NC 92	To see if rhizobium can improve pod yield, particularly in rice fallows
Foliar disease control	Daconil® (chiorothalonil) 50-60 days after sowing or when around 10 spots $plant^{-1}$ appear	To determine if foliar diseases are a constraint
Insect pest control	Folithan Sumithion® 0.5% at 40 days or when insects present	To determine if insect pests are a problem
Micronutrient spray	Tracel spray 30 days after sowing	To determine if micro-nutrient deficiency reduces yield
Seed rate (plant population)	60 kg ha^{-1}. 40x20 cm	To observe the effect of plant population on pod yield
Gypsum	400 kg ha^{-1} at peak of flowering with second weeding. Placed near base of plant on both sides of row	To determine role of gypsum in pod filling and pod yield

Table 2. Farmer-identified constraints to groundnut production in Tay Ninh and Long An Provinces, southern Vietnam;

Constraints	Ranking[1] Tay Ninh	Long An	Overall priority
Socioeconomic			
Lack of cash for input	2	3	High
Lack of irrigation water	1	3	Medium
High cost of input	-	2	Low
Input not available	-	1	Low
Unstable/ low prices	.1	1	Low
Spurious pesticides	-	1	Low
Abiotic			
Lack of coconut ash	3	2	High
Lack of farm machinery	2	2	Medium
Quality of canal water	-	2	Low
Biotic			
Weeds	2	2	Medium
Leaf eaters *(Helicoverpa* and *Spodoptera)*	3	3	High
Damping off disease	2	2	Medium
Lack of high yielding-variety	3	3	High
Yellow leaf disease (?)	1	2	Low

1. Ranking based on yield loss and temporal and spatial occurrence of the constraints: 1 = low; 2 = medium; 3 = high importance.

On-farm Research

The on-farm research in each project country followed a farmer-participatory approach. Extension staff and scientists discussed individual diagnostic experiments with the farmers and explained the rationale behind the selection of each factor. They then ensured farmer input into trial design and management. The farmers agreed to implement and manage the individual trials. Research scientists' input was to monitor the progress of trials and provide timely advice and suggestions on the operations to be undertaken.

On-station Research

Whenever the identified production constraints were complex and needed controlled experimentation, experiments were proposed to ascertain their efficacy prior to testing by farmers. For example, these back-up research plans included: identification of suitable pre- or post-emergence herbicides, determination of optimum levels for need-based fertilizers in different soils, optimum plant populations in different areas, and optimum irrigation schedules. In some cases, the long-term back-up research included varietal development and identification of suitable varieties for different locations/situations.

Results

Since the AGLOR Project is still new, few results are available. However, some results from trials in Vietnam are given here as examples.

In the rhizobium inoculation trial, plants in the inoculated plots gave 14% more pod yield than plants from nontreated plots. Seed treatment with fungicides gave 18-30% increases in yield over nontreated controls. One fungicidal spray reduced damage by leaf spots, resulting in a 22% increase in pod yield. Similarly, application of lime (400 kg ha^{-1}) gave yield increases of 11-23%.

These results indicate the advantage of each single factor and underline the usefulness of such experiments in assessing the importance of each factor. It is hoped that further testing at other locations next season will confirm the results. The data will then constitute an important component of a 'basket of technology options', and farmers will be able to choose one or more options, depending on their resources and requirements.

Feedback from the Field

Bacterial wilt was not an important groundnut disease in southern Vietnam. However, during a monitoring tour in January 1992, it was observed that several ICRISAT lines in the International Groundnut Varietal Trials were showing high mortality due to bacterial wilt (caused by *Pseudomonas solanacearum).* Subsequent visits to farmers' fields to conduct a disease survey confirmed the presence of bacterial wilt on introduced varieties in most areas, while local landraces appeared resistant to wilt. The research program was therefore modified to include screening and breeding for resistance to bacterial wilt. Future varietal introductions into Vietnam must have resistance to this disease.

As a result of this feedback from farmers' fields, seed of the Vietnamese landrace Ly was sent to Indonesia (where a sick plot was available) for screening against bacterial wilt.

Acknowledgement

The contribution of many scientists in the national programs of Indonesia, Nepal, Sri Lanka, and Vietnam, as well as of ICRISAT scientists involved in the AGLOR project, is gratefully acknowledged.

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Discussion

Freire: There are two main on-farm adaptive research methods: the first where the message is well tested and well known, and the second where the testing is conducted straight away in farmers* fields. Each has advantages and disadvantages. However, what happened in Vietnam with the bacterial wilt problem can be a major setback causing distrust of the packages under test.

Nigam: Agreed, each approach has both advantages and disadvantages. But when the research is participatory in nature (in this case, for example, farmers and scientists worked together to identify constraints and assign priorities), it also becomes a learning process. There was no claim made that suggested treatments will always work better. The failure of improved varieties due to bacterial wilt did not cause any setback. On the other hand, it revealed an additional constraint that had not been previously identified and gave a clear message to researchers that groundnut varieties will need to have resistance to bacterial wilt in addition to high pod yield.

Ndunguru: In Niger, farmers sow their staple food crop, millet, with the first rains. Because millet has a low seed rate, farmers can withhold enough seed to resow the crop in the event of drought. Groundnut, which has a lower priority than millet for Sahelian farmers, has a high seed rate, and is therefore sown only after the rains have stabilized to minimize risk of crop loss.

Nigam : We have heard this morning and also in the past that groundnut is always sown late by farmers in the region because they sow their staple food crops first. We are aware that this practice is unlikely to change and acknowledge the wisdom of the farmers' prioritization. Why, then, do we continue to conduct trials for varieties and cultural practices that require sowing at the onset of rains? These improved varieties and practices will have no value to the farmers who sow their groundnuts late. Should we not conduct our agronomic research and yield trials under late sowing conditions so that we develop something useful to offer these farmers? I submit that this issue is of crucial importance and that it be discussed thoroughly during the general discussion.

Ongoing Production Agronomy Studies with Groundnut at ICRISAT Center

M.M. Anders, M.V. Potdar, P. Pathak, and K.B. Laryea[1]

Abstract

Results from three distinct groundnut studies are **pr**esented. Initial field surveys indicated iron chlorosis was a significant production constraint in many groundnut growing areas of India, Village studies showed improved yields from using iron sprays ($FeS0_4$) and improved land management (broadbed and furrow system). These results were not consistent over all sites tested. A second study was initiated to quantify the effects of a broadbed and furrow land management system on groundnut production on an Alfisol. It showed that the broadbed and furrow system improved soil physical properties but reduced groundnut yields. This reduction was attributed to intermittent drought stress in plants grown on broadbed and furrow system. In a third study, cropping systems/rotation experiments showed that groundnut intercropped with medium duration pigeonpea is a very attractive system. Perennial pigeonpea intercropped with groundnut performed well the first season but was too competitive for groundnut in the second season.

Resumo

Estudos agronomicos em curso sobre amendoim no ICRISAT. Os resultados apresentados sao provenientes de tres estudos distintos sobre amendoim. Um levantamento preliminar no compo: indicou que a clorose era o nd do extrangulamento de producao na maior parte das areas de produgdo de amendoim da India. Estudos no campo em diversas localidades mostraram um aumento de producao com a pulverizagdo de sulfato deferro ($FeS0_4$) e uso de praticas melhoradas na armagdd do tereno para sementeira "broadbed and furrow system*'. Estes resultados nao foram constantes em todos os sitlos experimentados. Um segundo estudo foi iniciado para quantificar o efeito do emprego do sistema de "broadbed and furrow" no cultivo de amendoim em alfisolos, viu se que o sistema melhorou as condigoes fisicas do solo em determento de amendoim, a reduducao do rendimento atrihuiu-se a seca drdstisca que provocou "stess" no crescimento de amendoim no sistmea de " broadbed and furrow" .O tencioso estudo sistemas de produgao rotacao mostrou que a consorciagdo de amendoim com feijao boer de ciclo medio 4 o sistema mais atractivo. A consorcigad de feijdo boer perene com amendoim deu hem na primeira campanlia, mas foi muito competetivo na segunda.

Introduction

Research was initiated in the Production Agronomy Unit of the Resource Management Program at ICRISAT Center in 1989 with a focus on a series of village level studies aimed at identifying and quantifying farmer level production constraints. This work is done in collaboration with India's national program and to date has addressed issues in organic matter management, sorghum genotype selection, and iron chlorosis

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Table 1. Yield and yield components of groundnut as influenced by foliar iron sprays at Umri (Maharashtra) and Korvipad (Andhra Pradesh), India, postrainy season 1990/91.

Iron sources	Plant stand (0000 ha-1)	Dry yield (t ha^{-1})			Harvest index (%)
		Pod	Fodder	Biomass	
		Umri			
$FeSO_4$	193.5	1.73	1.72	3.45	49.56
Fe-EDTA	172.0	1.28	1.47	2.75	44.57
Control	161.5	1.19	1.19	2.60	42.56
SE	± 4.7**	0.08**	0.08*	0.04**	±1.40**
		Korvipad			
$FeSO_4$	195.1	0.77	1.26	2.03	38.66
Fe-EDTA	177.9	0.59	1.06	1.65	35.37
Control	167.6	0.57	1.05	1.62	34.62
SE	± 5.5**	0.03**	0.08**	0.10**	±1.09*

* *P* <0.05%.
** P <0.01%.
Source: After Potdar and Anders 1991.

- Severe iron chlorosis symptoms were evident as early as the seedling stage, and the intensity of chlorosis varied considerably within and between sites. Three out of four sites showed severe iron chlorosis symptoms.
- BBF was effective in reducing the incidence of iron chlorosis at one site.
- All genotypes tested were highly susceptible to iron chlorosis and yielded similarly.
- Foliar sprays with 0.5% $FeSO_4$ were more effective than Fe-EDTA in correcting iron chlorosis symptoms.
- Iron chlorosis can reduce pod yield up to 46% and reduce fodder yield up to 22%.

To extrapolate these results to other areas, we will be conducting intensive surveys on farmers' perceptions and management of iron chlorosis in groundnut. The survey results will be integrated into a Geographic Information System (GIS) to extrapolate the results to other SAT areas. We will continue these studies focusing mainly on developing management strategies to minimize yield losses from iron chlorosis.

Land Surface Management

During the 1970s, ICRISAT concentrated on developing a Vertisol technology package which included the BBF land form as an integral component. Recent village work has indicated that farmers are adopting this land form in groundnut-growing areas which have Alfisol and/or Vertisol soil types. The adoption of this land management strategy has generated some concern, particularly with Alfisol soil types where BBF may increase soil erosion (ICRISAT 1981).

To address this concern, a collaborative study between the Soil Physics and Production Agronomy Units of ICRISAT's Resource Management Program (RMP) was initiated in the 1990 rainy season. An Alfisol site (fine-loamy, mixed, isohyperthermic Udic Rhodustalf) was used with two land forms (BBF vs flat) and five replications. Broadbeds (1.5 m width) were formed with bullock-drawn equipment after the onset of rains. Groundnut genotype ICGS-11 was sown into 30-cm rows with five rows on each bed. A preplant banded fertilizer application of 18 kg N and 46 kg P ha^{-1} was given to all plots. Soil physical and plant growth measurements were collected during plant growth.

Soil penetration resistance was lower in the BBF treatment than in the flat treatment throughout the growing season (Fig.2A). Differences in soil oxygen content were significant for the first 60 days following BBF formation, but decreased with increasing bed age (Fig.2B). However, oxygen content was higher in BBF for all treatments. Soil bulk density increased with increasing time after tillage (Fig.2C) with significantly higher values for the flat land treatment at all measurements. All soil physical data suggest that groundnut production should increase in the BBF treatment because crusting, which results in poor peg penetration, is a major constraint to groundnut production in these soils.

Contrary to this assumption, there were no significant differences between land form treatments for

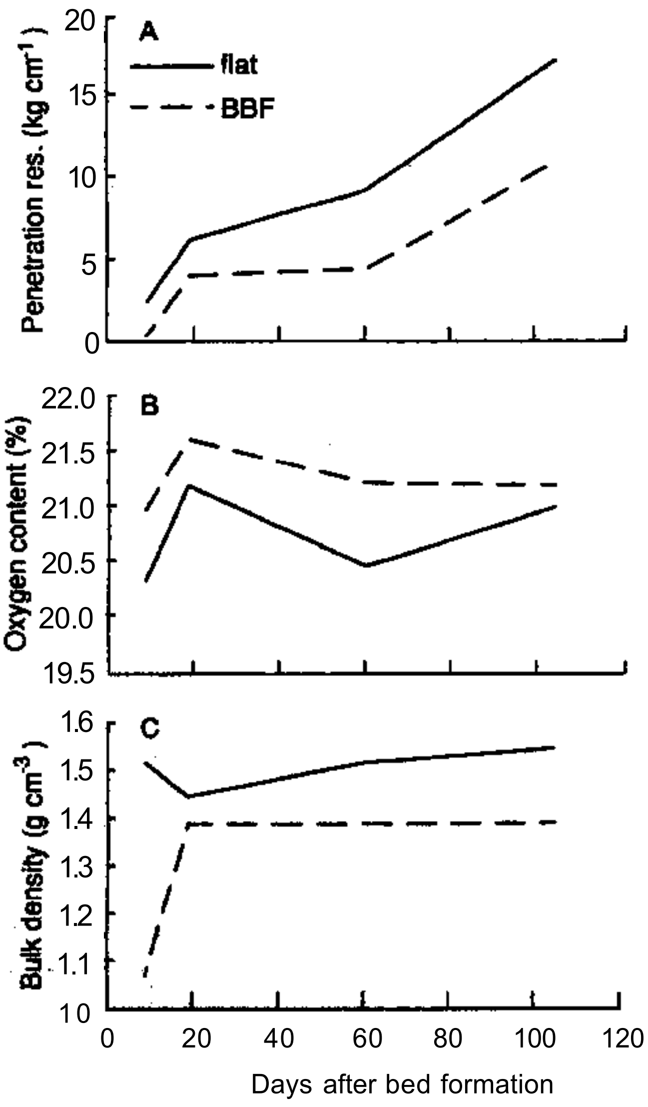

Figure 2. Soil penetration resistance (A), oxygen content (B) and bulk density (C) in the 0-5 cm soil layer for BBF and flat land forms.

Table 2. Effects of land form on fresh and dry groundnut pods and fodder yields.

Treat-ment	Popula-tion (ha^{-1})	Fresh pod (t ha^{-1})	Fresh fodder (tha^{-1})	Dry pod (tha^{-1})	Dry fodder (tha^{-1})
Flat	146 500	2.41	2.62	1.28	1.08
BBF	140 916	2.04	2.28	1.12	0.98
	NS	P<0.05	P<0.05	NS	P<0.05

plant population or dry pod weight (Table 2). Fresh pod and fodder and dry fodder weights were significantly ($P < 0.05$) higher in the flat land treatment. To better understand how these differences occurred, we looked at rainfall and plant growth indicators. This crop received approximately 250 mm rainfall between sowing and flowering. However, most of this rainfall occurred between 20 and 30 days after sowing (DAS).

Plant growth measurements taken at 31 DAS indicated a significantly higher leaf area in the flat treatment and a correspondingly nonsignificant higher fresh and dry leaf weight (Fig.3). Specific leaf mass was higher in the BBF treatment at 31 DAS, indicating possible drought stress. By 77 DAS, leaf area and leaf fresh and dry masses were higher in the flat land treatment. These results indicate that plant growth was not improved by using the BBF land treatment, even though some of the soil physical measurements indicated this should not be the case. We conclude that the efficiency of BBF in groundnut growth and development depends very much on rainfall distribution. Prolonged droughts in the rainy season has a pronounced effect on crop growth as the micropores in the beds lose water quicker than the micropores of the flat land. Probably supplementary irrigation during such prolonged droughts would eliminate this problem on BBF.

While BBF improves soil physical properties, it also results in faster soil drying, thus increasing the probability of intermittent drought stress during plant growth. In our study groundnut was unable to compensate for this stress. Our previous work also indicated that erosion may increase if a BBF land form is used on an Alfisol (ICR1SAT 1981). One MSc student in the Soil Physics Unit is continuing this research.

Crop Rotations and Intercropping

In 1989, a cropping systems study was initiated at Vertisol and Alfisol sites at ICRISAT Center. Even

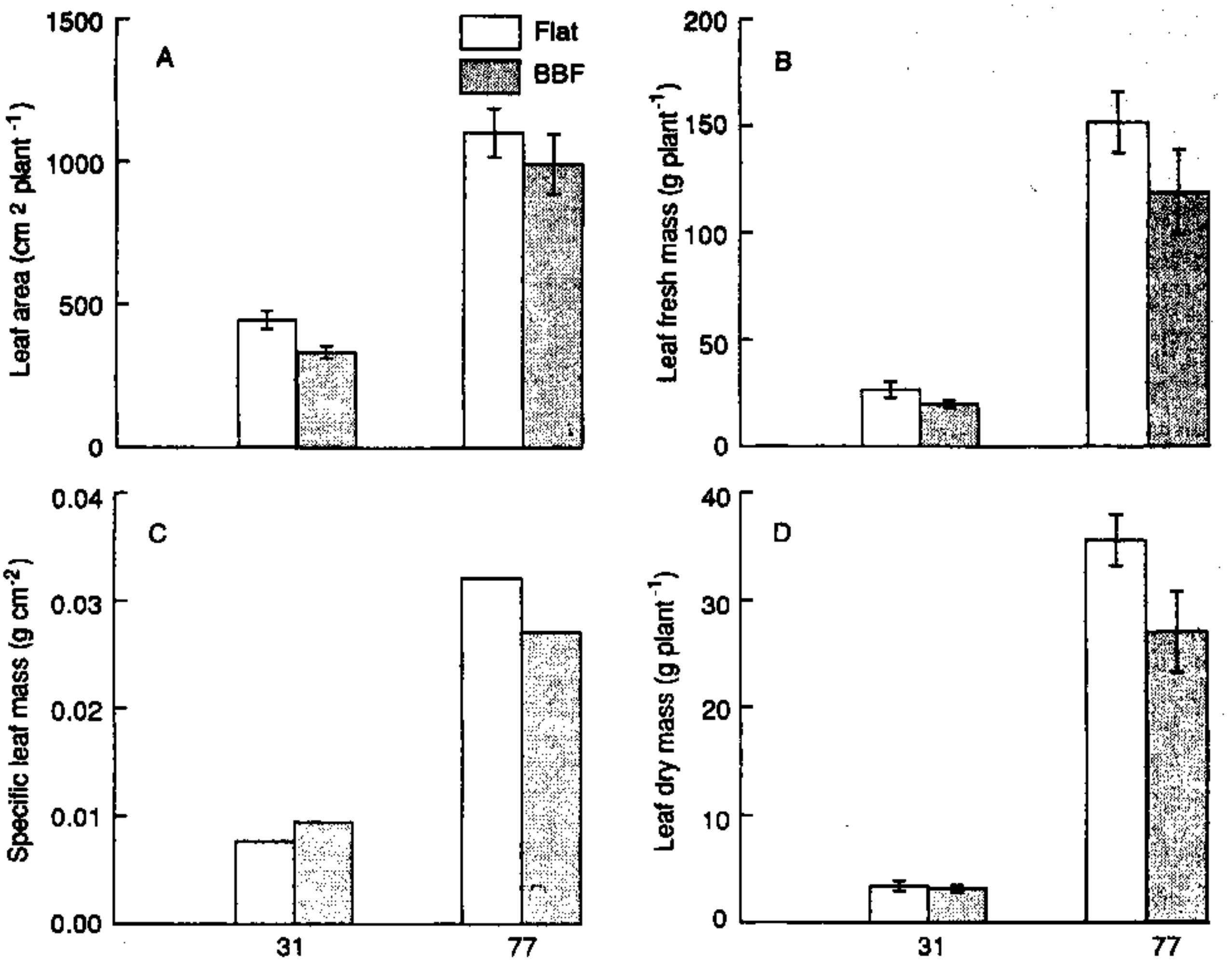

Figure 3. Groundnut leaf area (A), leaf fresh mass (B), specific leaf mass (C) and leaf dry mass (D) for BBF and flat land treatments.

though this study was termed a pigeonpea intercropping study, groundnut played a major role in many cropping systems (Table 3). From a total of 20 cropping systems evaluated, 9 (including 5 rotations) contained a groundnut component. Four replications were used with all rotation components included each year. Groundnut received a preplant application of 18 kg N and 20 kg P ha^{-1}. Row spacings in sole and intercropped groundnut systems were 30 cm with every 5th row utilized for the companion crop in intercropping treatments. During the first year of production, perennial pigeonpea genotypes were not thinned and were kept at a population of 35 000 plants ha^{-1}.

At the end of the first season, alternate pigeonpea rows were removed and plants thinned within rows, resulting in a population of 8000 plants ha^{-1}. All sowings were made the same day following the onset of rains. Improved groundnut genotype ICGS-11 was used in all sowings. Plant growth and yield data were collected each year.

Rainfall varied considerably during the 3 years of experimentation (Fig.4). It is unlikely that there was any drought stress in 1989, as total rainfall was approximately 400 mm more than the 15-year mean. While rainfall was above normal in 1990, distribution was poor and many crops suffered from intermittent drought stress. Total rainfall in 1991 was similar to

Table 3. Cropping systems and rotations containing a groundnut component on Alfisol sites at ICRISAT Center.

Year 1 (1989)	Year 2 (1990)	Year 3 (1991)
PPPVGroundnut, PPP [1]/Castor	PPPVCastor, PPPVGroundnut	Groundnut, Castor
PPP-/Groundnut, PPP[2]/Castor	PPPVCastor. PPP [2]/Groundnut	-
MDPP [3]/Groundnut, Castor	Castor, MDPP [3]/Groundnut	MDPP[3]/Groundnut, Castor
MDPP [3]/Castor, Groundnut	Groundnut, MDPPVCastor	MDPPVCastor, Groundnut
Groundnut	Groundnut	Groundnut

1. Perennial pigconpea 8094 intercropped with groundnut ICGS 11.
2. Perennial pigeonpea 8860 intercropped with groundnut ICGS II.
3. Medium-duration pigconpea ICP 1-6 intercropped with groundnut ICGS II.

Table 4. Dry grain yield (t ha*[1]) and standard error of the mean (SEM) for rotation treatments with groundnut components. AH groundnut crops are boldfaced.

System	1989	1990	1991
PPPVGroundnut,	0,38 (0.04V0.72 (0.05)	0.96 (0.15) /0.40 (0.10)	0.92 (0.05)
PPP/Castor	0.34 (0.06) / 0.34 (0.04)	1.19 (0.I3) /0.28(0.03)	1.02 (0.07)
PPP[2]/Groundnut,	0.37 (0.04) /0.72 (0.05)	0.97 (0.11) /0.44(0.07)	
PPP/Castor	0.40 (0.05V0.37 (0.06)	1.00 (0.09) /0.42(0.04)	
MDPP[3]/Groundnut,	0.48 (0.06V0.69 (0.07)	1.72 (0.12)	0.59 (0.04)/0.81 (0.05)
Castor	0.04 (0.09)	1.02 (0.09)/0.33 (0.04)	0.93 (0.07)
MDPPVCastor,	0.28 (0.05)/0.23 (0.03)	0.49 (0.04)	0.82 (0.07V0.69 (0.04)
Groundnut	0.70 (0.08)	0.53 (0.08) /1.01 (0.09)	1.11 (0.06)
Groundnut	0.70 (0.06)	0.58 (0.36)	1.05 (0.08)

1. Perennial pigconpea 8094.
2. Perennial pigconpea 8860.
3. Medium-duration pigconpea ICP 1-6.

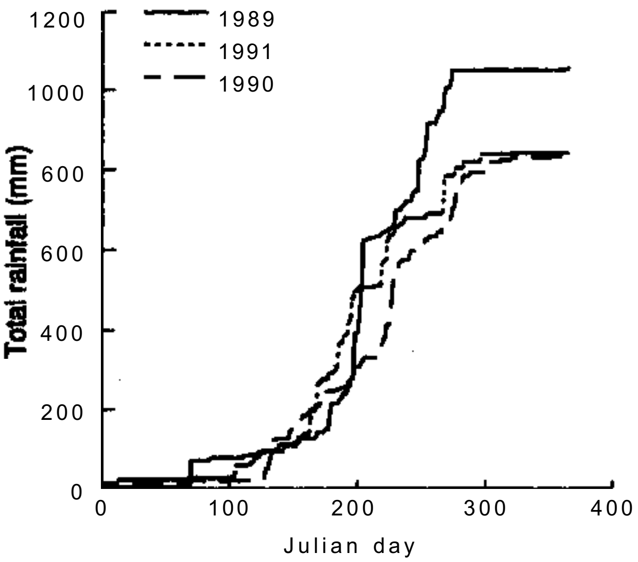

Figure 4. Total rainfall received at ICRISAT Center in 1989,1990, and 1991.

1990, but with better seasonal distribution. Our previous findings in the land form study indicated that drought stress was common in 1990, as all sowings were made on a BBF land form.

Groundnut yields in 1989 (Table 4) were generally low because of late sowing with no significant differences between cropping systems. From these data and other ICRISAT studies (Odongo et al. 1992, Willey et al. 1987), we concluded that groundnut/pigeonpea intercropping systems are more efficient in resource utilization than sole cropping either species.

Increased efficiency in intercropping systems can result from temporal and/or spatial complementarity. Pigeonpea/groundnut systems using annual pigeonpea are excellent examples of temporal complementarity. Pigeonpea plants develop slowly, while groundnut develops much quicker. On a per plant basis, pigeonpea achieves a similar leaf area to groundnut at approx-

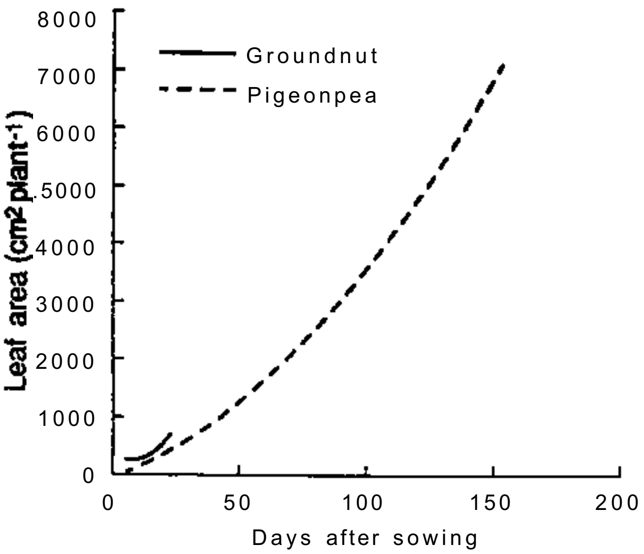

Figure 5. Groundnut and pigeonpea leaf area development from emergence to 50% flower.

Table 5. Land equivalent ratio (LER) values for pigeonpea/groundnut Intercropping in a pigeonpea-based cropping systems study at ICRISAT Center, 1989,

Mean values

1. Pigeonpea (8094)/groundnut	= 0.88 + 1.02= 1.90
2. Pigeonpea (8860)/groundnut	- 0.66 + 1.03 - 1.69
3. Pigeonpea (ICP I-6)/groundnut	= 0.53 + 0.98 = 1.51

High and low values using SEM as range

1. Pigeonpea (8094)/ groundnut	High Low	= 1.16 + 1.44 = 2.57 = 0.68 + 0.87 = 1.55
2. Pigeonpea (8860)/ groundnut	High Low	=0.82+ 1.20 = 2.03 =0.52 + 0.88 = 1.41
3. Pigeonpea(ICP 1-6)/ groundnut	High Low	=0.66 + 1.18 = 1.84 =0.42 + 0.81 = 1.23

imately 9 days following groundnut flowering, thus minimizing interplant competition (Fig.5).

In this study perennial pigeonpea types were used on the assumption that in subsequent years there would be reduced establishment costs for pigeonpea and better utilization of off-season rainfall, resulting in additional benefits from dry season fodder and fuelwood production. By 1990, groundnut yields were lowest in the intercropping treatment using perennial pigeonpea genotype 8094, a spreading type, and highest for genotype 8860, an upright perennial type. The medium-duration traditional genotype ICP 1-6 is intermediate to these perennial types. Unlike the previous season, all intercropped groundnut yields were lower than in sole cropping systems. Highest yields were from sole crops with continuous groundnut producing the highest yield (0.58 t ha^{-1}). During this season, it was observed that all intercropped groundnut competed for water with the pigeonpea. This was most evident with the perennial pigeonpea genotypes.

Our data indicate that in the second season, perennial pigeonpea canopy development in ratooned plants was more rapid than from seed plants, thereby reducing temporal complementarity and subsequent groundnut yield. By the flowering stage, perennial pigeonpea achieved leaf areas of 11000 cm^2 plant $^{-1}$, illustrating the increased competition following groundnut flowering. By 1990, plant mortality was a problem in perennial pigeonpea systems and it was felt that groundnut was not subjected to competition commensurate with that given by a full perennial pigeonpea stand. Reduced groundnut yields in the second year of a pigeonpea/groundnut intercrop were observed in other studies (Odongo et al. 1991). Reductions in groundnut yields in the medium-duration pigeonpea/groundnut intercrop treatment were attributed to below ground competition.

By 1991, plant mortality in perennial pigeonpea was so severe that all plants were destroyed with substitutions made in appropriate treatments (Table 4). Total rainfall in 1991 was similar to 1990, but distribution was more favorable for groundnut growth. Yields were highest in sole crops and lowest in the medium-duration groundnut intercrop. Groundnut yields remained constant or increased over all treatments over time. This suggests that none of the cropping systems are detrimental to production stability. We will continue this study for one additional season, after which promising rotations will be incorporated into our long-term rotation studies.

Agronomists are continually searching for ways to compare intercropping systems. Common indicators are land equivalent ratio (LER), area time equivalency ratio (ATER), and area harvests equivalency ratio (AHER). LER values for pigeonpea groundnut intercropping systems in 1989 ranged from 1.90 for perennial pigeonpea 8094 to 1.69 for perennial pigeonpea 8860 (Table 5). While these values appear attractive, it must be remembered that they represent a ratio between four variable values.

If we select standard error of the mean as a value for variance and recalculate using the best case scenario (e.g., maximum intercropping yield and minimum sole crop yield) there is a disproportionate shift upward in all LER values and all intercropping systems are extremely attractive (Table 5).

If we use the worst case scenario and select low intercropping values and high sole yields, there is a similar drop in LER values. These lower values will be achieved by some farmers if they adopt these systems and it is extremely important to keep these low values in mind when assessing advantages in intercropping. In our Production Agronomy Unit we are striving to develop new techniques which will better represent cropping systems production over time.

In this study a major consideration has been omitted: the nematology component. All plots are sampled for nematodes prior to sowing, during plant growth, and at the end of each season. From these samples we are able to follow cross-hosting patterns of those nematodes known to contribute to yield reductions in the crops we study. This work will lead us to a better understanding of rotational effects on pest and disease constraints.

Summary

In the village studies we found that using survey and diagnostic plots together was the most efficient and accurate way to elicit farmers' management practices and perceived production constraints; and then to quantify the extent of these constraints.

In the case of iron chlorosis in groundnut, we found that farmers were applying high amounts of nitrogen fertilizer and that they associated this problem with the introduction of irrigation. This allowed us to focus our researcher-managed village plot treatments on water and fertilizer management. Recognizing that possible solutions to this problem were iron sprays and improved genotypes, these treatments were added to our studies. When we realized that some improved groundnut genotypes are not iron-efficient, our crop improvement program initiated breeding work in this area. We have also been able to make extension workers aware of the effects of high nitrogen fertilizer applications and poor water management On this problem.

Work with land forms would have impact, particularly with respect to resource poor farmers, whose technologies are necessarily independent of substantial monetary input. We know that by using a BBF land form on an Alfisol soil type may result in increased erosion and that plant growth may not be improved under rainfed conditions. From these results we are better able to structure our future research focus and advise others on crop production strategies.

We understand that cropping systems/rotations work is essential for an institute like ICRISAT, which seeks to develop new technologies needed to fit into existing cropping and farming systems. We also recognize that this type of work requires long-term studies involving various disciplines. We are able to conduct this type of strategic research at ICRISAT Center and hope it will provide guidance to our partners in the national programs of the semi-arid tropics to conduct their own research. We are therefore anxious to establish links with as many national research systems as possible.

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Discussion

Schmidt: Was the soil very alkaline where you observed severe Fe chlorosis? How do you explain the difference in efficiency between Fe ETDA (not effective) and $FeSO_4$ (effective)?

Anders: Soil alkalinity was observed in Pakistan. We suspect that our spray concentration of Fe ETDA was not sufficiently high. Because chlorophyll levels increased in plants sprayed with $FeSO_4$, we are satisfied that we are getting an Fe effect and not an S effect.

Freire: 1. What are the reasons for the poor condition of the flat soil forms compared with the BBF form? Is the soil condition not linked to plowing depth, soil turning, etc.? 2. Because BBF requires more soil disturbance, is it not more prone to crust formation?

Anders: 1. The flat treatment received a shallow plowing. 2. No, only if the argillic (clay) layer is brought to the surface.

Ndunguru: At ICRISAT Sahelian Center, we compared tied ridge, flat, and raised bed forms, but we did not observe any significant differences. Our statistician believes that the split plot design, with a few degrees of freedom, may have been responsible for your nonsignificance in the BBF-flat comparison.

Anders: This may be true in the Fe chlorosis study, but it was not the case with the land form study that I reported. We also have supporting evidence from other studies.

Nigam: 1. Was there any difference in days to emergence between BBF and flat land forms? 2, Was lliere any difference in temperature in the podding zone under these two systems? 3. Were the furrows in the BBF system laid along the contour?

Anders: 1. No. 2. We did not measure temperature. 3, No.

Olorunju: You talked about structured surveys and rapid rural appraisal. Could you expound on the latter?

Anders: We use rapid rural appraisal in our preliminary work to get a general idea of how to structure our subsequent formal surveys. Once formal surveys are complete, we select specific concepts or management practices and test them across a range of conditions in a very structured rapid rural appraisal approach.

Nigam: Don't you think answers tend to be artificial in a structured survey?

Anders: Not if they are done on an individual basis. We have found biased answers when using group interviews and there is a senior farmer.

Bosch: I agree with the idea that more village-level diagnostic work should be done. By definition, this work has to be done by the national programs since it is site-specific. I wonder what the regional programs and ICRISAT can do to support this kind of work,

Schmidt: Our regional project will soon include only two senior scientists-a breeder and a pathologist-and they will be fully absorbed by their tasks. We have to leave farm and village studies to the national programs. In order to obtain a "complete picture", such studies should include all crops in a cropping system. The price of maize relative to that of groundnut, for example, determines how much is grown. Socioeconomic considerations have an important influence on overall productivity. Breeders and pathologists should concentrate on their crops, while agronomists and economists should consider all crops grown in an area.

McDonald: Most NARSs have systems for getting researchers, extension workers, and farmers to come together to discuss problems. How much feedback is obtained from farmers? Could discussion on farmers' perceptions of constraints be encouraged more? Could their reactions to "surveys" be examined?

Nkwanyana: Village-level studies are important. Before SADCC projects were started, NARSs were required to survey their crop situations through visits to farmers* fields and interviews with farmers. These survey results were consolidated in a document which formed the basis of SADCC's crop improvement program. However, we now need to go back and interview the farmers again to record their evolving perceptions of the problems and their preferences for certain crops. The earlier surveys were not exhaustive and possibly not sufficiently representative.

Ndunguru: A good deal of information has been obtained from various surveys and on-farm experimentation. Examples are the USAID, IDRC, and Bean and Cowpea CRSP work in Tanzania; Bean and Cowpea CRSP and University of Illinois work in Zambia; and the regional work of Bunda College of Agriculture and CIMMYT. Perhaps we need to dig out this information and digest it before we initiate yet more surveys.

Freire: One of the main questions is the identification of the target groups to receive the benefits of the research/extension system. A study in the so-called "greenbelt zone" of Maputo observed that the poorest households were those headed by women without men but often with children. At the same time, these households were among the most conservative amongst farmers. The question is: shall we target our work at the poorest or shall we focus on more progressive groups with higher impact on national production?

Anders; The question of which group will benefit most from a given system will always be argued. However, this does not negate the need to conduct this research.

Williams: I would like to suggest that surveys be undertaken with care. They are expensive and in some cases are used to replace the obvious conclusions arrived at by common sense and observation. Because ICRISAT deals with many problems at the regional level, it is frequently necessary to deal with them as generalities. National programs have a relative advantage at the local level.

Chiteka: It has been suggested that some trials be sown late (i.e., at the time that farmers are sowing). Delayed sowing invariably reduces the amount of moisture available to the crop, temperatures are reduced, and there is more disease. Is there information available from ICRISAT concerning genotype performance under stress conditions such as reduced temperatures, high disease rate, or reduced hours of sunshine?

Nigam: Although date of sowing studies have been conducted in the past, the main objective was to find out the optimal sowing time for a given location. In the southern African context, where farmers are likely to continue to sow groundnut late, we need to identify varieties that do not interact with sowing dates. Such varieties will necessarily be of relatively short duration. They may not be the highest-yielding varieties available, but they will yield more than the varieties currently grown under late-sown conditions. One set of advanced breeding trials should be sown under late-sown conditions to identify such varieties.

Effect of Plant Density and Sowing Pattern on the Yield of a Groundnut / Maize Intercrop

J.M. Eliseu[1] and M.J. Freire[2]

Abstract

Groundnut / maize intercropping is common throughout Mozambique, particularly in the south. Aiming at higher yields for subsistence farmers, researchers conducted experiments on plant density, sowing patterns, and sole versus intercropping systems. There was no significant difference in groundnut yield or yield components when the crop was sown either in rows or in a zigzag pattern. However, maize yield was significantly increased. Both groundnut and maize yield increased with increasing plant density. Although sowing alternate rows of groundnut and maize reduced groundnut yield, maize yield was comparatively unchanged from sole crop yields. Increasing groundnut density and reducing that of maize resulted in an increase in groundnut yield (higher than that of the sole crop) and a reduction in maize yield. Land equivalent ratio was larger than 1.00 in all intercropping treatments, ranging from 1.20 to 1.99.

Resumo

Efeito da densidade de plantas e metodo de sementeira na producao de amendoim e milho em consorciacao. A consorciaqao de amendoim e milho e uma pratica comum em Mocambique particularmente no sul. Com intuito de elevar a produqao da agricultura de subsistencia de componeses, investigadores fizeram ensaios sobre a densidade, metodos de sementeira, e cultura pura contra si sterna consorciado. Nao houve diferenqas significativas no rendimento do amendoim ou nos componentes quando o campo ter sido semeado quer em linhas quer em zig-zag. Porem o rendimento do milho aumentou significativamente. Ambas culturas milho e amendoim o sen rendimento. aumenton com o aumentou da densidade de plantas. Contudo a alternativa sementeira em linhas reduziu o rendimento de amendoim. O rendimento de milho nao mudou comparativamente ao milho puro. Aumentando a densidade de amendoim e reduzindo do milho resulta num alto aumento do rendimento do amendoim que a cultura pura e reduqao no rendimento de milho. O "land equivalent ratio (LER)" foi mais que I em todos os tratamentos consorciados, oxilando de 1.20 a 1.99.

Introduction

In Mozambique, groundnut and maize are very important crops, cultivated throughout the country under various cropping systems and environmental conditions (Nunes 1985, Malithano 1980). However, the vast majority (99% of the cropped area of groundnut and 96% that of maize) of these crops is produced by subsistence farmers using traditional management technologies (Bokde 1980, MIAM 1971), Yields are quite low, not surpassing 0.7 t ha^{-1} for maize and 0.5 t ha^{-1} for groundnut (MOA 1977, Malithano 1980),

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Eliseu, J.M, and M.J. Freire, M.J. 1992. Effect of plant density and sowing pattern on the yield of a groundnut/maize Intercrop. Pages 121-124 *in* Proceedings of the Fifth Regional Groundnut Workshop for Southern Africa, 9-12 Mar 1992, Lilongwe, Malawi (Nageswara Rao, R .C. and Subrahmanyam. P.. eds.), Patanchcru, A.P. 502 324. India: International Crops Research Institute for the Semi-Arid Tropics.

According to Bokde (1980) and Malithano and van Leeuwen (1980), these low yields are due to inadequate cropping systems, sowing methods, plant densities, and plant protection.

According to Mozambique's Ministry of Agriculture (MOA), at least 30% of the area sown to maize is intercropped with groundnut and other crops (MOA 1977), In most cases crops are sown without a particular row arrangement.

Aiming at higher yields and more efficient cropping systems, research was conducted to identify the best cropping system in terms of yield and land use efficiency.

Material and Methods

The experiment was conducted in southern Mozambique at the Umbeluzi Research Station on a medium textured soil under rainfed conditions. Rainfall during the growing season was well distributed, totalling 342 mm. The experimental design was a randomized block design with four replications and 12 treatments (Table 1). The groundnut variety used was Bebiano Branco, which matures in 90-100 days, while for maize Matuba (100-120 days) was used. Both genotypes are presently recommended for cropping under rainfed conditions in southern Mozambique.

Results and Discussion

As seen in Table 2, the plant density at harvest was consistently less in all cropping patterns except the am3 treatment. Reduction in maize plant density was due to the incidence of stem borer. The low plant stand in groundnut crop at harvest was due to lack of germination as well as pest and disease incidence during the growing season.

Groundnut had a tendency to produce fewer pods per plant with higher plant density when grown under sole cropping. Sowing pattern had no effect on the number of pods per plant.

Irrespective of the plant density or the sowing pattern, sole groundnut yield was constant. When intercropped with maize, groundnut showed no yield response to sowing pattern, but yield increased with the increase in groundnut plant density in the intercropping system. Treatments AAM1 and AAAM1 produced higher yields than either the sole crop or the intercrops with high maize and low groundnut density (am3, AMI, AM3).

Number of cobs per plant and maize yield were largely influenced by sowing pattern, with zigzag sowings producing far more than row sowing, in both sole cropping and intercropping regimes. Reduced maize density and increased groundnut density resulted in higher groundnut yield and lower maize yield. The higher intercropped yields were obtained

Table 1. Treatment description.

	No. seeds hill-[1]		Spacing (cm)		Row arrangement	
Treatment	Maize	Groundnut	Maize	Groundnut	(Maizc:groundnut)	Cropping system
am3		3 1			zigzag	Inter
AM3	3 1		90x90	90x10	1:1	Inter
AM1	1	1	90x30	90x10	1:1	Inter
AAM1	1 1		135x30	45x10	1:2	Inter
AAAM1	1	1	180x30	45x10	1:3	Inter
m3	3				zigzag	Sole
m1	1			-	zigzag	Sole
M3	3		90x90			Sole
M1	1		90x30	-	-	Sole
Ai		1	-	45x10	-	Sole
a1[1]-		1			zigzag	Sole
al /2[2]		1	—	-	zigzag	Sole

1. Same plant density as Ah
2. Half the plant density of A1.

Table 2. Yield and yield components of groundnut and maize grown as sole crops and intercrops.

Treatment	Plant density m^{-2} Expected Maize	Expected Gnut	At harvest Maize	At harvest Gnut	Groundnut No. pods $plant^{-1}$	Groundnut Pod yield (t ha^{-1})	Groundnut LER	Maize No. cobs $plant^{-1}$	Maize Grain yield (t ha^{-1})	Maize LER	Total LER
am3	3.7	11.1	2.8	8.5	11.5	0.40	0.45	5.4	2.13	0.98	1.43
AM3	3.7	11.1	2.2	5.2	13.5	0.49	0.55	1.8	1.25	0.62	1.20
AM1	3.7	11.1	2.1	3.5	11.0	0.42	0.47	2.2	1.85	0.85	1.32
AAM1	2.5	14.8	1.9	7.8	15.4	1.29	1.43	1.5	1.18	0.54	1.97
AAAM1	1.9	16.7	1.4	9.5	17.6	1.48	1.64	1.0	0.77	0.35	1.99
m3	3.7	-	3.7	-	-	-	-	4.2	2.18	1.00	1.00
m1	3.7	-	2.7	-	-	-	-	2.7	2.15	0.98	0.98
M3	3.7	-	2.6	-	-	-	-	1.6	1.41	0.65	0.65
MI	3.7	-	2.0	-	-	-	-	2.0	1.75	0.80	0.80
A1	-	22.2	-	11.3	14.8	0.90	1.00	-	-	-	1.00
al[1]	-	22.2	-	12.4	14.4	0.87	0.97	-	-	-	0.97
al/2[2]	-	11.1	-	5.3	25.6	0.83	0.92	-	-	-	0.92
CV (%)			22.2	20.6	28.3	27.3		47.3	31.6		
SE			±0.2	±0.9	±2.2	±0.12		±0.6	±0.29		

1. Same plant density as A1.
2. Half the plant density of A1.

using zigzag sowing and by sowing alternate rows of groundnut and maize.

In all cases, intercropping groundnut with maize showed a higher land-use efficiency with land equivalent ratios (LERs) ranging from 1.20 to 1.99, with LER increasing with each groundnut increment (Table 2).

Given that these results were obtained in a single year and that an overall analysis of similar trials has yet to be done, we can draw the following preliminary conclusions.

1. In good rainfall years, groundnut/maize intercrops produce higher yields and LERs.
2. Unless such factors as weeding, irrigation, or erosion dictate otherwise, there is no need to sow in rows because maize tends to yield better with a zigzag pattern.
3. When intercropping, it is better to increase the groundnut contribution, thus increasing its plant density and reducing that of the maize.

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Discussion

Chiteka: Would you explain why the yields from the zigzag sowing were higher than the row sowing?

Freire: We still do not understand it fully, but it may be related to more efficient pollination among other factors.

Williams: I believe that the nondestructive model approach described in our paper can provide a better understanding of the causes. It will separate the effects into those associated with the source and those associated with sink effects.

Nyirenda: What is the explanation for the increased number of pods $plant^{-1}$ with increase in plant density?

Freire: In sole cropping, the number pods $plant^{-1}$ increased with the reduction of plant density. In intercropping, the opposite happened. We assume this to be related to the reduction in maize density and the reduced temperature caused by shading,

Ndunguru: The size of the plots may have influenced your results. How large were they, particularly considering zigzag sowing?

Freire: I do not have the exact figures, but plot size was the same in all plots. We gave the field workers the exact quantity of seed required for the plot.

Busolo-Bulafo: I can see from your results that the shelling percentage (35.7%) is quite low. Is this normal with groundnuts in Mozambique?

Freire: Yes, the values are quite low. Normal figures range between 50 and 60%.

Kefi: Your third conclusion suggests an increase of groundnut population and reduction of maize population. Would the low maize population result in low yields? And which of the two crops is the more important in the farming system? In Central Province, Zambia, any technology tending to lower maize yield is unlikely to be adopted.

Freire: Reducing the population of maize (the main crop) will reduce maize yield, but will also allow groundnut yield to increase. There are three other considerations. First, the market price of groundnut is about four times higher than that of maize. Second, farmers (especially those living near cities) tend to be more market-oriented and therefore recognize the value of groundnut. Third, southern Mozambique has suffered from frequent drought during the last few years and farmers know that groundnut is more tolerant of drought stress than maize, which is difficult to grow in this region.

Combined Intercropping and Crop Rotation Trials at Chitedze Agricultural Research Station

G. Schmidt[1]

Abstract

In a trial to assess the comparative advantage of intercropping versus sole cropping using maize and four groundnut cultivars, maize yields increased when intercropped with groundnut. Groundnut yields were depressed by intercropping, but there was a differential response of cultivars to cropping systems. Intercropping was not advantageous compared with sole cultivation ofthe partners. In the subsequent season, maize yields on the same plots were slightly higher after sole groundnut titan after maize/groundnut intercropping, but in general preceding crops had little influence on subsequent maize, even withoutfertilizer application.

Resumo

Consorciaqdo combinada e ensaio de rotaqao de culturas na Estacao de investigacao agronomica de Chitedze, 1989-90, No ensaio para determinar a vantagem comparativa da consorciacao versus cultura pura usando milho e quatro variedades de amendoim, a producao do milho aumentou quando consorciado com amendoim. A producado de amendoim foi reduzida pela consorciaqdo mas houve respostas nas diferentes variedades ao sistema de producao. A consorciacao nao foi vantajosa comparando com a cultura pura dos pareceiros. Na subsequente estacao a producao de milho nos mesmos talhoes foi ligeiramente alia depois de amendoim puro que depos de consorciaqdo milholamendoim, mas em geral culturas procedentes tiveram pouca influencia no milho subsequente, mesmo sem aplicacao de fertilizantes.

Introduction

On small-scale farms in Malawi and other SADCC countries, cereal monoculture is prevalent and productivity is low In some areas, cereals are intercropped with groundnut or other legumes, in others sole cultivation predominates. Increased incorporation of legumes into cropping systems may lead to increased cereal productivity and thus contribute to sustainable land use.

According to results in West Africa, rotation of legumes and cereals may increase productivity to a considerable extent. An exploratory experiment was therefore initiated at Chitedze Agricultural Research Station in 1989/90 to assess the effect of intercropping maize with various groundnut cultivars on **the** productivity of the intercropping partners, and to assess the residual effects productivity the subsequent season.

Materials and Methods

The experiment was conducted **on** a dark **brown** loamy soil with a preceding crop of maize. The experimental area was treated with single superphos-

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Schmidt, G.,1992. Combined intercropping and crop rotation trials at Chitedze agricultural research station. Pages 125-1281in Proceedings of the Fifth Regional Groundnut Workshop for Southern Africa, 9-12 Mar 1992. Lilongwe, Malawi (Nageswara Rao, R.C., and Subrahmanyam, P., eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

phatc plus compound fertilizer at a cumulative rate (kg ha^{-1}) of 16.0 N, 62.0 P, and 8.3 K. In addition, 50 kg ha^{-1} N as urea was applied as a topdressing to maize.

The experiment was sown on 15 December 1989; topdressing followed about 5 weeks later. Spanish-type genotypes were harvested 105 days after sowing with maize and virginia-type after 131 days. Plowing was done on 29 June. A maize crop used for testing residual fertility effects was sown on 10 December 1990 and harvested after 134 days,

A randomized block design with 6 replications was used. The maize cultivar was R 201. Each plot consisted of six rows with 60 cm between rows. Within rows, maize spacing was 30 cm (55 556 plants ha^{-1}), Virginia genotype spacing was 15 cm (111 111 plants ha^{-1}), and Spanish cultivar spacing was 12 cm (166 667 plants ha^{-1}). When intercropped with Virginia genotypes, every other maize plant was replaced by 2 groundnut plants. When intercropped with Spanish genotypes, by 3.

Results and Discussion

In the 1989/90 season, maize had a dark green color, indicating a continuously high nitrogen supply to the plants even after flowering. Because of the excellent nutrient status of maize during this first season, and taking into consideration the high phosphorus application to the 1989/90 crop, no fertilizer was applied to the 1990/91 crop. Maize stands were regular and the plants grew vigorously on all plots. During the whole season, maize appeared to have been well supplied with nutrients, in particular nitrogen, and the various preceding crops had little effect on growth, leaf color, or cob formation.

Maize yields in 1990

Maize grown as a sole crop had very high grain yields (Table 1). Intercropping with groundnut by replacing every second maize plant by two Virginia or three Spanish groundnut plants resulted in an increase of 30% in maize yield $plant^{-1}$ Intercropping was thus advantageous to maize, as half of the number of maize plants averaged 65% of sole crop yields. No differences between groundnut genotypes with regard to the productivity of intercropped maize was observed.

Groundnut yields and overall results of intercropping

The high productivity of maize in maize/groundnut intercropping plots was achieved at the expense of the intercropping partner (Table 2). Groundnut productivity was depressed 65-77%, compared with sole cultivation, in which the average land equivalent ratio (LER) was 0.27.

The overall result (maize LER + groundnut LER: 0.90-0.97) did not indicate any advantage of intercropping compared with sole cultivation of the two

Table 1. Sole crop maize (M) yields, yields of maize intercropped with two Virginia and two Spanish type groundnut (G) genotypes, and maize LER, Chitedze, Malawi, 1989/90.

Cultivars	G/M[1]	Total yield (t ha^{-1})	LER	Net yield allocated to M[2] (t ha-*)	Yield (%)
M: R201 (density 55 556 plants ha^{1})		10.6	1.00	10.6	100
M/G:ICGM 42,	2	7.3	0.69	14.6	138
M/G: Chitembana,	2	6.9	0.65	13.7	129
M/G: Malimba,	3	6.8	0.64	13.7	129
M/G: iCGV-SM 85038	3	6.6	0.62	13.3	125
SE-		±0.25		±0.48	
Mean		7.6		13.2	
CV (%)		8.0		8.8	

1. G/M = no. of G plants replacing every other M plant.
2. Yields of identical numbers of maize plants in all treatments (i.e., yield on intercropping plots multiplied by 2).

Table 2. Productivity of Virginia and Spanish groundnut (G) genotypes in sole crop and in intercropping with maize (M), groundnut LER, and total LER, Chitedze, Malawi, 1989/90,

Cropping system	G sole crop genotype (plants ha-[1] or G/M[1])	Total yield (t ha-[1])	LER	Net yield allocated to G[2] (t ha-[1])	G yield	LER (M+G)
Sole crop	ICGMS 42 (111 000)	2.26	1.00	2.26	100	1.00
	Chitembana (111 000)	1.40	1.00	1.40	100	1,00
	Malimba (166 667)	1.00	1.00	1.00	100	1.00
	ICGV-SM 85038 (166 667)	1.43	1.00	1.43	100	1.00
	Mean	1.52	1.00	1.52	100	L00
Inter-cropping	ICGMS 42 (2G plants)	0.52	0.23	1.04	46	0.92
	Chitembana (2 G plants)	0.35	0.25	0.70	50	0.90
	Malimba (3 G plants)	0.26	0.26	0.52	52	0.90
	ICGV-SM 85038 (3 G plants)	0.50	0.35	0.99	69	0.97
	Mean	0.41	0.27	0.81	53	0.92
Varietal means	ICGMS 42	1.39		1.65		
	Chitembana	0.88	-	1.05		
	Malimba	0.63		0.76	-	-
	ICGV-SM 85038	0.96		1.21		
	Mean	0.96		1.17		
SE	Cropping systems	±0.043		±0.051		
	Varieties	±0.061		±0.072		
	Interaction	±0.086		±0.103		
CV (%)		22		21		

1. G/M = no. of G plants replacing every other M plant.
2. Yield on intercropping plots multiplied by 2.

partners. Groundnut genotypes differed considerably in productivity. In the case of sole cultivation, ICGMS 42 was highly superior to Chitembana, Malimba, or ICGV-SM 85038. However, in the case of intercropping, ICGMS 42 and ICGV-SM 85038 proved to be equally productive. This is an interesting case of interaction between genotypes and cropping systems. However, even under intercropping conditions, ICGMS 42 proved to be a good genotype.

Maize test crop yields in 1991

Maize yields were very high in 1991, even though fertilizer was not applied. This result is attributed to the excellent soil nutrient status, and maize productivity was hardly affected by preceding crops (Table 3). Only a factorial evaluation indicated a slightly more favorable residual effect on the subsequent maize crop in the case of sole groundnut compared with maize/groundnut intercropping.

Table 3. Influence of preceding sole crop of maize (M), sole crop of groundnut (G), and maize / groundnut intercropping on maize productivity, Chitedze, Malawi, 1990/91.

Treatments in 1989/90 (1 M and 4 G cultivars)	No. of G plants (ha-[1])	Seed yield in 1990 / 91 (t ha-[1])
Preceding sole crops (M at 55 556 plants ha-[1])		
M R201		10.2
GI ICGMS 42	111 111	11.1
G2 Chitembana	111 111	11.3
G3 Malimba	166 667	10.8
G4 ICGV-SM 85038	166 667	10.3
Mean G1-G4, result after sole G		10.9
Preceding intercrops (M at 27 778 plants ha-[1])		
M + GI	55 556	10.0
M + G2	55 556	10.3
M + G3	83 333	10.2
M + G4	83 333	10.4
Mean G-G4, result after intercropped G		10.2
SE (all treatments)		±0.357
CV (%)		11.4
Mean all treatments		10,5
SE (sole crop vs intercrop)		±0.187
SE (cultivars)		±0.264
SE (interaction)		±0.373

Conclusion

The results confirm earlier findings that maize yields are increased at the expense of groundnut in maize/groundnut intercropping systems. This intercropping combination is therefore rarely advantageous. In contrast to results obtained on poorer soils (Schmidt and Frey 1990), favorable residual effects of preceding groundnut on maize may be minimal if the soil is rich in nutrients. Such experiments should preferably be conducted on farmers' fields, and not on experiment stations with strong nutrient accumulation in the soil.

Reference

Schmidt G., and Frey, E. 1990. Importance of rotation with groundnut for cereal productivity. Pages 137-142 *in* Proceedings of the 4th Regional Groundnut Workshop for Southern Africa, 19-23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Discussion

Ndunguru: 1. At the ICRISAT Sahelian Center (ISC), we have found that lines that perform well in monocropping also perform well in intercropping. We therefore feel no need for inititating a separate breeding program for intercropping situations. 2. Intercropping and crop rotation are substitutes and crop rotation being an advanced stage. The problem arises because as long as the hoe remains the main farming tool, crop rotation becomes unfeasible. Perhaps rotation/intercropping trials should be linked to equipment. 3. For the information of the participants at this workshop, we started a complex rotation trial at ISC that addresses intercropping, rotations, and mixtures, and their implications for sustainability.

Schmidt: Thank you for sharing this information with us. I would like to add that other intercropping combinations such as root crops/groundnut or groundnut/pigeonpea are more likely to give beneficial results than maize/groundnut.

Olorunju: Because farmers are restricted in terms of land and have little choice of the crops they grow, they end up practicing what amounts to monoculture within an intercropping system. How can our research more accurately reflect the farmer's actual situation?

Schmidt: We try to compare farmers' practices with various alternatives and recommend the most promising ones.

Appendices

Recommendations

The workshop participants expressed their appreciation for GTZ's financial support for the SADCC / ICRISAT Groundnut Project and for the Project's contributions to groundnut research in the region. The following recommendations were unanimously approved by the representatives of the national programs.

1. The crop improvement component of the Project, together with the seed multiplication component, should continue to receive a very high priority. At the same time, the Project should assist and strengthen the agronomic research capabilities of the NARSs in the region. It should conduct research only on agronomic/ crop management areas with regional significance.

2. Agronomic research on fertilizer requirements, optimal plant population, improved cropping systems, etc., should be conducted by the NARSs for the specific groundnut-growing areas within each country. The Project should arrange to supply methodologies for economic analysis of agronomic experiments. It should also supply information on newer ways to design experiments and to interpret data. All agronomic experiments should record observations on pests and diseases.

3. The work on acid soil problems in Zambia was commended by the participants. It was recommended that this work should be expanded to Namibia and to other countries with similar problems. In time, this work could be linked to ongoing research in West Africa and Asia.

4. The drought research work in Botswana was applauded by the participants. It was recommended that the Botswana program, in collaboration with ICRISAT, should continue to develop drought-tolerant genotypes while other NARSs engage in agronomic research on ways to minimize the harmful effects of drought.

5. The project will assemble literature and information on drying methods, postharvest handling, and small-scale equipment for cultivation and crop processing, and make them available to the regional NARSs,

6. The NARSs and their extension agencies will be responsible for the transfer of new technology. The Project could assist these efforts whenever possible and appropriate.

7. The existing arrangement where the Project provides computing services for breeding trials of the NARSs should be extended to cover agronomic trials. ICRISAT will keep NARSs informed of the training courses at its various locations.

Field Visits

Chitala Agricultural Research Station

L.R. Mtuana, Officer-in-Charge of the Station, welcomed the participants and gave a brief introduction to the station's facilities and activities. Chitala is located 660 m above mean sea level. The mean annual maximum temperature is about 30°C; the minimum 16*C. Chitala receives a mean annual rainfall of about 900 mm during the rainy season (January to March). However, only 350 mm fell during the current rainy season, resulting in a very dry year-

Participants were shown two groundnut experiments at the station.

Foliar disease nursery

P. Subrahmanyam showed the participants a wide range of foliar disease-resistant material being screened for late leaf spot and rust diseases in the international nursery. A nursery in Swaziland is conducting similar trials. Infector row technique is used to raise the inoculum load and disease incidence. Although inoculum of rust and late leaf spot was sufficient, the disease intensity was very low due to dry weather. The crop, which was at podfilling phase during the visit, was clearly suffering from drought stress. Significant differences were apparent among genotypes for both late leaf spot and rust.

Apart from foliar diseases, we also noted pod borer damage. Juvenile and immature pods had been bored through the shell to the seed. We were told that the damage had been caused by the pineapple mealy bug, a sucking pest.

Cultivar screening trials

Participants were shown an experiment by one of the Chitala research scientists which compared the performance of ICGMS 42 with local cultivars. Although the crop was facing severe drought at the time of visit, the experiment will provide useful information on the performance ICGMS-42 under severe drought stress. All crops at Chitala Research Station are cultivated under rainfed conditions. Irrigation facilities are generally unavailable at all research stations in Malawi.

Visit to Farmers' Fields

Participants were guided through five farmers' fields by the local Agricultural Officer. Farmers participated in the discussion.

1. Farmer name: Lande

Under the resettlement proforma, farmers are allocated holdings of 6 ha. They are trained by the Agricultural Department personnel. The major crops grown on each holding were maize, cotton, and groundnut. The price of groundnut pods is greater when sold to private parties than at the Government price. The proportions of land allocated to each crop is not fixed. However, the farmers are expected to grow each of the three crops: maize as a food crop, cotton and groundnut as cash crops.

This farmer was growing three groundnut varieties: Chalimbana, Mawanga, and Malimba. The latter cultivar is the local variety. The groundnut was sown on ridges 90 cm apart. The furrows were unusually deep (40-50 cm from the top of the ridge). The seed-to-seed spacing was not uniform.

Mr Lande got his seed and other inputs (fertilizer and pesticides) on loan from the Government. He has to repay the loan after selling the produce. The fertilizer is ordinarily applied only to maize. The crop was facing severe drought the time of the visit.

2. Farmer name: Chibwe

Four varieties, Chalimbana, Mawanga, Kalisere and Malimba, were being grown. The crop was sown in December with the first rains and was clearly suffering from drought stress. This farmer's practice is to leave the haulms in the field as feed for his cattle. The haulms are not sold. Farmer Chibwe keeps his own seed. Fertilizer is applied only to maize. The standing crop of maize in sold to obtain cash.

3. Farmer name: Mpangalume

This farmer was cultivating maize and groundnut. The groundnut crop was a mixture of several varieties. Due to inability to obtain seed material, he collected whatever seeds he could lay his hands on. The plants were sown randomly and included all types of taxonomic groups, including long-duration runners. Farmer Mpangalume's practice of mixing seed for sowing is not common.

4. Farmer name: Chitanya

Farmer Chitanya was growing two groundnut varieties, Chalimbana and Malimba, on ridges with deep furrows. The crop was suffering from drought stress.

5. Farmer name: Banda

Four crops (cassava, cotton, maize, and groundnut) were being grown in strips. Cassava and cotton were showing remarkable drought resistance compared with groundnut and maize. Mr Banda told us that he practiced crop rotation among the latter two crops. Fertilizer was applied to only maize, and other crops are grown without any inputs.

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