HIGHLIGHTS OF GRAIN LEGUME IMPROVEMENT AT IITA 1970-73

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I. PROGRAM DEVELOPMENT

The improvement of grain legumes was included in the mandate of the International Institute of Tropical Agriculture from the outset of its establishment in July 1967. However, the Nigerian civil war, construction of research facilities and recruitment of scientists delayed initiation of experimental projects until late 1969. Although several scientists began research programs on grain legumes in 1969, the formation of a team of scientists in the program as presently structured did not occur until mid-1971.

The earliest work on grain legumes at the Institute was developed by the following scientists: W.K. Whitney (entomology), F.E. Caveness (nematology), R.J. Williams (plant pathology) and B.T. Kang (soil fertility). Dr. Royce P. Murphy, visiting Professor from Cornell in 1970, assembled a vast array of germplasm and initiated testing of elite genetic stocks in several species. During 1970 investigations were launched by S. Sadik on physiological problems, K. Moody in weed agronomy and R. Lal on interrelationships of legumes with soil physical problems. Although Drs. Caveness, Kang, Moody and Lal are members of the Farming Systems Program, they are continuing their activities on grain legumes as a part of their broader interests on crops/soils interrelationships. Other members of the Farming Systems who have contributed grain legume investigations during the past year include A. Ayanaba, on the rhizobial nitrogen fixing processes and F.R. Moormann on responses of cowpeas and soybeans in hydromorphic soils. Breeding activities were passed on to me early in January 1971 by Prof. Murphy on completion of his assignment. It was possible to take over by commuting from Makerere University during the first half of the year and with assistance from P.N. Mehta and M.A. Akinpelu.

Organizing IITA research activities into four major programs coincided with the appointment in August 1971 of Dr. J.L. Nickel as Associate Director. The Grain Legumes Improvement Program (GLIP) as presently structured has seven senior scientific posts, six of which have been filled. GLIP started with a breeder, an entomologist and a pathologist, with the last two also taking responsibilities for problems in the cereals and tubers programs. Recruitment in agronomy, biochemistry and physiology was started in 1971. Dr. H.C. Wien (physiology) joined GLIP in mid-July 1972 and Dr. D. Nangju (agronomy) arrived about a month later. Dr. R.A. Luse (biochemistry) was appointed late in 1972 and came to IITA in March 1973. Dr. S.R. Singh replaced W.K. Whitney as entomologist in October 1973. During the next two years we hope to add a geneticist and microbiologist, the latter to further develop investigations on the symbiotic rhizobial processes.

Several visiting scientists, post-doctoral fellows and graduate students have made or are making important contributions to GLIP. They include the following:

1. Dr. L.H. Camacho (ICA, Palmira, Colombia) - soybean breeding and management (June 1972 - June 1973).

2. Prof. W.H.F. Plarre (University of West Berlin) - Soybean breeding and management (July 1973 - June 1974).

3. Prof. R.M. Gilmer (Cornell University, Geneva, New York) - legume viruses (from late 1972, on a part time basis in connection with his assignment at University of Ibadan).

4. Dr. W.M. Porter (Post-Doctoral Fellow, Rockefeller Foundation) - Vigna breeding and genetics (from September 1972).

5. Dr. K. Rawal (formerly Geneticist and Assistant Lecturer with the University of Ibadan) - Botany and field collection of grain legumes and tuber crops in Africa (from September 1973)

6. Dr. J.D. Franckowiak (formerly Geneticist with the University of Wisconsin USAID contract with University of Ife) - cowpea breeding and genetics (August - December 1973).

7. Dr. J. Littleton (Research Fellow, University of Reading) and Mr. J.R. Knight (Instrument technician) - instrumentation for monitoring CO_2 exchange and assimilate transfer in field and greenhouse experiments,

8. Dr. J.O. Akinola (IAR, Samaru, Nigeria) - management and breeding of miscellaneous legumes (April - August 1973).

Collaboration has been established between IITA and several renowned British institutions, supported by the Overseas Development Agency. This arrangement has proved extraordinary successful in bringing the facilities and expertise of the following institutions to bear on several basic problems.

University of Reading. Extensive physiological investigations are being carried out, principally on cowpeas and soybeans, in the growth chambers and greenhouses of the Horticultural Department. This project, initiated in late 1970 is led by Prof. P.A. Huxley and Dr. R.J. Summerfield (and formerly included the late Dr. A.P. Hughes). It has contributed a vast amount of information on the responses of tropical legumes to light and temperature. Present activities continue in this area and have been expanded to include investigations on nitrogen metabolism and moisture relationships.

Universities of Reading and Nottingham. A research project to monitor CO_2 gas exchange and assimilate transfer in grain legumes and other tropical crops has been developed with the University of Reading (Dr. J. Elston). Dr. E.J. Littleton (physiologist) and Mr. R. Knight (Instrumentation) from Nottingham are in residence at IITA, setting up equipment for collecting data.

University of Durham. The protein quality of grain legumes, particularly cowpeas, have been studied by Prof. D. Boulter and co-workers. Experiments have been designed to find more efficient methods of screening for protein and the S-bearing amino acids methionine and cystine. Considerable information on the nutritive value of cowpeas, yam beans and other species have been obtained through biochemical analysis at Durham and by animal feeding trials done at the University of Newcastle.

Rothamsted Experimental Station. Environmental conditions affecting symbiotic nitrogen fixing processes in tropical legumes is the goal in experiments carried out by Dr. P.J. Dart and colleagues.

Wye College. The role of phytoalexins in protecting tropical legumes is being investigated by Drs. N.W. Preston and R.A. Skipp of the ARC - Plant Growth Substance and Systemic Fungicide Unit.

University of Cambridge. Investigations on evolution in *Vigna* species have been started by Dr. Alice M. Evans in the Department of Applied Biology. Prof. K.J. Carpenter has included Vignas and winged beans in his studies on protein and nutritive values of tropical foodstuffs.

Collaborative experiments and testing of germplasm have been developed with several Nigerian institutions. These include:

University of Ibadan. Collecting germplasm, cooperating on field experiments, exchanging information, supplying plant materials and germplasm and participating in joint seminars are some of the ways IITA and the University of Ibadan interact together. Principals in this collaboration include Dean A.A. Fayemi, Prof. T.A. Taylor (entomologist), Dr. H.R. Chheda (geneticist) and Mr. A.U. Patel (extension).

FDAR - Moor Plantation. Cooperation at the Federal Department of Agricultural Research involves exchange of germplasm, phytosanitary surveillance, testing of germplasm and experimentation in pathological and entomological problems. Cooperating scientists include Drs. U.U. Ebong (plant breeding), S. K. Ogundana (pathologist), D. A. Okusanya (pathologist), K. Ayoade (entomologist), S.O. Dina (entomologist) and M.L. Jerath (entomologist).

University of Ife. Particularly close cooperation has been developed at the University of Ife with members of the University of Wisconsin/USAID team and with other scientists stationed at Moor Plantation including Drs. A.O. Ojomo (breeder), S.A. Shoyinka (virologist), and P.O. Oyekan (pathologist).

IAR - Samaru and Kano. Exchange and testing of germplasm in cooperation with Prof. W.W. Worzella (in 1971) and Dr. O. Leleji have been major activities. Dr. O. Raheja has also contributed valuable information and advice on pest control in grain legumes.

IAR - Umuahia. Testing of elite germplasm of cowpeas and soybean has been the major collaborative activity here, in cooperation with Dr. L.S.O. Ene and Mr. F.M.O. Agbo.

Collaboration with U.S. institutions can also be important to IITA. Through the INTSOY (International Soybean Improvement Program) at the University of Illinois, several scientists have rendered invaluable assistance in developing soybean improvement technology at IITA. Equally important has been the help of Dr. E.E. Hartwig of the USDA-CRD at Stoneville, Mississippi. The USDA Federal Experiment Station and UPR College of Agriculture located at Mayaguez, Puerto

Rico are on a particularly advantageous position to study pest and disease problems of grain legumes in the Western Hemisphere. A double screening for disease and pest resistance could be accomplished through their collaboration.

The need to test germplasm and to conduct experiments in cultural practices and plant protection over a wide range of environmental conditions cannot be over-emphasized. Institutions in several countries have participated in this type of collaboration. Extensive testing has been carried out in Tanzania and Ghana. Yield trials of both cowpeas and soybeans have been widely distributed throughout tropical Africa, the Middle East, southern Asia and the Western Hemisphere.

II. PROGRAM HIGHLIGHTS

Grain legume improvement at IITA has only begun. We are still formulating strategy and policies, allocating resources and determining the scope of our activities. Only three out of the six subprograms have completed two full years of experimentation. Agronomy and physiology are beginning their second year and biochemistry has been activated for less than eight months. Nevertheless, within this short period we can count some substantial accomplishments, the most important of these are mentioned briefly here and will be discussed in more detail by the scientists involved.

The first achievement made by GLIP staff has been to gain experience in growing grain legumes at Ibadan. Although we are beginning to learn about a few species at IITA, we know very little of their performance in other environments. Most of us are amazed by the number and complexity of problems affecting grain legumes, especially indigenous species like cowpeas, in this region. This situation is partly offset by the discovery that we can do field experiments three seasons a year and thus can advance breeding materials by 4-5 generations for cowpeas and 2-3 generations for soybeans, lima beans and short duration pigeon peas within a 12-month period. Moreover, we are crossing continuously in the greenhouse.

1. Assembling and Evaluating Germplasm

Germplasm has accumulated at an increasingly rapid rate since starting a collecting project in West Africa. At present we have the following collections of legumes:

Crops	Accessions
Cowpeas	4579
Pigeon peas	1625
Soybeans	598
Lima beans	250
Asian grams	115
Yam beans	59
Mucuna beans	73
Bambarra groundnuts	45
Winged beans	9
Jack beans	5
Other species (8)	42
Total	7400

Major emphasis has been given to evaluating and cataloguing the botanical characters of cowpeas. Twenty-one important plant and seed characters have been recorded in up to five nurseries(different years and seasons) at IITA. These include separate plantings to assess pest and disease reaction where the developing plants are artificially inoculated or infested with specific disease and pest organisms or managed in such a way as to maximize attack of pests.

Soybeans. The soybean germplasm has been evaluated and catalogued in a manner similar to that of cowpeas, but with fewer parameters and seasons.

Pigeon peas. A representative nursery of 424 established at Makerere University was grown out during the second season 1971 and evaluated for 11 characters. This data will be combined with similar information from nursery growouts in East Africa for definitive studies on genotype-environment interactions.

Lima beans. The collection of 221 lima beans was evaluated for 13 characters during the second season 1972 and again in the second season 1973. Since this assessment included preliminary (but unreplicated) yield estimates, it was possible to select 14 trellis types and six bush limas for more intensive evaluation in replicated yield trials.

Asian grams. The collection of mung beans was evaluated in 1971 and 1972 and catalogued for 15 characters including a preliminary yield estimate. From these performance records 12 entries were selected for testing in replicated yield trials in the second season 1972 and both seasons in 1973.

Other species. Observation nurseries of several other species have been grown out at IITA. These have included phaseolus beans (*Ph. vulgaris*), winged beans, bambarra groundnuts, hyacinth beans, rice bean, jack beans, African yam beans, Mexican yam bean, mucuna beans and other species. In the present season 63 yam beans (*Sph. stenocarpa*) and 33 mucuna beans are in observation trials and growing on trellises.

2. Cowpea Breeding

Major activities on cowpea improvement can be grouped under selection, recombination and testing. This is a team effort involving participation by all disciplines.

Selection. The selection of genetic stocks for testing and as parents for recombination has been a major activity. It also involves extensive screening for reaction to pests, diseases and a range of environmental conditions. Artificial inoculation of disease or pest organisms is becoming more prominent in this activity. Intensive searches have been made for the following characters:

1. Disease resistance: anthracnose, cercospora leaf spots, bacterial pustule, viruses and root knot nematodes.

2. Resistance to pests: thrips, leaf hoppers, foliage feeders and pod borers.

3. Broad adaptation and relative insensitivity to variations in day-length, light quality, temperature and other ecological variables.

4. Efficient plant types: specific characters for erect branching, shortened internodes, short peduncles, small or narrow leaves, monopodal stems, better photosynthetic efficiency and greater harvest index, resistance to shattering and lodging, a range of maturities to meet different needs.

5. Good grain quality: light creamy, white or light brown seeds of moderate size and having a rough or wrinkled testa.

Recombination. The recombination process is carried out on a year round basis in the greenhouse where individual plants can be moved around, cuttings taken and flowering times controlled. Above all, insect pollinators are effectively excluded to obtain reliable and predictable F_1 generations. More than 1200 recombinations have been made for direct varietal improvement. An additional 800 crosses have been done in a preliminary step to merge the germplasm.

The utilization of controlled out-crossing would be of considerable advantage in population improvement breeding schemes. We therefore made a search for male sterility and discovered two distinct types: genetic male sterility caused by failure of the anthers to produce and shed pollen, and mechanical sterility in which flower petals are constricted in such a way as to permit extrusion of the style and stigma but prevent dehiscence of pollen. Both mechanisms appear controlled by single recessive genes. The constricted petal would have many advantages, but is difficult to cross in the Prima background in which found. Plans are presently underway to develop at least three base populations each, of which would be retained as fully fertile as well as transferred to the male sterile background.

Testing. Some thousands of lines have been tested to varying degrees in observation, preliminary and advanced trials. At the apex of this pyramid are advanced and uniform trials comprised of 14 elite entries plus two checks which were conducted in seven ecological zones in 1972 and at 39 locations in 1973. While local varieties sometimes performed better in regional trials, five entries, mainly New Era types, consistently produced higher yields. These included the following:

Pedigree	Mean ranking*	Mean yields (kg/ha)
TVu 37 Pale Green	2.7	1993
" 57 New Era	3.2	1884
" 72 N.59 - 25	3.5	1883
" 354 Hanbru 58 - 123	4.5	1850
" 335 Jebba Pea A	5.5	1717

*At IITA, Umuahia and Samaru (Nigeria); and Kpong (Ghana).

Uniform yield trials will be continued and expanded, substituting increasingly better performing entries and with improved quality as developed in breeding programs around the world.

3. Soybean Breeding

The same procedures have been followed in soybean except to a lesser scale and with greater reliance on exotic germplasm. Characteristics considered essential for growing in the lowland tropics include:

1. High, stable productivity levels
2. Broad adaptation and normal growth under short days and high temperatures
3. Resistance to shattering
4. Resistance to lodging
5. Resistance to bacterial pustule and rust
6. Resistance to nematodes (root knot)
7. Seeds with long viability and vigorous germination

Uniform yield trials comprised of 14 entries were distributed to eight cooperators in 1972. A similar trial was sent out to 19 locations in 1973. At two sites in Nigeria and in Ghana, five varieties including Imp. Pelican, Bossier, CES 486, Kent and Chung Ksing No. 1 exceeded mean dry seed yield levels of 2325 kg/ha. At Bende, Nigeria, Bossier yielded 3653 kg/ha and Imp. Pelican 3395 kg/ha. These high yields demonstrate the extraordinary potential of soybeans in the lowland tropics, but mask the problem of poor germinability in soil at high temperature (above 35°C or 95°F). GLIF scientists are working on this problem from several promising approaches.

Population improvement breeding methods could be expedited by use of outcrossing mechanisms. Two possibilities exist: (a) use of the slow dehiscent factor closely linked with puberulence and defective seedcoat resulting in readily detected outcrosses both in the seed and seedling stages and (b) male sterility. Genetic male sterility in well adapted "tropical" materials was discovered by Dr. Camacho who subsequently demonstrated it to be controlled by a single recessive gene. Populations have been started based on both the puberulent and male sterile backgrounds.

4. Miscellaneous Legumes

Lima beans. This crop shows extraordinary potential for the lowland humid tropics and is possibly the most reliable species for conditions similar to those in southern Nigeria. Preliminary investigations are underway at IITA starting with evaluation of germplasm and a crossing program designed to achieve the following:

1. Higher yield levels
2. Good quality seeds (white or green testa)
3. Bush and climbing forms for different purposes
4. Wide adaptation and environmental insensitivity
5. Nematodes and virus resistance

Lima beans are extraordinary free of diseases and pests at IITA. Moreover, exceptionally high yield levels (up to 3500 kg dry seeds per ha) have been obtained in less than five months on trellised plants.

Pigeon peas. This species has a particularly wide range of adaptation in the lowland tropics. Its root system has the ability to penetrate to deep layers of soil for water and nutrients. Breeding efforts begun at Makerere University have focussed on widely-adapted, short-statured, earlier maturing (less than 150 days) types. Some of these are erect-branching, or have monopodal stems, are profusely fruiting and respond to high plant populations. Eight of the most promising mass selections will be increased and offered as a uniform trial in 1974.

Green gram. Evaluation of 115 bulks and genetic stocks of green and black grams (mung beans) at IITA provided the basis for selecting 12 more widely adapted strains. These will be distributed either as a uniform yield trial or genetic materials and further investigations phased out on this species. Future requests for seeds will be referred to the Asian Vegetable Research and Development Center in Taiwan.

Yam beans. Seeds of the African yam bean (Sphenostylis stenocarpa) are exceptionally nutritious and highly relished in the African lowland tropics. It is also grown extensively for its tubers, which resemble the Irish potato in texture and taste. Germplasm is being collected and preliminary observations are being made at IITA, but viruses and wilt are major problems in this crop.

Other species. Observations have been made on rice bean, black gram, hyacinth beans, Mexican yam bean, winged bean, jack bean, dry bean (Phaseolus vulgaris) and Bambarra groundnuts. Some of these have demonstrated exceptional potential and high yields (jack bean dry seed yields up to 4500 kg/ha), but limited use impose limitations on the amount of time and resources that can be devoted to these species. However, seeds will be maintained and definitive studies carried out on some of them if and when the need occurs or opportunities present themselves.

5. Agronomy

Cultural practices. Considerable information and experience have been gained in management and culture of contrasting plant types of cowpeas and soybeans during the first year of experimentation. Optimal plant populations for both Prima (erect) and Pale Green (semi erect) cowpeas range from 110-166 thousand plants per hectare under conditions at IITA. Kent soybeans had maximum yields at 500 thousand plants/ha. Minimum tillage with fertilization for soybeans was nearly as efficient as conventional cultivation with fertilization. Soybeans responded to fertility levels up to 45-45-0 units of N-P-K, but cowpeas showed no response to fertilizers.

Seed pelleting. Coating seeds with plant protectants, nutrients, inoculants and growth regulators would be a highly economical and convenient method of solving some of the problems in growing legumes in the low humid tropics. Particularly promising are the new systemic fungicides (e.g. Demosan-65) and insecticides (Furadan) with the latter providing up to a month of protection from insect pests.

Weed agronomy. Several seasons of intensive work have shown that weed control for the first four weeks of growth is adequate to maximize seed yields in both cowpeas and soybeans. In the area of pre-emergence herbicides, promising results have been achieved using the following alone or in combination: trifluralin, linuron, alachlor, nitralin and diphenamid.

6. *Physiology*

Growth rates. Dry matter accumulation and partitioning have been determined for Kent and Imp. Pelican soybeans and for Prima and Iran Grey cowpeas. Under IITA conditions light saturation occurs at about leaf area index equal to 3. Maximum growth rate in both crops of about 200 - 250 g/m^2 in 14 days is reached 24 - 30 days after planting. Dry matter accumulates principally in stem and leaves during the first 45 days of growth, but thereafter mainly in pods and seeds in both species (Kent and Prima). The long cowpea peduncles accumulate up to 10 percent of the total dry weight compared with virtually none for soybeans.

Components of yield. In both cowpeas and soybeans, pods per unit area are the major component of seed yields. Seeds per pod and seed size have secondary importance.

Soil temperature. The inhibiting effects of high soil temperatures (above 35^{o}C) on germination of soybean seeds may explain why this crop has not been more extensively grown in the lowland tropics. This problem is being studied further.

Day length and temperature effects. Intensive and precisely controlled experiments in growth chambers and glasshouses at Reading demonstrate the major roles of these two factors in affecting growth and development of some genotypes of cowpeas and soybeans. They have also identified some comparatively insensitive cultivars including Grant, Fiskeby and Bossier soybeans. Other experiments show the importance of good nodulation and the deleterious effects of water stress particularly during the period between emergence and flowering or final yields.

7. Pathology

Host plant resistance. The disease problems of cowpeas and soybeans in southern Nigeria appear amenable to solution through host plant resistance. Good resistance to the major fungal diseases, bacterial pustule, viruses and root knot nematodes have been identified in a broad array of cowpea genetic stocks. More than 50 lines have been found that combine resistance to the four major fungal and bacterial diseases.

Transmitting diseases. Methods of transmitting viruses and anthracnose have been developed, making it possible to screen large numbers of breeding lines rapidly and efficiently.

Seed treatment. The systemic fungicide, Demosan-65 has been demonstrated to be highly effective in protecting young seedlings from soil borne diseases and is compatible with the systemic insecticide Furadan.

8. Entomology

Need for insecticides. The devastating effects of uncontrolled insect pests on susceptible species have been amply demonstrated. Seed yield increases of 10 to 30 fold may be achieved by proper insect control. Several newer insecticides have shown greater efficacy at lower rates of application and with less residue than present formulations. Excellent results have been achieved in treating seeds with Furadan followed by post flowering applications of a less toxic insecticide like Gardona in pest-susceptible cowpeas at IITA. Ultra-low volume sprays may prove easier and more effective method of foliar application.

Host plant resistance. The exciting possibility of host plant resistance to various insect pests in cowpeas is suggested by several screening trials in both the field and laboratories at IITA. A degree of tolerance or low level of resistance to thrips, leaf hoppers and pod borers may be available in cowpeas. Weedy or wild species with hairy and sandpapery pods demonstrate a reasonable level of resistance to Maruca and Laspeyresia pod borers, the most devastating and intractable pests of cowpeas in southern Nigeria. However, these results require confirmation and such genetic characters must be transferrable to cultivated species.

9. Biochemistry

Seed proteins. Analysis at Durham University of about 200 cultigens of tropical legumes, primarily cowpeas, indicate that storage protein in cowpeas comprise about 22 to 35% of dry weight and consist of 75% globulins (two forms). The energy fraction consists of 50% starch and 0.5 - 2.0% oil. Unsupplemented cooked cowpea meal has about half the biological value of egg albumen; but is nearly as good as when supplemented with 2% methionine.

S-bearing amino acids. Most grain legumes are low in methionine and cystine. Nevertheless, a range in genetic variation has been observed and a rapid screening method would facilitate genetic improvement of this quality. Work at Durham has demonstrated a possible relationship between total sulfur and S-amino acids suggesting that quick preliminary screening for sulfur might be done using an automated S-analyzer.

Product quality screening. About 2500 seed lots of cowpeas and other materials have been analyzed at IITA for crude protein and 1500 seed lots have been assessed for sulfur content. These indicate crude protein contents even higher than expected - some exceeding 40 percent. Sulfur to nitrogen ratios appear independent of protein content and range from 1 to 6%. Edible tubers occur in at least four different tropical grain legume species. In two of these (Pachyrrhizus erosus and Vigna vexillata) protein on a dry weight basis ranged from 9 - 19%.

III. TRAINING AND OUTREACH

Intensive efforts to build the scientific program have precluded activating a formalized training program during the first two years of GLIP. However, it is expected that within the next one or two years we will be fully operational and have a formalized training program. GLIP staff have participated in training University students on holiday appointments, by presenting lectures and by providing facilities and guidance for post graduate students from Nigeria and other universities. Mr. Ray Scheider of the University of Illinois, earned his doctorate degree by collecting data on Cercospora leaf spots at IITA under the joint guidance of Prof. J. B. Sinclair of the University of Illinois and Dr. R. J. Williams, GLIP Pathologist.

This is the second year of collaboration with other programs in Africa and elsewhere, primarily in the field of seed distribution and organization of uniform yield trials of cowpeas and soybeans. The scope of this project has increased nearly fourfold from seven cowpea and eight soybean trials in 1972 to 39 cowpea and 19 soybean trials in 1973. These trials have been distributed primarily in Africa and the Middle East, but also in southern Asia and the Western Hemisphere. We have participated actively in grain legume improvement in Central Africa, especially in Nigeria, Tazania and Ghana where GLIP staff members have had opportunities to contribute directly to research planning.

IV. POLICIES AND STRATEGY

Program activities described above will be expanded in coming years. However, the flexibility to anticipate trends and shift emphasis in directions leading to more rapid and profitable research developments will be an essential characteristic of GLIP in the future. This does not imply we will expand in all directions at once or leapfrog from one attractive problem to another. Rather, we may liken our main efforts to the strong downward movement of a pigeon pea taproot, which penetrates gravel layers by pushing through in places, circumventing the impenetrable and developing an occasional strong lateral to seek moisture and nutrients.

The species. In general terms, GLIP will substantiate its role as a global center for excellence in cowpeas and tropical lima beans, serve as a relay station for tropical soybeans in Africa with the University of Illinois and link up on pigeon pea improvement in the humid tropics with ICRISAT in India. Germplasm collections - both comprehensive and limited - will be assembled, evaluated, catalogued and maintained for the Vignas, Phaseolus lunatus, Glycine max, Cajanus, Sphenostylis stenocarpa, Mucuna and certain miscellaneous tropical species.

Orientation. Those areas of research with greatest potential for making a rapid direct impact on indigenous tropical farming systems will be pursued most actively. These would include improved varieties, more efficient cultural practices, better plant protection methods and enrichment of product quality. A particularly exciting area is seed treating and pelleting. New systemic fungicides and insecticides, in various combinations with contact protectants, rhizobial inoculants, plant nutrients, growth regulators and moisture absorbants, show exceptional promise for grain legume husbandry in the lowland tropics.

Plant improvement. This is an area in which all disciplines will participate. Improved varieties and populations by virtue of enhanced productivity potential and greater reliability will become now foundations on which more efficient cropping systems can be structured. Improved strains are one of the most economical inputs in advancing agriculture. The role of GLIP in this area will not normally be direct release of improved varieties to farmers in competition with national programs, but rather to provide a continuing supply of new material in the form of both pure-breeding lines and populations. These would be tested and further modified by genetic manipulation for specific regional requirements by national programs. To speed the process of improvement at least 3 - 4 successive generations of breeding materials will be grown out each year at IITA, utilizing the most advanced breeding technology with special emphasis on population improvement and wide crossing.

Resistance to diseases and pests. Available evidence amply demonstrates the devastating effects of uncontrolled insect, disease, virus and nematode attack. Therefore, highest immediate priority will be given to incorporating disease and pest resistance into conventional varieties and plant types with acceptable seed qualities. These improvements alone should be adequate to increase productivity levels by two to threefold where other inputs are not applied. To this end varieties with broad adaptation and high yields, but having inferior seed qualities and susceptibility to various pests and diseases would serve as a base for immediate improvement. In the longer term, pest and disease resistance can be transferred to more efficient plant types.

Improving the plant type. Very little is known of the comparative efficiency of plant architecture in most tropical species. We might speculate that the ideotype represented by the largely monopodal modern soybean plant is the model to be adopted in cowpeas and other pulses. Perhaps climbing types are inhererently more productive if adequately supported. Erect branching, semi-spreading and even prostrate cowpeas varieties all have advantages under certain conditions. Whether the plant should be robust, grow rapidly and cover the ground quickly or be compact with stout, erect stems and branches are problems requiring definite answers. Possibly a wholly different plant type than any presently envisaged will prove more productive and widely useful than conventional forms.

Greater physiological efficiency involving the photosynthetic process, translocation of assimilates and non-photo-respiration would be highly desirable, but these characteristics must also be compatible with drouth tolerance, good rooting habits and other essential attributes. More effective rhizobial production in the symbiotic process could be critically important especially in the more humid tropics. Perhaps a genetic compatibility factor operating between the plant and more efficient symbionts would be realistic goal to strive for.

Perhaps the most difficult and perplexing problem in breeding the less-developed grain legumes is determining which plant characters involving basic structure and physiological efficiency should be combined. The most immediate problem is determining which plant architecture will become most important in future cropping systems. Several plant types will probably be required for different purposes, depending on how they are used, but until the relative efficiency of a particular architecture is determined, the "art of breeding" will continue to play a major role in this effort. However, because erect determinate plants types are much easier to work with experimentally and in the breeding process, these forms can be expected to predominate in many improvement programs.

Identifying useful diversity. Genetic stocks from which a nearly infinite range of plant types can be created have been identified or developed in the GLIP cowpea breeding program. These include the following:

1. A broad array of plant growth habits

    i. very erect
    ii. erect bush
    iii. semi-erect bush
    iv. spreading
    v. semi-prostrate
    vi. prostrate
    vii. climbing types

2. Sensitivities to environmental conditions, particularly light, temperature and moisture availability

3. Varying leaf sizes and shapes (ovate to lanceolate or strap leaves),

4. Brachitic or compacted stem internodes as contrasted with tall and robust plants,

5. Monopodal stems versus profusely branching genotypes

6. Short compared with very long peduncles

7. Wide variation in seed and pod sizes, shapes and textures,

8. Good resistance to all major diseases and root knot nematode,

9. Possible partial resistance (or differential susceptibility) to thrips during early growth and to pod boring pests during fruiting,

10. A very wide range of seed qualities both for cooking and in terms of their nutritional values.

The availability of such a broad range of genetic diversity for economically important characters virtually assures progress in plant improvement. Nevertheless, it can be assumed that many characters will not respond similarly over a wide range of environment nor do resistances necessarily retain their effectiveness indefinitely. Thus, there is a need to test both the basic genetic stocks and recombinants from them over a wide range of conditions. Moreover, to prevent a disastrous breakdown in resistance it will be essential to incorporate horizontal resistance - another reason for pursuing population improvement breeding methods.

The complexity and immensity of improving a crop like cowpeas or other tropical legumes cannot be overemphasized. The problems are enormous - perhaps more than in most cereal crops - yet the tropical legume research workers are barely a handful compared with the hundreds of breeders devoting themselves to maize, wheat or rice improvement. In a recently published directory of plant scientists in the developing countries, only 35 were listed under cowpeas and 15 under pigeon peas (nine names common to both groups). This compares with 33 scientists working on wheat, 168 scientists on maize and 158 workers on rice. This disparity is even greater when the developed countries are included, since the number of scientists investigating the major cereals are many times greater than in less developed countries, whereas only a few scientists in developed regions work on cowpeas and none on pigeon peas.

While the IITA has a team of scientists devoting themselves to cowpeas, only a few problems can be investigated at any one time. However, it is hoped these efforts catalyze a broader international effort to improve two or three tropical pulses. Real progress can only be made through international cooperation involving the interchange of ideas, information and germplasm and through collaborative testing and experimentation. We need feedback processes whereby we help each other solve specific problems. I hope that this Workshop will help initiate this essential aspect of the world-wide tropical legume improvement process.

REFERENCES

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