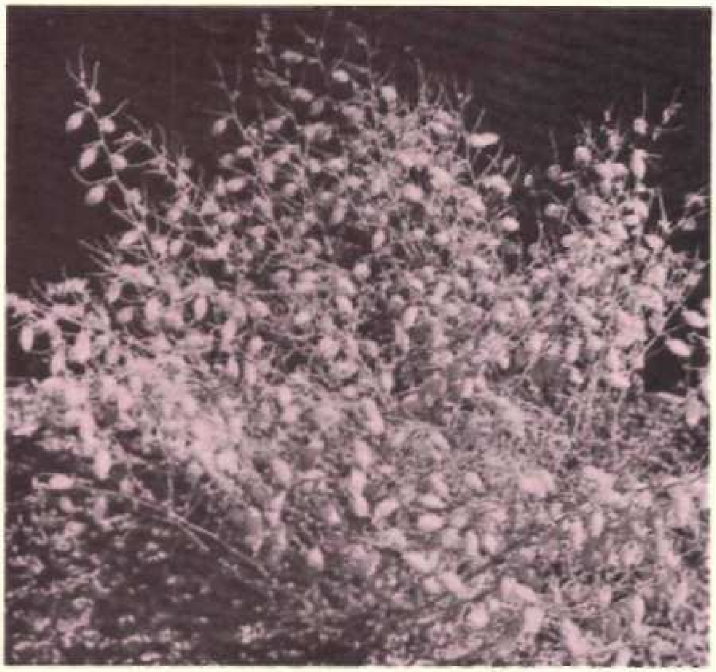
Research on Grain Legumes in Eastern and Central Africa



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Research on Grain Legumes in Eastern and Central Africa

Summary Proceedings of the Consultative Group Meeting for Eastern and Central African Regional Research on Grain Legumes (Groundnut, Chickpea, and Pigeonpea)

8-10 December 1986
International Livestock Centre for Africa (ILCA)
Addis Ababa, Ethiopia

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

1987

Objectives of the Meeting

- To develop an understanding of the ongoing national and regional grain legume research programs.

- To develop plans for ICRISAT's participation in supporting and strengthening research programs on grain legumes (groundnut, chickpea, and pigeonpea).

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Foreword

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) hosted a Consultative Group Meeting for Eastern and Central African Regional Research on Grain Legumes (Groundnut, Chickpea, and Pigeonpea) during 8-10 December 1986 at the International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia. Representatives from six national programs and seven international organizations working in the region joined 14 ICRISAT scientists in the deliberations.

This report summarizes proceedings at that meeting. Included in it are extended summaries of the welcome and keynote addresses at the opening session, status reports from participating countries, and papers presented by representatives of the international organizations. In preparing the summaries, prime coverage has been given to the three grain legumes that fall within ICRISAT's mandate: groundnut *(Arachis hypogaea)*, chickpea (*Cicer arietinum)*, and pigeonpea (*Cajanus cajan)*. Information on coordinating activities with other grain legumes has been retained where these offer interesting parallels.

Several helpful suggestions emerged for collaborative activities within the region, and these are reflected in the meeting's recommendations. ICRISAT, for its part, is considering how best to give them concrete shape.

We hope that this publication will be a useful reference and provide further impetus to collaborative research on grain legumes within eastern and central Africa.

L.D. Swindale
Director General
ICRISAT

Recommendations of the Consultative Group Meeting for Eastern and Central African Regional Research on Grain Legumes

(8-10 December 1986)

The meeting recognized the great agroecological diversity of Eastern and Central Africa, and the very disparate needs of the national programs in Burundi, Ethiopia, Kenya, Rwanda, Sudan, and Uganda with respect to chickpea, groundnut, and pigeonpea.

There was unanimous agreement that the priorities of all national programs with respect to these three crops included:

- germplasm collection, exchange, and evaluation;
- training at both scientific and technical levels;
- support and strengthening of national programs; and
- cooperation within the region, to promote and facilitate contacts across national boundaries.

It was recognized that ICRISAT already responds to individual national requests for germplasm, training, information, and scientific assistance. However, the meeting recommended that ICRISAT should now establish a physical presence within the region. Three possible mechanisms under which ICRISAT could operate in the region were discussed:

- to locate an administrative scientist as coordinator within the region to facilitate liaison between ICRISAT and national programs, training, and exchange of information, germplasm, and scientific visits;
- to station scientists within national programs, one of whom will act as regional coordinator; and
- to establish a small ICRISAT regional unit within the region.

The meeting requested that the ICRISAT management should consider these alternatives and respond in a positive fashion, with the objective of strengthening both ICRISAT's participation in the region and the work of the national programs.

Welcome Address

Y.L. Nene

Program Director (Legumes)
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On behalf of the Management of ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) and on behalf of my colleagues, I extend to you a most hearty welcome at this beautiful campus of ICRISAT's sister institute, ILCA (International Livestock Centre for Africa). We are grateful to you for having accepted our invitation to participate in this Consultative Group Meeting. We are also most grateful to the Director General, ILCA, and his colleagues, who readily agreed to extend all the required facilities for holding this meeting.

The Consultative Group for International Agricultural Research (CGIAR) has given ICRISAT a world mandate to conduct research on genetically improving three legumes—groundnut, chickpea, and pigeonpea. In the first few years of our research on legumes, we focussed our attention on (1) collection of world germplasm, (2) developing appropriate research methodologies, and (3) those geographical regions where these crops are most widely grown. Having made substantial progress in our initial objectives, we started investigating possibilities of sharing our knowledge and genetically improved breeding materials with countries in other regions.

For this meeting we have set two objectives before us:

- to develop an understanding of the ongoing national and regional grain legume research programs in some countries of eastern and central Africa; and
- to develop plans for ICRISAT's participation in supporting and strengthening research programs on the three grain legumes within its mandate.

When we look at the FAO statistics on these three crops for the countries represented at this meeting, we find that (1) groundnuts are grown in all the six countries, with relatively large areas in Sudan and Uganda, (2) chickpeas are grown mainly in Sudan, Uganda, and Ethiopia, with Ethiopia growing the most, and (3) pigeonpeas in fairly large areas are grown mainly in Kenya and Uganda. In this meeting, we look forward to carefully listening to the views of the country representatives and of several international organizations represented here on what role ICRISAT can play in strengthening the ongoing research in these three crops and whether cultivation of pigeonpeas and chickpeas could be expanded further.

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I am pleased to point out that ICRISAT already has some interaction with legume scientists in the countries represented at this meeting. Germplasm and breeding materials have been shared. So far 56 trainees (17 from Ethiopia, 11 from Kenya, 3 from Somalia, 22 from Sudan, and 3 from Uganda) have worked from 3 weeks to 115 weeks at ICRISAT Center as in-service trainees, in-service fellows, or research scholars.

Let me briefly go over the program that has been prepared by the Organizing Committee. First Dr. Kanwar will deliver his keynote address on the relevance of ICRISAT's research to Africa and then three of our crop research group leaders will summarize ICRISAT's research on groundnut, chickpea, and pigeonpea. You will also hear a presentation on how ICRISAT has put into effect a regional program for groundnuts for SADCC countries in southern Africa, based in Malawi. In the afternoon today, we will listen to the current status of research and production of the three legumes in each of the countries represented here. Tomorrow we will have the opportunity to learn about the ongoing relevant activities of various international organizations operating in this region, their future plans of action, or types of activities they would be interested in supporting or funding.

We hope the group assembled here will recommend a plan of action for ICRISAT so that we can make steady progress towards fulfilling our mandate.

Once again I welcome you to this meeting.

Thank you.

Keynote Address: Relevance of ICRISAT's Research to Africa

J.S. Kanwar

Deputy Director General
International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

Introduction

I wish to add my own warm welcome to you for this meeting and to convey to you a welcome from Dr. L.D. Swindale, Director General of ICRISAT, who has apologized for his inability to be present here owing to other pressing commitments. You will appreciate the importance that the ICRISAT Governing Board attaches to this meeting from the fact that Dr. N.L. Innes, Chairman of the Board's Program Committee, is present here. This is the first meeting of its kind in Eastern and Central Africa on the grain legumes within ICRISAT's mandate.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was created by the Consultative Group on International Agricultural Research (CGIAR) in 1972. It was the first new research center established by this informal association of governments and foundations brought together in 1971 by the World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Development Programme (UNDP) to increase food supplies in the developing countries, specially in the harsh environments of the semi-arid tropics (SAT) under rainfed conditions. The SAT are areas where monthly rainfall exceeds potential evapotranspiration for 2 to 7 months and the mean monthly temperature is above 18°C. According to Troll's classification, the areas with 2 to $4^1/_2$ wet months are called the dry SAT, and those with $4\ ^1/_2$ to 7 wet months the wet-dry SAT.

The semi-arid tropics comprise all or part of 50 countries of the world. The total area is around 19.6 million km^2, supporting a population of more than 700 million people. Some 24% of this geographical area lies in West Africa, 22% in eastern Africa, 20% in southern Africa, 10% in Latin America, and the rest in Asia. Thus, about two-thirds of ICRISAT's mandated geographic/climatological region is in Africa. But some 55% of the SAT's population lives in the Indian SAT. Thus Africa and India are both areas of great concern.

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ICRISAT's Mandate

ICRISAT's mandate is to:

1. Serve as a world center for the improvement of grain yield and quality of sorghum, millet, chickpea, pigeonpea, and groundnut and to act as a world repository for the genetic resources of these crops.
2. Develop improved farming systems that will help to increase and stabilize agricultural production through more effective use of natural and human resources in the seasonally dry semi-arid tropics.
3. Identify constraints to agricultural development in the semi-arid tropics and evaluate means of alleviating them through technological and institutional changes.
4. Assist in the development and transfer of technology to the farmer through cooperation with national and regional research programs, and by sponsoring workshops and conferences, operating training programs, and assisting extension activities.

The Mandate Crops and Their Production in Africa

Sorghum and millet are the 5th and 6th most important cereals of the world. Generally, they are the cereals of the poorest countries. In assessing priorities in 1985, the Technical Advisory Committee (TAC) of the CGIAR drew attention to the fact that cereals contribute some 60% of calorie supplies to human diets in developing countries, and that sorghum and millet together rank first among cereals in calorie intake in Africa.

Historically, sorghum production growth in the semi-arid tropics has been just about equal to projected demand growth in developing countries. However, there are major regional imbalances. As per FAO statistics, in 1985 Africa had 35% of the world's sorghum area but produced hardly 17% of the world's sorghum. The per hectare yields in Africa are 18.5% of those in USA, and just 50% of the world average. The major sorghum-growing countries are Nigeria and Sudan, which together constitute 63% of the African area.

Among the major pearl millet growing regions in the semi-arid tropics, West Africa had the poorest production record. Continued drought over the last 3 years in West Africa and Ethiopia has further reduced the growth rate of both sorghum and millet and caused greater concern for food availability in the region.

As per FAO statistics, Africa had 39% of the world's area under pearl millet in 1985, with a production share of 35%. The major millet-growing countries are Nigeria and Niger, which together constitute 50% of the African area. Low and unstable pearl millet yields in Africa are a matter of the greatest concern.

It is estimated that the developing countries within ICRISAT's mandate region will experience either increasing shortages of sorghum and pearl millet at present prices or, more likely, much higher prices and large numbers of low-income people with unmet food needs. One estimate from the United States Department of Agriculture (USDA) is that unmet food needs in sub-Saharan Africa could be between 9 and 13 million t by 1990.

Next to cereals in importance in the SAT are grain legumes, essential to balance the diet. They have been bypassed in the grain revolution, and the decline in their availability is causing great concern for human nutrition, particularly of the poor people.

Chickpea and pigeonpea are the most important pulses of the developing world and of the semi-arid tropics. The Indian subcontinent produces about 80% of the world's chickpea and 90% of its pigeonpea. Chickpea is important in north Africa around the Mediterranean sea, and in parts of eastern and southern Africa, specially Ethiopia, Uganda, Tanzania, Malawi, and Zimbabwe. Pigeonpeas are grown in eastern and southern Africa, specially in Ethiopia, Kenya, Malawi, Mozambique, Uganda, and Tanzania. Both crops have suffered serious neglect in the region. Their potential for diversification of agriculture, and for improving the productivity of rainfed farming in the SAT, has not been adequately explored by scientists and planners. Pigeonpea has been identified by the TAC in 1985 as deserving the highest priority for research attention in international agriculture.

Though groundnut is the most important oilseed crop of the semi-arid tropics, it has shown a poor production record in the region and its yields have remained virtually stagnant. The demand for this crop is expected to grow at a compound rate of about 3.9% annually. In semi-arid West Africa, groundnut production has been declining at a rate of 3.3% annually. India's growth rate of 1.3% is well below the projected growth of demand. It is unfortunate that many African countries, which were exporting groundnuts, have become today net importers of vegetable oils. The mounting bill for their import is crippling the economies of these countries.

As per FAO statistics, in 1985 Africa had 31% of the world's groundnut area but contributed hardly 21% to the production. Yield per hectare in Africa is about 40% of that in China, and about 67% of the world average. Senegal, Nigeria, Sudan, and Zaire are some of the important groundnut-growing countries in Africa; together they form about 48% of the area. In southern Africa, Tanzania, Malawi, Zimbabwe, Zambia, and Mozambique have significant areas under this crop. In fact, Malawi is a big exporter of confectionary-type groundnuts. In eastern Africa, groundnut has not received much attention, though the scope for its improvement is very large.

To meet the challenge of these projected deficits of cereals, pulses, and oilseeds in ICRISAT's mandated region, we must identify and develop technologies that will enhance growth and productivity and reduce instability in production. This is the mission of ICRISAT. But it cannot fulfill this mission without your help.

Priority Geographical Regions

Africa's continuing food crisis has captured headlines with accounts of famine and human misery. A compassionate world has responded with food aid to alleviate suffering. But providing food for Africa's future is a long-term project, a matter of increasing productivity on exhausted land that cannot make efficient use of the rain that falls. ICRISAT is carrying out agricultural research to help Africa to avoid future food crises. It has identified constraints to production and the areas of greatest concern.

For sorghum, high priority has been assigned to West Africa, eastern Africa, and also to southern Africa.

For pearl millet, Sahelian and sub-Sahelian Africa has been given high priority, as this region depends on pearl millet as a staple cereal and is faced with the possibility of a chronic food shortage in the next decade. Southern and eastern Africa are of second priority, because these regions are relatively less dependent on pearl millet, and finger millet is of equal or greater importance than pearl millet.

For chickpea, north Africa (Algeria, Egypt, Libya, Morocco, Tunisia) and eastern and southern Africa (Ethiopia, Malawi, Tanzania, Uganda) have been given first priority.

For pigeonpea, eastern and southern Africa (Kenya, Malawi, Mozambique, Tanzania, and Uganda) have been given first priority and West Africa the second priority. Pigeonpeas are grown in these countries as backyard crops and their yields are very low. The potentiality of this crop for increasing food production, enhancing cropping intensity, and improving soil fertility needs to be better appreciated in this region.

For groundnut, West Africa and southern Africa are high-priority regions where the compound growth rates of groundnut production have been negative and less than 1%, respectively. Eastern Africa has been given a second priority.

Target and Client Groups

ICRISAT mandate crops are subsistence crops, frequently grown by small farmers with few inputs under rainfed conditions. Their yields are low and severely reduced by drought, pests, diseases, and poor soil fertility. The risks involved in making monetary inputs for fertilizer and pesticide are high. In these circumstances, the small farmer needs stable cultivars—tolerant or resistant to diseases and pests—that do well under traditional management but are responsive to whatever improved levels of management can be provided.

While the small farmer and his dependents are the primary target, they are not our sole target group. ICRISAT can reach small farmers throughout the SAT only through the national scientists, who thus become the immediate users of its research products.

Thus ICRISAT's immediate clients—the direct users of our output—are the scientists of national institutions in the SAT countries. National scientists are responsible for producing cultivars and new technologies for the farmers of their countries; ICRISAT undertakes research that contributes to and complements their efforts. Our regional and cooperative programs are aimed at strengthening their research capability. From workshops and conferences, we obtain their assistance in planning our research. National research scientists and their technicians comprise most of our trainees.

We introduce genetic diversity by bringing together at one place a substantial germplasm collection, including most of the natural landraces that are available, and incorporating this diversity into the breeding materials that we make freely available. We offer advanced materials through our network of international trials, and through field days when national scientists can choose breeding material directly from ICRISAT fields. Our major thrust remains on germplasm enhancement and broadening the base for developing agronomieally superior and pest-resistant materials, which in the hands of national scientists can bring a significant increase in productivity under the harsh environments of the SAT.

We develop new methods of plant breeding, or improve old methods for new situations. Our thrust remains on developing technologies suitable for rainfed farming and for the harsh environments of the SAT, incorporating tolerance to yield reducers and giving significantly higher yields in the hands of resource-poor farmers.

Though extension is not our function, we act as catalysts in the transfer of technology to national systems. We are increasingly adopting a network approach for identifying specific research priorities by region and for evaluating improved technologies with the help of national scientists under a range of environments. This enables national scientists within a region to identify the best technology for their situation.

ICRISAT Center and Regional Activities

ICRISAT has its main Center at Patancheru, Andhra Pradesh, India, which serves the semi-arid tropics of the world. It has a 1400 ha experimental farm and excellent laboratory and library facilities to support all types of research—basic, strategic, and applied—relevant to the Institute's mandate. It has a regional center for the Sahelian region of Africa at Niamey, Niger, called the ICRISAT Sahelian Center (ISC). Set up in 1983, the ISC attempts to serve the Sahelian region and West Africa. This center is the major base for ICRISAT's work on millet and groundnut, and for farming systems research, relevant to West Africa. It also provides administrative and logistic support for ICRISAT's sorghum research in the region, and is an important site in West Africa for training scientists and agricultural technicians.

ICRISAT has another regional program at Bulawayo, Zimbabwe, for the SADCC (Southern African Development Coordination Conference) region of southern Africa. This is mainly for sorghum and millet improvement. It has a regional program on groundnut research for the SADCC region at Lilongwe, Malawi, and for kabuli chickpea research at the International Center for Agricultural Research in the Dry Areas (ICARDA) in Syria. ICRISAT is establishing a regional network for sorghum research in West Africa at a location to be selected soon. It also has a sorghum/ millet program coordinating center in eastern Africa at Kenya, Nairobi. To meet the needs of sorghum and millet research in Latin America, ICRISAT has a research program at the Centro International de Mejoramiento de Maiz y Trigo (CIMMYT), Mexico. The Institute has built a networking arrangement for grain legumes research in Asia. This workshop will aim to develop networking arrangements for grain legumes research in eastern and central Africa.

ICRISAT Center is carrying out research for improvement of its mandate crops for high and stable yields, and is looking to overcome abiotic and biotic constraints. It has developed a number of screening techniques that are now being employed in our regional programs in Africa.

ICRISAT has developed a gene bank which has more than 86 000 accessions of its five mandate crops. Africa has contributed significantly to this gene bank. During 1985, for instance, African accessions accounted for 42% of the collection in sorghum, 98% in pearl millet, 65% in chickpea, and 85% in pigeonpea. We will attempt to further enhance this collection in the years to come, and the material can be shared by all those concerned with improvement of these crops. We recognize that there is a vast, as yet unexplored genetic resource in this region which, unless collected quickly, is faced with extinction. And the material that is already in ICRISAT's collection needs to be evaluated under African conditions, as close to its source of origin as is possible. We need your help for both collection and evaluation.

In chickpea, we are pleased to report the release of a number of improved varieties developed by us in cooperation with national programs in India, Nepal, Bangladesh, Syria, Cyprus, Morocco, Tunisia, and Jordan. Chickpea varieties based on ICRISAT material are also nearing release in Ethiopia and Kenya. We have promising material, resistant to wilt, ascochyta blight, and the *Heliothis pod* borer. My colleagues will give you details about future possibilities in this regard.

In pigeonpea, we have developed some short-duration varieties, such as ICPL 87 and ICPL 151, that can be grown as a sole crop and also lend themselves to double cropping and a multiple harvest system. The new materials offer an exciting potential for increasing intensity of cropping under certain cropping systems. We have developed some hybrids that show promise. We work also on vegetable-type pigeonpeas, much in demand in the Caribbean, and in India and Kenya. The potential of pigeonpea for agroforestry and for cattle grazing also needs to be explored and exploited.

In groundnut, our scientists have identified lines resistant to foliar diseases with high yield potential. We have selected some confectionary types of groundnut, which have an export value. We recognize the need for shorter-duration (<90 days) and drought-tolerant varieties. We have made some progress on breeding for resistance to rosette and other virus diseases. We are selecting for resistance to aflatoxin and pod rot, which affect the quality of the produce seriously. We feel that the potential of groundnut has not been adequately realized.

Training

Recognizing that training plays an important role in agricultural development and transfer of technology, ICRISAT has enlarged its efforts to meet the growing training needs of African countries. We are creating a training facility for agricultural technicians at ISC (Niamey), besides expanding the training facilities at ICRISAT Center. We have trained more than 1300 scientists or scientific workers from 74 countries, since the inception of the Institute. Most of these trainees are from Africa.

In 1985, 6 in-service fellows, 9 research scholars, and 63 in-service trainees from African countries were imparted training at ICRISAT Center. We would like to attract more trainees, particularly at the M.Sc. and Ph.D. level, from African countries so as to train them in more location-specific research techniques, aimed at solving specific problems relating to grain legume improvement. We need your cooperation in this.

Conclusion

International agricultural research has been an instrument of major breakthrough in agricultural production in Asia, but its impact in Africa has yet to be realized. In Africa, there is a shortage not only of calories but also of proteins. While we need to continue the emphasis on increasing productivity and production of cereals, particularly sorghum and millet, attention has to be given also to the production of grain legumes, such as groundnut, cowpea, soybean, pigeonpea, chickpea, etc. The legumes supplement cereal foods in human diets and provide valuable feed to animals and poultry. They also help in building up soil fertility and in diversification of agriculture. Recognizing this need for stepping up production of grain legumes in Africa, ICRISAT has organized this workshop to focus attention on research on these important crops. ICRISAT is involved in the crop improvement of groundnut, pigeonpea, and chickpea, and our resource management studies include cowpea also. We recognize that any improvement in these crops will improve the economics and sustainability of agriculture in Africa. This workshop is thus both timely and necessary.

Related farming systems research can identify more effective cropping systems, using cereal/legume combinations. This workshop is aimed at creating an awareness about the status of these crops and at assessing the perception of national scientists from Africa about the importance and priority of grain legume research in the region. We believe that a cooperative networking system can help accelerate the research programs. We hope this workshop will enable you to better assess the potential and promise that grain legumes hold in this region and to determine the priority that they deserve in cooperative research. This is an opportunity for all of us who have assembled here to pool our resources, identify priorities, plan ajoint action program, and implement the program.

We are convinced that Africa has a vast potential for development and that this can be best realized through the cooperative efforts of national, regional, and international organizations.

ICRISAT's Research on Groundnut

D. McDonald

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Introduction

Production of groundnut *(Arachis hypogaea)* in the semi-arid tropics (SAT) exceeds that of any other legume and comprises 70% of the world production of this important food and cash crop. The seeds contain approximately 25% protein and 50% edible oil, the haulms are a valuable and nutritious animal feed, and the shells can be used in manufacture of particle board or burned as a fuel. In 1984, world production of groundnut in shell was approximately 20.6 million t from an area of 18.3 million ha, an average yield of 1123 kg ha^{-1}. In the same year, production in Africa was 3.8 million t from 5.8 million ha, an average yield of only 659 kg ha . Those average yields are low in comparison with those from the USA (3270 kg ha^{-1}), and much lower than the potential yields of over 10 t ha^{-1} reported from research farms. There is need for research to identify and overcome the factors responsible for low yields.

Constraints to Production

The low yields of groundnut in Africa, and in the SAT in general, may be due to such factors as:

- unreliable rainfall patterns with recurring droughts;
- damage by diseases and pests;
- poor agronomic practices;
- limited use of fertilizers; and
- lack of high-yielding adapted cultivars.

These constraints are particularly difficult to deal with in the small-farmer situation typical of the SAT.

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Relevance of ICRISAT's Groundnut Research to Africa

ICRISAT has integrated research in pathology, entomology, mi9robiology, physiology, cytogenetics, and breeding, aimed specifically at producing groundnut cultivars with sustainable high yield and resistance or tolerance to the major yield-reducing factors, and to develop disease and pest management systems applicable to the small-farmer situation. Drought and several major diseases and pests of groundnut are being studied intensively at ICRISAT Center in India. Other problems, more specific to particular regions, are being addressed by cooperative research with national programs. The establishment of the ICRISAT Regional Groundnut Program for Southern Africa at Lilongwe, Malawi, in July 1982 has extended the range of research and improved opportunities for effective cooperation with research workers within the region. A similar program is being established for West Africa at the ICRISAT Sahelian Center in Niamey, Niger. This paper outlines ICRISAT's facilities and research activities that are likely to be relevant to groundnut research in eastern and central Africa.

Germplasm Base

ICRISATs Genetic Resources Unit maintains the world collection of 11 372 accessions of cultivated groundnut and 216 accessions of related *Arachis* species. These are evaluated and supplied to ICRISAT scientists and cooperators throughout the world. The eastern and central African region is an important source for genetic diversity of groundnut. Somalia was visited in 1979 and 9 accessions collected, but collections have not as yet been made in the other countries of the region. Priorities for collection and numbers of groundnut accessions obtained from and supplied to the various countries are shown in Table 1.

Table 1. Groundnut germplasm collection priorities for eastern and central African countries, and numbers of accessions obtained from and sent to them by ICRISAT.

Country	ICRISAT's priority for collection[1]	No. of accessions supplied	
		To ICRISAT	From ICRISAT
Burundi	4	0	75
Egypt	2	15	0
Ethiopia	2	0	259
Kenya	3	42	75
Rwanda	4	1	20
Somalia	4	9	14
Sudan	1	198[2]	283[3]
Uganda	1	161[4]	148

1. Where 1 = the highest, and 4 = lowest priority.
2. Mostly from the old Tozi collection at Wad Medani, introduced into India 1947-75, and reselections from this material.
3. 192 of the 283 accessions comprised resupply of the old Tozi collection to Wad Medani.
4. Mostly introductions to India during 1947-8S.

Although the numbers of accessions obtained by ICRISAT from Sudan and Uganda are large, they include many genotypes originally introduced into India over the period 1947 to 1975, and reselections from such material. There is a long history of groundnut cultivation in Ethiopia, Kenya, Sudan, Uganda, and Egypt, and it is essential to collect and conserve groundnut germplasm from these countries as efforts to introduce new and improved cultivars threaten the survival of old landraces.

Drought

The importance of drought in the SAT is well recognized and the problem receives high priority in ICRISAT. Major objectives are to develop methods of screening germplasm accessions and breeding lines for tolerance to midseason and/or late-season droughts, and to understand the physiological basis of genotypic variation in drought recovery and tolerance. Field screening has been carried out on several hundred genotypes, using a line-source sprinkler system to create gradients of water stress, and several genotypes have been identified as tolerant to midseason or late-season drought stress. Interactions have been found between drought and calcium availability, and between drought and pod rots and seed invasion by the toxigenic *Aspergillus flavus.*

Nutrition

Nitrogen fixation. A large number of *Rhizobium* strains have been tested for nitrogen-fixing ability in combination with a range of cultivars and germplasm accessions. This was done mainly in India, and it has resulted in the recommendation of the *Rhizobium* strain NC 92 for use with some released Indian cultivars. It has been found possible under certain conditions to increase yields of groundnut by inoculation with *Rhizobium,* even in fields where the crop has been grown for many years.

Mycorrhizae. Groundnut roots usually show extensive colonization by vesicular arbuscular mycorrhizae (VAM). The symbiotic relationship between the zygomycetous VAM fungi and the root augments phosphorus uptake from soils deficient in this element. Preliminary pot-culture studies have shown that groundnut derives considerable benefits from VAM inoculation. VAM colonization and phosphorus nutrition are likely to be components in genotype and site interactions, and selection of groundnut genotypes with increased susceptibility to VAM could improve adaptation to varying nutritional environments.

Calcium. Calcium deficiency is a major factor limiting groundnut yield in several parts of Africa. Gypsum is commonly applied to groundnut crops to correct calcium deficiency, and research at ICRISAT has concentrated on the interactions among gypsum utilization, drought, and genotype. Gypsum applied at 500 kg ha^{-1} increased yields of groundnut in drought conditions by as much as 30% in some genotypes, by enhancing early pod initiation and so providing a drought escape mechanism.

Diseases and Pests

Diseases and pests are particularly important in those tropical developing countries where the small farmer cannot afford, has no access to, or is not equipped to apply, crop protection chemicals. In many countries, reliable data are lacking on crop losses from pests and diseases. ICRISAT carries out disease and pest surveys in cooperation with national institutes. Our priority has been on identifying genotypes with resistance to the diseases and pests that are important worldwide or in major groundnut-producing regions.

Foliar disease caused by fungi. Worldwide, the most important fungal diseases of groundnut foliage are rust (caused by *Puccinia arachidis),* early leaf spot (caused by *Cercospora arachidicola),* and late leaf spot (caused by *Phaeoisariopsis personata).* In southern Africa, web blotch (caused by *Didymella arachidicola)* is also important. At ICRISAT Center, field resistance screening has identified 42 germplasm accessions resistant to rust, 5 resistant to late leaf spot, and a further 39 resistant to both diseases. Breeding lines with resistance to rust and/or late leaf spot, and with acceptable yield and quality, are now in advanced stages of evaluation in national programs. Derivatives of crosses between cultivated groundnuts and wild *Arachis* species resistant to rust and late leaf spot are also doing well in advanced tests.

Screening for resistance to early leaf spot is being done at the ICRISAT Regional Program for Southern Africa in Malawi because this disease regularly causes severe damage in that region. Interspecific hybrid derivatives are the most likely source of resistance to this disease.

Aspergillus flavus and aflatoxins. Invasion of groundnuts by *Aspergillus flavus* and the subsequent production of aflatoxins is a serious problem in many countries. The infection may occur before or after harvest, the latter being associated with wet conditions during crop drying, or with poor storage. Preharvest invasion is linked to damage by pests and diseases. Drought stress during late stages of pod development, a common occurrence in the SAT, predisposes seed to invasion by *A. flavus* and consequently to aflatoxin contamination. Imposed drought stress has been used to improve field resistance screening of germplasm accessions and breeding lines. Several genotypes with resistance to preharvest invasion of seed by *A. flavus* have been identified, and they are being used in a breeding program. Some genotypes with preharvest resistance also have resistance to *A. flavus* invasion of rehydrated, mature, undamaged, stored seed. Their use, in combination with crop handling methods designed to minimize risk of aflatoxin contamination, could provide an answer to this serious problem.

Virus diseases. Virus diseases cause significant losses in groundnut yield and, as shown in the rosette epidemics in Nigeria and Niger in 1975 and 1985, can cause crop failure. Several groundnut viruses are seedborne and so are of considerable plant quarantine significance. One of them, peanut mottle virus disease, is of worldwide distribution. Screening at ICRISAT has identified several tolerant genotypes, and some that do not transmit the virus through the seed. Other virus diseases are important in specific regions of the world, e.g., groundnut rosette in sub-Sahelian Africa and peanut clump in West Africa. Virus characterization and detection methods developed at ICRISAT are now being used in disease surveys and should provide more reliable data on incidence and importance of virus diseases in Africa. Epidemiological studies on rosette disease and resistance breeding are in progress at the ICRISAT Regional Program in Malawi. Several long-duration, rosette-resistant genotypes have been bred, and priority is being given to getting the resistance into short-duration groundnuts required for several regions of Africa.

Virus vectors. Insect pests are important because of both the direct damage they do and their role as virus vectors. The groundnut aphid, *Aphis craccivora,* can cause severe damage to young plants but is more important as the vector of peanut mottle virus worldwide, groundnut rosette virus in Africa, peanut stunt in the USA and in Sudan, and peanut stripe in Southeast Asia. Similarly, thrips feed on foliage and transmit the tomato spotted wilt virus causing bud necrosis disease in groundnut. Research emphasis is on combining cultural practices and host-plant resistance to develop integrated pest management systems.

Termites. Research on termites is carried out at ICRISAT in collaboration with the Tropical Development and Research Institute of the UK. The particular importance of termites as pests of groundnut in Africa is recognized, pod losses in excess of 30% having been recorded. It is also known that by killing plants and scarifying pods, termites predispose groundnuts to invasion by *A. flavus* and subsequent aflatoxin contamination. Current research is aimed at finding insecticides and fungicides that control the pest but do not harm the environment.

Other pests. Research is also being carried out on the leaf miner, *Aproaerema modicella,* and the tobacco caterpillar, *Spodoptera litura,* two pests that cause sporadic damage to groundnut.

Breeding for resistance to pests. A breeding project to combine resistance to leafhoppers, thrips, and termites into high-yielding cultivars started in 1980 with an extensive hybridization program. Some high-yielding progenies with resistance to thrips and leafhoppers have been selected.

Plant Improvement

Some breeding activities have already been mentioned when dealing with specific production constraints. There is a need to identify groups of stress factors important in particular regions/countries, so that resistance to these can be combined with other traits for particular situations and uses. Such traits include crop duration, earliness allied with seed dormancy, seed size (such as large seed for the confectionary trade), high oil content, high haulm yield, and combinations of these factors. When breeding cultivars for use at different latitudes, or for different seasons at the same location, it is important to note that some genotypes show large differences in yield between short and long daylengths. Adaptive breeding is largely the responsibility of national research programs, but ICRISAT and its regional programs can assist by supplying suitable germplasm. In recent years, confectionary selections have been sent to Burundi, Egypt, Ethiopia, Sudan, and Uganda, rust and late leaf spot resistant selections to Sudan and Uganda, pest-resistant selections to Sudan, and short-duration selections to Ethiopia, Rwanda, Somalia, and Sudan. Specific hybridization can be carried out at ICRISAT Center at the request of national program scientists.

ICRISAT's Research on Pigeonpea

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Introduction

Pigeonpea *(Cajanus cajan)* is grown throughout the tropics, but India accounts for over 85% of the 3.5 million ha sown with this crop around the world. In Africa, it is important as a field crop in Kenya, Malawi, and Uganda; it is also grown in small plots, hedges, and kitchen gardens in several other African countries.

Pigeonpea is a perennial shrub, but it is cropped annually in most farming systems. Because its early growth is slow and noncompetitive, pigeonpea is commonly sown as an intercrop, particularly with sorghum and millets. The cereal is harvested before the pigeonpea completes its vegetative stage.

Much of the crop in India is grown primarily for its dried seed, mostly consumed as *dhal* (decorticated, split seed) in a variety of dishes. In several countries, pods are harvested when green and the seeds then cooked as a vegetable, often as a substitute for garden peas (*Pisum sativum).* The dried seed may be used as an animal feed and the plants as fodder. The dried stems are of considerable importance as fuel, and they can be used in construction and basket making. Pigeonpea has a beneficial effect on the soil, leaving behind considerable nitrogen and organic residues.

Although pigeonpea is a versatile plant with many uses, it has received little research attention. The crops grown in most countries are of unimproved landraces, with little or no purchased inputs. The average world yield of pigeonpea is estimated at about 700 kg ha^{-1}, with a lower average in Africa (600 kg ha^{-1})- Yields of over 5000 kg ha^{-1} have been recorded in experimental fields in Australia and India, however, and research workers in Kenya have also reported that the crop has a high yield potential.

Constraints to Production

The huge difference between the potential yield and the average yield in farmers' fields is caused by a variety of abiotic and biotic constraints. Poor soil fertility, droughts, and floods limit plant growth and a large number of diseases and pests can devastate

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the crop. There are only limited data on the quantitative losses caused by these constraints in farmers' fields. In Kenya, leaf spot *(Mycovellosiella cajani)* and wilt *(Fusarium udum)* are widespread and damaging, while several other diseases, including those caused by viruses, may be of localized importance. Many insect species have been reported to reduce yields, particularly in Kenya. Of these, pod boring lepidopteran larvae, sucking bugs, and a podfly, are considered to be the most damaging.

Research at ICRISAT Relevant to Eastern and Central Africa

Research at ICRISAT Center in India aims not merely to benefit pigeonpea farmers in India, but those in other countries of the world as well. Our main emphasis is toward breeding new genotypes that will yield more than the cultivars presently used in the farmers' fields. We are searching for resistances to the major constraints and combining these resistances into plants that have other desirable characters, particularly high yield of good quality seeds. Our research also produces new methodologies and other information that can be of value to scientists in the national programs of many countries. At ICRISAT Center, we have several major assets including a team of scientists and support staff with considerable experience of this crop, excellent laboratory and field facilities, and the world's pigeonpea germplasm bank.

Genetic Resources Unit

Our Genetic Resources Unit (GRU) holds 10 818 accessions of pigeonpea germplasm. The seeds are stored under low temperature and humidity conditions that ensure their viability. The characteristics of each accession have been evaluated by GRU scientists; these data are stored in our computer and summarized in a catalog. From this working collection, we have already supplied more than 50 000 samples of pigeonpea seed to scientists across many countries. The germplasm is screened for useful traits by breeders, biochemists, pathologists, entomologists, and agronomists. Plants with useful traits are then crossed to produce new genotypes that may be of value.

The collection contains less than 900 accessions that originate from Africa; most of these came from only three countries, Kenya (313), Malawi (245), and Tanzania (221). We have only one accession from Uganda and none from Sudan, Somalia, Rwanda, and Burundi. We need further accessions from farmers' fields in Africa, particularly from Uganda where the crop is widely grown. It is essential that the rich resource of landraces from all countries be preserved, for they may contain genes that could be valuable in the future. We will be seeking collaborators to help with such collections.

Currently, GRU is collaborating with national scientists in Kenya to evaluate 500 accessions, mainly large-seeded, long-duration types, that may be particularly useful in this area. Such types are photoperiod sensitive, and the natural expression of their characteristics is suppressed when grown at ICRISAT Center. The unit is also screening the entire germplasm collection for photoperiod insensitivity, a trait that will allow wider adaptability to differing latitudes and seasons.

Diseases and Pests

Pathology research. Our pathologists have screened the germplasm collection and found several pigeonpea genotypes with resistance to one or more diseases. In cooperation with the breeders, crosses were made and progenies have been selected with combined resistance to as many as four important diseases. Wilt resistance will be of particular value in eastern Africa, and trials of genotypes selected at ICRISAT Center have already shown that some are resistant to this disease in Kenya.

Entomology research. Much of the entomological research at ICRISAT Center has been focused on the pod borer *(Heliothis armigera)* and the podfly *(Melanagromyza obtusa).* Pigeonpea genotypes with some resistance to these and other pests have been selected, and they may be of use in eastern and central Africa where the pod borer and a podfly are important pests. ICRISAT's research on other elements in integrated pest management is also expected to be of benefit in Africa.

Physical Constraints

Agronomy. Our agronomy work combines aspects of physiology and microbiology. Our physiologists have studied the growth and development of pigeonpea under a range of environmental conditions and developed packages of agronomic practices that maximize returns. They are screening the germplasm for resistance to physical stress, including drought and salinity. Our microbiologists have studied the nitrogen-fixing rhizobia that give this crop "free fertilizer," and they have developed a bank of these bacteria adapted to various environmental conditions. They have also developed cheap, practicable methods for the multiplication and field inoculation of these rhizobia.

Management of resources. Our Resource Management Program is active in developing new farming systems that incorporate pigeonpea and in studying the economics of such systems. It has found that cereal/pigeonpea intercrops sown on broadbeds, with modest inputs of fertilizer and pesticide, can be particularly profitable. They are now studying the potential for perennial pigeonpea in agroforestry systems.

Breeding New Pigeonpeas

Our breeders are combining resistances to the various yield-reducing constraints into pigeonpeas of differing durations, so that they can be of use in the wide range of environments in which this crop is grown. Their overall objectives are to provide useful breeding materials to national programs and to develop genotypes that will give high yields of valuable produce in the real-world conditions of farmers' fields.

Genotypes originating from ICRISAT's breeding program have already reached farmers' fields in India, Fiji, and Australia. Several more genotypes are in advanced tests in several countries, and most national pigeonpea research programs now rely heavily upon ICRISAT breeding materials.

Hybrid pigeonpeas have been pioneered at ICRISAT. Several genetic male-sterile lines that incorporate many useful traits have been developed, and these have been used to make many test crosses. Some of these hybrids have shown considerable heterosis and have been widely tested. One short-duration hybrid (ICPH 8) has performed very well in national trials in India. Tests have shown that hybrid seed production, using natural insect populations as pollinators, is likely to be economically viable.

Vegetable-type pigeonpeas with large pods, containing many large, sweet seeds, appear to have great potential, particularly in areas or seasons where the garden pea cannot be grown. Such types of pigeonpea from the Caribbean, Africa, and India, have been collected, and our breeders are developing new, improved genotypes that combine the best traits from these.

In India, 60% of the crop is produced from long-duration types, and in Africa most pigeopeas grown are of long duration. Breakthroughs to higher yields in many crops, including wheat and rice, have resulted from the development of short-statured, short-duration plants sown at high densities. It is already evident that pigeonpea is no exception. Our breeders have developed short-statured plants that can be harvested in less than 100 days and their potential is exciting.

Short-Duration Pigeonpeas

ICRISAT scientists, in cooperation with national scientists from India and Australia, have developed packages of practices that produce very good yields from short-duration pigeonpeas. Yields of over 8000 kg ha^{-1} have been recorded from small-plot trials in Australia. In India, yields of up to 5000 kg ha^{-1} have been reported from multiple harvests in large plots of ICPL 87 in farmers' fields. ICPL 87 is a short-duration cultivar from ICRISAT that has recently been released in India and there is now tremendous demand for its seed. We expect that this and other short-duration cultivars will provide a much-needed boost in India's pigeonpea production, where consumers have suffered a shortage of this popular pulse in recent years.

Unlike the longer-duration genotypes, the short-duration types are expected to be normally grown as sole crops, in multiple cropping systems wherever the climate allows crops to be grown through much of each year. Such genotypes are already being grown in northern India and being harvested in time to allow timely sowing of wheat on the same land. Our agronomists and cropping systems scientists are experimenting with such types in a variety of systems.

Potential in Eastern and Central Africa

There is no doubt that pigeonpea can be grown in many areas of eastern and central Africa where it is not found at this time. Where it is already being grown, much greater yields can be obtained through use of improved cultivars, better agronomy, and through the moderate use of supplementary irrigation and pesticides. There is no use in producing a crop, however, unless there is a demand for the produce. Currently there is only a small international trade in pigeonpea, and the domestic demand for pigeonpea in Africa appears to be generally low, though variable. It is often commented that pigeonpea takes longer to cook than cowpea and dried beans. This may be a major reason why the latter crops are widely preferred in many areas of Africa. Our biochemists, who have shown that pigeonpea is very nutritious, have been screening genotypes for their cooking quality. We are also assembling recipes that incorporate pigeonpea into tasty dishes. It should not be difficult to popularize this crop in eastern Africa if increased production leads to marketable surpluses that can be sold at reasonable prices.

We do not expect to be able to transfer ICRISAT-improved genotypes and cropping systems to Africa with immediate increases in productivity. We can provide nurseries of genotypes that we think may be adapted to the climatic conditions in various areas of eastern and central Africa, so that they can be compared with local cultivars. Some of these genotypes might give higher yields and possess resistances or other desirable traits lacking in the local cultivars. We can also supply breeding materials, including wide-range crosses, and male-sterile lines that can be used to make hybrids with local cultivars as pollen donors. From such materials, locally adapted, high-yielding genotypes may be developed and selected. Of particular interest may be high-protein genotypes that have been selected at ICRISAT from crosses between pigeonpea and its wild relatives *(Atylosia* spp). Such material may be of particular value as animal feed supplements.

We do not restrict the supply of materials, methods, and information developed by pigeonpea scientists at ICRISAT. We will be pleased to share what we have with our colleagues in eastern Africa and would welcome collaboration in any activity that could increase the crop's productivity. We hope not only to give, but also to receive, for ICRISAT scientists can benefit from the knowledge and genotypes possessed by the scientists and farmers in Africa.

ICRISAT's Research on Chickpea

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Introduction

Chickpea *(Cicer arietinum)* is of ancient history, especially in West Asia and the Far East, where its cultivation dates back thousands of years. The oldest chickpea finds are from excavations at Hacilar near Burdur in Turkey. By ^{14}C dating, they were estimated to be from about 5450 BC. It is believed that the Hellenes took the crop from Turkey westward to the Mediterranean and eastward to India. The Greeks, Phoenicians, and Romans spread its cultivation through the Mediterranean region, northern Africa included, while some eastern African countries became acquainted with chickpeas through Asian immigrants during the 19th Century. Ethiopia, however, has a much longer history with chickpeas. Spanish and Portuguese merchants introduced the crop to the New World, while Asian settlers later supplemented, (in the West Indies, for example) the earlier importations. The latest expansion of the crop is into Australia, where interest in it is increasing considerably. What will happen with the production of chickpeas in the future is difficult to predict. The same applies to research on chickpeas. Available statistics and data, however, may help to indicate trends of production and the need for research. The following tries to present these in more detail, with special reference to the situation in eastern and central Africa.

Eastern and Central Africa

Marketing and Uses

Chickpeas are used in many ways. The crop may be harvested green and the seeds eaten fresh, but mostly dry seeds are consumed. These are often dehulled and split and used as soup or *dhal*; flour or *besan* is produced from split or whole seed; and dry seeds can also be used in many other ways. Interestingly, the acid exudate of the leaves can be applied for medicinal and other purposes. The exudate is captured by spreading a cloth over the plants and wringing out the liquid early in the morning. The International Chickpea Newsletter started a recipe section in 1983 and has continued it ever since; in the process, we have discovered a range of chickpea dishes. Both chickpea hay and seed are used as cattle feed and can find large markets as such.

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Most chickpea produced in the region is consumed locally. When Ethiopia produced around 200 000 t from 300 000 ha during 1970-1973, about 10 000 t (5%) was exported, but currently there is no export of chickpeas from Ethiopia, Sudan, Kenya, Uganda, or Tanzania. In Ethiopia and Sudan, the indigenous population eats chickpeas, while in the other countries the main consumers are people of Asian origin.

Production Areas and Productivity

The area and production patterns show significant annual fluctuations, but by and large there are no clear trends of increase or decrease over the past 20 years. Table 1 shows FAO estimates for 1984; these omit Kenya, which is estimated to have about 7000 ha. These figures add up to 166 000 ha, which is 1.4% of the world's total chickpea area. Most of this land is heavy clay. In Ethiopia, the main production area lies in the Central Highlands (altitudes over 1500 m). The soils there are black, Vertisols, on which tef thrives too. The production in Kenya is also mainly on black cotton soil at high altitudes, while in the Sudan, chickpeas are mostly found on river banks, islands, and basins that are flooded by the Nile.

The world average yield for 1984 was 663 kg ha^{-1}; for Africa as a whole it amounted to 721 kg ha^{-1}. Figures for Ethiopia, Sudan, Tanzania, and Uganda are shown in Table 1. Under favorable conditions, much higher yields can be obtained. For example, yields reported from Ethiopia have been as high has 4800 kg ha^{-1}, from Kenya 3000 kg ha^{-1}, and from Sudan 2230 kg ha^{-1}. Obviously the yield potential in the region is good, but production constraints prevent the farmers from achieving it.

Production Constraints

Agronomic deficiencies—such as poor plant stand, insufficient water supply, and inadequate weed control—cause yield losses. High temperatures are known to curtail growth and reduce yield. The nonavailability of stable, high-yielding varieties may also be a factor for low productivity. Biotic constraints reported are shown in Table 2.

The differences between the high yields that can be obtained (as mentioned earlier) and those that farmers produce are huge. Obviously, the constraints listed are a dominating factor in the production of chickpeas. They emphasize the need for ameliorative research.

Table 1. Chickpea production in eastern Africa, 1984.

Country	Area ('000 ha)	Production ('000 t)	Yield (kg ha^{-1})
Ethiopia	121	89	736
Sudan	3	3	933
Tanzania	30	9	300
Uganda	5	3	600

Source: FAO Production Yearbook, 1984.

Table 2. Biotic constraints reported from eastern and central Africa.

Constraint	Ethiopia	Sudan	Kenya
Diseases			
Fusarium wilt	+	+	+
Dry root rot	+	+	0
Collar rot	+	0	+
Ascochyta blight	+	0	0
Macrophomina disease	+	0	0
Stunt	0	+	0
Pests			
Pod borer	+	+	+
Cut worm	0	+	0

+ = reported, 0 = not reported.

Relevant ICRISAT Activities

Agronomy. ICRISAT's agronomic research is of direct interest in the African situation, as outlined above. Important, for instance, are screening for drought tolerance and identification of genotypes that can germinate in soils with limited moisture and withstand periods of drought during their growth. Plant nutrition studies, including those on *Rhizobium,* are also of relevance.

Germplasm. Certain genotypes are more adapted to specific environments than others, and the screening of a large collection of germplasm accessions is always rewarding when selecting a variety for a particular production zone. The ICRISAT Genetic Resources Unit held 14 875 chickpea accessions by the end of 1986, representing 41 different countries, and each of those can be made available. Apart from these, wild *Cicer* species are also maintained and supplied on request. The Plant Genetic Resources Centre, Addis Ababa, and the Alemaya University of Agriculture, Ethiopia, together with the ICRISAT Genetic Resources Unit, are at present jointly evaluating 940 germplasm entries at Debre Zeit, sown in September 1986.

Diseases. A number of diseases can be devastating for chickpeas, and unless a certain measure of resistance is present in a variety, it will not give stable yields and assurance of an economic return. ICRISAT scientists, together with colleagues in national programs, have studied in depth most of the diseases listed in Table 2, and sources of stable resistance have been found by screening large numbers of germplasm entries in the ICRISAT collection. This source material also can be shared with interested institutions or individuals. Because of their importance, two disease are briefly discussed here. Fusarium wilt, caused by the fungus *Fusarium oxosporum f.sp. ciceri,* is widely spread and can wipe out susceptible varieties. But stable resistance has been identified and its inheritance studied. Two recessive and one dominant gene play a part in controlling the resistance. They have been given the symbols, h1, h2, and h3, and any combination of two of these genes in homozygous condition, for instance h1h1/h2h2, will convey complete and stable resistance to a variety. Dry root rot is caused by *Rhizoctonia bataticola,* another fungus disease that is widely spread in areas where temperatures are relatively high and drought problems occur. Several sources of resistance have been found, and recent inheritance studies have revealed that the resistance trait is monogenic and dominant.

Insect pests. The major insect pest of chickpeas in central and eastern Africa, also in the Asian subcontinent, is the *Heliothis* pod borer. ICRISAT scientists were initially not very optimistic about finding sources of resistance against *Heliothis,* but such sources have been found and studied. The resistance character is controlled polygenically.

Breeding. The use of the resistance factors comes partly through breeding, when the resistance genes are combined with those that give high yield, good seed size, and other desirable traits. ICRISAT breeders have produced lines and varieties which possess resistances that can be combined with traits that help adaptation to the conditions of eastern and central Africa. The ongoing program is increasingly productive, and exchanges of seed material are always welcome.

Information and training. The importance of interaction and communication for agricultural research and extension is often stressed, and it applies to chickpeas no less than to other crops. ICRISAT can contribute through its publications, one of which is the International Chickpea Newsletter. Other publications cover the topics of agronomy, biochemistry, breeding, entomology, genetic resources, pathology, and resource management. Publications are available on request from ICRISAT's Information Services. The ICRISAT Training Program provides postdoctoral fellowships, in-service fellowships, research scholarships, in-service training, apprenticeships, and short-term courses. A total of 195 participants were trained during 1985. They came from 49 different countries: six were from Ethiopia, four from Kenya, eight from Sudan, two from Uganda, and six from Tanzania.

Summing Up

There is much scope for improving chickpea production in eastern and central Africa, where problems and constraints are very similar to those already being worked on by ICRISAT researchers. The activities outlined in this paper may help identify areas of useful collaboration in eastern and central Africa.

ICRISAT's Regional Groundnut Improvement Program for Southern Africa

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Introduction

During the past four years (July 1982-December 1986), ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) has been responsible for the execution of a successful regional groundnut improvement program in southern Africa. The program was established in response to an invitation by the Southern African Heads of State at the Lusaka Summit Conference in 1980. In February 1982, a formal memorandum of understanding between ICRISAT and the Government of Malawi, as host country, was signed. The project became operational in July 1982.

The program has been funded by the International Development Research Centre (IDRC) in two phases, each of two years: IDRC provided 590 000 Canadian Dollars for phase 1 (July 1982-December 1984) and 750 000 Canadian Dollars for phase 2 (January 1985-December 1986). During 1986, the status of the program was changed to an ICRISAT Core Program supported by the IDRC grant. ICRISAT has since injected a further US $ 50 000 for equipment, and it has also made available additional funds for operational costs.

In October 1984, the Southern African Development Coordination Conference (SADCC) Consultative Technical Committee for Agricultural Research approved the subsuming and future expansion of the ICRISAT regional groundnut program into a regional Grain Legume Improvement Program. This will take effect in 1987, with ICRISAT retaining responsibility as executing agency for regional groundnut research.

Groundnut Cultivation and Research in Southern Africa

Groundnuts have long been of major importance in smallholder agriculture in southern Africa and are the main legume crop in extensive areas of Malawi, Mozambique, Tanzania, Zambia, and Zimbabwe. They constitute a principal source of protein,

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vitamins, and dietary oil for subsistance farmers and poor urban dwellers in southern Africa, and they provide a significant source of smallholder cash income through either official or village markets. Current shortages of edible oil and of foreign exchange have added further to their importance.

FAO estimates of area, production, and average yields of groundnuts in SADCC member states are shown in Table 1. Yields are low, varying between 400 and 950 kg ha^{-1}, in marked contrast to yields of over 4000 kg ha"[1] obtained on research stations and by large-scale commercial enterprises in the region, notably in Zimbabwe. The potential for increasing smallholders' yields in the region is, therefore, very high.

Constraints to increased production are many and vary within and between each country. Those most amenable to amelioration through the efforts of a regional program of only modest strength are (1) lack of good, suitably adapted varieties (particularly in Mozambique, Tanzania, and Botswana) and (2) yield loss from diseases, particularly leaf spots *(Cercospora arachidicola* and *Phaeoisariopsis personata),* rust *(Puccinia arachidis),* and groundnut rosette virus.

While groundnuts have received research attention because of their export potential for SADCC countries, varieties developed for higher elevation, high-rainfall areas (Malawi, Zambia, Zimbabwe) are not suitable for low-elevation, low-rainfall areas, where groundnuts are at present primarily a food crop. Research programs in Malawi and Zimbabwe have been in existence for many years and have made significant contributions to improved production in those countries. In the past, the Zimbabwe program was geared towards the improvement of long-duration varieties grown under irrigation on large commercial estates, but these contribute only 8% to total national production. A great deal of effort is now urgently required to develop short-duration varieties appropriate to smallholder farmers.

Table 1. Area, production, and yield of groundnuts in SADCC countries.

	Area ('000 ha)		Production ('000 t)		Average yield (kg ha-')	
Countries	1981	1982	1981	1982	1981	1982
Angola	40	NA	20	NA	500	NA
Botswana	4	NA	2	NA	395	NA
Malawi	250	250	180	180	720	720
Mozambique	170	170	80	80	471	471
Swaziland	3	NA	1	NA	481	NA
Tanzania	94	96	56	58	596	604
Zambia	50	50	30	30	600	600
Zimbabwe	240	240	239	115	955	479
SADCC Region	851	-	608	-	710	-
Africa	6470	-	5201	-	804	738

NA = Not available.
Source: FAO Production Yearbook 1982; FAO Monthly Bulletin of Statistics, 1983: 6(1).

Zambia and Tanzania have had groundnut programs in the past, but these lapsed and have only recently been reactivated (Tanzania with assistance from IDRC and ODA, the Overseas Development Administration of the UK; Zambia with assistance from FAO and World Bank). Some of these aid-assisted programs have been or are to be discontinued. Botswana has only recently initiated a formal groundnut improvement program; the Mozambique national program is assisted by IDRC, but lacks research experience.

There is thus great scope for enhancing groundnut research in the region. Most of the varieties released through the national programs were, and continue to be, direct introductions or reselections from such research. Hybridization and selection from a greatly expanded germplasm base is now imperative for further significant progress.

ICRISAT Regional Program

Staff and Facilities

Project staff consists of two groundnut scientists (a breeder and a pathologist), supported by two technical officers (with agricultural college diplomas), four technical assistants (agriculture school certificate holders), and a clerk/typist.

Chitedze Research Station, our regional base, is located 16 km west of Lilongwe, Malawi's capital city, at 14 ° S and 33 ° 45'E, and at an altitude of 1050 m. Chitedze is situated on the Lilongwe Plain, the major groundnut-producing area of Malawi.

The Malawi Department of Agricultural Research has provided laboratory and office accommodation for the program within the Chitedze Research Station complex. We will continue to enjoy these facilities until May 1988. Thereafter, because of major organizational and structural changes, the Malawi Government's generous support of the program in regard to accommodation will be withdrawn. However, it is expected that the program will build its own research facility at Chitedze during 1987.

Our experimental land area is about 8 ha. We enjoy excellent cooperation from Chitedze in the allocation and preparation of land, and in many other respects.

Review of Progress, 1982-1986

Objectives and strategies. We acknowledge the smallholder as our principal target. He has extremely limited financial and other resources, and it is unlikely that his situation will alter significantly in the forseeable future. Recognizing this, we conduct our research under conditions of low input, and our initial evaluation of germplasm is made under rainfed conditions, without any form of crop protection. We also acknowledge the national groundnut improvement programs of the region as our immediate clients and recognize that their needs are of paramount importance. Our work is, therefore, directed towards these needs.

Our objectives continue to be the development of high-yielding breeding lines and populations, adapted to the region and containing tolerance to factors limiting production by small-scale farmers. We are, therefore, primarily concerned with the effective broadening of the genetic resources of southern Africa, and our priorities are vested in breeding and selecting for increased yields, quality, and earliness.

Research progress. We have built up and continue to broaden our genetic base, by introducing selected germplasm lines from ICRISAT Center and elsewhere. Over the past four crop seasons, we have evaluated more than 2500 accessions, from which we have already selected more than 100 lines that are being tested in preliminary, advanced, and elite yield trials.

Material has already been released to national programs in Angola, Botswana, Malawi, Mozambique, Tanzania, Zambia, and Zimbabwe, where, in cooperative regional trials, promising selections are being tested against local recommended varieties. The Zimbabwe and Malawi national programs have already selected and included some of these superior lines in their national district trials. Our cooperation with national programs, thus, augurs well for the future.

We consider hybridization a priority area and, consequently, have trained 20 field assistants who have attained an acceptable level of expertise. They have assisted in making over 400 crosses for the high yield and quality breeding program, for rosette disease resistance, and for early leaf spot tolerance. We offer this service to national programs and are currently assisting Mozambique and Zimbabwe with selected hybridizations.

We also assist national programs by evaluating and documenting landraces, and have evaluated 345 Zambian, 60 Tanzanian, and 45 Mozambican lines.

We have made progress with our studies on rosette disease and early leaf spot. By studying natural disease distribution patterns of rosette virus and by simulating these, we have developed a highly successful screening technique, which enabled us last season to screen effectively over 30 000 plants of F_2, F_3, and F_4 generations. We have also identified a number of high-yielding lines that apparently contain tolerance to early leaf spot. Several of these are Valencia landraces of South American origin, a group of great interest, but one hitherto largely neglected by breeders in our region.

Networking activities. We have developed an effective regional network, linking together groundnut scientists of the SADCC countries.

We organized two multidisciplinary workshops, the first in Lilongwe, Malawi, in 1984 and the second in Harare, Zimbabwe, in 1986. These have facilitated and sustained close professional contact between all research scientists engaged in national groundnut improvement programs and have engendered a spirit of regional cooperation. The workshops have also provided invaluable opportunities for periodic reviews of the regional program by national programs where, as an active regional forum, national scientists have discussed how ICRISAT might best continue to respond to the needs of the region. We supplemented the workshops with a Groundnut Breeders' Group Meeting in 1985, which visited national breeding programs in Zimbabwe, Zambia, and Malawi.

In order to facilitate the exchange of information on results and techniques, we initiated an annual newsletter (Regional Groundnut News), based almost entirely on contributions from the national programs themselves. We also distribute groundnut abstracts and other literature to all national programs, several of whom have limited access to relevant scientific literature.

Our small professional strength and other research and regional commitments have precluded any venture into formal training schemes. However, we assist where necessary with the placement of national program technicians in the ICRISAT Center 6-month in-service training scheme. During the past 3 years, groundnut research support technicians from Botswana, Malawi, Mozambique, Tanzania, and Zambia attended the course, which has led to a steady strengthening of national program research capability. We also offer local training in hybridization and disease screening techniques.

Some Background Factors

To conclude this brief review, some reflection may be appropriate on factors which, either by design or fortuitously, have contributed to the overall success of our regional endeavors.

1. The most important of these has been a matter of political geography. ICRISAT's presence in southern Africa was by invitation of the Heads of State of an effective regional grouping of countries (SADCC). We went to an area that not only has a clear perception of the advantages of regional cooperation in agricultural research, but also possesses an efficient official and legal entity for its coordination, the SACCAR (Southern African Centre for Cooperation in Agricultural Research). Such circumstances alone must constitute an ideal situation for the establishment and operation of any regional program. From the outset, we were seen to be a functional precursor of a future SADCC Grain Legume Improvement Program.

Our path was thus made a great deal easier than it might otherwise have been. The Departments of Agricultural Research of the SADCC countries supported our official presence in Malawi and understood the broad objectives of our program. This greatly facilitated the organization of our various regional activities, including regional cooperative research and workshops.

2. The SADCC choice of host country for our regional base has been of profound significance. Groundnuts are one of Malawi's most important crops and there has been a long-established tradition of crop improvement by a strong national groundnut research team. We came to a country with a vested interest in groundnut research, and worked with a research department committed to its furtherance.

3. The host country's choice of site for our regional base has been ideal. Chitedze Research Station is situated in the heart of Malawi's main groundnut-producing area, which is contiguous with extensive groundnut areas of eastern Zambia, and is also similar in climate, altitude, and rainfall to the northern groundnut districts of Mozambique.

Within the borders of Malawi itself are to be found two further, climatically distinct, areas of groundnut cultivation, the moist lake lowlands, and the drier and more erratic rainfall areas of the south. The value of these in proximity to our base is obvious. In addition, our base is 16 km from Malawi's capital city, and we enjoy all the advantages of efficient international communications and an international airport.

4. We consider that we have successfully established an appropriate balance between our on-base research and other important regional commitments. It is of manifest importance to establish and to sustain the many facets of an effective regional network, but quality research, pertinent to the region's more pressing needs, is perhaps of at least equal value. We have, therefore, given high priority to the selection and distribution of promising germplasm lines for local evaluation and utilization. The ultimate extent and utilization of such new germplasm is a direct measure of the success and impact of any regional program.

5. We have listened to what our donor (IDRC) expected of us, and we have listened to the views and criticisms of our colleagues, the national program scientists, at our successive regional meetings. We have done our best to respond, wherever it has been possible to do so.

6. Finally, the program could not have been successful without adequate financial backing from a donor that was involved and interested in the development and well-being of the project from its inception.

Groundnut and Pigeonpea Cultivation in Burundi

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Groundnut

Groundnut is grown in Burundi at altitudes between 850 m and 1500 m, but mainly in the lower regions where it is cropped intensively. It is produced mostly by small farmers of limited means; total production is estimated at 80 000 t, with an yield average of 1230 kg ha^{-1}.

Groundnut was first introduced in the Moso region (1200-1300 m) of Burundi; it was later extended to the Imbo region (850-1100 m), where there is a great farmer demand for this crop. In Moso, a wide range of germplasm is found and farmers have selectively adopted improved varieties. Groundnut production is limited in other regions at altitudes above 1400 m.

Introduction of varieties has occurred over a long time in Moso. This region, situated in the southeastern part of the country at 4° S, is characterized by a mean temperature of 23° C and a rainfall average of 1200 mm between October and May. Groundnut grows best on soils with intermediate texture (60-65% fine elements) and though it is cultivated on light-textured soils, yields there are very low.

Uses

Groundnut has long been grown in kitchen plots for its snack and confectionary value. But during the last five years, it has begun to be used as a source of edible oil, which will possibly lead to extension of the area under its cultivation.

In villages, the pods are usually dried on the ground in family enclosures. Most farmers dry the groundnuts in pods, and shell them manually before selling or consuming them.

Groundnut is fast becoming a cash crop for its confectionary value. Farmers have gradually started selling their marketable product. In 1978, only 45% of the production was estimated to be reserved for home consumption, whereas more than 60% of the production was so reserved in beans, for example.

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Cropping Methods

Groundnut can be grown in either of the two cropping seasons in the country. It is grown more extensively in the second cropping season (February to May).

In low-altitude regions, such as Imbo (800-1000 m), groundnut can be cultivated with irrigation in the dry season, after cotton. In the first season, sowing is done in September-October and harvesting in January-February. For the February sowing, harvesting is carried out in June-July.

Groundnut is often grown in pure stands after maize in the second rainy season. Early drought can seriously damage the yields.

Seed Conservation and Adoption

Most of the groundnut is produced by small farmers who also look after the seed conservation. Seeds are conserved mainly in June-July. The State Agricultural Department, however, annually produces on an average 6 t of pods for distribution to individuals or farmers' societies.

The varieties commonly grown by farmers have a growth duration of 95 to 115 days, at an altitude of 1200 m. The released varieties—A 65, A 1055, G 18, and Fatui—have their own regions of adaptation and have been adopted by farmers according to soil and climatic conditions.

Varietal Research

Accessions from INEAC. Around 1950, erect-type groundnuts were introduced in Moso from the Yangambi Research Station, Zaire. For several successive years, from 1954 to 1962, cultivation in the rainy season without applied fertilizer on clayey ferrisols showed that the medium-late 130-day variety, A 3393, with an average grain production of 920 kg ha^{-1}, outyielded the variety A 65 (685 kg ha^{-1})-

Since 1971, the best selections of the Institut National d'Etude Agronomique du Congo (INEAC) have been introduced in Burundi through Rwanda. INEAC Virginia bunch varieties (150 days to maturity), 1034, A 1035, 1040,1046,1171, and 1172 have also been included in comparative trials and have shown a low productivity. The volete and Valencia type varieties, which showed a high yield potential, have been retained. These varieties had a shorter growth duration (105-110 days), except for A 67 and PI 206 (130 days).

Accessions **from Central African Republic and Rwanda.** Five varieties originating from the Central African Republic were evaluated during three wet seasons and one dry season (1971-74). In the dry-season trial, the Valencia types performed poorly on the alluvial soils. In the wet-season trials, differences in varietal performance were not significant, except for 1973-74, where the grain quality was mediocre.

Based on their performance in the trials, three varieties were selected: E 78, A 1055, and AR 1969/4. Among these, variety A 1055 outperformed all other entries in further trials (1974-75).

Accessions from the United States. In 1975, the varieties introduced from the United States were compared. The Virginia runner spreading type needed more labor during its growth and harvest, and thus fared less favorably than others, while the erect types Starr and Georgia were selected for their high yields.

The following results emerged from the trials: (1) The late-maturing groundnut varieties (Virginia type) had a lower yield than the short-duration varieties (volete, Spanish, and Valencia types); (2) The volete and Spanish types were about equal in yield, though the pods of the Spanish type were harder to shell; (3) The Valencia type is not recommended for poor-structured soils. The A 1055 variety (volete type) and the Georgia 119-20 (Virginia type) were selected and recommended for release; (4) All the accessions were susceptible to the leaf spot disease, *Cercospora arachidicola.*

Other accessions. New accessions from the Institut de Recherches pour les Huiles et Oleagineux (IRHO) in Mali and in Burkina Faso were introduced into Burundi from 1979 onwards, after being tested against the control A 65. Variety G 18, released in Burundi from selections made in Rwanda, was also included in the trials.

From 1979 to 1983 the elite materials selected earlier, A 65 and A 1055, still gave the best yields. Variety G 18, which gave an equally good yield, was extended to a larger scale. Groundnut accessions with a duration of 130-150 days were also introduced from IRHO in Burkina Faso. Variety RMP seemed more productive and better adapted to the low-altitude region (850-1200 m), because its shorter growth duration helped its integration into the traditional cropping system.

Accessions from Zimbabwe (the ICG series) and from Senegal, introduced in 1982, were multiplied and evaluated against varieties already released in Burundi. The varieties ICG 8009 from Zimbabwe and 75-33 and 75-50 from Senegal outyielded the controls significantly.

Since 1985, research is under way to identify varieties resistant to rosette and drought. Groundnut varieties with a higher oil content are also in demand.

Conclusion

Groundnut production in Burundi can be considerably increased, given the following conditions: if the farmer has varieties that tolerate drought better and are easier to harvest; with a tighter control on the sowing date; and with dormant-type plant material for the postrainy season. The use of groundnut for extracting edible oil is a new incentive for the farmer to increase his production.

Pigeonpea

In Burundi, pigeonpea is grown in regions with altitudes ranging between 850 m and 1800 m, especially in the eastern savanna regions between 1200 m and 1400 m, where most farmers have shown interest in it. In the central plateau (1400-1800 m), the area under pigeonpea decreases with increasing altitude.

Pigeonpea has been essentially a traditional food crop, not given as much importance in national research as haricot bean *(Phaseolus vulgaris)* soybean, and groundnut. However, present interest in pigeonpea as a valuable source of human nutrition and cattle feed indicates a greater importance in the future.

Farmers' demand for pigeonpea in the lower altitudes, its suitability for intercropping with such crops as beans and sorghum, and its drought tolerance are important factors that favor the extension of its cropping area and indicate the need for research on genetic improvement and adaptation to various ecological conditions of the country.

Uses

Pigeonpea is generally consumed as a food crop. It is harvested when mature and then sun-dried in the family enclosure; sometimes it is cut with all its stalks and left to dry directly in the field. It is mostly consumed as dried seed. Farmers have recently begun to use it as a feed for small ruminants, and the area under pigeonpea cultivation for this purpose is expected to grow.

Cropping Practices

Farmers seldom grow pigeonpea as a sole crop. It is estimated, however, that about 70% of the area under cultivation includes pigeonpea in intercrops with haricot beans or sorghum. In the first growing season, pigeonpea is mostly sown with haricot beans, the main grain legume of Burundi, to coincide with the first showers in October in medium-altitude regions (> 1300 m). In the second season, pigeonpea is cultivated either with sorghum or in pure stands.

The area sown to pigeonpea is now estimated to be 1000 ha, with an average yield of 1000 kg ha^{-1} in Moso, the main pigeonpea-growing region of the country.

Germplasm

No genetic improvement work has been done in Burundi on pigeonpea. The varieties in use today are mostly introduced, with the Burundi farmers adopting them where they proved adaptable. No research has yet been carried out on the conditions under which the farmer uses different varieties in his traditional cropping system. But the farmers seem able to distinguish between two maturity groups—long and short—at the time of sowing.

Main Constraints to Expansion

Very little is known about the adaptation of pigeonpea to the various ecological conditions in which it can grow in Burundi. Traditionally, it has served only as a subsistence food crop, consumed totally on the farms where it is produced. At present, it is beginning to be marketed and this may lead to expansion of the area under its cultivation.

The pigeonpea plant seems to be hardy and fairly resistant to fungal diseases. But insects on pods appear to be a problem, and further research is needed to estimate losses and reduce them.

Conclusion

Pigeonpea could become an important legume crop in Burundi. Its hardiness and resistance to drought and fungal diseases, its capacity to integrate into existing cropping systems, and its recent use for animal feed are all factors that indicate a growing interest in the crop for both human food and animal feed. Research is needed to give us exact data on the present conditions under which pigeonpea is grown, its production potential, and its possible extension in Burundi.

Research on Groundnut, Pigeonpea, and Chickpea in Ethiopia[1]

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Introduction

Groundnut, although a legume, is categorized as a lowland oil crop in Ethiopia. It is grown mostly in warmer regions, in the low-to-mid altitude areas (up to 1900 m) of the country. Despite its importance as an oilseed crop, groundnut has had a minor share of the resource allotment for crop improvement. It is mostly intercropped with major crops, but also grown in marginal lands. The varieties and cultural practices used by the farmers are still traditional

Pulses, traditionally grown, occupy 12-14% of the total cropped area in Ethiopia. Among the highland pulses (grown 1800-3000 m above sea level), chickpea ranks second to faba bean in area and production. Pigeonpea, a minor pulse crop in Ethiopia, is grown predominantly in the warmer lowlands. Research on these two pulse crops is the responsibility of the Institute of Agricultural Research (IAR), and on groundnut that of Alemaya University of Agriculture (AUA).

Groundnut

Production and Productivity

Production area under sesame, groundnut, and castor bean is estimated to be 186 000 ha. Despite its importance, groundnut has been given inadequate attention in the past and, as a result, average yields are low. The varieties used by farmers are traditional.

Production Practices

Groundnut is mostly intercropped with cereals; if planted alone, it is assigned to marginal lands. It is grown in both rainfed and irrigated situations. The cultural practices used by farmers are also traditional.

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1. Amare Abebe presented the part relating to groundnut and pigeonpea, and Abebe Tullu that relating to chickpea.

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Production Constraints

The production constraints include: nonavailability of high-yielding and early-maturing varieties; low plant populations in farmers' fields; diseases, such as *Cercospora* leaf spots, rust, and storage diseases; insect pests; and weeds.

Research Efforts

Research on groundnut was initiated in the mid-1960s, but it has received more systematic and intensified attention since the advent of the team concept in 1980. With aid from the International Development Research Centre (IDRC), Canada, the program has been able to get reasonable manpower and material support to broaden its activities. As a result, a large number of trials have been conducted in experimental and coordinating stations during the 1986 crop season. The overall objectives are to increase productivity through small farmholds, cooperatives, and state farms for local consumption, agroindustrial projects, and for exports.

Breeding. Research on groundnut was initiated in 1966 with a number of new introductions and collections. Of these, AK-11, Shulamit, GA 119-20, PI 250680, NC-4X, and NC-343 have shown outstanding performance. The mean yield of these varieties is about 5 to 6 t ha^{-1} under irrigation in Melkawerer, and 2 to 2.5 t ha^{-1} under the rainfed conditions of Bisidimo, Babile, Bele, and Abela sites. Moderately disease-resistant and early-maturing varieties have been obtained from ICRISAT and of these, ICG 273, 274, 1008, 1529, 7283, 7484, and 7636 were found high yielding. A few local collections, Bisidimo, Olole, and Sartu, have also done well at Melkawerer, Bisidimo, and Babile.

Groundnut national yield trials—carried out at Melkawerer, Bisidimo, and Baile for a number of years—showed that the varieties Shulamit, NC-4X, NC-343, NC-2, MH-383, Bambey, and Ashford are reasonably good at both rainfed and irrigated locations (Table 1).

Shulamit, which has been released to the Western Agricultural Development Enterprise, remained a higher yielder, though it was susceptible to rust and leaf spot diseases, while PI 250680 showed low yields. Besides Shulamit, NC-5 and NC-343 are candidate varieties for release in the near future. All of them are Virginia types with different morphologies. The small-seeded Spanish/valencia types were found to mature earlier, contain more oil, and give lower yields than the large-seeded Virginia cultivars.

Agronomy. Sowing date trials at Melkawerer indicated that March-April sowing gave better yields than July-September sowing. Practical experience and observations show, however, that groundnut sown in mid-May gives good yield and is preferred for technical reasons. Sowing dates used in other groundnut-growing regions are mainly based on rainfall pattern and farmers' habits. Planting in May-June is favored by many rain-dependent farmers, especially in eastern Ethiopia.

Flat and ridge planting did not show significant yield differences under irrigation. However, ridge planting permits easy flow of water, and is favored for technical operation. Using shelled seeds as planting material was found to result in rapid

Table 1. Mean pod yields($kg\ ha^{-1}$) of selected groundnut varieties in Ethiopian national trials, various years[1].

Variety	Rainfed locations	Irrigated locations
Ashford	2320 (7)[2]	4000(3)
MH 383	2300 (7)	3730 (3)
Shulamit	2250 (8)	5300 (2)
Bambey	2180 (7)	3430 (3)
NC-343	2130 (3)	4800 (2)
NC-5	2040(5)	6600(1)
NC-2	1960 (8)	3900(4)
AK 11	1880 (7)	3660 (3)
GA 119-120	1860 (5)	5900(2)
PI 250680	1440(3)	4050 (2)
NC-4X	1330 (3)	5050 (2)

1. Trials were carried out during 1972-84, but the number of years each variety was tested ranges widely across locations.
2. Figures in parentheses indicate number of locations.

germination, better initial plant establishment, and higher final yield than using unshelled nuts. A spacing of 60-80 cm between rows and 10 cm between plants was found to give fairly good pod yields.

Studies on irrigation and other cultural practices at Gode and Melkawerer revealed that a good yield response was obtained with 12.5 cm water applied at intervals of 2 or 3 weeks. Supplying the crop with water at peak flowering and pod development (60-80 days after planting) has shown yield increments.

Several trials were conducted on both heavy and light soils of Melkawerer to determine the fertilizer requirement for high yield. No significant yield responses to NPK were observed, either in combination or independently.

Pathology. As a result of the yearly disease survey, 10 groundnut diseases have been identified. *Cercospora* leaf spot, rust, and storage diseases are the major ones. *Cercospora* leaf spot was severe at Didessa and caused an average yield loss of 65%. The disease is also observed in the eastern and northwestern parts of the country. No variety is observed to be immune to the disease, but chemicals such as benomyl (Benlate®), copper oxychloride (Cupravit®), and Bordeaux mixture can control it.

Groundnut rust was found prevalent at Arba Minch and Bisidimo, while it was slight at Melkawerer. Variety screening against rust did not show any variety to be immune, though Chalimbana, PI 250680, 298115, 315608, NC-2, and NC-4 showed good resistance. Storage diseases, which reduce the germination capacity of the crop, can be avoided by treating the seeds with thiram and mercury compounds.

Insects. Eight insect pests are known to attack the crop in Ethiopia. Of these, termites and *Spodoptera* spp have a relatively high damage potential in most groundnut-growing areas.

Weeds. Herbicide studies in groundnut revealed that terbutryne, trifluralin, nitralin, and vernolate gave fairly good control over grasses. The herbicides alachlor, vernolate, and nitralin were found effective in controlling most weed species in groundnut, without adversely affecting the crop. Hand weeding is found effective, but it is expensive and minimizes economic returns.

Socioeconomics. Cost-of-production trials conducted for 5 years at Melkawerer showed that costs were uniformly high. Over 3 of those years, a net profit of Birr 220 t^{-1} was achieved, while the other 2 years showed a loss of 200 Birr t^{-1}(1 US $ = 2.1 Birr). Weeding and harvesting were found the most expensive operations, accounting for half the total production cost. The mechanization of these and other costly operations could raise the net profit.

Pigeonpea

Production Areas and Productivity

Pigeonpea is not a popular crop with the farming community of Ethiopia; it is a very minor pulse crop, with limited production in southern parts of Ethiopia. It is also grown as a backyard crop in warmer areas. No productivity estimates are available.

Production Practices

In warmer areas of the country, tall pigeonpeas are mainly grown to serve as a canopy and provide shade for animals during the hot period. The leaves are used as livestock feed and the dry stem as fuelwood. Pigeonpeas are also planted to protect soils from water erosion and as windbreaks in some state farms.

Major Uses

Pigeonpea dry seeds are used in many forms by the farmers. These include roasted flour for *wat,* a strong spiced sauce used in many parts of the country with *injera* (thin pancake-like bread). The seeds are also boiled and eaten as grains or together with soups.

Production Constraints

Major production constraints are as follows: lack of high-yielding varieties suited to existing farming systems; lack of information on agronomic practices for better yields; insect pest problems, especially the pod borers; and shortage of seeds of better-yielding varieties.

Research Efforts

Very little research has gone into improvement of this crop, mainly due to shortage of trained manpower. Some adaptation trials were carried out during 1973-1977, in cooperation with ICRISAT and IITA (International Institute of Tropical Agriculture). Of the six locations where the trials were conducted, better mean grain yields were obtained from Bele (2110 kg ha^{-1} over 5 years) and Bako (3300 kg ha^{-1} over 2 years), where soil moisture was not limiting during crop growth and development. Mean grain yields were low at Humera (200 kg ha^{-1}, one year) and Kobo (1320 kg ha^{-1} over 2 years) because of dry weather and insect problems, especially the pod borer. The maximum mean grain yield of 2000 kg ha^{-1} was obtained by varieties CME (6 locations) and 68/183 (3 locations), closely followed by 68/197 (1990 kg ha^{-1}, 4 locations). Research activities on pigeonpea were terminated at the end of 1977 due to lack of resources and trained manpower.

Chickpea

Production Areas and Productivity

Chickpea in Ethiopia is cultivated to a large extent at altitudes of 1400-2300 m, where the annual rainfall ranges from 700-2000 mm, mainly on Vertisols with pH 6.4-7.9. Ethiopia has more than one-third of the total chickpea area in Africa, and about half of the total chickpea production. The area, yield, and production of chickpeas over the past 24 years is shown in Table 2. Total chickpea production increased in the two 5-year periods following 1961-64, reaching a peak during 1970-74, but fell sharply thereafter. Decrease in area chiefly accounts for this, as productivity increases achieved in the earlier decade have remained nearly stable in recent years.

Among the highland pulse crops, chickpeas used to rank first in both production and hectarage up to 1970-74, but faba bean took first place thereafter. This downward trend in chickpea production should not be overlooked. The reduction in area under this crop for the last decade is a cause for concern. More land is being cropped under tef, wheat, or pulse crops other than chickpea, because of their high local prices and the high yield potentials possible with modern production practices and improved varieties. If this decline in chickpea production is to be arrested, ways must be found to make it more competitive with the cereals through increased productivity and better prices.

Table 2. Estimates on average area, yield, and production of chickpea in Ethiopia, 1961-64 to 1980-84.

	5-year average				
Chickpea	1961-64	1965-69	1970-74	1975-79	1980-84
Area ('000 ha)	271 (41)[1]	285 (39)	276 (37)	168 (26)	149 (22)
Yield (kg ha^{-1})	600	620	730	660	710
Production ('000 t)	164(35)	178 (34)	201 (37)	111(18)	105(15)

1. Figures in parentheses represent percentage of total estimates for four important leguminous crops, chickpea, faba bean, fieldpea, and lentil.

Source: Statistical Abstracts (1964-1984), Planning and Programming Department, Ministry of Agriculture, Addis Ababa, Ethiopia.

Production Practices

In Ethiopia, chickpea is grown on small farms and, even there, receives little attention. It is grown under rainfed conditions after the main rainy season (Sep-Oct). Tillage operations are minimal, depending upon weed conditions, and oxen-drawn local implements are used. Fertilizer is rarely applied. At harvest, normally around January-February, plants are pulled out by hand and then stacked and dried before being walked on by oxen for separating seeds. In some regions, chickpea is grown in rotation after tef, wheat, or barley. The crop is generally grown in monoculture, although admixtures with safflower, sorghum, maize, and niger seed can also be found across regions. Often, chickpea is found in heterogenous populations, with farmers ignoring selected types even where they know which types are better.

Major Uses

Chickpea is consumed in various ways and plays a big role in subsistence farms, where it forms a part of the daily diet with cereals and other pulses. It is especially important during the fasting period when no animal product may be used. Seeds are eaten raw, or boiled as a vegetable, or cooked and roasted with or without oil. Chickpea flour is used in soups eaten with meat or bread, as also in flour mixes to make *injera.* Green seeds are also eaten, while dry stems and seed hull are used as animal feed. Sometimes the dry straw is used as fuelwood.

Production Constraints

The major constraints in chickpea production are: the low-yield potential of existing landraces and nonavailability of high-yielding cultivars to farmers; susceptibility to an array of diseases, such as root-rots/wilt, *(Fusarium* spp, *Sclerotium* sp, *Macrophomina* sp), ascochyta blight *(Ascochyta rabiei),* and chickpea stunt (bean leaf roll virus); susceptibility to insect pests, such as the pod borer *(Heliothis armigera),* cutworm *(Agrotis* spp), and bruchids *(Callosobruchus* spp) and other storage pests; growing the crop in marginal lands with poor management practices; lack of yield stability; and poor response of varieties to management inputs, such as fertilizers.

Research Efforts

Since Ethiopia is considered as a secondary center of diversity for chickpea, there is a huge reservoir of variability in the populations. The Debre Zeit Experiment Station (DZES) of the Alemaya University of Agriculture (AUA) has assumed research leadership in the improvement and production of chickpeas. It is located at 8°50' N and 38°58' E in the central region, where genetic variability for this crop is maximum. There are also three substations located in different agroecological zones.

Research on several pulse crops (chickpea, faba bean, lentil, fieldpea, soybean, haricot bean, and grasspea) was initially handled by expatriate staff. As a dilution of resources and efforts was noted, a decision was made to concentrate only on chickpea and lentil. Accordingly a coordinated national research program was started in 1972. The projects include research on breeding, agronomy, pathology, and entomology. These research activities are well documented in the station Annual Reports and only a brief account is given here.

Germplasm. During the early 1970s, collection and evaluation of indigenous genetic material were initiated on a limited scale. Beginning in 1978, systematic collections have been made by the Plant Genetic Resources Centre/ Ethiopia. This has been done partly in collaboration with ICRISAT and DZES. So far, a total of 728 crop samples have been collected from different Administrative Regions, the highest being from Shoa (203), followed by Gondar (110) and Gojam (106). But this represents only a small fraction of the available genetic variability.

Selection. The bulk of chickpea production comes from local, unselected sources. Productivity is low (730 kg ha^{-1}). With a view to identify new high-yielding varieties of chickpea, varietal investigation has been attempted with available resources. Based on efforts during 1972-1978, some outstanding varieties were identified for their high yield potential. During 1979-1981, the national yield trials were discontinued because of ascochyta blight disease. But research resumed in 1982 at three locations, under the close supervision of a pathologist, following the decision passed in the National Crop Improvement Conference. Introduced materials supplied by ICRISAT and ICARDA in the form of nurseries, cooperative yield trials, and populations in different generations have also been grown for testing and selection under our conditions. Some promising cultivars have been found and, among them, 850-3/27 x F 378 and JG 62 x Radhey have been accepted by the National Variety Release Committee for initial release. Yields of superior varieties identified in the national yield trials are presented in Table 3.

Table 3. Mean yield of promising chickpea varieties identified in Ethiopian national yield trials, 1980-1985.

	Seed yield (kg ha^{-1})	
Variety	Range (1980-1985)	Mean
JG 62 x Radhey[1]	1470-3060	2100
NEC-756	1710-3300	2090
NEC-979	1490-3280	2080
Annigeri	1540-2500	1910
850-3/27 x F 378[1]	1020-2690	1980
H-54-10 (Local)	1220-2770	1860

1. Variety now released.

Hybridization. The crossing program in chickpea has attempted a number of crosses to combine root-rot and wilt resistance with desirable seed color (light, rather than dark). But little or no success has been achieved, perhaps because of lack of trained manpower. Similar work was initiated in 1982/83 with wilt-resistant lines obtained from ICRISAT, and several crosses were made to transfer resistant genes to the local high-yielding cultivars. Success has been limited with only a few seeds obtained; the materials are now in F_5 stage.

Plant pathology. Of the various diseases of chickpea, wilt *(Fusarium oxysporum* f.sp. *ciceri),* root rot *(Rhizoctonia solani),* dry root rot *(Rhizoctonia bataticola),* and collar rot *(Sclerotium rolfsii)* are the most common, inflicting yield losses up to 50-80% in farmers' fields. Research became operative in 1977. A sick plot was developed, and 537 lines obtained from the local germplasm collection and from ICRISAT were screened for 3 years (1977, 1978, and 1979). Among the lines tested, 850-3/27 x 378, H-208 x Pant 110, P-324, NEC-756, Annigeri, P-1267, G-130, H-355, G-124, P-1270, JG 62 x Radhey, and NEC-123 have been found promising. A study of 1700 surface-sterilized seeds of chickpea revealed the presence of several fungi and a bacterium. Considering the seriousness of ascochyta blight, lines were obtained from ICRISAT and tested for 2 years at Arssi-Negele, 230 km south of Addis Ababa, and some lines were found promising. They are: NEC-1583, NEC-979, C-235, G-543, and GG-588.

These activities were discontinued after 1980/81, chiefly because trained personnel were not available and much headway could not be made. In 1985/86, however, the DZES has provided an impetus to renew collaboration with ICARDA and ICRISAT.

Entomology. Entomological studies have been centered on the major chickpea pests and methods of control. The pod borer *(Heliothis armigera)* is the number one pest, followed by bruchids (probably *Callosobruchus* spp) and cutworm *(Agrotis* spp). Much of the research has been on the pod borer, but inferences are difficult because the research was discontinuous. However, there are indications that the closer the spacing between plants, the higher is the percent pod damage with early-planted chickpeas; kabuli chickpeas have been found less tolerant than desis to the pod borer.

Agronomy. Though some work had been done at Kulumsa, Mekele, and Debre Zeit stations on a moderate scale, the information generated has not adequately found its way into published scientific literature but just remained in the station Annual Reports. After DZES became the coordinating center, efforts have been made to identify the problems of production at Debre Zeit, Akaki, Chefe, and Ejere stations. Different agronomic aspects of the crop have been investigated to develop a package of production practices. But the whole range of agroclimatic zones in which this crop is grown is yet to be covered, and appropriate recommendations for many zones are still lacking. Findings to date are as follows:

1. Sowing early, during last week of August or first week of September, increased chickpea yields 25-50%.
2. Seed rate trials showed no or minimal yield differences. Seeding rates high enough to ensure a good plant stand are found useful, even when confronted with an adverse environment or poor seedling growth. Seeding rates of 65-80 kg ha^{-1} have been recommended, depending on seed size.

Extension

The existing control of extension by the Ministry of Agriculture has posed some difficulty in transfer of technology. Realizing the problem, the station created its own extension wing to disseminate information through demonstrations and field days. But as our extension capabilities are limited, we are limiting our efforts to a few production areas.

Grain Legume Production in Kenya

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Introduction

Grain legume production in Kenya is characterized by a high degree of diversity, as indicated by the number of crops and their distribution into varied agroecological zones. Bean *(Phaseolus vulgaris)*, pigeonpea *(Cajanus cajan)*, cowpea (*Vigna unguiculata)*, green gram (*Vigna radiata)* and groundnut *(Arachis hypogaea)* are the major ones. In addition, other grain legumes such as garden pea *(Pisum sativum)*, hyacinth bean *(Dolichos lablab)*, chickpea *(Cicer arietinum)*, bambara nuts (*Voandzeiasubterranea)*, and soybean *(Glycine max)* are grown on a small scale in some areas.

The grain legumes are grown in a wide range of soil types and in mixtures, or intercropped with maize, sorghum, millets, or among themselves. Eastern Kenya, which is largely semi-arid and arid, contributes over 50% of the total area under various grain legumes, with the relatively drought-tolerant cowpea, pigeonpea, green gram, and hyacinth bean dominating. This report is limited to information on the three legumes included in ICRISAT's mandate: pigeonpea, groundnut, and chickpea.

Agroclimatic Environments

Kenya is divided into six main agroecological zones, defined on the basis of temperatures and rainfall characteristics (Table 1). The zones are further classified into lowlands (0-900 m), medium altitude areas (900-1850 m), and highlands (above 1850 m).

Large variations exist in the soil types commonly found in Kenya. In the arid and semi-arid zones of Eastern and North Eastern Provinces, the shallow reddish-brown sandy clays of the undulating uplands are common. Volcanic soils are found mainly in the highlands. Because of climate, topography, and soil types, only 30% of the total area in Kenya is suitable for agriculture. Areas that can be utilized for future expansion of the drought-tolerant grain legumes would fall mainly under zones IV-VI, as described in Table 1. These include the Eastern, Rift Valley, and Coast Provinces.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1987. Research on grain legumes in eastern and central Africa. Summary proceedings of the Consultative Group Meeting for Eastern and Central African Regional Research on Grain Legumes (Groundnut, Chickpea, and Pigeonpea), 8-10 December 1986, International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia. Patancheru, A.P. 502 324, India: ICRISAT.

Table 1. Classification of agroclimatic zones in Kenya, based on rainfall, temperature, and altitude.

Zone	Classification	Average annual rainfall (mm)	Mean annual temperature (°C)	Altitude (m)
I	Humid	1100-2700	10-16	2450-3050
II	Subhumid	1000-1600	12-18	1850-2450
III	Semi-humid	800-1400	16-18	1850-2150
IV	Semi-humid to semi-arid	600-1100	16-20	1500-2150
V	Semi-arid	450-900	20-24	900-1500
VI	Arid	300-550	24-30	0-900

Source: Braun et al., Republic of Kenya, Ministry of Agriculture, Kenya Soil Survey, Nairobi, Kenya.

Pigeonpea

The production of pigeonpea is mainly concentrated in the semi-arid and arid areas. The area under cultivation has not been accurately recorded, and estimates vary up to 164 000 ha (Kenya Ministry of Agriculture 1981), making Kenya the world's second largest pigeonpea producer, exceeded only by India. Yield levels in the farmers' fields are usually low (300-500 kg ha^{-1}). The Eastern Province is by far the largest producer of pigeonpea, followed by the Central and Coast Provinces. Production is mainly concentrated in Machakos, Kitui, Embu, and Meru districts.

Production Practices

Tall, late-maturing local cultivars of pigeonpea are grown in mixtures or intercropped with maize, sorghum, millets, and short-duration grain legumes such as cowpea, green gram, hyacinth bean, and common bean. The crop is also grown as a hedge or windbreak on small farm holdings. Very few farmers plant pigeonpea as a monocrop, and these are mainly commercial farmers who export green pods. No fertilizer or pesticide is applied due to lack of water and the high costs of these inputs. Pigeonpea is planted during October-November (short rains) and is ready for harvesting by July-September, two months after the long rains. Two harvests of short-duration crops are taken within the one crop of late-maturing pigeonpeas. Ratooning is a common practice. Land is prepared mainly by oxen plow and tractors, while weeding, harvesting, and threshing are done by hand.

Processing and Utilization

Pigeonpea is consumed both as green pods and as dry grain. Shelled green and dried peas are commonly boiled in combination with maize grains, or mashed with Irish potatoes and green vegetables. In the coastal areas, grains cooked with coconut flesh form a popular breakfast dish. *Dhal* (split grain) is common only with the Indian community in the country. Grain size, color, and cooking time are crucial when pigeonpea is boiled with maize, unlike the *dhal where* the testa is removed. Pigeonpea has a potential as livestock feed in the dry areas. No factory exists that can process pigeonpeas for export or urban markets. For export markets, green, nearly mature, clean pods are harvested and packed into small cartons.

Production Constraints

Pigeonpea is generally grown on marginal soils in areas with limited, unreliable, and poorly distributed rainfall. The traditional, late-maturing types are exposed to dry periods at the end of each rainy season, and their maximum yield potential may not be realized due to poor soil fertility and lack of moisture. Suitable cultivars that can utilize the limited moisture are lacking.

Insect pests are major yield reducers in farmers' fields. Among the pests, pod sucking bug, pod borer, and pod fly cause tremendous yield losses in the field. Thrips and aphids can also cause serious damage, depending on the season. Bruchids are a major storage pest of pigeonpea grains. Wilt caused by *Fusarium udum* is the principal disease of pigeonpea in Kenya. Leaf spots are also common, but of less economic importance. Lack of high quality seeds for planting in most cases reduces the area planted. Farmers often do not have seeds for planting. They keep their own seeds, which are usually damaged by bruchids, resulting in poor germination and establishment.

Pigeonpea is planted in mixtures with many crops and is widely spaced, resulting in low population density. The plant population in the farmers' fields is usually less than 10 000 plants ha^{-1}. Weeding is a problem in the first 40 days when demand for hand labor is high.

Research Achievements

Research on pigeonpeas started at the University of Nairobi in 1976, helped by IDRC funds. Realizing the importance of the crop in dryland areas, the Government gave the National Dryland Farming Research Station (NDFRS, Katumani) a national mandate to improve the crop. Pigeonpea improvement work started at Katumani in 1979, with the objectives of developing high-yielding, drought-tolerant, early, medium, and late-maturing cultivars with resistance to local diseases and insect pests. Wide adaptability and superior quality were also to be researched.

The University of Nairobi developed and released NPP 670, an early-maturing line taking $5\frac{1}{2}$ months in the field. At Katumani, lines in three maturity groups (early, < 150 days; medium, 150-180 days; late, > 180 days) have been developed, and they are in prerelease testing. Lines 60/8, 50/3, and II RA in the early group have performed quite well and can give over 3 t ha^{-1} of dried grain with ratooning. In the medium group, 576/6, 777, and 81/3/3 are superior to the local cultivars, while E9/6, 788, and E31/4 are late types which give good grain and fodder yields. Sources of resistance to the pod sucking bug have been identified in local selections 423/85 and 423/20; however, these lines are not yet stabilized. A line, 657/1, was found less attacked by both wilt and insect pests. Two lines, 81/3/3 and 657/1, are sources of wilt resistance.

Groundnut

Annual groundnut area has ranged from 26 000 ha to 9000 ha over 1977-84, with a declining trend. The average yield is 800 kg ha^{-1}. Nyanza and Western Kenya are the major growing areas. A significant area is also planted along the coastal strip.

Production Practices

The majority of the area under groundnut is intercropped with maize. The crop is planted during the long rains (March-April) and matures in August-September. Only one crop is grown in a year, and it is rainfed, with no irrigation. Fertilizer, rhizobial inoculation, and pesticides are not generally applied to the crop. It may, however, benefit from the fertilizer that is applied to the maize crop. Land is prepared by either hand or oxen-drawn implements. During weeding, soil is heaped around the plant to help pegging. Harvesting and threshing are done manually.

Processing and Utilization

Harvesting and threshing are done by hand in the field. The seeds are then taken to oil-processing factories, where cooking fat is obtained. The byproducts are made into a groundnut cake, which is used as animal feed. The seeds are also roasted and utilized as a snack, or pounded to form an oily paste, used in vegetable and other preparations.

Constraints to Production

The main constraint is lack of good quality seeds for planting. This sometimes reduces the area under the crop considerably. Groundnut rosette and leaf spot are the major diseases, while leaf miner, jassids, leaf hoppers, and thrips are the major insect pests. Practices demanding high labor, such as harvesting and threshing, accompanied by low and fluctuating market prices, also affect production.

Research Achievements

Little effort has been directed toward the improvement of groundnut in Kenya, despite its importance. Presently, there are two agronomists conducting agronomic trials at the Western Agricultural Research Station, Kakamega, and the Kisii Research Station in South Nyanza. The varieties used in these trials are Homabay, Valencia, Makulu Red, Mani Pintar, Serere 116, Texas peanut, Bukere, and Altika. Priority in groundnut improvement should be on high-yielding, early-maturing cultivars for semi-arid and arid areas; high-yielding varieties for medium-to-high potential areas; disease and insect pest resistant varieties; and finally, agronomic packages to go with the newly developed cultivars.

Chickpea

Chickpea production remains relatively low in Kenya, compared to other grain legumes, but the demand is steadily increasing. Although chickpea in Kenya does not appear in published FAO production estimates, the country appears to have a much greater area of the crop than previously suspected. It is mainly grown in eastern Kenya, on the deep Vertisols commonly found in Machakos and Embu districts. The area and production levels for the crop have not been estimated.

Production Practices

Chickpea is planted on black cotton soils, nearing the end of both short rains and long rains to utilize the residual soil moisture. Farmers plant mainly a chickpea/maize intercrop in the ratio 5:1. The crop thrives rainfed, without supplementary irrigation, fertilizer, or rhizobial inoculation. It is protected against insect pests through pesticides. Weeding, harvesting, and threshing are not mechanized.

Processing and Utilization

Chickpea is grown as a cash crop and is sold to the Indian community living in urban centers. It is commonly used in the form of *dhal* and eaten with cereals.

Production Constraints

Fusarium wilt and dry root rot are the major diseases of chickpea, while the pod borer is the major insect pest. Lack of improved cultivars and certified seeds for planting may substantially reduce the area under the crop.

Research Achievements

Research at Katumani has identified an ICRISAT line, ICCL 83110, as high yielding and less affected by wilt disease and pests. Seed of this line is presently being multiplied for prerelease testing.

Kenya's Agricultural Infrastructure

Extension

Kenya's Agricultural Extension Services are organized through the Director of Agriculture down to the Provincial Director of Agriculture, District Agricultural Officer, and to the frontline extension staff and farmers. The T and V (training and visit) system of extension has been recently introduced. In this system, subject-matter specialists (SMS's) have been appointed at Provincial and District levels. Workshops are held monthly in each district, where SMS's, Divisional Extension Officers, and Research Officers discuss the technological messages to be passed on to the farmers.

The impact points of a new technology are identified, and then frontline extension officers pass it to farmers by demonstrations. The farms of agreed "contact farmers" are used for teaching. Through this system, extension staff is encouraged to promote production.

Research

Kenya's agricultural research is organized under the Directorate of Agricultural Research, with national and regional research in various agroecological zones for different crops. NDFRS (Katumani) has the national mandate for the development of grain legumes (cowpea, pigeonpea, mungbean, chickpea, and hyacinth bean) for the semi-arid and arid areas of the country. The improvement of phaseolus beans is being done at the National Horticultural Research Station, based at Thika. The development of oil crops, which include groundnuts, is supposed to be at the National Plant Breeding Research Station (NPBRS), Njoro. However, the improvement of groundnuts at NPBRS, Njoro, has not gone beyond acquisition of germplasm. Some agronomical work on groundnuts has been going on at Western Agricultural Research Station and Kisii Research Station, which are regional centers.

Training

Lack of properly trained staff has tremendously retarded the improvement and production of grain legumes in Kenya. Little research attention was directed in the past toward the improvement of grain legumes, despite their importance. At NDFRS, Katumani, there are four breeders, two for pigeonpea and cowpea, and two handling mungbean, hyacinth bean, phaseolus bean, chickpea, and soybean. The four breeders have master's degrees.

There is need for further training for grain legume researchers and short-term training for their technical assistants.

Collaborative Work

Support is needed from ICR1SAT or other donor agencies for

1. grain legume germplasm collection and evaluation;
2. an intensive survey of factors limiting grain legume production (insect pests and diseases);
3. the exchange of scientists and visits by subject-matter specialists;
4. guidance in the development of research programs; and
5. funds for equipment, training, and research staff.

Future of Grain Legumes

Grain legumes are a valuable source of protein and they help balance the diet for the majority of people living in Kenya. A vast scope exists to improve productivity. Thus, the first step will be to develop high-yielding varieties and good crop husbandry methods, including pest control.

With widely adapted varieties, availability of high quality seeds, and good market prices, the area under grain legumes can be greatly expanded. Because of their short duration, the grain legumes fit well into a number of cropping systems common in the semi-arid and arid areas of the country, characterized by a bimodal rainfall pattern. There is room for expansion of grain legumes in these areas, without affecting the other crops that farmers are used to growing. Grain legumes can also be grown as catch crops, preceding or following the main crops such as wheat or rice.

Grain Legume Production in Rwanda[1]

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Of the four major grain legume crops in Rwanda, beans are of the greatest importance, followed by peas, groundnut, and soybean. Cowpea, chickpea, and pigeonpea are well adapted to the semi-arid region of eastern Rwanda, but are of only minor importance. Of the three ICRISAT mandate legumes, groundnut is of most interest to Rwanda, while chickpea and pigeonpea are currently only of potential importance. The Grain Legumes Program of ISAR (Institut des Sciences Agronomiques du Rwanda) carries out research on groundnut.

Groundnut

Groundnuts are used almost exclusively for human consumption and are highly regarded. However, production has remained constant at a relatively low level for several years. Groundnuts are grown in the regions of Imbo, Impara, on the shores of Lake Kivu in the west, and in the Mayaga, Bugesera, Eastern Plateau, and Eastern Savanna region in the east. The crop is grown mainly in the 800-1800 m altitude. In 1985 some 17 000 t of dried pods were produced from 18 000 ha, giving an average yield of 944 kg ha^{-1}. While this yield is below the world average, it is greater than the average for Africa of 757 kg ha^{-1}. But yields of over 2000 kg ha^{-1} have been recorded on research stations, and the potential obviously exists to increase groundnut production substantially without increasing the area cropped.

Constraints on groundnut production include low soil fertility, diseases, and the high labor demand. Potential expansion is limited by difficulty in maintaining seed viability during storage from one season to the next, and by low multiplication rates. Also, farmers tend to underestimate their sowing needs and fail to retain sufficient seed.

Groundnut research has concentrated on introduction and selection of exotic germplasm and on agronomic practices. Multilocational trials in recent years have shown several introduced varieties, notably HNG 18, HNG 17, and HAD 30, to

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1. While the original presentation contained information on several grain legumes of interest to Rwanda, this summary extracts portions relating only to groundnut, chickpea, and pigeonpea, in view of the focus of this meeting.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1987. Research on grain legumes in eastern and central Africa. Summary proceedings of the Consultative Group Meeting for Eastern and Central African Regional Research on Grain Legumes (Groundnut, Chickpea, and Pigeonpea), 8-10 December 1986, International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia. Patancheru, A.P. 502 324, India: ICRISAT.

significantly outyield the national check cultivar, Fatui. Yields of over 2000 kg ha^{-1} of dried pods have been regularly achieved in Rubona. In agronomic research, optimum sowing dates, plant spacing, and levels of organic and inorganic fertilizers have been established. A spacing at 20 cm x 10 cm has proved effective in giving high populations with good ground cover, besides reducing groundnut rosette disease severity. While there has been good response to fertilizers, no significant increase in yield has been obtained from *Rhizobium* inoculation.

Various foliar fungal diseases occur and may be severe, but application of fungicides has not shown significant increase in pod yields.

Chickpea

Chickpeas were introduced to Rwanda in 1968, and by 1985 some 100 genotypes had been collected and tested in Karama. Seed yields obtained during 1972-1974 ranged from 466 to 1925 kg ha^{-1}. Chickpeas are considered suitable for the semi-arid conditions of eastern Rwanda.

Pigeonpea

At present pigeonpeas are grown only occasionally as a garden crop. They may also have potential in eastern Rwanda. Six genotypes are being maintained in the ISAR collection.

Chickpea and Pigeonpea Production in Sudan

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Introduction

Sudan is the largest country in Africa, with an area of 2.5 million km^2 and a population of 22 million. It lies between 3° 53' and 21° 55' N, and 21° 54' and 38° 30' E. Most of the country is a vast plateau, crossed and watered by the Nile and its tributaries.

Sudan's national economy is predominantly dependent on agricultural commodities; they contribute over 35% of the country's Gross Domestic Product and 95% of the foreign currency earning. About 80% of the population is involved in agriculture or related activities. The total arable land in the Sudan is 84 million ha, of which only 6.7 million ha are under field and horticultural crops. The most important crops grown in the country are cotton, sorghum, millet, wheat, groundnut, sesame, sugarcane, gum arabic, leguminous food crops, and a wide range of horticultural crops.

This paper deals with aspects of production of chickpea and pigeonpea in Sudan. As chickpea is among the more important leguminous food crops grown in Sudan, its current status of production will be discussed first, while the situation of pigeonpea will be presented later.

Soils, Climate, and Agroecological Classification

The soils of Sudan are broadly classified into: (1) sandy soils (in the north); (2) heavy clay soils (in central parts); and (3) lateritic soils (in the south).

Chickpea is generally grown on the banks of the Nile and in island soils after the floods recede. The soils of these areas are called 'Gezira' or 'Gureir' soils, and they contain high amounts of silt with fairly recent deposition. These soils are permeable and very fertile, and the crop is grown without resort to irrigation. The crop is also grown in basins and depression soils, which lie further from the Nile. These are old river soils, called 'Karu' soils; they are heavier and crack deeply when they get dry. Chickpea is also grown in sandy loam soils in the Rubatab area.

Sudan is characterized by a wide range of climatic conditions. The rainfall varies from nil in the north to 1524 mm in the south. These extremes of climate produce deserts in the north and rain forest areas in the south. Temperatures are generally high,

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ranging from around 38°C during the summer to 16°C in the north and 27°C in the south during winter. Sudan is broadly divided into three agroecological zones, as described below.

Northern zone. It is mainly a desert and semidesert zone; rainfall varies from nil in the north to 254 mm in areas near Khartoum. Crops are grown under irrigation from the Nile on areas close to the river.

Central zone. It occupies nearly half the area of the country, with a rainfall of 254-800 mm, and includes the most important agricultural zone in the country, where cotton, sorghum, wheat, groundnut, and sesame are grown.

Southern zone. This zone occupies one-sixth of the country, and the rainfall varies between 800 mm and 1524 mm. The main crops grown here are equatorial crops, including tea and coffee.

Chickpea

Area, Production, and Yield

Chickpea is traditionally grown in the northern region of Sudan, where about 98% of the most important leguminous food crops are produced. These include, besides chickpea, faba beans, haricot beans, lentils, peas, and lupins.

Table 1 presents data on the cultivated area, production, and yield of chickpea for 1980-86. Chickpea ranks third in area after faba beans and haricot beans. The area annually planted with chickpea is affected by the height and extent of the Nile floods and the prices prevailing in the preceding season.

Table 1. Chickpea production in Sudan, 1980-86 (Economic Planning Department, Regional Ministry of Agriculture, Northern Region).

Season	Area (ha)	Production (t)	Yield (kg ha^{-1})
1980/81	375	512	1364
1981/82	459	621	1353
1982/83	374	425	1136
1983/84	512	776	1516
1984/85	333	490	1472
1985/86	1072	1276	1190

Domestic Utilization, Overseas Trade, and Marketing

Chickpea (kabuli type) is consumed in many popular dishes, both as dry pods and as a green vegetable. After harvest of pods, the remains, such as dry stem, leaves, and pod walls, are fed to livestock.

To date, chickpea is expensive and beyond the reach of the poor. The price prevailing at Ed-Damer town, at the centre of the production area, in October 1986 was US $ 1 kg^{-1}. Still higher prices prevail in the capital city and in other consumption areas, owing to transport cost and middlemen.

At present, Sudan's chickpea production is consumed locally. The prospects of expansion are bright. The area under chickpea production may go up in the near future as new production schemes are implemented to expand chickpea to nontraditional areas, like the eastern region, and as demand increases. Besides this horizontal spread, vertical increase in chickpea production also could be achieved by quick transfer of improved technology and by providing the necessary inputs for production. Chickpea production could potentially play a prominent role in the national economy, as surplus production can be exported and valuable foreign exchange earned.

Production Practices

Chickpea is grown as a pure stand, mainly in river basins, banks, and islands. It is usually sown in October/November, after the floods recede. Several methods of planting exist, including broadcast of seeds. Where the crop is grown under irrigation, the seedbed is plowed and levelled and the land is split into small plots to help control irrigation. Seed rates employed by farmers vary from 30-90 kg ha^{-1}. Some hand weeding may be required in irrigated crops; no weeding is usually needed where areas have previously been flooded. No fertilizer, pesticide, or rhizobia is usually applied. And chickpea is often grown on soils where cereals, particularly sorghum and wheat, were previously grown.

The chickpea crop normally matures in 4-5 months, except under warmer winters and high temperatures, where the crop matures in less than 4 months. The bulk of the crop is taken by lorries from the production areas to big markets at the capital city or other urban areas, where chickpea fetches better prices. Some farmers, however, store their produce until prices are rewarding.

Constraints to Production

Chickpea production is affected by several problems. Remarkable losses are observed from the wilt/root-rot disease complex and from stunt disease. Severe losses can also occur from damage of green pods by the pod borer, *Heliothis armigera,* and postharvest losses occur from infestation by *Bruchidius incarnatus* and *Trogoderma granarium.* Weeds, particularly *Cyperus rotundus, Cynodon dactylon,* and *Indigofera* spp, are also troublesome in certain areas.

Other factors that limit chickpea production are lack of machinery and adequate agricultural inputs: improved certified seeds, fertilizers, insecticides, and herbicides.

Research and Extension Infrastructure

Hudeiba Research Station is the main center for research in pulse crops. Improved techniques of crop production developed by research workers are conveyed to farmers through the Extension Service Department of the Regional Ministry of Agriculture, Northern Region.

Breeding. Research on chickpeas was initiated in 1967/68, with collection and evaluation of local germplasm. From 1972/73 onward, an intensive breeding program has been conducted in collaboration with international organizations, such as ICRISAT, the Arid Lands Agricultural Development Program of the Ford Foundation (ALAD, previously), and the International Center for Agricultural Research in the Dry Areas (ICARDA). Through this cooperation, valuable germplasm entries, segregating populations, and disease-screening nurseries were tested and yield trials conducted at Hudeiba Research Station. The main objectives of the breeding program are the selection of erect plants with white seeds, early maturation, high harvest index, tolerance or resistance to wilt, root-rot, or stunt virus disease, and tolerance to soil salinity.

Nineteen promising introductions have been evaluated for yield at two sites in the north, Hudeiba and Shendi. The mean grain yield at Shendi (2101 kg ha^{-1}) was more than three times that at Hudeiba (598 kg ha^{1}), attributable largely to difference in soil types. The range of yields at Shendi was 1374-2687 kg ha'^{1}, while at Hudeiba it was 302-843 kg ha^{-1}. When some of these promising varieties reach the release stage through the appropriate authority, they can have a profound impact on chickpea production in Sudan.

Agronomy. Intensive agronomic research has been conducted with the main objective of identifying management practices that maximize chickpea yields. Sowing date trials have shown that the optimum date lies between end of October and end of November, with marked yield reductions from earlier or later sowings. Seed rate increases also increased yields, with 59.5 kg ha^{-1} proving the optimum seed rate. Neither ridge direction nor plant orientation was found to affect seed yield.

Chickpea has been found very responsive to applied nitrogen. At Hudeiba, where nitrogen status of the soil was low, a 90% increase in seed yield was obtained with 43 kg ha^{-1} of applied N; with 86 kg ha^{-1} the increase was 170%. Inoculation with a *Rhizobium* strain, IC-53, gave responses similar to those from 86 kg ha^{1} applied N. While no response was obtained from applied K, marked yield responses were gained from applying 30 and 60 kg ha^{-1} of P_20_5.

In an irrigation trial over 3 years, using a factorial combination of three varieties and four frequencies of irrigation (7, 14, 21, and 28 days), highest seed yields were obtained at the 7-day frequency, with progressive reductions of 34% at 14 days, 60% at 21 days, and 72% at 28 days. The drier treatments had lower pod numbers $plant^{-1}$ and plant numbers m^{-2}.

Investigations have shown that losses in grain legumes are also caused by *Bruchidius incarnatus.* The most susceptible leguminous crops to this pest are, in order, undecorticated lentils, faba beans, chickpeas, peas, pigeonpeas, and cowpeas. The pest development was affected by temperatures, with oviposition lowest during the winter months (Nov-Feb). This means that pest control should start immediately after harvest and storage hygiene should be applicable to all legumes, since the infestation can spread from one legume to another.

Preliminary studies on chemical weed control are in progress, to test a number of herbicides for their selectivity to chickpeas and activity against prevailing weeds.

Pigeonpea Production in Sudan

Pigeonpea is also an important legume traditionally grown in Sudan. It is rarely seen as a pure stand, but grown extensively on field borders and as a windbreak on irrigated and flood lands. The crop is also grown in small quantities throughout areas receiving heavier rain. No statistical data are available on cropped area and total production, but it appears that production is sufficient to satisfy local demand.

The seeds of local pigeonpea cultivars are characterized by a wide range of colors, such as light brown, red, or white. The plant height ranges from 1.2 to 2.4 m, and the earliest pods take 5-6 months to mature. Successive hand picking of pods may continue for several weeks, and the seed yield ranges between 1200 and 2400 kg ha^{-1}. The ripe dry seeds of the crop are normally eaten as *balilah,* while the tender green parts of the crop are fed to animals. The hard, dried stalks are used as firewood.

The main constraints to pigeonpea expansion are: (1) hand picking of the small pods is a time-consuming and laborious operation; (2) the local varieties require a long growing season to mature; (3) a high proportion of the crop is too woody to be relished by animals; and (4) because of low demand, pigeonpea prices are low, compared to other food legumes.

Studies on crop improvement and some agronomic management of pigeonpea were undertaken at the Hudeiba Research Station during 1975-80. The main objectives of the program were to select high-yielding, adapted pigeonpea varieties, and to obtain information on maturity, plant type, and seed size and color. In this respect, 40 varieties received from ICRISAT were grouped by maturity period into early, medium, and late varieties and compared with the standard 'Baladi' variety for three seasons. Three ICRISAT varieties were found high yielding. Mean seed yields for three seasons were 2364 kg ha^{-1} for ICRISAT No. 7188 (early), 2887 kg ha^{-1} for ICRISAT No. 7118 (intermediate), and 3030 kg ha^{-1} for ICRISAT No. 7065 (late), compared to 1329 kg ha^{-1} recorded by 'Baladi'

The seed yield of pigeonpea was found markedly affected by sowing date. High seed yields were obtained from early-sown plants (15 Jun or 15 Jul), compared to late-sown plants (15 Aug). The low seed yields recorded from the late planting were caused by the short growing season affecting flowering and maturity. Increasing the plant density also had a marked effect on yields of pigeonpea; high seed yields were obtained from plants grown at 80 $\times$ 20 cm spacing, compared to plants grown at 80 $\times$ 40 cm or 80 $\times$ 80 cm spacing.

Preliminary studies indicated that applied N at 43 kg ha^{-1} resulted in a 35% increase in seed yield over untreated plants. There was no response to the application of P, either alone or in combination with N. Results of trials with water regimes were inconsistent, but they indicated that pigeonpea has some tolerance to drought.

The effects of frequency of vegetative cut on seed yield were also tested. Plants were either left uncut or cut once or twice to 30 cm above the soil surface at intervals of 80 days and then left to grow and give seeds. Vegetative cuts resulted in a remarkable reduction in seed yield and its components. The reduction in seed yield from cutting was attributable to removal of flower buds, inflorescences, and losses in plant stand.

Vegetative parts of the pigeonpea plant, when cut at a certain age before they become woody, are used as green fodder for animals in Sudan, especially goats. The effects of different combinations of cutting intervals (80, 95, and 110 days from sowing) and number of cuts (2, 3, and 4 per season) on the yield of fresh vegetative parts were investigated for two seasons. Green forage yields were significantly affected by the number of cuts, and the highest yield was recorded when four cuts were employed. Also, high forage yields were obtained at the cutting time of 95 and 110 days.

Training: Availability and Need

Training of scientists and their support staff (technicians) at the international centers for research on chickpea (ICARDA and ICRISAT) and pigeonpea (ICRISAT) could play an important role in strengthening national research. Participation in symposia and workshops on these crops is also beneficial for the scientists, as it gives them a chance to present their recent research findings to colleagues working in the same field of specialization.

Future Prospects

Production of both chickpea and pigeonpea could be improved in Sudan by sustained research effort, with support from ICRISAT and donor agencies. Efforts in chickpea will have to be geared toward selection of breeding lines with appropriate growth durations for seasonal variations and with resistances to known biotic and abiotic stresses. Improved management practices also need to be identified to effectively overcome production constraints. On-farm research is a priority need. Pigeonpea is at present a minor crop, but it can be expanded if its uses as fodder and for export are further explored.

At present, the International Development Research Centre (IDRC) provides funds to support research on chickpea and other leguminous crops. Contributions from other donors, and support from international organizations such as ICARDA and ICRISAT, especially in training, exchange of breeding materials, and providing minimum research facilities, will greatly help.

Groundnut Research and Production in Sudan

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Introduction

Sudan is one of the leading groundnut-producing countries, accounting for about 2.2% of the total world production in 1983, according to FAO estimates. Groundnut is an important source of foreign exchange. Groundnut exports constituted 18.6% of the total value of all exports in 1981, but the share declined sharply to only 1.7% in 1985. The decrease is mainly due to increased domestic oil consumption and reduction in area because of recent drought in western Sudan.

The area planted to groundnut varied from a high of 1.12 million ha in 1977/78 to a low of 0.4 million ha in 1985/86 (Table 1).

Table 1. Area, yield, and production of groundnuts in Sudan (1976/77-1985/86).

	Irrigated			Rainfed		
Season	Area ('000 ha)	Production ('000 t)	Yield (kg ha-')	Area ('000 ha)	Production ('000 t)	Yield (kg ha-')
1976/77	145	255	1756	644	483	750
1977/78	160	426	2663	958	601	628
1978/79	131	231	1756	846	567	669
1979/80	171	405	2363	816	447	547
1980/81	84	159	1901	810	548	676
1981/82	173	280	1620	812	441	543
1982/83	97	181	1873	685	311	452
1983/84	104	180	1735	666	233	350
1984/85	137	257	1875	601	129	214
1985/86	61	94	1532	338	180	533

Factors to which the variation in planted area is attributed are (a) availability of labor; (b) erratic price behavior; and (c) prevailing weather conditions.

1. The author could not attend the meeting, but sent his paper for distribution.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1987. Research on grain legumes in eastern and central Africa. Summary proceedings of the Consultative Group Meeting for Eastern and Central African Regional Research on Grain Legumes (Groundnut, Chickpea, and Pigeon-pea), 8-10 December 1986, International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia. Patancheru, A.P. 502 324, India: ICRISAT.

In 1982, groundnut occupied 13.5% of the total cropped area, compared to 42.5% for sorghum, 13% for millet, 12.6% for sesame, and 7% for cotton.

Groundnut is planted across the agricultural regions of Sudan. It is grown both under intensive, high-technology, irrigated agriculture and under traditional methods in rainfed areas. Looking at the regional breakup of groundnut area and production in the 1985/86 season, South Darfur with 48% area produced 39% of the total yield, North Kordofan with 14% area produced 9%, and Gezira and Managil with 11% area produced 28%. The three regions, together, thus account for 73% of groundnut area and 76% of production, with Gezira and Managil by far the most productive of the regions. Mean yields vary annually from 210-750 kg ha^{-1} in the rainfed sector, and from 1530-2660 kg ha^{-1} in the irrigated sector.

The Traditional, Rainfed Sector

In the traditional rainfed sector, groundnut competes vigorously with food crops, such as sorghum and millet, and other cash crops, such as sesame and gum arabic. From 66 to 83% of the groundnut area is in this sector.

The major soils in western Sudan are stabilized sand dunes, called 'Goz'. They are deep, even-textured, coarse to fine sands, and the mineral (particularly Ca and Mg) and organic-matter contents are extremely low.

Crop rotation is absent in most areas and shifting cultivation is practiced. The cropping pattern is generally 4 years in crops, followed by 5-10 years of *Acacia Senegal* fallow. In some areas, millet-groundnut rotation is dominant, but this is not adequate to prevent the buildup of pests, diseases, and weeds.

Rainfall is the most critical factor influencing groundnut production in western Sudan. The mean annual rainfall ranges between 225 mm and 400 mm in northeastern Sudan, and between 400 mm and 650 mm in the southwestern part. In the last decade, rainfall has declined both in quantity and in dependability of distribution. As a result, groundnut production and yield have declined (Table 1). The rainy season is short, 90-110 days, usually starting in July and ending in early October. Average daily maximum temperature during the growing season ranges from 33-38°C.

Groundnut cultivar Barberton (subsp *fastigiata* var *vulgaris)* is grown in western Sudan.

Intercropping is extensively practiced. Groundnut is sometimes intercropped with millets and watermelons. Low yields of groundnuts in western Sudan can be attributed to drought, declining soil fertility, unadapted cultivars, aflatoxin, unavailability of labor, and poor credit and marketing systems.

The Modern, Irrigated Sector

Groundnut is grown in the irrigated schemes of the central clay plain, which includes the Gezira and Managil, Rahad, New Haifa, and other small schemes.

The soils of the central clay plain are Vertisols, with high clay content (40-65%), high cation exchange capacity (pH values 7.2-9.6), and low organic-matter content.

The climate of the irrigated areas is semi-arid, with abundant sunshine and a solar radiation of 560 cal m^{-2} day^{-1}, and the rainy season is from May to October with the heaviest rainfall during July-August. The average rainfall varies from 160-470 mm.

Crop rotation is adopted in the irrigated sector. Four course rotation (cotton-wheat-groundnut/sorghum-fallow) is followed in Gezira and Managil, and two course rotation (cotton-groundnut/sorghum) in the Rahad scheme.

Late-maturing, alternately branching groundnut cultivars (subsp *hypogaea* var. *hypogaea)* are grown in the irrigated sector.

Research Achievements and Objectives

Past Research

Little research has been done in rainfed areas of western Sudan. One of the earliest attempts to select cultivars for western Sudan was conducted as part of a United Nations Special Fund Project in Kordofan. The results showed the superiority of Barberton, an early-maturing upright bunch cultivar. A newly introduced cultivar EM9, a line from Oklahoma given the local name Sodiri, also gave high yields and proved more drought tolerant than Barberton.

In the irrigated sector, agronomic research was directed towards basic aspects of groundnut production. The highest pod yield was obtained when the land was disc plowed to a depth of 20 cm, followed by harrowing or disc plowing at the same depth, followed by rotovation. Highest pod yield for semispreading cultivars was obtained from 60 cm between ridges, 15 cm between planting holes, and two seeds per hole.

It was found that MH383 outyielded other cultivars, and it exhibited drought tolerance. Weeds reduced pod yield of groundnuts by about 80%. The preemergence herbicides, oxadiazon (Ronstar®) at 1.07-1.43 kg a.i ha^{-1}, and benefin (Balan®) at 1.43 kg a.i. ha^{-1}, were found effective in controlling weeds. Groundnut in irrigated areas responded to nitrogen and phosphorus fertilization. It was observed that the addition of 40 kg N ha^{-1} increased pod yield of Barberton, a Spanish cultivar. Adding 120 kg N ha^{-1} resulted in improved growth parameters, indicating that not all nitrogen requirements were being met by nitrogen fixation. Total water requirement for groundnut in irrigated Gezira was found to be 486-597 mm. Plants in sparse population were more sensitive to water stress than plants in dense population.

Present Research Program

The primary objective of the present research program is to improve groundnut production in both the traditional rainfed sector and the irrigated sector.

The national groundnut breeding program is currently located at the Gezira Research Station at Wad Medani. It aims at the selection and development of new, improved groundnut cultivars for both the irrigated Vertisols of central Sudan and the sandy rainfed areas of western Sudan.

The following varietal attributes constitute the main objectives of the program: high pod yield; high shelling outturn; high oil content; earliness; drought tolerance; adaptation to Vertisols; resistance to seed infection by *Aspergillus flavus* and aflatoxin production; tolerance of common pests and diseases; and conformity to recognized market types.

Over 500 cultivars and germplasm lines were introduced since 1980, mainly from the United States and ICRISAT. New cultivars of the Virginia type for the irrigated Vertisols will be advanced for release next year.

Hybridization is viewed as a long-term reliable source of variability. Almost 200 crosses (including reciprocals) have been made since 1981. Some of the advanced breeding lines are now in different stages of on-station yield evaluation.

In 1982/83, with the establishment of El Obeid Research Station, a groundnut improvement program was initiated there with the following main objectives: introduction and selection of cultivars with improved yielding abilities; reducing causes of slow seed emergence to ensure good crop stand; development of improved agronomic practices; and improvement of harvesting methods.

Many experiments are carried out in the irrigated areas to find out the appropriate cultural practices and cultivars to suit the climate and soils of the central clay plains.

Crop sequence. The crop immediately preceding groundnut can affect yield and quality. In irrigated Gezira, the establishment of groundnut was best if it was preceded by safflower, wheat, or maize. Soil physical conditions and growth of groundnut were seriously affected when the previous crop was pigeonpea.

Nitrogen and phosphorus. There is an indication that groundnuts respond to application of N and P. In the Vertisols of the Gezira, phosphorus was fixed as calcium phosphate when it was put in contact with seeds.

Factors Affecting Groundnut Production

Many factors can affect the yield and production of groundnut in Sudan. The most important of them are as follows.

Moisture deficit. Moisture deficit decreases pod number, seed weight, and quality. Dry spells before harvest can increase invasion by *A. flavus* and, consequently, aflatoxin accumulation. In rainfed areas, particularly on sandy soils, groundnuts suffer from drought stress. In irrigated areas, groundnuts should receive 5 irrigations but problems of supply may reduce this to 2-3 irrigations.

Nutritional stress. Previous work showed the response of Spanish cultivars to nitrogen fertilization. Recent studies in irrigated areas indicate that Virginia cultivars respond to nitrogen and phosphorus application. Fertilization of nitrogen can be effectively and economically replaced by inoculation with efficient strains of *Rhizobium.* Inoculation trials using several *Rhizobium* strains and different genotypes are needed in both irrigated and rainfed areas.

Weed competition. Groundnut is very sensitive to weed competition. In irrigated areas, weeds are the predominant factor reducing yields. In rainfed areas of western Sudan, no weeding resulted in 75% decrease in yield. Hand weeding is time consuming and integrated weed control methods are needed.

Extension and marketing. Four requisites have been noted for increasing farm production: an improved farming system; adequate instruction of farmers; supply of inputs; and availability of markets.

Credit availability is a major constraint facing groundnut producers in both the rainfed and the irrigated sector. Pricing policies at present do not encourage farmers to produce more groundnut of a high quality. Although minimum guaranteed prices are announced in advance of the season, these prices are far below the prices offered in auction. Unless groundnuts are made profitable in the market, more productive procedures are not likely to be adopted.

Groundnut and Pigeonpea Production and Improvement in Uganda[1]

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Groundnut

Groundnut, *Arachis hypogaea,* is the second most widely grown grain legume in Uganda, the first being kidney beans, *Phaseolus vulgaris.* However, according to its value and varied uses, groundnut is considered the most important legume crop in the country. Groundnut is very well established in the country and it is highly acceptable for both cultivation and consumption by the Ugandan populace. The crop is thought to have been introduced into East Africa by Portuguese sailors in the 16th and 17th centuries. In Uganda, groundnut was probably introduced by traders and travelers, and the crop may well have been cultivated in the country for more than 200 years.

Production Methods and Uses

Records show that, as early as 1908, groundnut was a valuable item of export in Uganda. While a trend towards increased area, production, and yields lasted from then through 1971/72, thereafter both area under the crop and yields have declined year after year (Table 1). Political instability, beginning in 1971, may have adversely affected groundnut production.

Groundnut is mainly produced on the light, loose, and fertile sandy loams of eastern Uganda, but appreciable amounts are also produced on the clay loams of southern Uganda. The highest yield of about 5000 kg ha^{-1} has been obtained on the Vertisols (black cotton soils) of Namalu in South Karamoja district. In the tall grass ecological zone of southern Uganda, with a bimodal rainfall pattern, groundnuts are grown during both the first and second rainy seasons, but mainly during the first rainy season, whereas in the short grass ecological zone with monomodal rainfall, the crop is grown to coincide with the rainy season. Rainfall is more reliable and well distributed in the first rainy season (Mar-Jun) than in the second rainy season (Aug-Sep).

1. The section on groundnut in this paper was written by the first author, that on pigeonpea by the second. Mr. Nalyongo presented both parts at the meeting, as Mr. Emeetai-Areke could not be present.

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Table 1. Area and production of groundnuts in Uganda, 1971-1985.

Year	Area ('000 ha)	Production ('000 t)	Yield (kg ha-')
1971	291	251	860
1972	291	234	800
1973	222	212	950
1974	267	200	750
1975	243	194	800
1976	213	177	830
1977	234	193	820
1978	234	187	800
1979	122	80	660
1980	95	70	740
1981	110	80	730
1982	120	90	750
1983	124	99	800
1984	172	118	690
1985	160	107	670

Groundnut is usually grown in the 3rd year of the 3 x 3 year arable rotation (3 years of arable phase and 3 years of resting/pasture phase). More than 50 percent of the crop is intercropped with maize, cassava, or Bambara groundnuts. Since the crop is solely rainfed, it is sown early in the season immediately after the first heavy showers, so as to take advantage of available moisture during the whole season. Many farmers cannot afford to apply phosphate fertilizers and spray their crop. Groundnut is either broadcast or sown in rows. Weeding is usually done once, especially in the broadcast crop. Both bunch and spreading types of groundnuts are produced, with the bunch types now preferred because they are easier to cultivate and harvest, coupled with their inherent earliness.

The crop from the first rainy season is harvested during the July dry spell, and that from the second rainy season in the November and December dry season. Valencia and Spanish types are pulled out of the soil, but the spreading types are dug out using hand hoes. All farmers sun-dry the groundnut and when it is fully dry, store it in the shell in various types of granaries.

In the 1960s groundnut used to be processed for cooking oil and soapmaking, but with the advent of the 1970s the processing ground to a halt, as did groundnut export. Groundnut is mainly used as a condiment, in various soups and dishes. Groundnut butter prepared from the roasted and pounded kernels is very popular in Teso districts. The confectionary groundnuts, roasted and salted, are enjoyed throughout the country.

Production Constraints

The major and most devastating constraint in Uganda is the groundnut rosette virus disease, transmitted and spread by the aphid *Aphis craccivora.* This disease has significantly reduced yields in the main producing areas in eastern Uganda. Other biotic constraints include *Cercospora* leaf spots, bacterial wilt in the Buganda area, aphids, and thrips.

With the southern advance of the Saharan desert, rainfall is becoming unreliable and unpredictable, leading to long spells of drought during the growing season. The low priority placed on groundnut by the past governments in Uganda has limited the exploitation of its full potential in the country. Other constraints are: lack of inputs, especially fertilizers, insecticides, and fungicides; lack of high-yielding, disease-resistant, adapted groundnut varieties; and poor agronomic practices, such as farmers maintaining low plant populations. The Uganda Seeds Project is now in its formative stage and, as such, it is not fully operational, leading to lack of an assured source of fresh and good quality seeds to farmers at the beginning of the growing season.

In addition, relatively small numbers of groundnut researchers are available to combat the natural hazards. There is a lack of well-trained and qualified groundnut extension specialists in areas of high groundnut potential. Groundnut production in this country is heavily dependent on manual labor, which limits the area managed by a farmer, depending on his family size and resources and machinery available to him.

These constraints have been compounded and aggravated by political instability in the country for the past two decades.

Research Activities and Achievements

Research on groundnuts is based at Serere Research Station, situated within the main groundnut-producing area in Uganda. Research work started in 1920 with the introduction of new varieties to Uganda. Since then, work has included various aspects and disciplines, such as agronomic studies on spacing and plant densities; entomological studies on the ecology and control of groundnut aphids; hybridization, selection, and evaluation of crosses; and introductions for rosette resistance and confectionary qualities, etc. The overall objective, like in any other crop improvement program in the world, is to produce high-yielding varieties with acceptable agronomic traits.

The main objective of the groundnut improvement program at Serere in the early 1960s was to obtain one or two varieties of groundnut which, when planted by farmers on soils of average fertility, would give high yields and at the same time would, on shelling, yield high proportions of kernels of a quality suitable for the confectionary trade in Europe. This was oriented to export. Since 1976, the objectives have been redrawn, taking into consideration priority problems and local needs, as follows: to screen and breed for rosette resistance; to screen and breed for short-term varieties resistant to *Cercospora* leaf spots and bacterial wilt; to utilize induced mutations with the aim of improving grain yield, quality, plant architecture, and earliness; to collect and maintain groundnut germplasm, both local and foreign, for use in breeding programs; to maintain and evaluate cultivars released to the Uganda Seeds Project for adaptability and stability; to screen new insecticides against *Aphis craccivora* and to continue the study of the ecology of this pest; to determine the effects of inoculation with *Rhizobium;* to breed for drought resistance; to improve the size and yield of the red Valencia, which is locally popular; and lastly to test and evaluate the end products of the improvement work for adaptability in various ecological zones.

Although our major activities are directed toward the achievement of those objectives, their full implementation is limited by inadequate research funding, lack of proper and modern research facilities, inadequate staff, and lack of properly trained research workers on the crop. Unless these limitations are removed, both the quality of research and the validity of the research findings will continue to be seriously affected.

The highlights of research can be summed up best in technologies that have been transferred to the farmer, which should enable him to produce high yields of the crop at low costs of production.

Varieties released. These include: Red Beauty (a multiline of red Valencia), which matures in 90 days, Bukene; Mani Pintar; ROXO; Tatu; Makulu Red; and 55-437. A number of rosette-resistant crosses and lines for confectionary purposes are on the verge of release.

Germplasm. Serere Research Station used to maintain one of the largest groundnut collections in eastern and central Africa (900 accessions), but due to poor storage facilities and lack of cold storage, many accessions were lost. The Station now maintains about 700 accessions.

Agronomy. Row cropping was found superior to the traditional broadcast method, and it was recommended to farmers at a spacing of 60 cm between rows and 10 cm within the row for most of the varietal types.

Crop protection. Several chemicals (Aphox 70®, Rogor®, Endosulfan 35 ML) were tested and found to be effective in controlling aphids. Brestan® was recommended for the control of *Cercospora* leaf spots, as was Dithane M 45®, for the control of groundnut rust. Fernasan D® was recommended as the best seed dressing. Early planting and close spacing have been recommended as cultural control measures against aphids and, hence, rosette.

Fertilizers. After extensive trials countrywide, only phosphate fertilizers were recommended for use at the rate of 25 to 50 kg ha^{-1} of P_2O_5. Nitrogen fertilizer has not been recommended for use on groundnut.

Training

There have been very few training opportunities for research workers on groundnuts. Only recently, two workers attended a 6-month in-service course on crop improvement at ICRISAT, and one attended a course on the use of induced mutations conducted by IAEA, Vienna. There is an urgent need to initially train research workers at M.Sc. level in the following disciplines: groundnut breeding, groundnut pathology/virology, groundnut entomology, groundnut physiology, groundnut microbiology, groundnut agronomy, and genetic resources conservation and utilization. Short courses, like the ones conducted at ICRISAT, would be of great value in orienting our graduate and diploma staff toward a better understanding of their responsibilities in a groundnut improvement program.

The Uganda government, in cooperation with ICRISAT and interested donor agencies, should organize short courses in groundnut production for our extension staff, who would on completion of such courses be posted to work as groundnut specialists in the extension service in areas of high groundnut production.

Future Strategy

Now that there is hope of political stability in the country and the present government is laying great emphasis on production of food crops (maize, groundnuts, sorghum, etc.), it is hoped that government will not only encourage the production of these crops, but will also provide the means with which to minimize the constraints and thus boost production.

Research efforts will continue to be directed toward increased and stabilized groundnut production. Average yields of groundnut in the country are about 800 kg ha^{-1}, whereas average yields of 2500 kg ha^{-1} are realized on Serere Research Station and its affiliated experimental stations, with moderate technology and management. The aim of our research and extension should be to establish targets that will progressively lift the national average yield toward the research average yield.

Our major research thrusts will be in breeding for stable and multiple resistance to groundnut diseases (rosette, bacterial wilt, foliar fungal diseases); groundnut pests (aphids and thrips); and drought. Work on biological nitrogen fixation should also be intensified. Re-collection of groundnut landraces should be conducted in the country. Research on biological and cultural control of groundnut pests, and screening new chemicals for the control of these pests, will continue. Intercropping studies should also be intensified, since over 50 percent of groundnuts in Uganda are grown as mixtures with other crops. Emphasis should also be laid on on-farm research, now that a Farming Systems Research Unit has been added to the research establishment at Serere.

Other aspects worth investigation are: agronomic studies on spacing and plant densities; groundnut nutrition studies, with particular emphasis on phosphorus, nitrogen, and calcium; and research on simple and cheap mechanization of groundnut production.

We also recognize that our close cooperation with ICRISAT will enable us to keep pace with improvement efforts at ICRISAT Center and elsewhere in the world. ICRISAT, and donor agencies willing to assist us, should aid us to improve our research facilities, train our research and extension staff, provide funds for conducting trials, and assist in the reorganization of both research and extension services in this country. The focal point of aid should be toward research, since this is the alpha of improvement.

Conclusion

The future of groundnuts in Uganda is bright. There is a high potential for increased production, but this can only be achieved with concerted efforts on the part of the government, interested donor agencies, and all those that work on this crop, to develop a package of production technologies that incorporate new discoveries and that are feasible and practicable under our conditions.

Research on groundnuts should be reorganized, expanded, and strengthened so as to meet the increased challenges and demands. Given the necessary requirements to overcome the constraints outlined in this paper, groundnut can recapture its past role in our economy as an important export crop, and as an important component of the people's diet.

Pigeonpea

Pigeonpea, *Cajanus cajan,* is among the many legumes grown for human consumption in Uganda. Like other legumes, it offers hope for balancing the diets of the people of Uganda, considering the high cost of meat or animal products. The production and the yields obtained from the local cultivars are currently low. The bulk of the crop is grown as an intercrop, and agricultural inputs are hardly applied. It is grown solely for its grain and the current production satisfies domestic or local demand; any surplus is sold to neighboring countries. Research and extension infrastructure need to be improved and intensified. Pigeonpea has good potential for increased production in Uganda.

Production Trends

Pigeonpeas are mainly produced in the northern region of Uganda, including the districts of Lango, Acholi, West Nile, and Madi. Some amount is produced in the eastern region, particularly in the district of Teso. The bulk of the crop is produced as an intercrop (most commonly with millet).

Some pigeonpea is sown as pure stand and in small backyard gardens. Because of the present cultivation practices, the area under pigeonpeas may be grossly underestimated as small backyard plots are overlooked and yet these small house-garden plots contribute substantially to the crop's production and meet considerable domestic demand.

Table 2 provides total area and production figures for the crop from 1971 to 1985 (source: Ministry of Agriculture and Forestry). The overall trend shows a decline in area planted, total production, and yields per hectare.

The decline is owing to several factors. Farmers continue to grow local, low-yielding cultivars. Also, as pigeonpea is mainly grown as an intercrop with millet, the millet competes with pigeonpea throughout its critical stages of growth from seedling establishment up to pod formation and grain filling. An optimal pigeonpea stand is not attained in this system as pigeonpeas have to be sparsely sown to avoid the millet crop being smothered.

Cultural Practices

Pigeonpeas are often sown in rotation, following a cotton crop the previous year. Land preparation is often by ox-drawn plow. There may be one or two plowings, depending on the nature of the field; then millet and pigeonpea are sown together and

Table 2. Total area and production of pigeonpeas in Uganda, 1971-1985.

Year	Area ('000 ha)	Production ('000 t)	Average yield (kg ha^{-1})
1971	91	40	440
1972	121	48	400
1973	78	31	400
1974	115	46	400
1976	86	37	430
1977	105	40	380
1978	105	42	400
1979	58	19	330
1980	50	26	520
1981	55	25	450
1982	60	28	470
1983	62	29	470
1984	72	25	350
1985	63	22	350
Average	80	33	410

the seed buried into the soil by walking animals repeatedly over the seedbed. Because millet seeds are small, requiring a fine seedbed, the pigeonpea/millet crop is sown on well-prepared fields, normally in March/April at the onset of the first rainy season. There are two pigeonpea types grown: a medium-maturity type is harvested during the short dry spell, marking the end of the first rainy season (August), and a late-maturing tree-like cultivar is harvested in December/January. The medium-maturing type is low-yielding, of medium height, and small seeded, while the late-maturing type is tall, higher yielding, and large seeded. In both cases, millet is harvested before the pigeon-pea crop matures; with the late-maturing pigeonpea, the millet stubble may be dug or plowed in and sesame or sorghum sown during the second rainy season, to be harvested with the pigeonpea in December/January.

Pigeonpea can grow well in nearly every part of Uganda. It is a rainfed crop and no irrigation is applied. Hardly any inputs are applied by the farmers, due to high costs and low economic returns from the crop. Rhizobial inoculation has never been tried. The crop is left in the field until the pods mature. Pod-bearing branches are then broken or cut off and carried to drying floors at the homesteads, where they are sun-dried for several days.

Processing and Utilization

Pigeonpeas are grown for their grains, important in human nutrition. After the pods have dried, people beat off pods from the branches with small sticks. The pods are then beaten with bigger sticks to thresh out the grains, which are consumed in several forms. In fresh form, mature green pods are harvested and shelled. The fresh green grains are then boiled or cooked and sesame or groundnuts added. In dry form, dry grains are cooked as with fresh green grains, or they are split by grinding on a large stone (this also serves to remove the seed coat). The seed coat is winnowed off, and the split grains are cooked and stirred to make a homogeneous paste. In all forms, sesame or groundnut is added to enrich the taste and indirectly add other nutritional requirements (such as fat or oil). In the dry form, cooking is hastened by adding soda ash, which softens the grains. Pigeonpea utilization can be diversified to include its uses other than as a vegetable. This could be done by improving upon, or introducing new, processing technology. The grain could be dehulled and fine flour produced, using hammer mills. The flour could be used in preparing a variety of recipes, and it could increase both domestic and overseas trade.

Constraints to Production

In Uganda, farmers grow local, unimproved cultivars. As per current cultivation practices, farmers are able to grow only one crop in a year. Early-maturing cultivars could be grown in the short, second rainy season to enable two crops a year. Weeds are a serious yield reducer. Pigeonpea is mainly grown as an intercrop with millet and the latter crop acts as a weed throughout the crop's critical stage of growth (i.e., seedling establishment to pod formation and grain filling). Besides the cereal crop, there are also other weeds, as millet is often weeded only once and hence not weed-free. These factors may be partly responsible for the low yields reported.

Insect pests are another major constraint. At flowering, thrips and *Zonabris* spp cause heavy flower losses. Pod borers and sucking bugs are a great threat at podding. Insecticides are costly, and very few farmers can afford the effective, recommended insecticides. Storage facilities are often poor, and this, coupled with almost constant ideal temperatures for storage pests (27°C to 31°C), causes heavy losses by the storage weevil. The grains cannot, therefore, be stored for long periods, causing a seed shortage for the next sowing. Fusarium wilt is the only disease that causes serious damage.

Marketing problems also cause low production. There is no directed marketing and no system to control quality or price. Nonavailability of good quality seeds is also a constraint. Tribal or traditional and geographical inclinations have played their part as well. Some tribes in certain geographical zones grow pigeonpeas as a traditional crop, whereas others do not grow the crop, though they may be consuming it. In some areas, present local cultivars do not conform to the cropping or rotation patterns practiced. Improved varieties are needed to suit various cropping patterns in different areas of the country, as are better processing and utilization technologies. Because of the low and unstable yields currently realized from pigeonpeas, farmers have been forced to devote greater attention to highyielding cereals and other alternative crops.

In sum, the major constraints to pigeonpea production are: lack of high-yielding varieties; lack of suitable short-duration varieties to be grown as sole crops in the short second rainy season, to enable two crops in a year; inability of farmers to afford effective inputs to boost production; nonavailability of certified seeds; high harvesting costs and losses; poor marketing structures; poor processing and limited utilization; and tribal inclinations and existing cropping patterns.

Research and Extension Infrastructure

Research on improvement of pigeonpea has for long been given a low priority compared to other food legumes, such as groundnuts and beans. No improved varieties have so far been released to farmers, and this has led farmers to rely on their low-yielding cultivars. Germplasm, both local and foreign (though limited), has been assembled, screened, and evaluated for various agronomic traits. Currently, selection is based on high yield potential, seed size and color, maturity period, and good plant architecture. Sixteen lines, selected for their yield potential, are undergoing preliminary yield evaluation. While yields of over 1500 kg ha^{-1} have been realized, yet higher yields are the target.

A study of the status of insect pests and their effect on pigeonpea yields is being undertaken. Screening for resistance to major insect pests is under way, with a view to develop insect-resistant varieties and workable pest management systems. Agronomy trials have been planned to establish optimal plant populations, both in pure and mixed stands. Introduction of earliness is proposed into local cultivars with large seeds, which are presently late-maturing.

With the introduction of adaptive research and the Training and Visit (T & V) system, the research-extension liaison is improving. By carrying out on-farm trials, we can help our farmers more readily adapt new technologies developed at the research station.

Training

There is a great need for training grain legume researchers, so as to strengthen the country's research work on these important food crops. At least a breeder, an agronomist, and an entomologist need to be trained for higher degrees. Other support staff need to be trained in ICRISAT's 4-to-6-month in-service courses. Opportunities to attend international or regional workshops, seminars, and field days at ICRISAT should be availed to help grain legume researchers, as this would serve to broaden and refresh the minds of such personnel. Some personnel should also be trained in food processing and utilization technology. These opportunities are not currently available in Uganda, and donor agencies can help promote grain legume improvement by funding training of research personnel.

Future Prospects

Pigeonpea is at present limited in area and production. There is scope for increasing both. As we are aware, prices for animal products are sky-rocketing. Pigeonpea, as the other food legumes, offers hope for compensating and balancing nutritional requirements where cereals are predominantly used as staple foods. As the crop is not entirely new but known to most Ugandans, prospects to improve it are bright.

But we need to introduce new processing technology and diversify uses of the crop. As a crop grown under rainfed conditions and being drought tolerant, pigeonpea can give yields where other crops would fail completely under adverse weather conditions.

A lot of assistance is to be desired from ICRISAT and from donor agencies. In addition to the urgent need to train staff, as already mentioned, ICRISAT should effectively make available elite material from its germplasm. Supply of relevant literature is needed. Funding for necessary inputs and research facilities or equipment is required. There should also be funding for research into more effective utilization and processing of pigeonpea products. Funding for germplasm collection is also a necessity. Cooperation with ICRISAT through international trials should be intensified. ICRISAT's participation in guiding and monitoring national programs is, thus, very welcome.

The Role, Organization, and Management of CIAT's[1] Activities in Support of National Bean Improvement Programs in Eastern Africa

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Bean Production and Research Opportunities

Beans *(Phaseolus vulgaris)* were introduced into Africa from the Latin America gene center by West European traders over the last few centuries. Currently Africa is the second most important common bean producing region of the tropics, following Latin America. The total average annual African production, according to FAO production statistics, amounts to 1.4 million t per year over the last decade. Production estimates vary greatly. A large part of the total bean production is consumed locally and thus not reflected in the FAO estimates shown in Table 1. For example, Kenya reports production of 467 000 t for 1977-79 against the FAO estimate of 161 000 t, and Uganda 300 000 t against the estimated 175 000 t.

Total bean production in Africa has increased over the last decade. However, this has been achieved through area increases, while productivity has been stagnant (currently around 500 kg ha^{-1}). Production increases have not kept pace with population growth. Per capita consumption is falling, and price increases have been above inflation rates in most countries.

Beans play an extremely important role in the human nutrition of eastern Africa, providing up to 45% of total protein consumption in Burundi and Rwanda (the highest in the world) and over 10% of protein consumed in Kenya and Uganda. Beans contribute nearly as much protein to average national diets as all animal products combined in Malawi and Uganda, and far more in Burundi and Rwanda. Because beans are cheaper than animal products, they are of even greater significance in the diet of the poor, who are the most vulnerable to malnutrition. This applies especially to those countries where diets based on cassava and banana are associated with serious protein deficiencies, such as Uganda.

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1. CIAT = Centro International de Agricultura Tropical, Cali, Colombia.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1987. Research on grain legumes in eastern and central Africa. Summary proceedings of the Consultative Group Meeting for Eastern and Central African Regional Research on Grain Legumes (Groundnut, Chickpea, and Pigeonpea), 8-10 December 1986, International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia. Patancheru, A.P. 502 324, India: ICRISAT.

Table 1. African bean production in the 1960s and 1970s.

Country	Annual production ('000 tons)		Annual increase 1962-1979 (%)		Apparent annual per capita grain legume consumption (kg)
	1966-67	1977-79	Area	Yield	1977-79
Uganda	175	175	6.7	-2.3	29.3
Burundi	133	162	3.6	-0.9	44.0
Kenya	133	161	-	-	21.0
Rwanda	126	174	3.7	0.3	50.6
Tanzania	108	150	2.7	0.9	12.0
Ethiopia	68	13	-8.8	-0.2	21.2
Others	284	515	-	-	-
Total	1027	1350	3.8	-0.1	-

Source: FAO Production Yearbook, various years.

Small farmers are the principal producers of beans in most of Africa. The major share of the crop is cultivated in cropping systems associated with maize, sorghum, or bananas. In Kenya, for example, only 6% of total production is estimated to be in monoculture. Most bean production is for subsistence, with less than a third of the output being marketed. Use of fertilizers, pesticides, and fungicides in bean production is rare. However, large differences in management practices of farmers can be found, for example, within relatively short distances in Ethiopia. Very little research has been conducted there on the improvement of the subsistence intercropping system, although results available from other countries in the region indicate some promising directions. On-farm research is needed to identify local priorities.

Diseases and insects, low soil fertility, and periodic water deficits form the principal natural constraints associated with low average yields. African bean researchers have identified anthracnose *(Colletotrichum Lindemuthianum)*, bacterial blight *(Xanthomonas phaseoli)*, angular leaf spot *(Isariopsis griseola)*, bean common mosaic virus, and rust *(Uromyces phaseoli)* as the most important diseases across the region. The beanfly {*Ophiomyia* spp) is the principal insect problem. Although sources of resistance have been identified, they often occur in materials with grain types lacking consumer acceptance, or are not agronomically appropriate for farmers' circumstances. To reduce disease pressure, farmers in many countries plant at suboptimal densities and accept a lower potential yield by planting beans dangerously close to the next dry season.

Beans in Africa are mostly consumed as mature beans, either dried or before the seed drying process has started. Green pods are also important, and young tender leaves are sometimes consumed as a vegetable. Large red, red-and-brown-mottled, or speckled seed types are preferred in many areas, but seed color preferences seem less stringent than in Latin America. As beans take longer to cook than most other common foodstuffs in the diet, a short cooking time is important where, as in Rwanda, the firewood problem is acute. Taste is also important in determining acceptance of a new variety, but generalization is difficult: for instance, a commercially unviable, small-grained variety was found to be popular with the poorest sector of the rural population of Kirinyaga in Kenya, because seed for planting was less expensive.

While there are many similarities between the bean production systems and problems in Africa and Latin America, favoring the selective transfer of technology components from Latin America to Africa, there are also differences. Thus, transfer of finished technology to Africa can be, at best, a short-term expediency and no substitute for the permanent strengthening of local research capability.

National Bean Research Programs

Bean research has a long history in Africa and has continued to gain importance over the past few years. Many national programs are backed by a reasonable infrastructure, although seed storage, transport for on-farm research, and field equipment are generally inadequate for efficient deployment of available research staff.

The adequacy of human resources available to these national research programs varies greatly. In recent years, agronomy in general appears to have received less attention than breeding and crop protection. All countries, however, place priority on improving the training of their research staff, both graduates and technical assistants. These two categories of staff require different types of training; a concentration of training efforts upon those at the graduate level does not necessarily lead to a concomitant improvement in the practical skills of their assistants.

Exchange of germplasm, research methodologies, literature, and other results among the various national and international programs has been largely lacking until recently. A questionnaire survey of all known bean researchers in Africa, conducted in 1985, identified the critical need for improved access to information and documentation in the region. One bright spot was the emergence three years ago of the *Phaseolus Beans Newsletter for East Africa,* compiled and published by Kenya's national program with financial support from the Netherlands.

CIAT Bean Program in Africa

Objectives

CIAT activities in support of national efforts in bean research have the following three broad objectives:

1. To increase the productivity and production of food beans by breeding for higher-yielding, stable genotypes identified from among a more diverse germplasm base, both from introduction and from locally adapted landraces.
2. To develop more productive systems of cropping, utilizing promising new cultivars and varietal mixtures when appropriate, while ensuring that such innovations of cropping system and cultivar remain acceptable to producers and consumers and do not disrupt existing farming systems adversely.

3. To assist strengthening of national research programs, to a degree that is both appropriate and sustainable nationally, through giving substantial emphasis to training.

Organization of Activities

In a first meeting of bean researchers in Africa, held in Lilongwe in March 1980, CIAT was asked by delegates from the chief bean-producing countries of eastern Africa to mount a regional program to support national bean research in Africa.

By 1983 CIAT was able to set up a regional program for the Great Lakes countries of Burundi, Rwanda, and Zaire with Swiss (SDC) support, and a full regional team is now in operation from a coordinating center in Rwanda. Towards the end of 1984, funds from the Canadian and U.S. agencies for international development became available for operations in the rest of eastern Africa, including Kenya, Uganda, Ethiopia, and Somalia. CIAT placed one bean scientist at Thika, Kenya in September 1984 to start operations. The regional coordination center for these countries is now in Ethiopia, with two other staff to be located in Uganda. Further funding from CIDA (Canadian International Development Agency) has enabled CIAT to start a third regional base in Arusha, Tanzania to serve the SADCC (Southern African Development Coordination Conference) countries, and a regional coordinator was posted there in July 1986.

Each of the three regional programs is located, by agreement, with the respective national bean improvement program. The southern African program is a joint program of CIAT with the Southern African Center for Cooperation in Agricultural Research (SACCAR). Each regional program includes a breeder and an agronomist, while specialists in entomology, pathology, nutrition, economics, and anthropology are shared across regions.

One member of each regional program acts also as coordinator. The distribution of regional staff is intended to combine elements of centralization (conferring advantages of interdisciplinary teamwork and a critical mass) with the advantages of decentralization (daily contact with a large number of national programs and agroecological zones, and smaller groups of expatriates less likely to dominate national program decisions). The decentralized model is felt to be particularly appropriate to eastern Africa, where national programs are generally better endowed than in the other two regions.

Philosophy of Operations

CIAT's philosophy in operating these programs is to strengthen national programs in such a way that they become fully effective, practically oriented, interdisciplinary research teams that remain effective after withdrawal of external support. A key factor, we believe, is working alongside national bean teams as colleagues on their research sites. Care is taken that regional staff guide, encourage, and supplement (but do not replace) the activities of national scientists. CIAT's regional programs usually do not run separate field trials; they try to fully support national teams in conceptualizing, planning, and executing field research, for which each national team retains responsibility. Varietal releases and recommendations of improved cultural practices that emerge from this collaborative research are made by the national program, who can thus claim credit for any achievement.

The foregoing "bilateral" component of a regional program requires care in recruiting international staff. They must be scientists of such caliber as to earn the respect of colleagues in national programs when working together routinely. They must also be sympathetic to the needs and aspirations of the national programs and scientists, willing to assess their own achievements in terms of the performance of national programs. Concern with achieving rapid research progress needs to be balanced by an equal concern for fostering long-term sustainability of national capability.

As similar agroecological zones can be found in neighboring countries, national programs can benefit greatly from regional collaboration. Sharing of information and experiences among countries on previous and present research activities is an essential first step. Regional trials and technical meetings have a lasting effect by providing personal contact among scientists working on related problems. Problem-specific workshops or monitoring tours provide opportunities for in-depth discussions among scientists; they can also inject relevant external experience through participation of international center staff or other specialists working in the region. Purposeful collaboration among national programs in solving one or more common research problems can also result. The limited resources of national programs are thus used more efficiently through complementarity of effort, and the planning and analytical abilities of national-program scientists are also enhanced through collaborative planning and review of research progress.

The role of the regional program in these "network" activities is twofold: (1) it can catalyze collaboration among countries, so that research opportunities are better exploited than would be likely with national research conducted in isolation; (2) it can provide technical backup and feed into national programs the new germplasm, research methods, and scientific documentation that is requested.

Management by Steering Committee

Each regional program is monitored by a steering committee that meets at least once a year (intervals of 6 to 9 months have been found useful in the early stages of a program). The committee is composed of the national bean research coordinators or team leaders and the regional coordinator. Donor representation (as observer) is common.

The general functions of the steering committee are to guide CIAT in its functions and to set priorities for the region in implementing specific plans. It approves an annual regional plan of work and expenditures on training, workshops, collaborative research, and equipment purchases for national programs. Chairmanship and venue of the meeting rotates among countries. The chairman serves until the following meeting and may be consulted by the regional coordinator on matters pertaining to the regional program. The regional coordinator provides secretariat services to the steering committee and represents CIAT.

CIAT encourages meetings to be small and informal because this creates an atmosphere that encourages communication among individuals and, in time, builds the professional trust upon which the establishment of a regional network depends.

A regional variety trial, such as the African Bean Yield and Adaptation Nursery (AFBYAN), is one way in which information can be shared usefully across countries with similar agroecological zones or cropping systems niches. The purpose and design of these trials will change as understanding of the region improves. Collation, interpretation, and feedback of results across countries will continue to be important.

Another approach to improving the efficiency of national resource use, for overcoming researchable problems shared by several countries, involves purposeful division of effort among collaborating national programs. The complex of widespread bean diseases has triggered this form of collaboration, enabling selection for genetic resistance in the best hotspots available in the region.

The following collaborative subprojects are currently in progress among the Great Lakes countries: screening of germplasm for resistance to halo blight (Institut de Sciences Agronomiques du Burundi); screening of this germplasm for resistance to anthracnose (Institut de Sciences Agronomique du Rwanda); and screening of this germplasm for resistance to angular leaf spot (Programme National Legumineuse, Zaire). In eastern Africa, the following priority research topics have been provisionally agreed upon: screening for rust resistance (Ethiopia); screening for drought tolerance (Somalia); and screening for bacterial blight and ascochyta resistance (Uganda).

Proposals for collaborative research projects can arise from the regional priorities set by the steering committee, and from independent applications submitted by interested scientists through a national coordinator. A simplified application form has been made available to facilitate the development and assessment of proposals. Regional funds can be allocated for successful proposals, in recognition of their regional responsibilities.

The steering committee considers in each proposal: (1) relevance of the expected research output to the region as a whole; and (2) progress made (in the case of renewals). Progress is assessed from reports required of the researchers, from presentations at regional workshops, and from visits by one or more members of the steering committee.

Bean Information Services in the Region

CIAT operates a Bean Information Center at its headquarters in Cali, Colombia, utilizing core funding and special project funds from IDRC (International Development Research Centre). In addition to publishing *Abstracts on Field Beans,* CIAT has compiled and distributed three bibliographies on bean research in Africa. The most recent volume includes "fugitive" literature obtained by a consultant's personal visits to bean researchers in the region.

A free monthly service provides researchers and libraries with current contents lists for a range of agricultural journals. Expenses for photocopies requested by researchers are met by coupons distributed by regional and national coordinators. Regional coordinators assist also in updating the distribution lists.

Results of research emanating from professional collaboration between regional and national program scientists are reported jointly. Where collation or extrapolation of research results across the region is done by a regional scientist, results are sent to the national programs.

Conclusion

Regional activities undertaken through the steering committee mechanism can thus enable international organizations to respond more directly to national interests, reducing the risk of paternalism. The judicious provision of technical assistance needs to be accompanied by attention to other forms of support that can strengthen long-term research capability. For example, a recent African Beanfly Workshop recommended that beanfly resistance screening work be coordinated in the future from within the region, rather than from CIAT headquarters. A degree of such decentralization is inherent in the philosophy.

The risk of a surfeit of regional programs and networks, making competing demands or offers, can be reduced by coordination among international centers and similar bodies. Active collaboration between CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo) and CIAT in training for on-farm research in Rwanda has avoided the risk of confusion, and it is enabling a wide range of national programs to benefit from a single activity. Collaboration with other centers in other areas of training is planned for 1987.

Acknowledgement

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FAO Grain Legume Program in East and Central Africa

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Introduction

The importance of grain legumes in Africa is manifested in their high daily consumption as a natural supplement to cereals, especially by the rural poor, and the role they play in the farming systems of the region, either in rotation or in mixed or multiple cropping. Because of their diverse growth habit and tolerance of poor soils, they are grown over a wide range of environments and are particularly suitable for small-scale subsistence agriculture.

Yield of grain legumes in many developing countries is low compared to other food staples, but yield of grain legumes in Africa is the lowest when production figures in the developing countries are compared. Both yield and nutritional quality require research action, so as to promote commercial production.

Various grain legume species are grown in eastern and central Africa: groundnut *{Arachis hypogaea),* chickpea *(Cicer arietinum),* pigeonpea *(Cajanus cajan),* bean *(Phaseolus vulgaris),* cowpea (*Vigna unguiculata),* and broad bean (*Vicia faba)* are among the important ones. Groundnut is grown in all the countries, while broad bean and chickpea are predominant in Ethiopia. Significant areas are planted annually with pigeonpea in Kenya and Uganda. Harvested area and yield for five of those crops are shown in Table 1.

Role of FAO

In recognition of the importance of grain legume crops in the agricultural development of many less developed countries, the post of Grain Legume Officer was established during 1965 at the headquarters of the Food and Agriculture Organization of the United Nations (FAO) in Rome, with responsibility for coordination, improvement, and implementation of programs related to improving productivity. Further involvement in grain legume improvement arises from FAO's position as one

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Table 1. Area ('000 ha) and yield (kg ha^{-1}) of groundnut, chickpea, pigeonpea, bean, and broad bean in eastern and central African countries.

	Groundnut		Chickpea		Pigeonpea		Bean		Broad bean	
Country	Area	Yield	Area	Yield	Area	Yield	Area	Yield	Area	Yield
Burundi	65	1231	-	-	-	.	300	967	-	-
Ethiopia	32	875	180	750	-	-	40	800	350	1429
Kenya	12	708	-	-	164	635	-	-	-	-
Rwanda	18	944	-	-	-	-	250	1000	-	-
Somalia	4	875	-	-	-	-	61	344	-	-
Sudan	476	723	3	1000	-	-	3	1600	16	2500
Uganda	120	833	5	600	62	483	300	800	-	-

Source: FAO Production Yearbook, Vol. 39, 1985.

of the three sponsors of the Consultative Group on International Agricultural Research (CGIAR). The CGIAR has, in turn, sponsored the establishment of International Agricultural Research Centers (IARCS), two of which, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Center for Agricultural Research in the Dry Areas (ICARDA), are actively involved with research and development programs on groundnut, chickpea, and pigeonpea.

FAO Activities

Past and current FAO Activities in the region comprise the following.

Country projects. Since 1951, under the auspices of the United Nations Development Programme (UNDP), Government Cooperative Programme (GCP), Trust Fund (TF), and recently under FAO's Technical Cooperation Programme (TCP), the Organization has assisted member governments in the form of small, medium, and large-scale deprojects. During 1985, over 30 field projects were in operation in East and Central Africa embracing grain legumes as an important component of the development of food crops.

An FAO grain legume agronomist was posted at the Institute of Agricultural Research (IAR), Ethiopia, from 1972 to 1977 to initiate and coordinate research programs on grain legume crops. Groundnut, chickpea, and pigeonpea were among the legumes covered. An FAO grain legume agronomist worked in Kenya for about 3 years to develop improved agronomic practices associated with grain legume production. For the last 6 years, an FAO plant breeder has been working in Kenya on the improvement of pigeonpea, chickpea, and groundnut.

Consultancies. A short-term consultant has been commissioned to visit Kenya in October 1986, to evaluate the present grain legume breeding program and make appropriate recommendations for strengthening and reorientation of the program.

Although the consultancy described next hereunder was performed in West Africa, it has some relevance to this meeting. Short-term consultants were commissioned to the Cape Verde Islands during 1982, 1983, 1984, and 1986 for the development and expansion of pigeonpea cultivation there. Other consultancies on different grain legumes were also commissioned in many African countries.

Surveys. In order to review and survey the prevailing grain legume production practices, identify major research priorities, identify major constraints and the need for accelerated development programs, FAO undertook a review for the West Africa subregion in 1980. Another general review on "Pulses Production in Africa" was undertaken during 1986. A review on grain legume research and development in East Africa is planned for 1988.

Training, seminars, workshops. FAO is involved in developing increased national competence, updating technical knowledge, promoting regional cooperation among scientists, and strengthening research facilities. In collaboration with other agencies, FAO has organized many training courses, seminars, and workshops, and several hundred researchers and agronomists from the region were trained on various aspects of grain legumes. Such training also includes fellowship awards for postgraduate training for M.Sc. and Ph.D. degrees.

FAO organized a 3-week regional seminar for 30 participants on increased field food crops production, which included grain legumes, in Nairobi, Kenya, in 1982. Another regional seminar on increased food production through low-cost food crops technology is planned for March 1987 in Harare, Zimbabwe. In collaboration with the Institute of Agricultural Research (IAR) and the Directorate of Agricultural Extension (DAE), Ethiopia, FAO is organizing a 2-week training course for 30 extension staff in 1986 on improved crop production technology. The course will be repeated in 1987.

On-farm demonstrations. The objective of the FAO on-farm demonstration program is to provide a practical contribution to the dissemination of already acquired and proven technologies on cereals and selected grain legumes, through the establishment of field demonstrations on a large scale and under farmers' real conditions. All activities, from site selection to data collection, are conducted in close cooperation with national research and extension workers. During 1985 and 1986, Ethiopia, Kenya, Somalia, Burundi, and Rwanda participated. During 1987, it is planned to extend the program to other countries.

Biological nitrogen fixation. The present aim of the FAO program on Biological Nitrogen Fixation (BNF) is to stimulate the development of national programs that can assure the transfer of BNF research into farming. This includes the strengthening of all activities dealing with grain and forage legumes related to BNF.

FAO assisted in the setting up of microbiology laboratories to facilitate work on BNF in Rwanda and Sudan. FAO was directly involved with the creation of the African Association of BNF, and it is providing funds to the Microbiological Resources Center in Nairobi, Kenya.

Seed production. The development of sound national seed multiplication and distribution programs for the production of quality seed of newly developed varieties of grain legumes is considered by FAO to be of vital importance. FAO acts as a forum for the channeling and coordination of assistance offered by governmental, nongovernmental, and international agencies in the development of seed production, quality control, and distribution activities. It assists in the identification, formulation, and implementation of national seed programs and field projects at all stages, with the overall objective of enabling countries to become self-sufficient in seeds. FAO has a wide range of seed projects in operation in many eastern and central African nations, and it has trained several hundred seed technologists in various aspects of seed production and distribution. Furthermore, seeds of grain legume cultivars obtained from a variety of sources are distributed to research institutions and scientists through the FAO Seed Exchange Laboratory.

Information services. Collection and dissemination of information concerning new developments in grain legumes improvement and production is an important part of FAO's central assistance role. This is achieved through the preparation of technical publications, reports, and other information materials. Since the early 1960s, FAO has published several publications, including: "Legumes in Agriculture", 1963; "Legumes in Human Nutrition", 1964; and "Grain Legumes in Africa", 1966. Some recent publications and reports on grain legumes are listed below:

- Improvement and Production of Food Legume Crops, 1977
- Food Legumes: Distribution, Adaptability and Biology of Yield, 1977
- Food Legumes in the Caribbean, Central America and Panama, 1978
- Food Legume and Oilseed Crops in the Near East, 1978
- Food Legume Production in Mediterranean European Countries, 1979
- Food Legume Production Practices in Tunisia, Algeria and Iraq, 1979
- Grain Legume Development in the Humid and Semi-Arid Lands of the West Africa Sub-Region, 1980
- Food Legumes in the Andean Countries, 1981
- Legumes in Human Nutrition, 1982
- Technical Handbook on Symbiotic Nitrogen Fixation: Legume/Rhizobium. FAO, 1983
- World Catalogue on Rhizobium Collection. FAO/UNESCO, 1983
- Legume Inoculants and Their Use. FAO, 1984
- Pulses Production in Africa, 1985

Assistance. FAO anticipates that this meeting will develop recommendations and suggestions for both long-term and short-term needs for research on groundnut, chickpea, and pigeonpea in the region. FAO will cooperate and collaborate with governments, international centers, and bilateral and multilateral aid-giving agencies to implement the meeting's recommendations to the extent its resources permit. The following are of special interest:

- FAO has recently initiated a new Technical Cooperation Programme, under which assistance up to the value of $ 250 000 is granted to any project of 1-2 years' duration requested by member governments, subject to certain criteria being met.
- Provision and collaboration for holding meetings, consultations, seminars, and workshops are always offered if such gatherings are programmed and planned well in advance.
- Under FAO's regular program, short-term consultancies and contractual services can be commissioned when advice is urgently required for any particular situation.
- FAO staff, based at headquarters in Rome and at the FAO Regional Office for Africa in Accra, provide technical advice and policy guidelines when requested by governments.

Significance of Cool-Season Food Legumes and ICARDA's Role in their Improvement in Sub-Saharan Agriculture

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Introduction

Food legumes play an important role in the traditional agricultural systems of most African countries. They contribute to the farmers' income, to human diet, and to soil fertility. Their byproducts also serve as an important animal feed. Pulses occupy about 12.58 million ha of land and account for an annual production of 5.56 million t in Africa. Production has remained static in the last 15 years, whereas population has increased by 50%. Consequently, domestic availability of pulses per capita has declined, necessitating imports at high costs using convertible currency. During 1983, 414 000 t of pulses were imported into Africa, against a total food crops export of 221 000 t.

Among the pulse crops grown in Africa, faba bean *(Vicia faba),* chickpea *(Cicer arietinum),* and lentil *(Lens culinaris)* are the main cool-season food legumes, and they are generally grown rainfed. These crops occupy about 1 299 000 ha of land and produce 1 283 000 t of food legumes annually.

Faba bean occupies the largest proportion of this area (61.7%), followed by chickpea (27.3%) and lentil (10.9%). The most important countries growing these crops include Ethiopia, Morocco, Egypt, and Algeria, which together account for 84% of the total area under these crops in Africa. Apparently, for countries other than Ethiopia and Sudan in eastern and central Africa, these crops are of minor importance because of their lack of adaptation to prevailing ecological conditions.

ICARDA's Objectives and Operations

The International Center for Agricultural Research in the Dry Areas (ICARDA) has the major responsibility for research and training in support of the improvement of faba bean and lentil. These crops are well adapted to the rainfed farming systems in the West Asian and North African region with a Mediterranean type of climate. Jointly with ICRISAT, it also has major responsibility for the improvement of kabuli type

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chickpea, which is also well adapted to this region. The primary objective of ICARDA is to increase the productivity and yield stability of these crops wherever they are important. Toward this goal, it works very closely with scientists in the national programs to develop improved genotypes and production practices, and to test them in fields with full participation by farmers. A strong interdisciplinary research program on crop improvement at ICARDA's headquarters in northern Syria, and training activities, provide the needed support for the national programs. Breeding material and production technology is transferred to the national programs through the system of international nurseries and trials for local evaluation and adaptation and eventual field verification. For augmenting the research capability of the national programs in improving these food legumes, training is provided as per specific needs. This includes residential training courses and individual nondegree or degree-related training at ICARDA headquarters, as well as in-country or regional training courses conducted in collaboration with national program scientists.

The distribution of ICARDA's international nurseries and trials in sub-Saharan Africa is shown in Table 1, with emphasis on Ethiopia and Sudan. They have received a large share of the test materials because the crops are economically important in these countries. The numbers for the other countries have been rather low, and most nurseries sent there have been exploratory in nature. In contrast, the Sudan and Ethiopian national programs have made excellent use of these materials and have made recommendations for their use by farmers. In addition to the international nurseries and trials, ICARDA has also provided thousands of germplasm lines and segregating material from special crosses made for adaptation to the local conditions, and the two national programs are evaluating and selecting them. Senior scientists from Ethiopia and Sudan have also spent various lengths of time at ICARDA as visiting scientists and worked together with ICARDA scientists.

Table 1. Supply of ICARDA and ICARDA/ICRISAT nurseries and trials from ICARDA to national programs in Ethiopia, Sudan, and other sub-Saharan countries.

	Ethiopia			Sudan			Others[1]		
Season	C	F	L	C	F	L	C	F	L
1977/78	2	2	2	1	1	1	-	-	-
1978/79	-	5	-	1	2	1	-	-	-
1979/80	4	6	6	3	10	3	-	-	-
1980/81	2	12	2	-	8	-	-	-	-
1981/82	7	11	7	15	15	6	-	-	-
1982/83	4	-	5	7	12	8	9	-	-
1983/84	6	9	8	9	5	11	8	3	2
1984/85	10	12	12	9	5	8	6	6	2
1985/86	6	9	15	3	5	2	4	1	2
1986/87	3	8	8	9	9	6	2	-	-

C = Chickpea; F = Faba bean; L = Lentil.
1. Includes exploratory supplies to Malawi, Kenya, Sudan, Tanzania, Zaire, and Zambia.

In-country training courses on 'crossing techniques' relating to these crops, have been conducted. As of 1986, a total of 188 junior scientists and technicians have been trained in crop improvement techniques at ICARDA headquarters. The breakdown by region and country of trainees is as follows: sub-Saharan Africa—Sudan 56, Ethiopia 10, Djibouti 1; North Africa—Morocco 42, Tunisia 34, Egypt 31, Algeria 12, and Libya 2.

In order to meet the needs for research information of the national programs, ICARDA has operated a faba bean and a lentil information service, FABIS and LENS, respectively. Scientists regularly receive newsletters, journal abstracts, and comprehensive reviews on these two crops. Scientists have also been invited to attend six regional and international conferences and workshops held at ICARDA over the past 8 years.

Sudan

In addition to the activities supported by the ICARDA core budget, a special project funded by the International Fund for Agricultural Development (IFAD) has supported an applied research project on faba bean, linking Sudan and Egypt strongly with ICARDA. This Nile Valley Project started in 1979 and completed two phases of 3 years each in 1985. Although major efforts in this project were on faba bean, a small component was also devoted to lentil improvement, as the latter is becoming an economically important crop because of high local demand and difficulties with imports.

The project provided an opportunity to the Sudanese national scientists to field-test the improved genotypes and technology for faba bean in major production areas in the Northern Region of Sudan in the first phase of the project, and to demonstrate its economic viability and adoption feasibility through a pilot-production-cum-demonstration program, executed by farmers under supervision of scientists and extensionists. The achievements have been recorded in the report of the first phase. During the second phase (1982-1985), newer production areas in the regions traditionally growing faba bean were covered, and back-up research was undertaken for adoption of faba bean cultivation in the nontraditional areas south of Khartoum. It was found possible to introduce faba bean in the Gezira, Rahad, and New Haifa production schemes in Sudan, where there is a need for a leguminous crop to diversify cropping and improve the productivity of the system.

Studies at the Hudeiba, Shendi, and Shambat research stations, using the elite genotypes and the international agronomic trials provided by ICARDA, as well as the research programs jointly planned in coordination meetings, have led to identification of superior varieties and production practices for lentil and kabuli chickpea. Water management and identification of short-duration genotypes has been the high priority. Since many areas south of Khartoum suffer from salinity and alkalinity, future research on chickpea has to take this into account. Establishment of an effective host-*Rhizobium* symbiosis is an important prerequisite for success of chickpea in this area, and ICARDA has assisted the Sudanese national program in developing the needed laboratory facility and in training of personnel for microbiology work.

Ethiopia

ICARDA's collaboration with the Highland Pulses Team of Ethiopia has been long-standing and intimate. Since the 1985/86 season, Ethiopia also became a part of the Nile Valley Project for research on faba bean. With a loan from the World Bank for strengthening research on highland pulses, the Institute of Agricultural Research (IAR) in Ethiopia requested ICARDA to position a pathologist/breeder in Ethiopia, so that progress on improvement of faba bean, lentil, chickpeas, and dry peas could be speeded up. ICARDA has promptly met this request and posted a scientist in IAR starting 1986.

The major research thrust in faba bean improvement has been to increase the yield potential of the crop, reduce its lodging, increase its tolerance to chocolate spot *{Botrytis fabae)* and rust (*Uromyces viciae fabae),* and improve seed size. The current research program at Holetta, Denbi, Debre Zeit, and several other high-elevation sites, is one of the largest in the region and is making excellent use of germplasm, breeding material, and international agronomy trial designs provided by ICARDA.

Collaborative research with scientists of the Alemaya University at Debre Zeit research station and other sites on chickpea and lentil has been quite rewarding. As a result of multilocation and multiseason evaluation of lentil genotypes, lentil ILL 358 has been released. Production agronomy for lentils and chickpeas has been improved. Ascochyta blight seems to be a major constraint to production of lentils, and systematic screening of the world collection of lentil germplasm for this disease and for root rot and wilt will be started in the coming season. A few lines of lentil, with a high level of tolerance to *Ascochyta lentis,* have already been identified in 1986, from the International Yield Trials and Screening Nurseries of lentil supplied by ICARDA.

Progress on identification of kabuli-type chickpeas for Ethiopian conditions has been slow, because most of the ICARDA-developed material appears to be too late for Ethiopian conditions. Of the material identified as promising, ILC 482 has appeared to be the earliest. Future efforts will be aimed at generating more early-maturing material for this area.

Other Countries

As already mentioned, there has been little demand for ICARDA-developed, cool-season food legumes in other countries in eastern and central Africa. Personal contacts with the national programs have been limited, because the area under these crops is currently insignificant. However, there is a need to better understand the agroecological conditions prevailing in different geographical regions, so that the potential of introducing cool-season food legumes into their cropping systems can be evaluated. The success in expansion of faba bean cultivation in nontraditional areas in Sudan should encourage similar efforts in other countries in eastern and central Africa.

The Food Legume Improvement Program of ICARDA will give this priority in the future, and it will seek active cooperation with sister international agricultural research centers operating in the region to mount a research thrust that could lead to expanded introduction of cool-season food legumes in the cropping systems of eastern and central African countries.

The Oilcrops Network and IDRC Involvement in Groundnut Research

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Oilcrops Network

In Ethiopia, the availability of edible vegetable oil is estimated at only 1.3 liters per capita per year. In neighboring eastern and southern African countries, the estimates go from 0.5 to 1.0 L per capita. Faced with population increases and stagnating yield levels, many countries are forced to import increasing amounts of oil and oilseeds. The oil cake that remains as a byproduct after extraction of oil forms a potentially useful source of high-quality protein, which is presently poorly utilized in many countries in the region.

Over 90% of world oilcrop production comes from the annual oilcrops. Of these, soybean is receiving concentrated research attention from INTSOY/IITA (International Soybean Program/International Institute for Tropical Agriculture), and cotton has received strong commercial support mainly as a fiber crop. Recently, groundnuts have received increasing research support from ICRISAT. Research on sunflower and rapeseed has been concentrated in Europe and North America. The remaining annual oilcrops—safflower, sesame, *noug* (niger), linseed, and castor—have received little research support. In general, oilcrop research in developing countries has been sadly neglected, considering the importance of these crops.

In the late 1970s, the International Development Research Centre (IDRC) became increasingly involved in supporting national research programs on oilcrop improvement. Up to 1986, there is IDRC support for rapeseed, mustard, safflower, and sesame in four separate projects in India, while a project in Sri Lanka works on groundnuts and sesame improvement. In Ethiopia, two projects cover the highland and the lowland oilcrops, and projects in Sudan and Egypt each cover several oilcrops. There is support for groundnut research in Tanzania and Mozambique. Support has also been provided for the ICRISAT groundnut project in Malawi, but this support is now being phased out.

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Implementing a network was seen as the best strategy to meet the needs of oilcrop improvement, as individual projects could greatly benefit from being linked together in a network. This approach has already proved its value through the IDRC networks on cassava and farming systems. The oilcrops network project was thus implemented, with a Network Advisor stationed at Holetta Research Station in Ethiopia, beginning July 1981.

Initially, most of the Advisor's time was spent in providing advice and technical support to the Ethiopian Highland Oilcrop Improvement Project, started in April 1981, and similar support was provided to the Lowland Oilcrop Project started in November 1982. Close interaction with the national programs has been established in both projects, with the Advisor helping to plan ongoing and future research, and in training activities. In both programs, the Advisor has functioned as Plant Breeder, and has special input in the breeding of various oilcrops. The close involvement of the Network Project in the activities of the Ethiopian programs has not only strengthened the national oilcrops research, but has also given the Advisor the opportunity to be actively involved in research, to become familiar with appropriate methodologies for improving a variety of oilcrops, and to keep abreast of current developments on each crop.

Information on oilcrops is available in the form of textbooks, some relevant journals, reports, and reprints. Computer references on oilcrops are being regularly received and filed. Cover pages were distributed to research stations, and reprints of requested articles disseminated. Specific requests for literature on identified subjects were met.

After two phases of hard work, the network is beginning to achieve many of its original objectives. Contacts among scientists in the IDRC-supported oilseed projects are established through a newsletter, workshops, and exchange of visits. However, many scientists in self-supported national projects still work in remote stations, facing problems of scientific as well as psychological isolation.

Efforts so far have resulted in the production of three oilcrops newsletters. The first annual meeting of the Oilcrops Network, held in Cairo in September 1983, was attended by 25 scientists from seven national programs and, in addition, speakers were invited from Canada and the United States. A second workshop, held in India in February 1985, was attended by 38 scientists from 12 countries, with guest speakers from UK, Canada, USA and the Philippines. The first training course is scheduled to be held in January-February 1987. A third workshop was held here in Ethiopia in October 1986, and it was attended by 35 scientists from 10 countries with guest speakers from Canada, Sweden, and UK.

The Network activities are not restricted to recipients of IDRC grants. All scientists involved in annual oilcrops research throughout eastern and southern Africa and the Indian subcontinent have been invited to participate. Network participants now realize that this is their network. Young scientists from national programs have a strong voice in the workshops and the newsletter, and activities are reoriented as per participants' recommendations. Changes in activities, and in the number of crops and extent of region covered by the Network, are underway following recommendations at the Third Oilcrops Network Workshop.

Constraints to Oilcrops Research and Production

Oilcrops cannot be viewed in isolation from food production, oil being an important and necessary food item. The situation of oilseed production in the Third World is alarming. A questionnaire directed to the Network participants in Egypt, Sudan, Ethiopia, Uganda, India, Sri Lanka, and Nepal revealed that yield levels on the country average did not reach even 50% of experimental yields. Some of the major constraints to oilcrops inprovement identified by the questionnaire are:

- nonavailability of high-yielding, resistant varieties for varying agroecological zones;
- inadequate measures for transfer of technology to the farmers, with the existing extension gap;
- lack of competent researchers and trained manpower;
- lack of backup research, good sources of resistance, and lab and field facilities; and
- obstacles to germplasm exchange.

Priorities of research differed from crop to crop, and from one country to another. Priorities reported for groundnuts are:

Mozambique: breeding for aflatoxin resistance
Ethiopia: breeding for drought resistance
Egypt: on-farm testing
Egypt and Sri Lanka: germplasm availability and exchange

The IDRC Approach

Although the Network is proud of the IDRC approach in supporting oilseed research, it welcomes multidonor coordination. IDRC concentrates on research projects developed by Third World institutions that try to find their own solutions to problems. Most, if not all, IDRC-supported projects are conceived, planned, and executed by Third World scientists. They are usually cosponsored by the recipient institution's research program. IDRC may provide expert advice in research design and techniques if requested, but project recipients often consult their colleagues in other developing countries by way of research networking. Though many countries share common problems, the impact is felt differently in each country. Production solutions must be tailored to each local tradition, farming method, and access to technology and other inputs.

IDRC Involvement in Groundnut Research

More than 20 African countries now suffer from food shortages, with recurring drought conditions that have been particularly severe in eastern and southern Africa. Population growth rates over 3% are leading to increased pressures. Oilseeds and edible oil are in short supply, and most of these countries are importing edible oils at a high cost in foreign exchange. Yet, agricultural conditions in many of these countries can favor the production of oilseed crops such as groundnuts, sesame, and safflower. ICRISAT has global responsibility for groundnut improvement, and it has developed an excellent breeding program in India. For the past 5 years, a similar program has been developed in Malawi, with help from IDRC. Groundnut is an important source of protein and oil for small farmers in eastern and southern Africa. Yet, little sustained research has been devoted to this crop. Consequently, IDRC has given priority to groundnut research by supporting projects in Mozambique and Tanzania, and in northeastern Africa: in Egypt, Sudan, and Ethiopia.

The ICRISAT/IDRC program in Malawi gave a lead: it strongly complemented these activities by developing improved germplasm adapted to the region. The emphasis placed upon breeding for disease and pest resistance raised average yields: it also reduced risks associated with production in small farms that are unable to use appreciable amounts of pesticides. The objectives of that program have been fulfilled. Some of the objectives were: (a) to introduce groundnut germplasm from ICRISAT, and to test and select groundnut material adapted to different agroecological conditions of eastern and southern Africa; (b) to cooperate in strengthening the national groundnut research and development program in Malawi, Mozambique, Tanzania, Zimbabwe, and other participating countries in the region; (c) to enable these countries to carry out breeding and agronomic research and testing in research stations and farmers' fields, to increase groundnut production; and (d) most important, in conjunction with ICRISAT scientists in India and other centers and national programs, to train scientists from eastern and southern Africa. These activities have been going on for some 5 years now. The main breakthrough was the success of a rosette disease screening nursery; the genetics of resistance to rosette was found to be governed by two recessive genes, and variety RG 1 was found to be homozygous for resistance. Hybridization techniques perfected at Malawi have helped scientists in many countries.

In Mozambique, with all the uncertainties and problems in the country, a groundnut project was started in 1979 when the Government of Mozambique expressed concern about the drastic reduction in groundnut production. The project had for its specific objectives establishing a germplasm collection and selecting high-yielding, disease-resistant cultivars. Groundnut production systems in Mozambique were to be studied and Mozambican scientists to be trained. Groundnut is an important component of cropping systems in two of the four principal agroecological regions in Mozambique and, phase by phase, the objectives were achieved. Newer objectives were specified to promote strong links between the project and other crop-related research, and to strengthen national production activities, university training functions, and links with neighboring southern African countries.

In Tanzania, the project deals with pulses and groundnuts. The main objective there was to develop high-yielding varieties with early and late maturity, suited to various agroecological zones. More specific objectives were concerned with developing varieties resistant to drought, insects, and diseases. Agronomic packages were yet another objective, to help utilization by farmers in various parts of the country. The project could provide useful information for farmers in improving groundnut production. Local and exotic germplasm were collected, planted, and carefully studied.

In Sudan, the main objectives of groundnut improvement were to develop improved high-yielding cultivars in rainfed cofditions and to develop cultural practices for irrigated groundnuts. The achievements have been presented by the Sudanese participants here.

In Egypt, groundnut is mainly used for human consumption and export, and not for oil production, limiting our interest in the crop. Yet, they succeeded in developing a new variety, NA32, which matures in 120 days, 30 days earlier than the commercial variety, Giza 4. It has better pod characteristics, with about 10% higher pod yield.

In Ethiopia, where one phase of 3 years has almost elapsed for the Lowland Oilcrops Project, which includes groundnut, sesame, and safflower, groundnut adaptability tests in major groundnut-growing areas of the country have been continued, and screening methods are being developed for disease resistance, especially to leaf spot and rust. This offers hope for increased oil production with impact on local consumption, agroindustrial potential, and export potential.

Overview

One recommendation of our last oilcrops workshop held here in October 1986 was that some crops could be better handled by relevant institutions, avoiding duplication of effort. In the Network, soybean was left out as more relevant to other international organizations (INTSOY/IITA). Brassica and sunflower may be similarly phased out. With groundnuts, IDRC has been supporting the crop through projects in Egypt, Sudan, Tanzania, and Mozambique and through ICRISAT in Malawi. We have now decided that ICRISAT is in the best position to coordinate all groundnut work in Africa and Asia. This does not affect existing or forthcoming projects involving groundnuts, but emphasizes the coordination needed from ICRISAT. During visits to many of the national projects in Africa, I have found that scientists there appreciate the germplasm, breeding lines, and assistance already given to them by the ICRISAT regional program in Malawi. We can rest assured that ICRISAT will fulfill its role in developing groundnut research and production, suited to countries in eastern and southern Africa, and that such improvements will spread to other regions as well.

IITA's Grain Legume Improvement Program in Relation to Eastern and Central Africa

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IITA's grain legume improvement program has the responsibility for the improvement of cowpeas, *Vigna unguiculata,* and soybeans, *Glycine max.*

Cowpeas

Cowpeas are believed to have originated in Africa, with some studies pointing to East Africa, stretching as far north as Ethiopia, as the primary center for domestication of the species, and others concluding that West Africa is the center of domestication.

Cowpeas are cultivated mostly as a mixed crop with cereals and cotton in hot, dry regions. They are well adapted to low rainfall and tolerate drought and acid soils. Therefore, in most arid regions, it is a favored food legume at subsistence-farm level. Like other grain legumes, cowpeas fix nitrogen efficiently, up to 240 kg N ha^{-1}. They provide a high proportion of their own nitrogen requirement, besides leaving a fixed-N deposit in the soil of up to 60-70 kg ha^{-1} for the succeeding crop.

It is difficult to accurately estimate the area cultivated or production levels, due to the diverse cultivation and utilization of the crop. The best estimates for eastern Africa, based on data collected by scientists at IITA through national program scientists, are indicated in Table 1. However, there appears to be a far greater potential for cowpea in this region, due to the continuous drought situation that has prevailed in recent years.

Cowpeas are consumed as green leaves, green pods, green peas, and dry seeds. Not only are they important as a source of human food, but they are also used as fodder for cattle and as a cover crop. Dry cowpea seeds have about 24% protein and 62% soluble carbohydrates. Lysine content is relatively high, making cowpea an excellent improver of the protein quality of cereal grains. Cowpea leaves are also high in protein content. The fresh leaves contain about 5% protein, and dry leaves about 23%. The

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Table 1. Estimated cowpea production in eastern Africa.

Country	Area ('000 ha)	Production ('000 t)
Ethiopia	136	34
Uganda	150	42
Tanzania	120	30
Kenya	160	48
Sudan	60	15
Somalia	70	20
Total	696	189

leaves are rich in calcium, iron, phosphorus, zinc, β carotene, ascorbic acid, and folic acid, thus offering an excellent source of green vegetable, particularly in arid regions.

Cowpea yields, however, have remained low, with dry grain yields of traditional varieties estimated at about 250 kg ha^{-1}. However, cowpeas harvested as green pods in the humid tropics yield up to 20 t ha^{-1}, with cowpea varieties where leaves are harvested as green vegetable, giving yields that approach 30-40 t ha^{-1} or 3-4 t ha^{-1} of dry weight. Low grain yields in Africa are generally attributed to poor crop husbandry, insect pests, diseases, drought, and poor plant type. In the midaltitude ecologies, cowpeas also suffer from the effects of cold temperatures. In spite of these constraints, cowpea area has remained stable; the potential for further expansion is significant, once the pests constraint is significantly reduced.

IITA 's Research

IITA's scientists, working in close collaboration with national program scientists and with advanced institutes/universities in Europe and North America, have made significant advances in solving some of the constraints. The major thrust and emphasis within the program has been to develop cowpea genotypes that have high and stable yield potential. The cowpea lines developed so far have the following traits: multiple resistance to several diseases; resistance to one or two major insect pests; resistance to drought; tolerance of high temperature; determinate, nonphotosensitive lines with high yield potential; semideterminate and semiphotosensitive lines with high yield potential; early (60 days) and medium (75-80 days) maturing lines; grain type, harvested as dry grains; vegetable type, harvested as green pods; dual purpose, leaves harvested as green vegetable or fodder for cattle as well as dry grains; and different seed color—white, brown, black, and red—with different seed size and smooth or rough seed coat.

Each year, advanced nurseries in the form of international trials are sent to national programs, upon request, for evaluation by national scientists. Some of the lines selected from these trials are utilized in national breeding programs; others have been released or seeds are being multiplied for cultivation by farmers. Tests conducted in Kenya and Tanzania indicated that IT82D-889, a red-seeded, early-maturing line that has multiple disease resistance, is a promising line for eastern Africa. Two early-maturing lines, IT82E-16 and IT82E-32, are being multiplied for cultivation in Ethiopia. Several other cowpea lines that appear promising for Africa have also been identified.

Soybeans

Soybeans are believed to have originated in northeastern China and were first domesticated in that region around the 11th century BC. It appears they were first introduced in North Africa in the late 1800s and later spread to East Africa. It is believed that earlier efforts to grow soybeans were undertaken either by those who were interested in exporting the crop or by missionaries interested in alleviating malnutrition problems.

Soybeans are best cultivated in ecologies where maize is grown. It forms an excellent grain legume crop that can be grown in association with maize, either as a mixed crop or in rotation. It tolerates excessive moisture and drought stress better than maize. In regions where maize often suffers drought, soybean is recognized as an important alternative crop. Soybeans, as with other grain legumes, provide their own nitrogen requirements through symbiotic nitrogen-fixing bacteria, and it has frequently been observed that a cereal crop following soybeans is superior to a cereal following a cereal. For example, long-term experiments on two different soil types in Zambia have shown a 30% yield advantage for maize following soybean over maize following maize.

The production and utilization of soybeans in this region is still in its infancy. Recently, however, several countries including Kenya, Tanzania, Egypt, Sudan, Ethiopia, and Zaire have indicated keen interest in the research and development of this crop. Soybean is a protein rich crop; it contains about 40% protein. The nutritional quality of the protein is also high, since it contains a high amount of the essential amino acid, lysine.

Most cereals, which form the major part of the people's diet in many developing countries, generally lack adequate amounts of high quality protein since they are low in the essential amino acid, lysine. However, they contain relatively adequate amounts of methionine, the amino acid in which soy protein is deficient. Therefore, combining soybeans with almost any cereal results in a well-balanced diet of high quality protein.

Soybeans also contain about 20% good quality edible oil. Therefore, there is considerable potential for soybeans not only as a source of high protein food for human beings, but also for animal feed and oil. Soybean yields are high (about 1500 kg ha^{-1}) compared to other grain legumes. Soybeans are also comparatively free from insect and disease infestation.

IITA 's Research

Research on soybean was initiated at IITA during 1970, considering that it is a protein-rich crop with much potential in Africa. It can produce the highest yield of protein per unit of land area of any plant or animal food source, while at the same time producing calories. Therefore, it is the crop most likely to reduce the malnutrition problem, by reducing the protein deficiency in the shortest period.

During this early phase of research, IITA identified the major constraints preventing widespread cultivation of soybeans in tropical Africa. These were: poor seed longevity; inadequate nodulation with indigenous soil rhizobia; pod shattering; lack of improved varieties adapted to the region; and little knowledge at home or village level of soybean utilization as food.

It was recognized that seeds of most varieties did not store well under the conditions of high humidity and temperature that prevail through much of the tropics. This made soybean production extremely risky for tropical farmers, since the seeds from one season were not viable till the next. Most of the improved/introduced varieties often could not be stored for more than 3 to 6 months under ambient conditions without complete loss of seed viability.

Another major constraint to production was that most of the improved introduced varieties required incorporation of rhizobium inoculum in the soil. Without this inoculum, the plants did not nodulate sufficiently and remained yellowish, resulting in poor yields. This was due to the incapability of the soybean varieties to utilize the natural rhizobium present in the soil. Pod shattering was also common in many varieties. This problem was particularly aggravated with intermittent rainfall and hot dry conditions at the time of harvest.

IITA's research concentrated on solving these three major biological constraints to soybean production. By screening a large collection of tropical germplasm, "promiscuous" soybean cultivars were identified that nodulate freely, utilizing the natural rhizobium present in the tropical soils. Similarly genotypes were identified that were of the nonshattering type and also had good seed longevity. Through a well-organized and extensive breeding program, these traits have been incorporated in soybean lines with desirable agronomic characters. Many of these lines have already been tested by the national programs in the region and several lines appear to be promising.

A constraint to the expansion of soybean cultivation as an important nutritious food for African people has been the lack of proper technology for postharvest utilization. Even though this is well-established in Southeast Asia, there is an urgent need to develop a suitable technology at village and household levels to suit local or regional requirements. IITA, in collaboration with the International Soybean Program (INTSOY), has recently initiated a soybean utilization program, which includes the development of soybean utilization at the household and village level. Under this program, simple methods of utilization of soybeans are being developed.

Future Potential

IITA has developed cowpea and soybean genotypes that appear to be suitable in the region. However, there is a need to extensively test the material for local adaptability, disease and insect reaction, and other desirable plant characters.

There is enormous potential for cultivation of cowpeas in the arid regions and also during the short rainy seasons. Preliminary tests conducted in the region have indicated a yield potential as high as 2000 kg dry grain ha^{-1} when cowpea is cultivated as a monocrop with improved practices, involving improved varieties and insecticide protection. Similarly, several genotypes appear to be suitable for mixed or relay cropping systems. Multiple disease resistant lines, with resistance to aphids and bruchids (storage pest), form a valuable part of the improved germplasm (Tables 2 & 3).

Table 2. Cowpea lines with multiple resistance to diseases[1] and to cowpea aphid.

Variety	Seed color	Maturity	Mean yield ($kg\ ha^{-1}$)
IT81D-1020[2]	Red	Medium	1300
IT82D-812	Red	Medium	1500
IT83S-720-2	Red	Medium	1000
IT83S-725-18	Red	Medium	1300
IT83S-742-11	White	Medium	1200
IT83S-872	Red	Medium	1400
IT84E-1-108	White	Early	1400
IT84S-2246-4[2]	Brown	Early	1500

1. Bacterial pustule, bacterial blight, anthracnose, cowpea aphid-borne mosaic virus, cowpea yellow mosaic virus, brown blotch, septoria, web blight, scab, and cercospora.
2. Also resistant to bruchids.

Table 3. Cowpea lines with multiple resistance to diseases[1] and to cowpea bruchid.

Variety	Seed color	Maturity	Mean yield (kg ha-')
IT81D-994	White	Medium	1500
IT81D-1007	Red	Medium	1400
IT81D-1020[2]	Red	Medium	1300
IT81D-1137	White	Medium	1400
IT82D-453-2	Brown	Early	1500
IT82D-504-4	Red	Medium	1300
IT82D-716	Cream	Medium	1300
IT84D-460	Brown	Early	1400
IT84S-2246-4[2]	Brown	Early	1500

1. Bacterial pustule, bacterial blight, anthracnose, cowpea aphid-borne mosaic virus, cowpea yellow mosaic virus, brown blotch, septoria, web blight, scab, and cercospora.
2. Also resistant to aphids.

Most countries in the region have large dry arid regions and, in addition, several countries have experienced drought for extended periods. In severely affected areas, there appears to be a widespread malnutrition problem and unless some long-term measures are undertaken to enhance the cultivation of drought-resistant crops, this problem will continue. Cowpea, as a protein-rich crop and one of the most drought-resistant grain legumes, has a definite advantage over other crops. Its value is even greater when flexibility of utilization and consumption are considered: leaves, green pods, green peas, and dry grains. The early availability of green leaves following the long dry season, and the utilization of dry leaves which are stored and consumed during the off-season, are of critical importance. Several countries in the region have indicated keen interest in the development of this crop, especially for hot dry regions. Soybean, though still not well established, has a great potential as a source of animal feed and edible oil. Almost all the countries in the region, where animal feed is important and there is a deficit in edible oil, have indicated keen interest in the development of this crop. At a 1985 symposium on soybean for eastern Africa, held at Nairobi, Kenya, it was concluded that:

- The soil and climatic conditions in East Africa are conducive for growing soybeans.
- Soybean is a comparatively low-cost crop in terms of inputs, when compared to other edible oilseed crops grown in these countries.
- It will not only help countries to make up edible oil deficits, but will go a long way in alleviating protein deficiency.
- Livestock is an integral part of the farming systems in most of the eastern African countries, and the protein-rich soybean meal can be used in the livestock feeding industry.

Soybean lines developed at IITA appear to be suitable near the equator (10°N or 10°S). They can be grown from sea level to an altitude of 1600 m. However, there is a need to extensively evaluate the material and to identify lines suitable for the different ecologies and cropping systems.

There is a great potential to develop this crop as a major nutritious food for people in regions where population continues to grow at very high rates. Therefore, a strong case exists to initiate and support research on soybean utilization in the region to meet the needs of the people. Unless well-planned research is undertaken for utilization of soybeans at the household and village levels, it will remain a commercial crop used mainly as a source of edible oil and animal feed and its undoubted advantages in human nutrition may not be fully realized. Soybean products, such as soy milk and weaning foods, are already in great demand in several countries in Africa.

In conclusion, cowpeas and soybeans are primarily grown in different ecologies, and they complement each other as grain legume crops. Cowpeas are traditionally cultivated in marginal soils in diverse ecologies in association with millets and sorghum, and these can be cultivated with maize and cotton. Soybeans are best suited as an alternative crop to maize, but can be grown with sorghum and cotton. IITA's effort continues to develop stable, high-yielding lines suitable for the different ecologies and cropping systems, with the principal aim of improving the income and nutrition of farm families. The most recently developed cowpea varieties are more suitable and adapted to the needs of small-scale farmers. Similarly, soybean lines with free nodulation and good seed longevity also show promise for small farm cultivation.

Nutritive Value of Crop Residue and Byproducts of Groundnuts

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The major crops in agropastoralist farming systems in Africa can supply important feed resources in the form of crop residues and agroindustrial byproducts. This is well recognized for cereals, but it is also true for the grain legumes, groundnuts and cowpeas, in West Africa. However, the importance of crop residues and byproducts as livestock feed has been ignored in programs for improving crop production. Crop breeding can have a tremendous impact on the quantity and nutritive value of crop residues produced, and it may also influence the nutritive value of byproducts. This paper discusses the nutritive value of the crop residue and byproducts from groundnuts, in relation to the potential influence that crop improvement programs could have on improving their utilization by livestock.

The Crop Residue from Groundnut

The nutritive value of the crop residue from groundnut is highly variable. In West Africa, it is referred to as hay, which implies a higher nutritive value than other available feed resources. Analyses presented in Table 1 indicate that both leaf and stem fractions are above maintenance levels in crude protein and digestibility. This sample came from Gambia, where groundnut hay is fed on farm to N'dama oxen or sold to traders who use it to fatten sheep for sale during religious festivals. The leaves contain a low level of neutral-detergent fiber, which would allow a high level of intake.

However, other studies have reported a lower nutritive value of groundnut straw or haulms. The crop residue in these reports had crude protein contents of approximately 9%, although goats were able to eat over 3% of their body weight. The variation in nutritive value could be related to method of harvest, amount of leaf shatter, and the vegetative characteristics of the variety grown. The amount of crude protein and fiber reported for the straw are similar to the stem fraction reported in Table 1. Leaf loss may have occurred before and during harvest, or the varieties used may have had a low leaf-to-stem ratio.

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Table 1. Nutritional composition and *in vitro* apparent digestibility of the leaves and stems from the crop residue of groundnuts.

Component	Leaves	Stems
Crude Protein (% DM)[1]	14.6	10.8
Neutral-detergent fiber (% DM)	36.7	49.7
Acid-detergent fiber (% DM)	31.1	44.2
Lignin (% DM)	8.3	9.5
Silica (% DM)	11.0	0.7
Soluble phenolics (% DM)	23.8	28.2
Insoluble proanthocyanidins (A_{550})[2]	0.274	0.234
In vitro digestibility (% DM)	58.7	52.9

1. DM = Dry matter.
2. Absorbance at 550 nm.

The leaves and stems also contain a moderate amount of polyphenolic compounds (lignin, insoluble proanthocyanidins, and soluble phenolics: Table 1). The high amount of lignin in leaves is characteristic of plants containing proanthocyanidins and may explain the low digestibility of the fiber in high quality groundnut hay. Polyphenolic compounds lower protein digestibility, but the effects of tannins on protein utilization in ruminants can also be positive.

More research is needed on factors affecting the nutritive value of the crop residue, such as harvest and storage methods, varietal differences, and the influence of crop breeding. This research should be linked with laboratory determination of nutritive value and feeding trials, with the objective of developing improved animal production systems through better utilization of the crop residue.

Agroindustrial Byproducts from Groundnuts

Groundnut cake is the most important byproduct of the oil extraction industry. Other byproducts such as hulls, dust, and skins (testa) have also been used to feed livestock.

Groundnut cake is high in crude protein and digestibility, and low in fiber content, compared to other oilseed cakes such as cottonseed and niger seed *(Guizotia abyssinica)* (Table 2). This composition makes groundnut cake a better protein supplement for simple-stomach livestock, especially poultry. Niger seed and cottonseed are usually not dehulled before oil extraction. Therefore, they contain relatively high levels of lignified fiber, which lowers digestibility.

The greatest constraint to the utilization of groundnut cake is the presence of aflatoxins produced by the fungi, *Aspergillus flavus* and *A. parasiticus.* These fungi grow on groundnuts both before and after harvest. Conditions in many groundnut-producing countries in Africa and elsewhere favor the growth of these fungi. Aflatoxins are potent hepatocarcinogens and also cause liver necrosis, depressed immunity and resistance to disease, and death when present in toxic levels. At subclinical levels, aflatoxins depress growth rate, feed efficiency, and overall productivity. An outbreak of Turkey X disease in Great Britain in 1960 was caused by feeding contaminated groundnut cake and led to the discovery of aflatoxins. However, aflatoxins have now been found in several other livestock feeds including maize, cottonseed meal, and copra meal. All samples of groundnuts and groundnut pellets from edible oil plants in Nigeria were found contaminated with aflatoxins. All samples of groundnut meal (n = 14) imported into Poland were also contaminated.

The magnitude of the problem of aflatoxins in groundnuts should not be underestimated, because the cake is an important export in many countries and could also replace imported feeds for poultry and swine. The development of *Aspergillus*-resistant varieties would help solve the aflatoxin problem. Polyphenolic compounds, such as flavanoids and tannins, are known to inhibit fungi, and these compounds are present in mold-resistant cultivars of sorghum. The testa of some groundnut varieties are also rich in these compounds, as discussed below. The interaction between varietal differences in susceptibility to *Aspergillus flavus* and the content and types of polyphenols compounds present needs to be determined in relation to the utilization of groundnuts as food for humans and livestock.

Groundnut hulls have a high content of neutral-detergent fiber and lignin and a low digestibility (Table 3). They are useless as livestock feed, except possibly as a roughage addition to feedlot diets at a level below 10% of the ration. Incremental additions of hulls to rations for swine caused a linear increase in feed intake, which allowed for no change in average daily gain but caused a linear decrease in feed efficiency. NaOH treatment of groundnut hulls decreased neutral-detergent fiber and increased *in vitro* digestibility, but it had no effect on nutrient utilization by lambs fed treated hulls compared to untreated hulls. The best use of the hulls is as a fuel at or near the oil-extraction plant, or as a source of fiber for pulping.

The composition of groundnut dust indicates that the fiber fraction is indigestible (Table 3). This fraction may originate from the hulls. However, the crude protein content is 3 times that of the hulls. The high crude protein content may derive from the testa and nuts cracked during the dehulling process. The dust would make a good protein supplement for ruminants fed for moderate levels of production.

Table 2. Nutritional composition and *in vitro* digestibility of groundnut cake, cottonseed cake, and niger-seed cake.

Component	Groundnut cake	Cottonseed cake	Niger-seed cake
Crude Protein (% DM)[1]	55.9	22.9	28.9
Neutral-detergent fiber (% DM)	18.6	49.2	39.5
Acid-detergent fiber (% DM)	11.7	38.6	31.5
Lignin (% DM)	2.9	10.2	13.8
Soluble phenolics (% DM)	28.7	-	-
Insoluble proanthocyanidins (A_{550})[2]	0.107	-	-
In vitro digestibility (% DM)	74.1	54.3	55.5

1. DM = Dry matter.
2. Absorbance at 550 nm.

Table 3. Nutritional composition and *in vitro* digestibility of groundnut hulls, dust, and skins (testa).

Component	Groundnut hulls	Groundnut dust	Groundnut skins
Crude Protein (% DM)[1]	6.7	18.9	19.0
Neutral-detergent fiber (% DM)	78.8	45.6	33.1
Acid-detergent fiber (% DM)	73.1	40.1	25.0
Lignin (% DM)	31.4	17.8	6.4
Soluble phenolics (% DM)	12.7	27.6	44.6
Insoluble proanthocyanidins (A_{550})[2]	0.020	0.094	0.483
In vitro digestibility (% DM)	9.6	47.8	53.2

1. DM = Dry matter.
2. Absorbance at 550 nm.

Although groundnut skins (testa) have a relatively high crude protein content, they also contain high levels of tannins and other polyphenolic compounds (Table 3). Inclusion of skins in diets for swine and cattle depressed protein digestibility, nitrogen retention, and average daily gain. Increasing the crude protein content of the diet with soybean meal or urea have been shown to overcome the detrimental effects on growth of feedlot steers fed diets containing skins. The most important aspect of polyphenolic compounds in the skins is the possibility that they inhibit the growth of *Aspergillus flavus*. While this possibility has reportedly been studied, references on the research are not readily available.

Conclusion

The importance of animal nutrition in improving the utilization of groundnuts is thus apparent. The crop residue can be a valuable feed resource as already realized in Gambia, Senegal, and other parts of West Africa. Improvements in yield and nutritive value could be gained through better agronomic practices and the use of dual-purpose varieties. The problem of aflatoxins in groundnut cake needs to be solved, in order to improve the utilization of this important agroindustrial byproduct.

Multiple Uses of Pigeonpea

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Grain as Human Food

Pigeonpea is primarily grown for its grain as human food—usually as a pulse, but also as a green vegetable. The grain contains about 20% crude protein, with an excellent balance of essential amino acids. Pigeonpea grain yield has been reported to be as low as 162 kg ha^{-1} in Uganda under intercropping with maize and sorghum, and as high as 5000 kg ha^{-1} as a monoculture in Queensland, Australia. The average pigeonpea grain yield in Kenya is estimated at about 1000 kg ha^{-1} when intercropped with maize or sorghum.

Grain as a Source of Protein in Livestock Feeds

Although the major market for good quality pigeonpea grain is for human food, byproducts of split pigeonpea *(dhal)* and shrivelled grain go for livestock feed. The present high cost of animal sources of protein feeds, such as fish and bonemeal, makes it likely that high quality plant proteins will be increasingly utilized because they are many times cheaper.

Pigeonpea Grain in Poultry Nutrition

There are several reports in the literature on feeding various rations of pigeonpea to poultry. Inclusion of up to 30% pigeonpea in meals increased the growth rate of chickens above the basal growth rate obtained when soybean and maize were the only sources of protein. However, growth was depressed where higher levels were used and this has been ascribed to inadequate levels of typtophan, phenylalanine, and cystine amino acids. But the reports conclude that pigeonpea is a highly acceptable protein source for all classes of poultry.

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Pigeonpea Grain in Pig Nutrition

There are few studies reporting the use of pigeonpea grain as a protein source in pig rations. But pigeonpea seed, comprising about 63% of the dry-matter (DM) intake, has been used for this purpose with chopped banana stalk and rice bran in Thailand. Results showed that boiled pigeonpea, when added to the ration, increased the liveweight gain by 596% when compared to the basal feed, and 35% when compared to the commercial feed.

Pigeonpea as Forage

Pigeonpea provides an excellent forage to livestock. Yield of forage depends on growing conditions, including soil fertility, variety planted, and cutting frequency. Forage yields of pigeonpea have varied from 2200 kg ha^{-1} in Trinidad to 57 600 kg ha^{-1} in Colombia. Actual yields of edible forage must be estimated, since stem content can be as high as 50% of the DM yield.

Pigeonpea forage has a high percentage of crude protein (CP). This changes with the age of the crop, with the protein content higher when the crop is young. At Maseno in Western Kenya, a cutting frequency trial was conducted on two pigeonpea spacings. Cutting treatments were after 2, 3,4,5, and 6 months from planting. CP yields per unit area of land were then calculated for the various cutting stages. CP in pigeonpea forage was highest (28%) in the 2-month cutting and lowest (14%) after harvesting dry pods. The highest yield (over 1000 kg ha^{-1}) was obtained at the 6-month cutting, with a spacing of 61 $\times$ 31 cm.

In another cutting frequency experiment at Maseno, comparing the forage productivity of pigeonpea, sesbania, and leucaena to a single crop of maize stover, all the crops were planted at 90 x 30 cm. The legumes were cut at a height of 60 cm from the ground every 2 months. Three cuttings were done by the time the maize crop was harvested. Sesbania, with a DM yield of 7529 kg ha^{-1}, significantly ($P = 0.05$) out-yielded maize and pigeonpea, whose yields were 2769 and 3118 kg ha^{-1}, respectively. There was, however, no significant ($P = 0.05$) difference between sesbania and leucaena, or between leucaena, pigeonpea, and maize. The same trend was true for CP.

The data showed that only sesbania was clearly superior in forage DM and CP yields, while leucaena and pigeonpea were about the same. Pigeonpea establishes faster and is more drought resistant than leucaena initially, and its forage does not contain any known toxic substances like the mimosine in leucaena; therefore, its potential as a forage is certainly higher than that of leucaena.

Sixty pigeonpea forage samples from western Kenya were collected and analyzed over 3 years for their ash, CP, neutral-detergent fiber (NDF), and acid-detergent fiber (ADF) contents. Some cultivars showed significant differences ($P = 0.05$) in these characters. Significant differences are also probable in other nutritional characteristics, like digestibility and palatability. While the observed quality differences must have been strongly influenced by both the plants' phenology and the environment, genotypic differences must have also been a major factor. Because of this possibility, an experiment was set up in 1984 to test several pigeonpea genotypes for their agronomic, forage yield, and quality differences.

Table 1. Means of some nutritional qualities of the five pigeonpea cultivars yielding highest crude protein (CP) from a 35-entry trial at Maseno, western Kenya.

Accession	%Ash	%CP	%NDF[1]	% ADF[2]
NPP[3] 688/5	6.76	28.94	27.88	28.84
NPP 673/2	7.11	27.25	47.30	42.58
NPP 675/3	6.89	26.72	49.71	32.89
NPP 695/1	6.51	26.69	51.84	30.04
NPP 707/2	5.83	26.47	41.63	32.98
Mean of 5 cvs	6.62	27.21	45.67	33.47
Mean of 35 cvs	6.80	24.12	46.14	36.40
Range of 35 cvs	5.14-8.51	19.51-28.94	37.88-56.10	28.07-51.00

1. NDF = Neutral-detergent fiber.
2. ADF = Acid-detergent fiber.
3. NPP = Nairobi pigeonpea.

In this trial, 35 accessions from the largest pigeonpea germplasm bank in Kenya at the University of Nairobi were screened in a replicated trial. Table 1 shows the performance of the five cultivars that had the highest CP contents, with their ash, NDF, and ADF contents also shown.

Pigeonpea has an excellent forage potential, and there is a tremendous scope for selecting cultivars with not only higher grain yields but also higher forage yields and CP. National and international germplasm banks should include in their descriptor lists forage quality aspects of crops. This would be a great advantage to small-scale farmers, who not only grow food crops but also keep some type of livestock, often raised on a diet deficient in protein.

In the African countries where pigeonpea is grown on a large scale (such as Kenya, Uganda, Tanzania, and Malawi), once the pods have been harvested, livestock rush into the fields and strip off all the foliage and young twigs as forage. Goats and sheep also pick up leaf litter from the ground. Although this forage is rich in protein and it benefits the livestock a great deal, the large quantities of biomass left over in the fields after harvesting are eaten away within a day or two by large herds and flocks from the neighborhood. It is, therefore, important to find a way of preserving the valuable feed and releasing it slowly to the livestock as a protein supplement, especially during periods of shortage.

Pigeonpea haymaking has been studied in Maseno, Kenya. One approach was to preserve surplus pigeonpea forage from fence-rows and fields, while another was to preserve the leftover forage after harvesting pods. In both cases, stems are cut and left in the field for two sunny days. Dry leaves then shatter from the stem. These are shaken off the stems, gathered, and stored in bags. The quality of several hays from grasses and three forage legumes—sesbania, leucaena and pigeonpea—were compared after 6 months (Table 2). The CP levels of sesbania and pigeonpea increased above those of fresh forages, while that of leucaena decreased. While reasons for such increases are not clear, it was obvious that pigeonpea and sesbania hays retained good qualities. At CP levels above 30%, these legume hays become protein concentrates that can play an important role as protein supplements in livestock nutrition.

Table 2. Crude protein (CP) contents of forages and their hays.

Species	% CP in fresh forage	% CP in 6-month old hay	% Change in CP content
Sudan grass	13.8	13.4	- 2.9
Bana grass	14.4	16.0	+ 11.1
Mixed grasses	10.3	9.4	- 9.7
Leucaena	26.6	19.3	-27.4
Pigeonpea	28.2	36.7	+ 30.1
Sesbania	26.9	36.0	+ 33.8

As far back as 1920, pigeonpea was grown in Hawaii for beef fattening. Carrying capacities of good stands of pigeonpea varied from 1.2 to 3.7 head ha^{-1}, with average stocking rate of 25 animals ha^{-1} a^{-1}. Average daily gains were from 0.7 to 1.25 kg ha^{-1} day^{-1}, resulting in live weight gains of 1120 kg ha^{-1} a^{-1}. These results indicate that pigeonpea has a high nutritive value as reflected in high levels of gains head^{-1} day^{-1}, while the high production demonstrates this legume's steady production of DM throughout the year.

In another study conducted in Hawaii, where pigeonpea was utilized as a standover forage for the dry season in two major trials, the performance of beef cattle on pigeonpea was compared to that on mixed grass pasture. Here again, pigeonpea was much superior to good quality mixed grasses; in one experiment, the live weight gain from pigeonpea was 248 kg ha^{-1} against 140 kg ha^{-1} from mixed grasses, in another 280 kg ha^{-1} against 181 kg ha^{-1}. Similar results have been reported in Australia, Zimbabwe, and Brazil.

Experiments at Maseno in Western Kenya with pigeonpea as a source of protein for dual-purpose goats (meat and milk) owned by small-scale farmers again showed that pigeonpea is a versatile crop. It can be planted in pure stands, intercropped, or alley cropped with a wide range of food and cash crops, as fence rows, and even as volunteer wild plants. In all these conditions, pigeonpea yields both human food and forage. Other experiments at Maseno, using pigeonpea as part of a weaner feed for goat kids, have shown that kids can be successfully weaned at 30 days instead of 60-70 days of age, increasing milk available for the family. Kids weaned on pigeonpea or sweet potato vines show no retarded growth.

The potential role of pigeonpea as a high-value forage can be extensively exploited in the 19 countries of Africa where this crop is grown on a large scale. This is particularly relevant in arid and semi-arid countries, where a feed shortage coupled with low quality herbage is widespread.

Use of Crop Residues

Pod shells. The DM yield of pod shells is approximately equal to that of grain. However, its nutritive value to livestock is limited due to low CP and high fiber contents. Sheep and goats readily consume pod shells; however, these should be supplemented with high protein sources like pigeonpea hay or forage.

Harvest trash. From a harvested pigeonpea field, harvest trash made up of unfilled pods, leaves, and young twigs still contains 10-25% seed and can weigh, on DM basis, up to 20 t ha^{-1}. The mean CP content of such harvest trash is estimated at 13.0%.

Uses of Pigeonpea Stem

Pigeonpea stems have a variety of uses after pods have been harvested. In the pigeonpea-growing districts of Machakos and Kitui in eastern Kenya, farmers were seen to gather between 5 to 20 t ha"[1] of dry pigeonpea stems after harvesting pods. They often utilized it as fuelwood in the energy-short villages. Stems are also utilized for fencing crop fields, and in weaving cribs and baskets. Tall, perennial pigeonpeas are often also used as live fences in Africa and the Caribbean.

Nitrogen Fixation and Soil Fertility

Although pigeonpea usually produces fewer nodules than legumes such as cowpea (*Vigna unguiculata),* it produces more nitrogen from plant biomass per unit area of land than many other legumes. Pigeonpea has been used as a green manure crop in sugarcane, banana, and pineapple plantations and in crop rotations. In Zimbabawe, pigeonpea green manure significantly boosted yields of a following maize crop.

Cutting frequency trials at Maseno have shown that by cutting at 2-month intervals three times (6 months from planting), the cumulative nitrogen yields can be substantial. Converting the amount of atmospheric nitrogen fixed by the legumes into its commercial nitrogen equivalent, e.g., urea (46% N), pigeonpea fixed equivalents of 146 kg urea ha^{-1}, leucaena 308 kg urea ha"[1], and sesbania 470 kg urea ha^{-1} within 6 months from planting.

These legumes thus fix and return to the soil as green manure adequate amounts of nitrogen for general crop production. Moreover, the plant biomass returned to the soil other essential micronutrients such as Mg, Mn, Co, Mo, and organic carbon, making their fertilizer values far superior to that of an inorganic source of nitrogen, such as urea. The soil fertility improvement potential of pigeonpea as a food crop certainly outweighs the better nitrogen-fixing performance from leucaena and sesbania, which are nonfood crops. This role makes pigeonpea a valuable crop to the millions of poor peasant farmers in Africa and Asia, who cannot afford the exorbitant cost of inorganic fertilizers.

Conclusions

In Africa, pigeonpea is primarily grown in arid and semi-arid tropics by peasant farmers who grow it mainly for human food as a pulse or as a green vegetable. The little research that has been done on this crop has been mainly for improving its grain yields by reducing losses from weeds, pests, and diseases, selecting for higher-yielding genotypes, and improving general crop agronomy. However, the other potential uses of pigeonpea, as livestock feed and forage, have barely been realized. The tremendous genetic diversity that exists in this crop in forage yields and its various qualities, such as CP, should be screened for, along with grain yields, in all national and international centers that collect and screen pigeonpea germplasm. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), which has the global mandate for this crop, should consider including forage yields and other related qualities in their descriptor lists for each pigeonpea entry in their germplasm bank. This information would be very useful to the poor farmers in African and Asian countries where new improved pigeonpea varieties would be most useful if they were high-yielding in both foodgrain and good-quality forage for livestock.

Attention should also be given to more integrated and complete utilization of pigeonpea as a good source of nitrogen for the farmers' land, which is nitrogen deficient, and to the many uses of its stems.

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