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Health Hazards

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CIAT Centro Internacional de Agricultura Tropical

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Annual Report 1987

Bean Program

Working Document No. 39, 1987

CIAT Centro Internacional de Agricultura Tropical

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C

THE BEAN PROGRAM

Beans are the most important food legume in Latin America and the highlands of eastern and southern Africa, where for hundreds of millions of people, especially among the poor, beans are not only the main source of dietary protein but also one of the leading sources of calories. There are, however, strong local preferences for many distinct grain types. Production systems are also highly varied as a result of major differences in soil/moisture/temperature regimes, as well as in the objectives and resource endowments of producers. Poor farmers, for whom capital is a scarce resource, produce a large share of beans in semi-subsistence systems.

Of the major food crops, beans are among the most susceptible to disease. Bean productivity is limited by an array of pathogens and pests. Growth in productivity has been slow in the tropics where farmers' traditional landraces are still widely grown. Beans are frequently grown intercropped with other food staples. With few exceptions beans have not been the subject of extensive research or improvement in the tropics, where research resources have been generally meager.

The overall goal of the Bean Program is to improve food availability and income for poor people by improving the productivity of beans through the rapid development and transfer of technology in collaboration with national agricultural research institutions in countries where beans are an important food. The Program's goal will be realized by accomplishing three objectives:

1. Developing scientific innovations that overcome major productivity-limiting constraints in beans.

2. Strengthening national bean research and technology transfer capacity.

3. Accelerating the transfer of bean production technology through international networks exchanging germplasm, scientific methodologies and information.

Program strategy focuses on <u>research</u> to improve bean productivity; <u>training</u> to increase research capacity in tropical bean research institutions; and <u>networking</u> to speed up the generation and diffusion of improved bean production technology.

Research

Program research is strategically oriented to maximize impact in the context of research carried out by other institutions. NARIs have a comparative advantage in adapting technologies to the specific circumstances of diverse production systems. Developed country research institutes are the source of many advances in basic science. The Program concentrates on

applied research of broad applicability, while undertaking basic or adaptive research where this serves as a valuable complement to the efforts of others, both capitalizing on strengths and filling in gaps.

Genetic improvement is the Program's main research focus given its substantial potential impact and broad adaptability. The Program emphasizes the genetic improvement of resistance to diseases and insects, while minimizing reliance on agrochemicals and giving priority to important widespread constraints. Genetic improvement is also sought for yield potential, drought resistance, earliness, nitrogen fixation and adapration to acid and low phosphorus soils. Research in pathology, virology, entomology, physiology, microbiology, agronomy and economics - all interact with and support the Program's plant breeding effort. Improved cultural practices to accompany new germplasm are a second-order priority. Agronomic research is also conducted to address problems for which genetic solutions are not readily available.

Training

The research capacity of national agricultural research institutions is strengthened by their partnership with the Program in research networks, as well as through training.

Training is strategically adapted to the individual needs of national programs. Multidisciplinary production courses develop the capacity to participate in the international bean network. NARI research capacity is strengthened through courses and internships emphasizing breeding and plant protection. Training in on-farm research receives major attention to improve problem definition and technology evaluation. A great deal of training is through regional or in-country courses where trainees develop work plans for future activities. The Program follows up most ex-trainees in order to backstop them in implementing their new skills.

Networking

The Program actively promotes the exchange of information, scientific methodologies and germplasm. This network approach makes the results of advances in basic science more accessible in an applied form. Network relationships among tropical bean-producing countries capitalize on specialization in research, while also facilitating the horizontal transfer of technology they generate.

Regional networks are formed around common problems, with each individual national program taking the responsibility for research leadership in a specific problem; and the results of their research are shared among all network participants. This not only improves the multisite reliability of data, but also makes results quickly available to all participants. Such

regional networks have been formed in Central America, the Andes, Eastern Africa, Central Africa, Southern Africa, as well as Brazil and the Southern Cone. Most networks have annual research meetings and a steering committee, which coordinates activities of mutual interest. Exchanges at the continental or world level are also maintained through periodic workshops, International Bean Nurseries, and Program publications.

Program organization

In order to complement these strategies, the Bean Program has formed a critical mass of scientists at headquarters. This interdisciplinary team conducts research to find practical solutions to major widespread bean production problems. The close coordination of activities across disciplines is crucial to the Program's research strategy: pathology, virology, entomology, physiology and microbiology work closely with breeding in the identification of parental sources of desirable characters and in the selection of progeny for high expression of these traits. Agronomy and economics conduct diagnostic farm-level studies to help set design priorities for new technology and also to evaluate the performance of promising technology.

Research is organized first around character improvement projects (e.g., anthracnose, leaf hoppers, nitrogen fixation), in which a breeder works closely with at least one disciplinary specialist. The products of these character projects are then made available for use as parents to all Program breeders, both in Colombia and outposted, as well as to NARIs. Multiple characters are then combined in cultivar improvement projects for eight distinct grain classes. Segregating populations and fixed lines are then distributed to NARIs and are also evaluated in uniform nurseries by the entire headquarters team. Only through a critical mass of research scientists working in tight integration can rapid and significant progress be made in finding solutions to the numerous factors that limit bean productivity in cultivars of diverse grain type and architecture.

Outposted staff are an essential complement to the Colombia-based activities. Both in Africa and Latin America, outposted staff have a major responsibility for working with NARIs in evaluating improved characters for their local performance and developing improved cultivars with local adaptation. Moreover, studies of major problems in the regions provide information needed to set research strategies. Outposted staff work closely with NARI scientists on a daily basis, and training and networking activities are as important as research. Although Colombia-based staff devote more effort to research, they also are heavily involved in training and network support. Both headquarters and outposted staff collaborate in cultivar improvement projects, local evaluation, training and networking.

The bulk of outposted staff are currently located in Africa, reflecting the great importance of African bean production; the

Program's relatively recent commitment to supporting national research efforts in Africa; and the challenges of finding locally adapted solutions to the diverse, often intense, and sometimes unique problems limiting bean productivity in Africa.

Specific activities

The central research activity of the Program is genetic improvement to overcome principle production constraints with minimum use of agrochemicals. Priority is placed on improving disease and insect resistance, as well as on tolerance of drought, low phosphorus and acid soils, improved nitrogen fixation, early maturity and yield potential.

The CIAT bean germplasm bank is a key resource for genetic improvement. CIAT maintains the world's largest collection of *Phaseolus vulgaris* accessions, as well as wild ancestors and related species. Evaluation of this germplasm for useful traits, study of its genetics, and continued strategic collection for needed variability provide a foundation for the Program's breeding effort.

Given the large number of constraints that limit bean productivity and the great differences in grain type requirements, growth habit, cropping systems and growing environments, the division of responsibilities and a decentralized approach are crucial to the Program's bean germplasm improvement activities. Genetic improvement concentrates on four activities:

1. Developing high and stable levels of expression of desirable characteristics for incorporation in a variety of grain types.

2. Providing NARIs with multiple-factor, bulk segregating hybrid populations or advanced lines according to their needs and requests.

3. Strengthening NARI capacity in crossing and selection.

4. Promoting the regonal and international exchange of promising germplasm.

Responsibility for twenty-two character improvement projects is allocated among three breeders at headquarters, who also divide responsibility for cultivar improvement in eight separate grain classes, corresponding to regions for which their character projects are particularly relevant. Sources of high character expression are shared and used as parents by all Program breeders and NARIs. Incorporation of desired characters in locally adapted cultivars requires decentralized selection achieved through strong NARIs.

The NARIs are supported by providing them with specific genetic variability, through joint research projects, and training. Outposted breeders have particular responsibilities in strengthening NARIs through training, assisting them in local selection, and building regional networks so that their activities are complementary.

The major responsibilities of pathologists, virologist and entomologists are to participate in breeding programs and conduct studies on host plant resistance mechanisms, screening methodologies, pathogenic variability, insect biology, and intensity and incidence of crop losses. Emphasis is placed on developing a wide range of genetic sources of resistance in order to ensure production stability through the use of a broad genetic base. As multiple-resistance germplasm becomes increasingly available, more attention is being devoted to developing integrated control strategies for diseases and insect pests.

A pathologist and virologist at headquarters conduct research on high priority diseases of worldwide distribution (e.g., bean common mosaic virus, rust, anthracnose, angular leaf spot and common bacterial blight), while also supporting NARIs in Latin America. Outposted pathologists in Rwanda and Tanzania support African NARIs and assist in germplasm evaluation through the use of a broad genetic base.

The headquarters-based entomologist works on pest problems of worldwide significance (leaf hoppers, bruchids, whitefly), as well as those of purely Latin American importance (bean pod weevil). The Africa-based entomologist will be primarily concerned with control of the beanfly, one of the most serious production problems in Africa.

Nitrogen is an almost universally limiting constraint to bean productivity and a critical factor in bean yield physiology. Increased biological fixation of nitrogen is a low-input technology that can contribute substantially to nitrogen availability. A headquarters-based microbiologist is identifying characteristics that can be used in bean breeding, as well as working closely with breeders in developing methods of screening for improved nitrogen fixation. Rhizobia strains are also being screened for effectiveness and competitiveness. The results of this research are being tested in Africa and Latin America by forming a network in which previously isolated microbiologists are being encouraged to work closely with plant breeders and agronomists.

Strategic research on yield physiology, earliness and drought mechanisms is undertaken to guide breeders seeking genetic improvement for these characteristics. Priority is given to identifying traits that can be useful to breeders selecting for yield or drought. This research is carried out by the headquarters-based physiologist.

A high proportion of beans, both in Africa and Latin America, are produced on heavily weathered acid soils with low phosphorus availability and high levels of aluminum. Physiologists at headquarters are working to identify traits useful in breeding superior bean genotypes in order to optimize bean productivity in these low-fertility soils. This research integrates whole-plant nutritional physiology with soil fertility and chemistry, and is closely coordinated with research on rhizobial symbiosis. This research is currently being conducted by a postdoctoral fellow.

Major emphasis in agronomy is on the on-farm testing of new lines for adaptation to farmers's current cropping systems. Research is also carried out on improved cultural practices and intensified cropping systems, both to exploit fully the advantages of new bean genotypes and to increase productivity where genetic improvement is not the most efficient strategy. Because of the location-specific nature of much of this research, training NARI personnel is a high-priority activity. Agronomists are outposted to Brazil, Ethiopia, Guatemala, Tanzania and Uganda; while two headquarters-based agronomists are responsible for on-farm research in South America and international yield trials, respectively.

Understanding user criteria for evaluating new technology provides essential guidance to the design of new technology. Studies of farmers' production systems, resources, problems and objectives are critical as are studies of consumer preferences for new grain types. Socioeconomists participate with agronomists in on-farm evaluation of new technologies and have the additional responsibility of generating feedback on the adoption of new technology. A headquarters-based economist is responsible for strategic studies on the demand for improved bean technology and producing input to the setting of research priorities in Latin America. An anthropologist in Rwanda attend Africa, where the emphasis is on farm-level evaluation of new technological alternatives.

The Program Leader, based in Colombia, is responsible for coordinating the Program's research, training and network activities. An All-Africa Coordinator insures consistency and integration of activities across three separately funded special projects.

HIGHLIGHTS 1987

The year 1987 saw major changes in the program as activities to increase bean productivity in Africa expanded and significant adjustments were made to respond to the evolving situation in Latin America.

Program developments

After serving as Program Leader with great vision since 1977, Dr. Aart van Schoonhoven left CIAT. Dr. Douglas Pachico, formerly Program Economist, was selected Program Leader.

New appointments strengthened the Program's efforts in Africa. Dr. Oghenetsevbuko Todo Edje joined CIAT as cropping systems agronomist for Southern Africa, stationed in Arusha, Tanzania. Dr. Charles Wortman joined CIAT as cropping systems agronomist for Eastern Africa, stationed in Kawanda, Uganda. Dr. Barry Smithson was transferred from temporary duty station in Ethiopia to serve as breeder for Southern Africa, stationed in Arusha, Tanzania.

To provide consistency of approach and integration of activities across separately funded special projects in Central, Eastern, and Southern Africa, Dr. Roger Kirkby, already stationed in Addis Ababa, Ethiopia, was named All-Africa Coordinator. Dr. Jeremy Davis, formerly a Program Breeder at Palmira, Colombia, became Coordinator and breeder for the Central African Project, stationed in Rubona, Rwanda.

Dr. Michael Dessert, formerly Regional Coordinator and breeder for Central Africa, will assume a similar responsibility in Central America, with his duty station in San Jose, Costa Rica. Dr. Guillermo Galvez, formerly Regional Coordinator and pathologist for Central America, has been shifted to Lima, Peru, to coordinate a newly formed Andean Regional Project.

Dr. Julia Kornegay has been named Program Breeder in Palmira, replacing Dr. Davis, and Dr. Willem Janssen has been appointed Program Economist in Palmira.

Dr. John Bowman completed his post-doctoral Fellowship in pathology and left CIAT. Dr. Jonathan Lynch became a postdoctoral Fellow in Physiology, stationed in Palmira, Colombia, while Dr. Gustavo Frias was named a post doctoral fellow in Pathology, stationed in San José, Costa Rica.

Research highlights

Low soil phosphorus is perhaps the most widespread limitation of crop production in the tropics. Due to intensified land scarcity in Africa, and competition from commercial export crops in Brazil, beans are increasingly being grown on low phosphorus soils. While some Brazilian cultivars have long been found to be

tolerant in low phosphorous screening carried out at the Quilichao, Colombia, station, recently some advanced CIAT breeding lines have shown superiority over the previously best checks under phosphorous stress. Progress for selection of this trait continues to be severely impeded by the lack of an adequate selection criterion in early generations. Without research to identify selection criteria, the best that can be achieved is to screen advanced lines to ensure that tolerance levels available in commercial cultivars are at least maintained.

Program strategy has emphasized improving disease resistances, and continued progress is evident in combining multiple resistances. Henceforth only lines with resistance to BCMV as well as a resistant or intermediate reaction to CBB and anthracnose will be included in the international yield nursery (IBYAN).

While progress in improving resistances has been accumulating over time, in 1987 for the first time materials coming from the high yield potential breeding project markedly outyielded all best checks in the preliminary yield trials (EP). These results must be confirmed now in other seasons.

Advances in identifying sources of resistance to major diseases in Latin America is also paying off in Africa. This year evaluations of resistance to Ascochyta blight in Popayan, Colombia and Rwerere, Rwanda clearly showed a strong similarity in ranking of bush bean materials, indicating that resistant materials selected in Popayan also perform well in Africa.

Continued screening for BCMV resistance in collaboration with ICTA in Monjas, Guatemala, has led to the identification of some 40 new sources of BCMV resistance in a variety of seed colors. This will permit a broadening of the genetic base of resistance in black seeded beans where BCMV resistance has largely been based on one line: Porrillo Sintetico. Furthermore, the new sources will be used in crosses by CNPAF since older sources have not been very effective in Brazil. In collaborative research with the University of Wisconsin involving the sequencing of DNA genomes of Brazilian and other BCMV isolates, significant differences in nucleotide sequences have been demonstrated, consistent with previous field observation of differences in reaction of Brazilian and Central American BCMV isolates.

The bean pod weevil causes major economic loss in Central America. Studies conducted in Honduras with SRN found that while there are no differences in oviposition rates on resistant and susceptible lines, significantly lower larval populations were observed on the resistant line, suggesting that antibiosis is the mechanism responsible for resistance. Furthermore, several bush bean breeder's lines have shown resistance as well as good adaptation and seed color. For the first time, climbing lines have also been selected for resistance and adaptation.

A continental map of bean production area in Latin America has been prepared by the CIAT Agroecological Studies Unit. These data are being combined with soils and climate data to characterize bean production regions. For example, preliminary results indicate that nearly half the area sown to beans has less than adequate phosphorus (less than 10 ppm), while one-quarter of the area is clearly phosphorus deficient for beans (less than 5 ppm). Such soils were found in Brazil, the Mexican highlands, and the Andean region. A similar mapping study is planned for Africa.

An economic study of the importance and potential of snap beans (edible pods) in the tropics was initiated in 1987. Case studies are being conducted in collaboration with national programs in Brazil. Colombia, Costa Rica, Indonesia, Philippines, Rwanda and Taiwan. Preliminary results indicate that most snap bean production is by small farmers. Demand growth is projected to be rapid, with annual production growth of 4% or more needed just to maintain prices constant. Thus, snap beans appear to offer an attractive income earning opportunity for small farmers. The first International Workshop on Snap Beans was held at CIAT in May, 1987 to form the basis of a network of researchers on tropical snap beans.

Drought is the single most important cause of major bean crop failures, and over 60% of bean production area suffers from drought. A study of 10 genotypes confirmed that greater root depth can be an effective drought resistance mechanism in the deep soils at Palmira. Data from the CIAT agroecological unit suggests that this mechanism could be useful in up to 80% of soils where beans are grown. Although this mechanism is not effective in the acid soils of Quilichao station, there was a significant correlation in root growth across sites, indicating cultivar differences in root growth over contrasting soil types. Moreover, in Quilichao a grafting experiment found a clear association between root genotype and drought tolerance. This suggests the existance of root characteristics other than root growth that determine performance under moisture stress.

Besides the promising results of root characteristics in improving drought tolerance, it is also well known that early maturity (less than 70 days) can be useful for drought avoidance. Earliness can also be desirable for easier integration into crop rotations and in a subsistance economy to obtain an early harvest in a period seasonal food shortage. Many different sources of earliness have been recently identified. Currently a study of the inheritance of earliness in a dozen different sources is under way in order to develop a breeding strategy to transfer this trait into desirable commercial cultivars.

Regional projects

On-Farm research has received a considerable boost from the East Africa regional project. Diagnostic surveys of farmers on their bean production problems and practices were initiated in Uganda with a study conducted by the national program, while on-farm varietal trials of beans were also planted for the first time. In Ethiopia national program research on intensifying cropping systems by growing beans intercropped with sorghum or maize is being supported.

In Rwanda, where the Central Africa regional project has been active since 1983, an important achievement has been the recent withdrawal of the CIAT agronomist from the management and planning of on-farm varietal trials, as this task is now being fully done by ISAR researchers and technicians.

The African Bean Yield and Adaptation Nursery (AFBYAN) has been established to evaluate the best available lines from national programs in all three of the CIAT regional projects in Africa. In 1987 AFBYAN trials were conducted in Ethiopia, Rwanda, Uganda, Zaire and Zambia, providing national programs with promising materials. For example, K20, a Ugandan line, ranked top in yield in Rwanda and second in Zambia.

The impressive progress of the Central America and Caribbean regional project is reflected in the decision of the Regional Steering Committee (composed of the national coordinators of bean research in the 10 participating countries) to remove BGMV from among their top research priorities, due to achievements already made in developing resistant varieites that are now widespread among farmers in Guatemala and parts of Mexico.

In the regional project for Brazil and temperate South America, the increased breeding capacity in Brazil has led to a decline in shipment of advanced lines to Brazil. Crosses have been planned jointly by CNPAF and CIAT. CIAT produced segregating populations and CNPAF breeders are selecting the advanced lines. Similarly, several breeders from Brazilian state institutions have received training at CIAT, and are now receiving segregating populations from CNPAF and CIAT.

Training and workshops

Program training activities are specifically targeted to meet the priority needs of national programs. Individualized training in specific disciplines is offered principally at CIAT, while most training courses are now conducted in the regional projects. Recently there has been a major emphasis on on-farm research courses in Central America, where a great deal of promising materials have been developed on-station by national programs. These lines now have to be tested on-farm, and the best ones must be transferred to farmers. The Program's training

strategy for the region is clearly focused on improving capacity to meet this high priority need.

CIAT works closely with other international centers in its training activities. In Africa one technical training workshop on grain legume research was conducted in Rwanda and another in Malawi, both in collaboration with IITA. A course for graduate agronomists in Ethiopia was co-organized with CIMMYT, and CIAT and CIMMYT both supported a regional seminar for on-farm research in Central Africa. In Latin America, CIAT is working with CIMMYT in the co-writing of training materials for on-farm research.

The Fifth International Bean Trials Workshop was held at CIAT, with participation of scientists from 17 countries in Latin America and 7 countries in Africa. The workshop provided a forum for the exchange of information and experience as well as serving as a feedback mechanism to CIAT.

An International Bean Drought Workshop was conducted for the first time in 1987 at CIAT bringing together experts in breeding and physiology from Latin America and Africa as well as developed countries to review the latest advances in methodologies for drought screening.

Varietal release by national programs

Brazil, Rio Grande do Sul	Capixaba Precoz (BAT 304)
Brazil, Algoas, Mato Grosso do Sul, Minas Gerais, Sergipe.	EMGOPA Ouro (A 295)
Chile	Blanco Inia 87 (WAF 9)
Costa Rica	Chirripo (HT 7719)
Cuba	Siboney (NAG 20)
Honduras	Catrachita (RAB 205)
Venezuela	Montalban (BAT 58)

A. GERMPLASM RESOURCES

Aquisition-Introduction

The acquisition and introduction of new germplasm continued to be a major activity in the management of the *Phaseolus* germplasm bank during 1987. A total of 2,145 accessions were introduced into the bank, of which almost 55% corresponded to germplasm collected in expeditions or donated from national collections; the remaining 45% are accessions included as parental materials of varied origin (Table 1).

Of the total germplasm acquired, 85% comprised common bean (*P. vulgaris*), 6% lima bean (*P. lunatus*), 6% runner bean (*P. coccineus*), and 2% wild *Phaseolus* species. Three sets of the germplasm introduced require special mention-- (1) the Bulgarian collection corresponds mostly to landraces collected in 1984; (2) the African collections were the result of expeditions funded by IBPGR, with multiplication of collected materials being carried out in a third quarantine country (Wellesbourne,England or Gembloux,Belgium);and (3) the germplasm from Belgium corresponds to materials collected in Mexico and Colombia a few years ago. The details of the germplasm collected by CIAT's collector in Mexico, Guatemala, Costa Rica and Peru are included in the section entitled Collection.

Status of the Phaseolus collection

With the new germplasm acquired during 1987, the *Phaseolus* collection is currently comprised of 40,000 accessions (Table 2). The germplasm of wild species now held increased greatly in the last year; however, cultivated species other than *P. vulgaris* did not increase greatly.

Of the almost 23,000 increased and/or available germplasm accessions, 90% is *P. vulgaris*, 7% other cultivated species, 2% wild ancestral species, and about 0.3% is wild non-ancestral species.

Increase - Multiplication

The increase of new germplasm in the greenhouse and meshhouse added up to a total of 2,436 accessions, of which 82% corresponded to *P. vulgaris*, 8% to *P. lunatus* and *P. coccineus*, and about 10% to the wild species.

The highest percentage of materials increased were from Europe (33%), followed by Central America (18%) and South America (18%); the germplasm from Africa had previously been increased in Wellesbourne (England) and Gembloux (Belgium).

In the fields of CIAT stations in Palmira, Popayan and Dagua a total of 5,467 accessions were planted, including materials

that followed the post-quarantine initial increase (9%), the rejuvenation of germplasm already stored in the bank (55%), and characterization of the collection (36%).

Characterization

The search for similarities among germplasm groups is facilitated by means of seed description (color, brilliance, size, shape, hardness etc) as well as field characterization of plant phenotypes. The objective is to measure the available variability of the collection stored in the Genetic Resources Unit, in order to provide more complete information on the species to bean researchers. The first major division of germplasm groups is based on seedcoat color and plant growth habit (Table 4), which indicates that the white and black colored beans are the most common in the collection, followed by creams, yellows, and reds. Likewise, growth habit III is the most common followed by type IV and type I; with type II appearing least frequently in the collection. In dividing germplasm into groups using a combination of seedcoat color and growth habit, the order of frequencies from high to low is as follows: cream- type III, followed by white- type I, black- types II, III, IV, red- type III, and white- type III. The combination of all colors with type II is the least frequent except for blacks. More refined groupings using cluster analysis and electrophoresis are being used.

Seed distribution service

A total of 9,004 accessions of Phaseolus beans were distributed to 33 countries to fulfill 66 requests (Table 5). Most of the requests for germplasm came from Africa (43%), followed by Europe (17%), and Central - South America (13%). The majority of the germplasm requested was P. vulgaris (83%), followed by P. lunatus (6%), P. acutifolius (4%), P. coccineus (3%), and (4%) wild species.

The Bean Program at CIAT-Palmira is also actively requesting and using the germplasm available in the bank. The different disciplines in the Bean Program received a total of 31,780 samples during 1987 (Table 6).

Collection

The Genetic Resources Unit continued broadening the genetic basis of the different bean crops, through the collection and study (in their native habitats) of primitive landraces of the five cultivated species, their wild ancestral forms, and the wild Phaseolus species.

In addition to their potential value to breeders (e.g. searching for resistance to bruchids), wild ancestors can also be used as evolutionary markers, which will increase understanding

of the thousands of poorly documented accessions of the five cultivated species.

Phaseolin analyses carried out in cooperation with the BRU of CIAT and previous studies on morphological characters have shown that several regions in Peru act as transition zones between the North Andean center and the South Andean center of primary diversification. The semidomesticated types, and zones where possible natural introgression could have occurred were both variables taken into account during field work in these areas.

A study on secondary centers of diversification was begun to appraise the relative newness of that diversity, using morphological characters and the phaseolin marker. This study employed the African collection of cultivated common bean available in the Genetic Resources Unit.

Results

Three field explorations were carried out this year resulting in a total of 307 samples representing 32 different species or taxa.

All the collection data were entered into a data base. After compiling accession data of current holdings in the GRU, it was possible to prepare a set of maps showing real distribution of the seed accessions for each *Phaseolus* species. Knowledge of the potential distribution of each *Phaseolus* species (provided by herbarium data also processed in a data base) enabled the researchers to fill in gaps in genetic diversity in a more realistic way.

Costa Rica

Field work was carried out together with the Estacion Experimental Fabio Baudrit of the Universidad de Costa Rica.

The following 46 materials were collected in the central part of the country where genetic erosion is most severe.

Species	No. of accessions
Phaseolus leptostachyus	2
P. lunatus (wild)	14
P. oligospermus (type locality)	1
P. polyanthus	1
P. tuerckheimii	6
P. vulgaris (wild)	2
P. vulgaris (semidomesticated)	2
P. sp. (natural hybrid with *P. polyanthus*)	1
P. sp. (new taxon of the *P. striatus* complex)	11
P. sp. (new taxon of the *P. coccineus* complex)	1
P. xanthotricus	5

The most interesting finds from the Costa Rican study were:

- the presence of wild P. vulgaris in Costa Rica where it was not reported before. When analyzed biochemically, this material could tell us what happened in that part of Central America, an area for which we are especially lacking in evolutionary data.

- the existence of a new taxon in the P. striatus complex (wild scarlet runner bean with purple flowers) with epigeal germination, thus linking with P. polyanthus and P. vulgaris.

Peru

Field work was conducted in Peru together with the Banco de Germoplasma of the Instituto Nacional de Investigation y Promocion Agropecuaria (INIPA). Several parts of Junin and Apurimac were visited, in a search for the ancestral forms of the numerous phaseolin types found so far in the cultivated P. vulgaris. There were 176 samples collected:

Species	No. of accessions
P. augusti	4
P. lunatus (landraces)	4
P. lunatus (wild)	1
P. pachyrrhizoides	17
P. vulgaris (landraces)	139
P. vulgaris (semidomesticated)	3
P. vulgaris (wild)	7
P. sp. (close to P. pachyrrhizoides)	1

The most interesting finds from the Peruvian collections were:

- the wild P. vulgaris. They have larger seeds in comparison with the Mesoamerican forms, although morphologically they are not equivalent to the P. vulgaris v. aborigenecus extending from Cuzco southwards.

- the semidomesticated P. vulgaris. Two kinds of material were observed--escaped forms present in cultivated fields, and weedy types growing in shrubby habitats together with true wild forms.

- the wild P. lunatus. They were found on the eastern Andean slopes and are morphologically different from the interandean forms reported elsewhere. There are thus two wild lima (P. lunatus) beans in Peru, of which only one had been domesticated.

- the landraces of P. vulgaris. They are disappearing from that region, as mixture size becomes smaller and lighter colors are becoming dominant--progressive substitution of improved varieties is taking place.

Mexico

The field work was carried out jointly with the Unidad de Recursos Geneticos of the Instituto Nacional de Investigaciones Forestales, Agricoles y Pecuarias (INIFAP). A total of 85 samples was collected from several sites in central Mexico which are undergoing important and relatively recent natural vegetation changes.

Species	No. of accessions
P. acutifolius v. tenuifolius	2
P. chiapasanus	*1
P. coccineus (wild, several taxa)	21
P. esperanzae	*8
P. hintonii	1
P. leptostachyus	15
P. maculatus	2
P. marechalii	2
P. microcarpus	10
P. oaxacanus	*2
P. pedicellatus	4
P. perplexus	*5
P. pluriflorus	1
P. polymorphus	2
P. sp. (2 taxa)	*2
P. vulgaris (wild)	6
P. xolocotzii	*1

Important finds in this study include:

- for the first time, germplasm is now available for six more species (marked *).

- additional material of wild P. vulgaris found in Guerrero, Oaxaca, and Puebla would confirm previous observations that wild P. vulgaris present in the Huestaca are more recent escaped materials.

- several materials of P. coccineus cannot be considered as true ancestors of the scarlet runner bean; the presence of other species in their vicinity indicates that we should look for "bridges" for widecrossing.

- the most endangered species (P. chiapasanus, P. esperanzae, P. marechalii, P. perplexus, P. xolocotzii) in that list are those which cannot survive outside undisturbed woody

habitats. A list of sites for *in situ* conservation of several species has been established.

Africa

The ongoing study of the African collection held at CIAT has so far resulted in the following conclusions:

- an important part of this collection is made up of breeding lines.

- a low proportion of the collection (5%) is composed of rare phenotypes as judged by unusual seed color characters (green, citrine, flesh, grey).

- the majority of phaseolin types found so far (for Kenya and Malawi) is of 'T', followed by the 'C' type; only a few 'S' types have been found, mostly in 'panamitos'. No recombinants have been discovered to date, nor have other types.

- the majority of the different genotypes would have been introduced from the Southern Andes, probably indirectly via Spain and Portugal.

Table 1. *Phaseolus* accessions to the germplasm bank added in 1987.

Region	*P. vulg.*	*P. lun.*	*P. cocc.*	*P. acut.*	*P.* wild	Others
North America						
United States	139	-	-	5	-	26
Subtotal	139	-	-	5	-	26
Central America						
Costa Rica	29	-	-	-	30	17
Guatemala	16	9	59	-	-	50
Mexico	296	-	-	-	69	-
Subtotal	341	9	59	-	99	67
Caribbean						
Puerto Rico	1	-	-	-	-	-
Subtotal	1	-	-	-	-	-
Andean South America						
Bolivia	64	3	2	-	-	13
Colombia	57	60	32	-	2	1
Ecuador	7	-	-	-	-	-
Peru	137	46	8	-	20	1
Subtotal	265	109	42	-	22	15
Non-Andean South America						
Argentina	16	-	2	-	-	-
Brazil	106	-	-	-	-	-
Subtotal	122	-	2	-	-	-
Europe						
Belgium	22	2	5	-	40	2
Bulgaria	411	-	-	-	-	3
France	6	-	-	-	-	-
Portugal	105	-	16	-	-	-
Rumania	-	-	10	-	-	-
Subtotal	544	2	31	-	40	5
Africa						
Burundi	86	-	-	-	-	-
Madagascar	6	-	-	-	-	-
Malawi	72	-	-	-	-	-
Rwanda	32	-	-	-	-	-
Zaire	78	-	-	-	-	-
Subtotal	274	-	-	-	-	-
Asia-Oceania						
Turkey	37	-	-	-	-	-
Subtotal	37	-	-	-	-	-
TOTAL	1,723	120	134	5	161	113

Table 2. Status of the bean collection held at the CIAT Genetic Resources Unit as of December 1987.

Species	No. of accessions	
	Introduced	Increased
P. vulgaris	34,665	20,743
P. vulgaris wild ancestors	410	357
P. lunatus	2,835	844
P. lunatus wild ancestors	97	41
P. coccineus subsp. *coccineus*	928	439
P. coccineus subsp. *polyanthus*	460	246
P. coccineus wild ancestors	102	24
P. acutifolius	143	116
P. acutifolius wild ancestor	57	57
Wild non-cultivated *P. angustissimus*, *P. leptostachyus*, *P. esperanzae*, *P. filiformis*, *P. glaucocarpus*, *P. pauciflorus*, *P. glabellus*, *P. grayanus*, *P. jaliscanus*, *P. macrocarpus*, *P. macrolepis*, *P. maculatus*, *P. pedicellatus*, *P. polystachyus*, *P. pluriflorus*, *P. pachyrrhizoides*, *P. polymorphus*, *P. scabrellus*, *P. ritensis*, *P. ovalifolius*, *P. tuerckheimii*, *P. wrightii*, *P. anahuacensis*, *P. floribundus*, *P. neglectus*, *P. striatus*, *P. xanthotrichus*, *P. parvulus*	307	61
Total	40,005	22,928

Table 3. Country frequency of new *Phaseolus* germplasm increased and/or rejuvenated in CIAT's greenhouse in 1987.

Region/Country	No. accessions
North America	
United States	171
Subtotal	171
Central America	
Costa Rica	45
Guatemala	8
Mexico	439
Subtotal	492
Caribbean	
Dominican Republic	6
Subtotal	6
Andean South America	
Colombia	135
Ecuador	12
Peru	313
Subtotal	460
Non-Andean South America	
Argentina	40
Brazil	138
Subtotal	178
Europe	
East Germany	97
Belgium	49
Bulgaria	460
France	9
Netherlands	1
Portugal	177
Subtotal	793
Africa	
Burundi	97
Madagascar	6
Malawi	75
Kenya	2
Rwanda	37
South Africa	28
Tanzania	4
Zaire	87
Subtotal	336
TOTAL	2,436

Table 4. Percent distribution of the available *P. vulgaris* germplasm, according to seed color and growth habit (1987).

Growth Habit	Seedcoat color (%)								
	White	Cream	Yellow	brown	Pink	Red	Purple	Black	Total
I	7.2	3.7	4.9	1.2	1.2	2.0	1.7	1.6	23.5
II	1.6	1.1	0.4	0.4	0.3	0.4	0.5	7.2	11.9
III	6.3	8.0	3.2	1.5	1.9	6.7	2.0	6.9	36.5
IV	5.3	5.8	3.0	1.6	1.4	2.3	1.7	6.2	27.3
Total	20.4	18.6	11.5	4.7	4.8	11.4	5.9	21.9	100.0

Table 5. *Phaseolus* seed distribution outside CIAT (1987).

Region	No. of countries	No. of requests	No. of accessions
North America	2	12	404
Central America	5	6	1,192
Caribbean	4	3	480
Andean South America	3	13	1,119
Europe	6	16	1,549
Africa	7	9	3,871
Asia-Oceania	6	7	389
Total	33	66	9,004

Table 6. Bean seed distribution within CIAT (1987).

Program	No. of requests	No. of accessions
Breeding I	14	14,001
Breeding II	49	7,407
Breeding III	15	1,982
Physiology	11	3,086
Entomology	18	3,976
Virology	15	357
Pathology	8	180
Economy	1	4
Microbiology	2	3
Farming Systems	2	25
Biotechnology	11	333
Total	146	31,780

B. AGROECOLOGICAL STUDIES

The aim of the Agroecological Studies Unit is to collect, manage and analyze information on the target areas of CIAT commodities. This information includes data on soils, climate, cropping system and socioeconomic factors.

During the past years, the AEU has developed a hierarchic approach to the definition of the target area and the data collection. The highest level is a continental study of the geography of the crop, defining crop distribution and, by combining this distribution with soils and climate information, compiling a catalog of existing crop environments.

This catalog is then used to produce a classification of the environments in which the crop is found. Knowing the amount of the crop found in each potential environmental subclass greatly assists this process. The classification can then be used to subdivide the target area into homogeneous units for the subsequent management of further target area data. These units are designated microregions and form the basis for storing cropping system information such as sowing dates, pest incidence, cultivars used and associated crops and also relevant socioeconomic data such as farm size, distance to markets, tenancy types etc.

The last stage can be to conduct detailed studies within certain strictly defined areas to refine the data and to answer specific problems put by members of the Bean Program.

This report deals with the first stage of this process for beans in Latin America which has occupied the AEU during 1987 and is now almost complete. A continental survey of beans was produced for Latin America some years ago (CIAT Annual Report 1978-79) that yielded useful information on some aspects of bean climates but it proved impossible to digitize and very difficult to associate with soils information. Also, since the information is almost 10 years old, it was decided to repeat the process using the best techniques available today.

Continental study of Latin American bean distribution

For each country information on the area of production of *Phaseolus* beans was extracted from all available sources. These included national agricultural census', agricultural production statistics, regional extension publications and personal information from CIAT and national program scientists.

A dot representation of bean distribution was constructed and matched to the FAO Soil Map of the World.

Major and associated soil types were identified with physical and chemical properties being tabulated for the soil

types included in the distribution, using information from representative soil profiles and laboratory analyses.

The bean distribution file with identified soil type was merged with the tabulated soil properties. Climate data was merged with the soils identified distribution file. (For detailed information on methodology, consult CIAT's Agroecology Section).

Results

Some preliminary results of the characteristics of Latin American beans soils are presented here. Analyses of the climate information, and particularly joint effects of climate and soil are still proceeding and will be reported later.

Figures 1 to 8 show the distribution of bean areas classified by certain soil properties. Most bean soils would appear to have adequate levels of potassium if we assume that levels from 0.2 to 0.3 me $100g^{-1}$ are sufficient for the bean crop, nevertheless around 15% of the soils are seriously deficient (less than 0.1 me $100g^{-1}$). These are mainly in Brazil (Figure 1).

The bean physiology section has previously reported an effective drought tolerance mechanism which operates via deeper rooting and more efficient water extraction. It would appear (Figure 2) that this may be ineffective in about 20 percent of bean soils where potential rooting depth is restricted to less than 35 cm. Further studies of the interaction of rooting depth and soil texture with climate are under way.

Soil organic matter (Figure 4) total nitrogen (Figure 3) and pH (Figure 6) will affect the efficiency of rhizobium nitrogen fixation, both through direct effects of pH and rates of nitrogen mineralization. These effects will also be modified by climate. No attempt has yet been made to analyze these combined effects, but the information on file will allow such an analysis in the future.

Figure 5 shows the levels of available phosphorus in Latin American bean soils. The data on phosphorus levels were obtained from a variety of laboratory tests but efforts were made to correct the readings to an equivalence with Bray II. It would appear that about half of the area sown to beans has adequate levels of phosphorus, with greater than 10 ppm. About one quarter should benefit from either phosphorus fertilization or varieties with greater phosphorus use efficiency. These are the areas with between 5 to 10 ppm. The remaining quarter of the bean areas are phosphorus deficient for beans. A significant proportion of these areas are on highly acid soils in Brazil (Maps 2 and 3) however other important areas in Colombia and Mexico are not related to low pH. These soils are mainly Andosols which have a moderate pH and high levels (up to 3000

ppm) of total phosphorus but because of amorphous clay minerals are highly phosphorus fixing.

The total distribution of Latin American beans is shown in Map 1. A considerable body of soils and climate data are now on file to describe these areas. Much analysis still remain to be done and the next challenge will be to construct a useful environmental classification. This will proceed in close cooperation with bean team scientists.

FIGURE 1. POTASSIUM

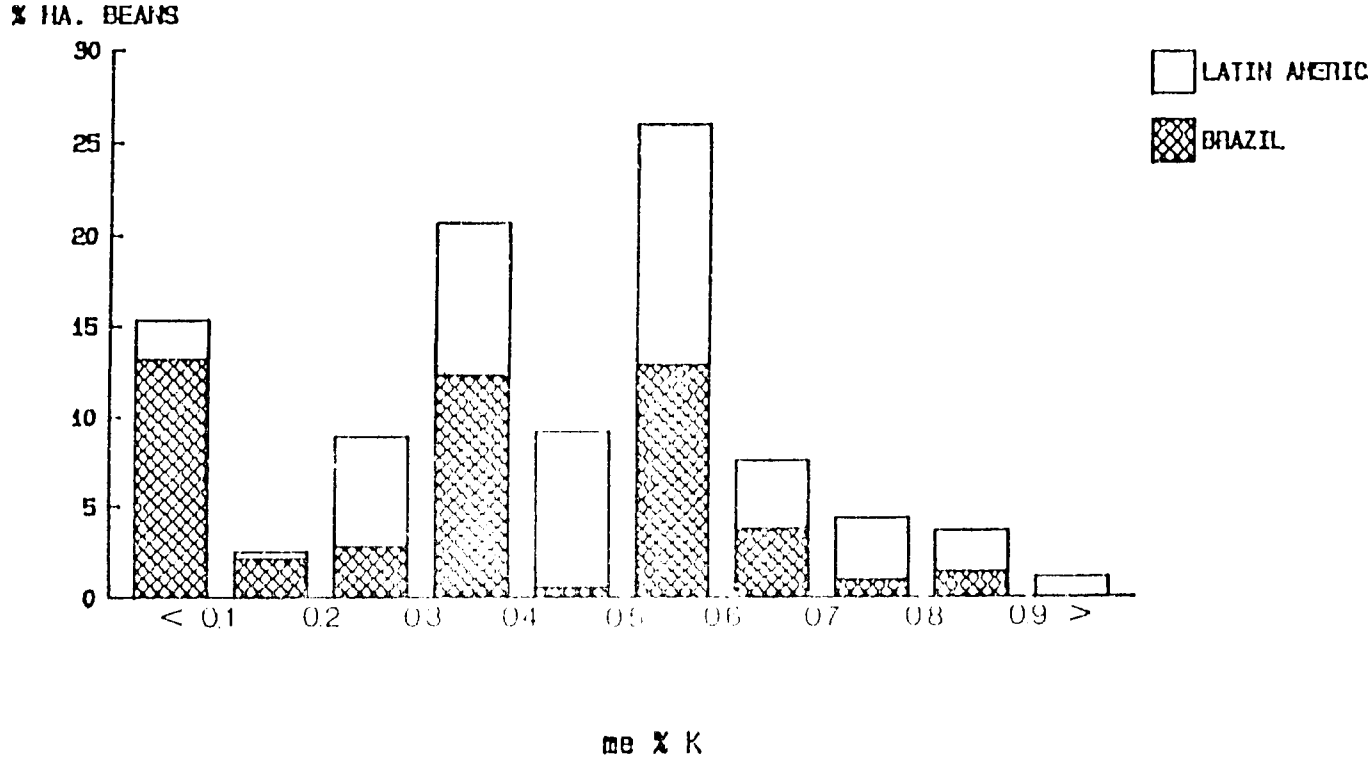


FIGURE 2. ESTIMATED ROOTING DEPTH

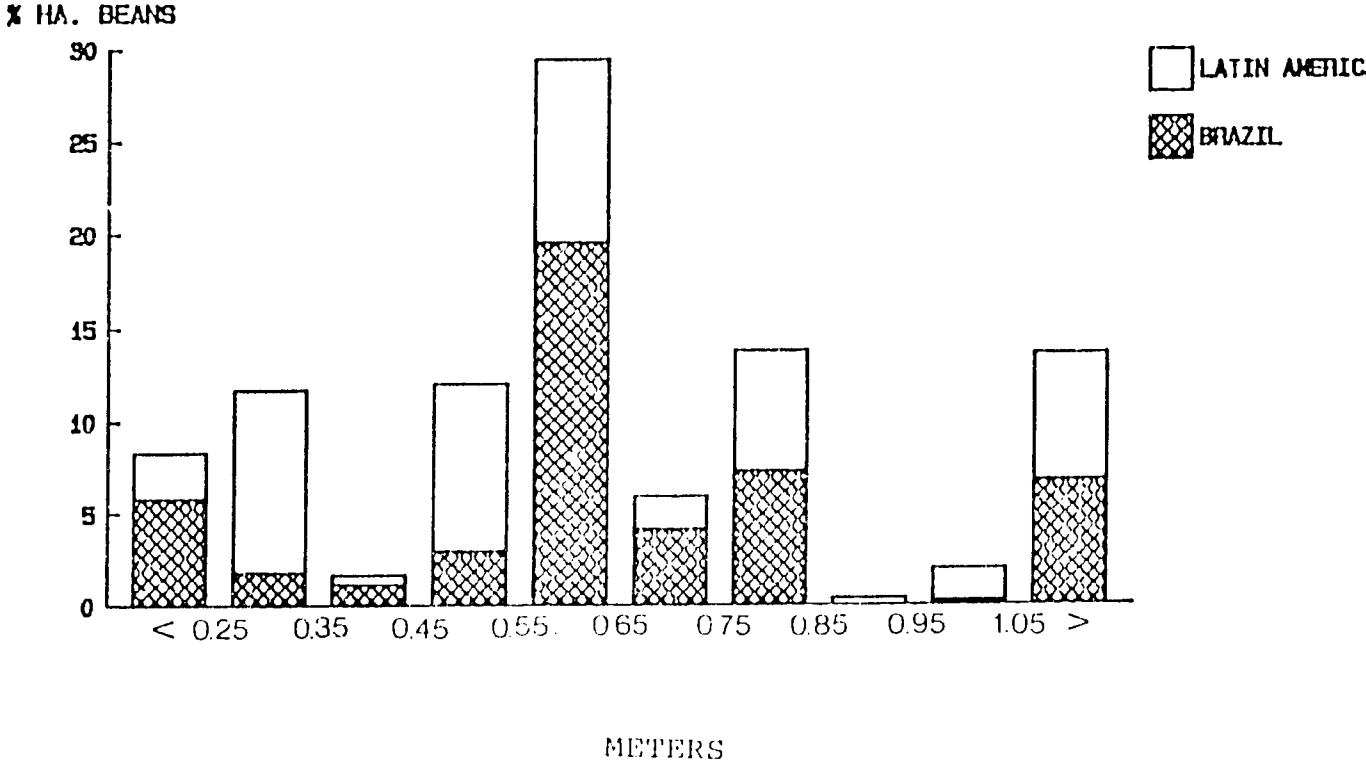


FIGURE 3. TOTAL SOIL NITROGEN

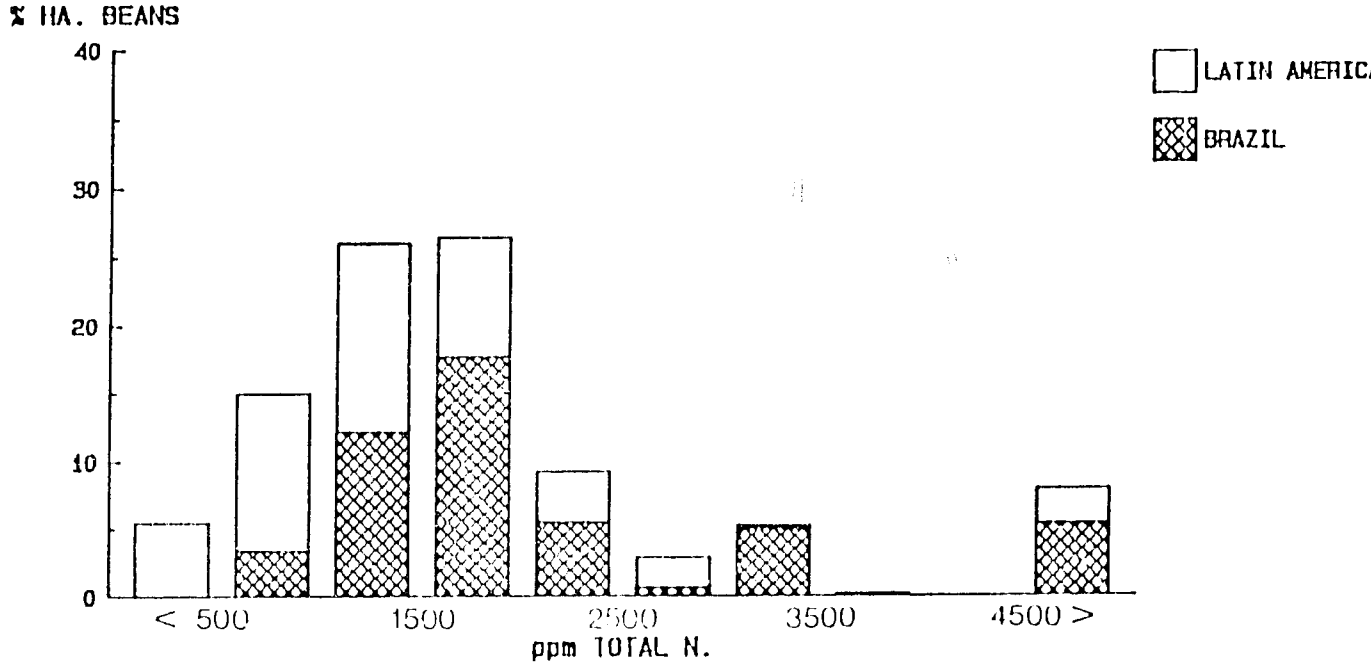


FIGURE 4. SOIL ORGANIC MATTER

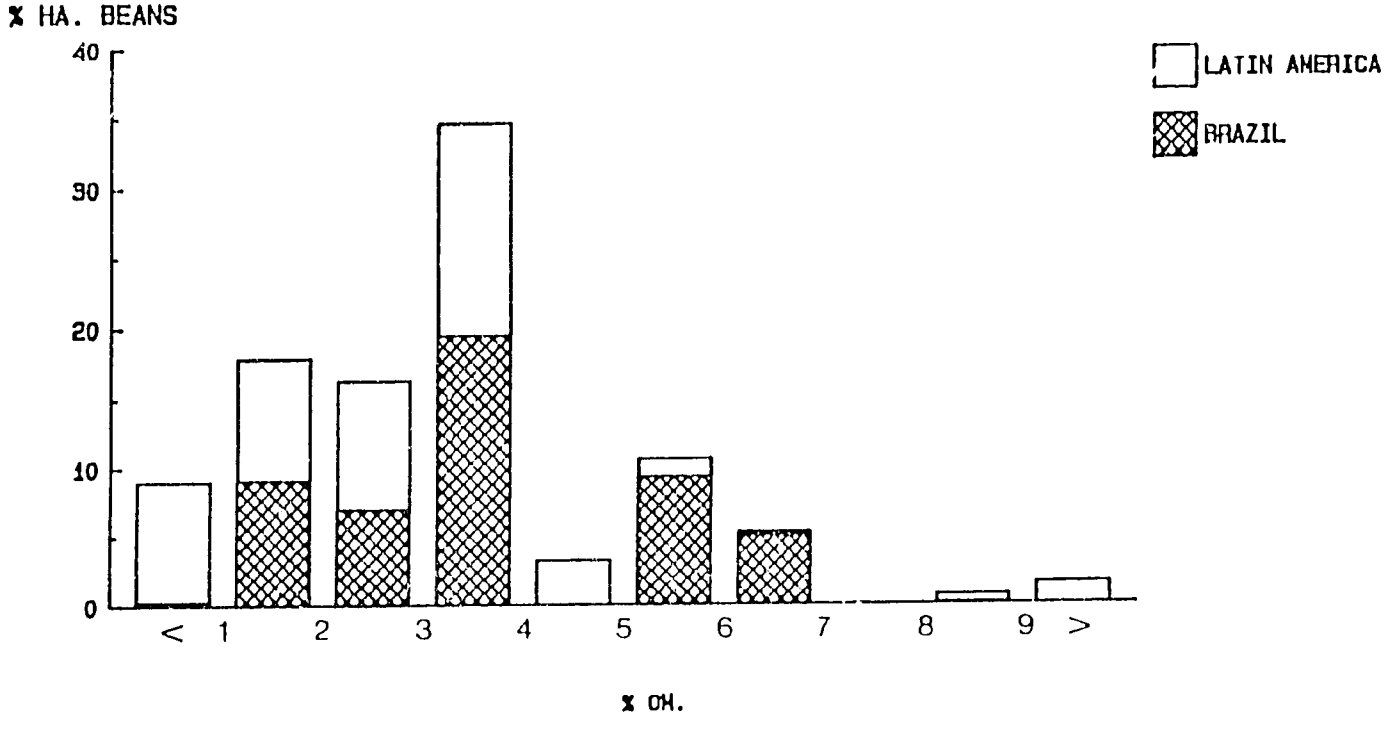


FIGURE 5. AVAILABLE PHOSPHORUS

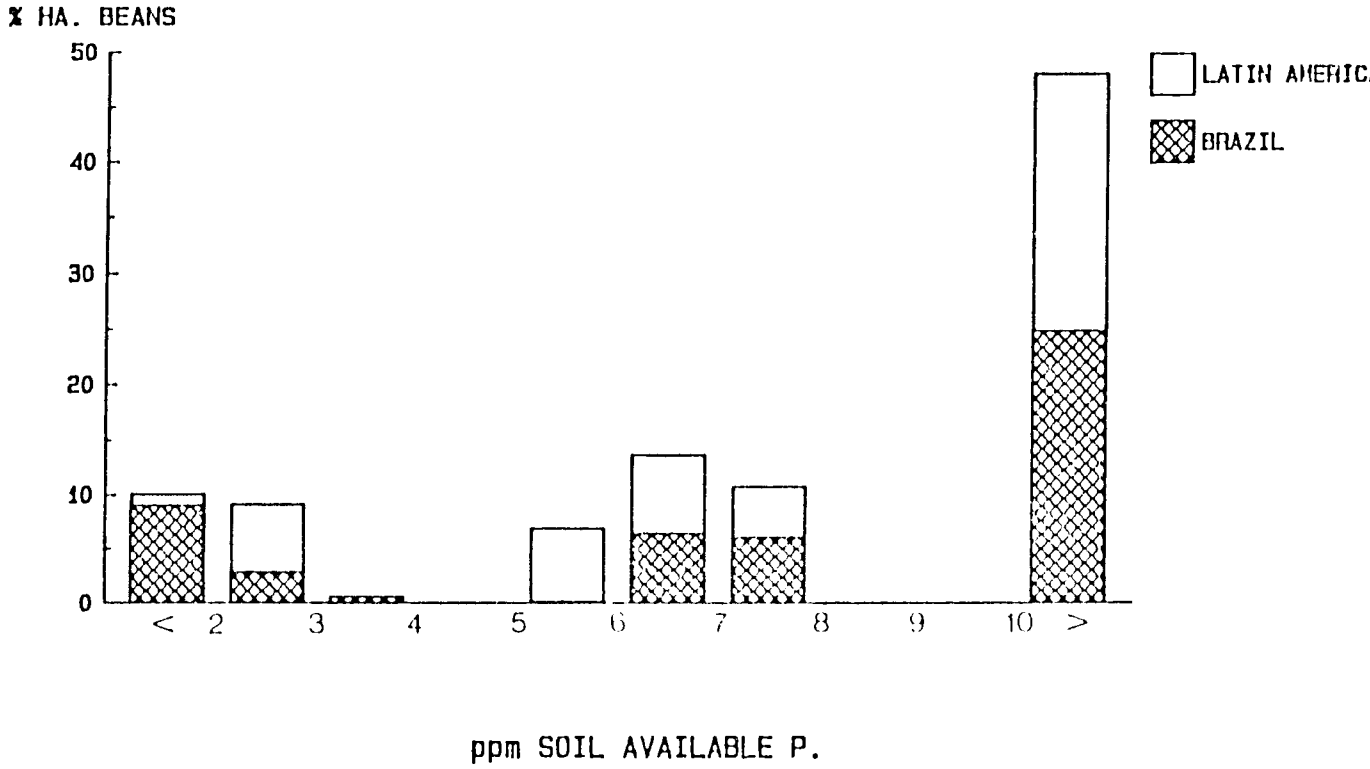


FIGURE 6. SOIL pH

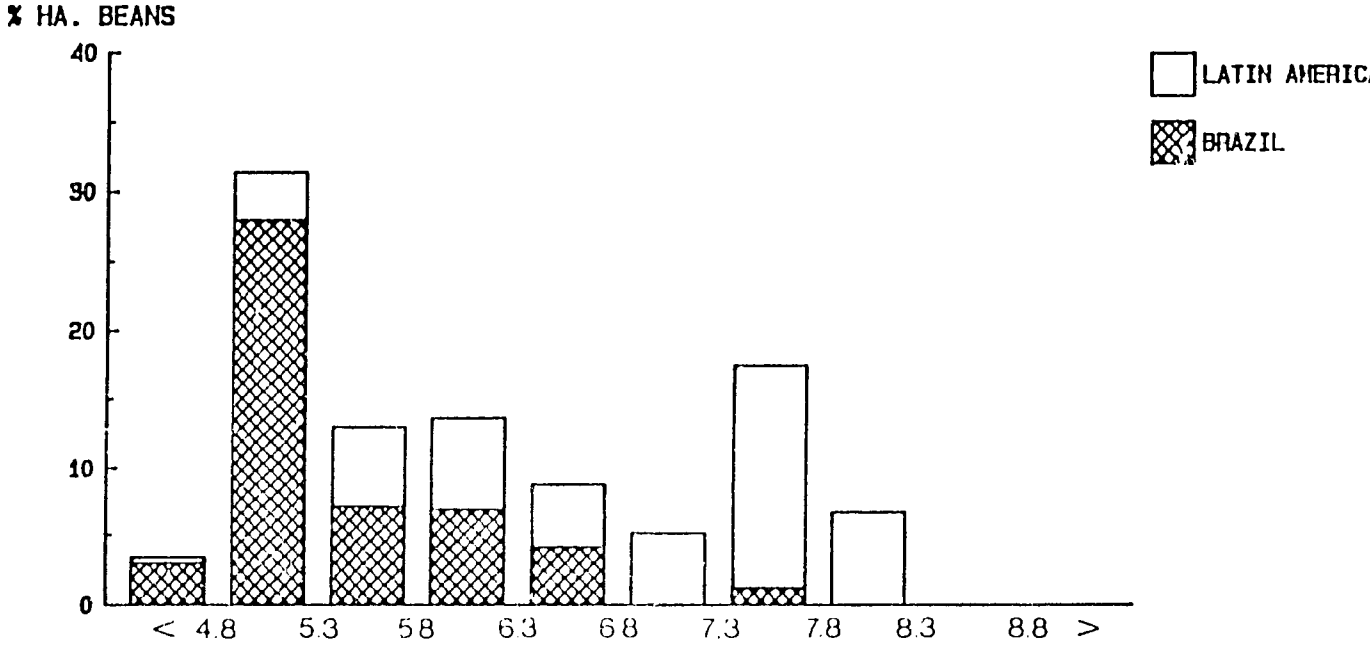


FIGURE 7. CATION EXCHANGE CAPACITY

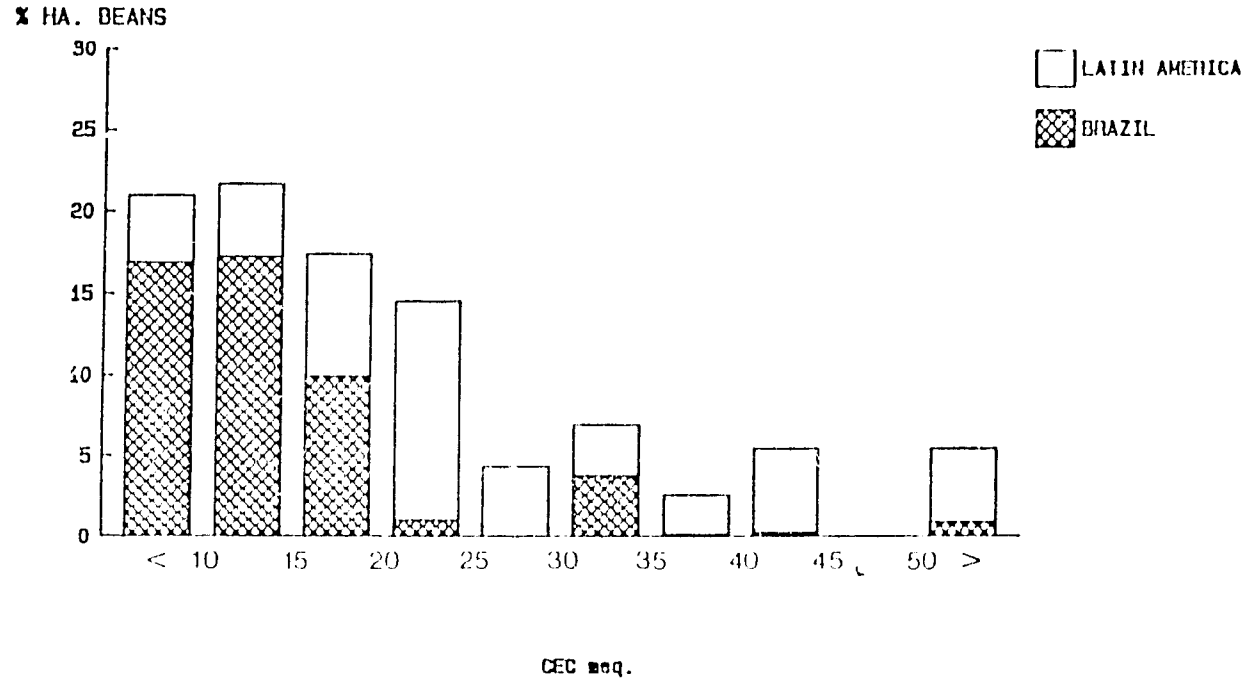
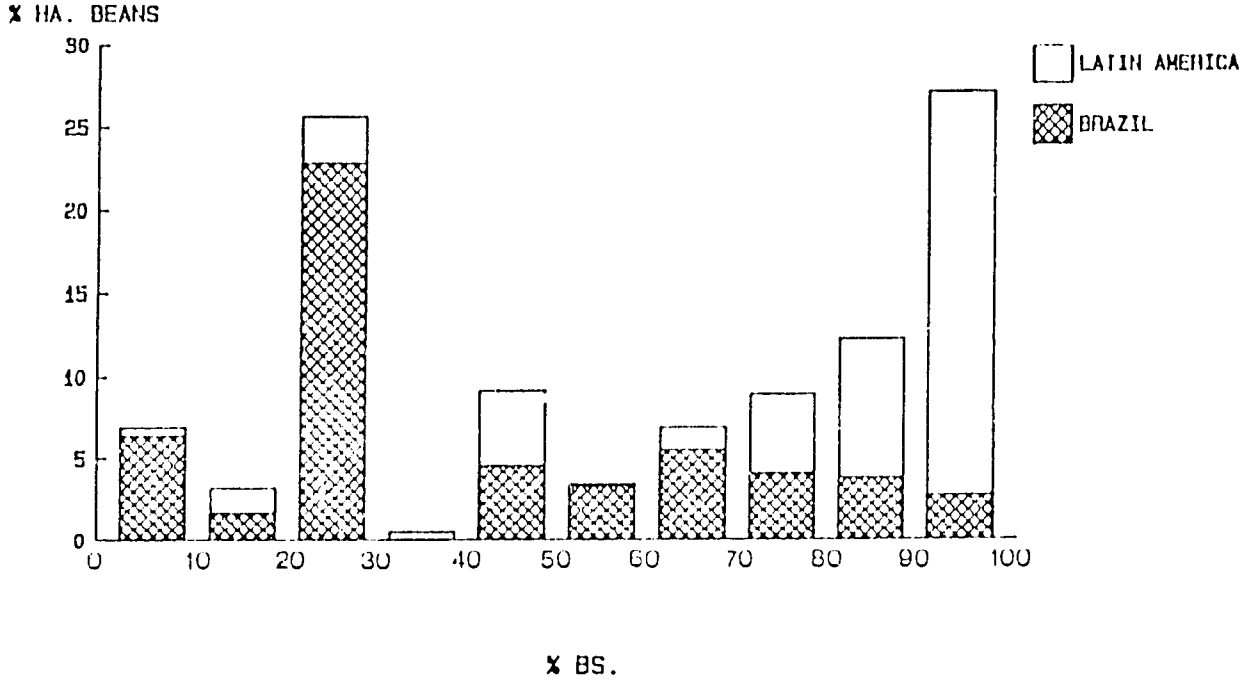
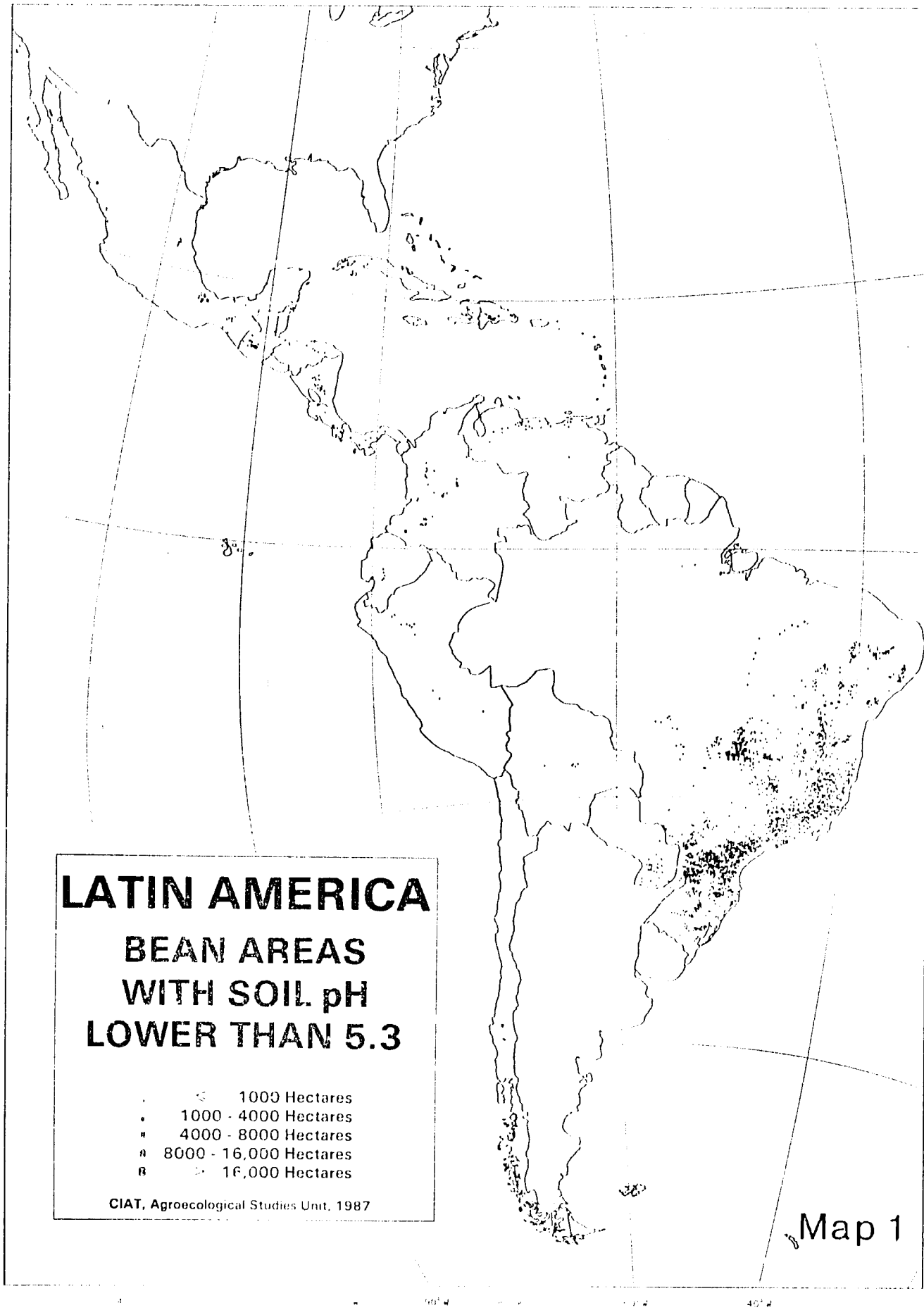
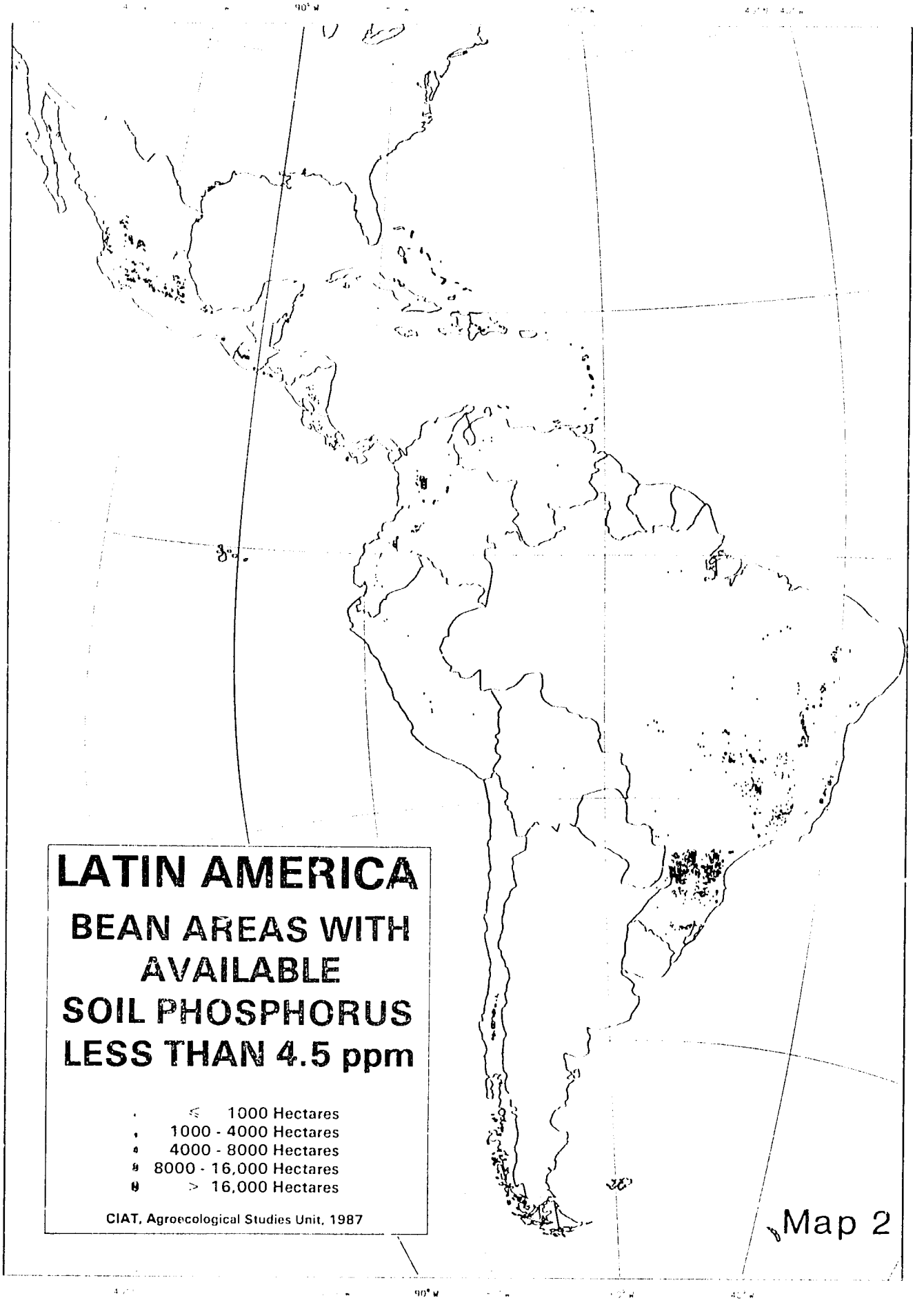
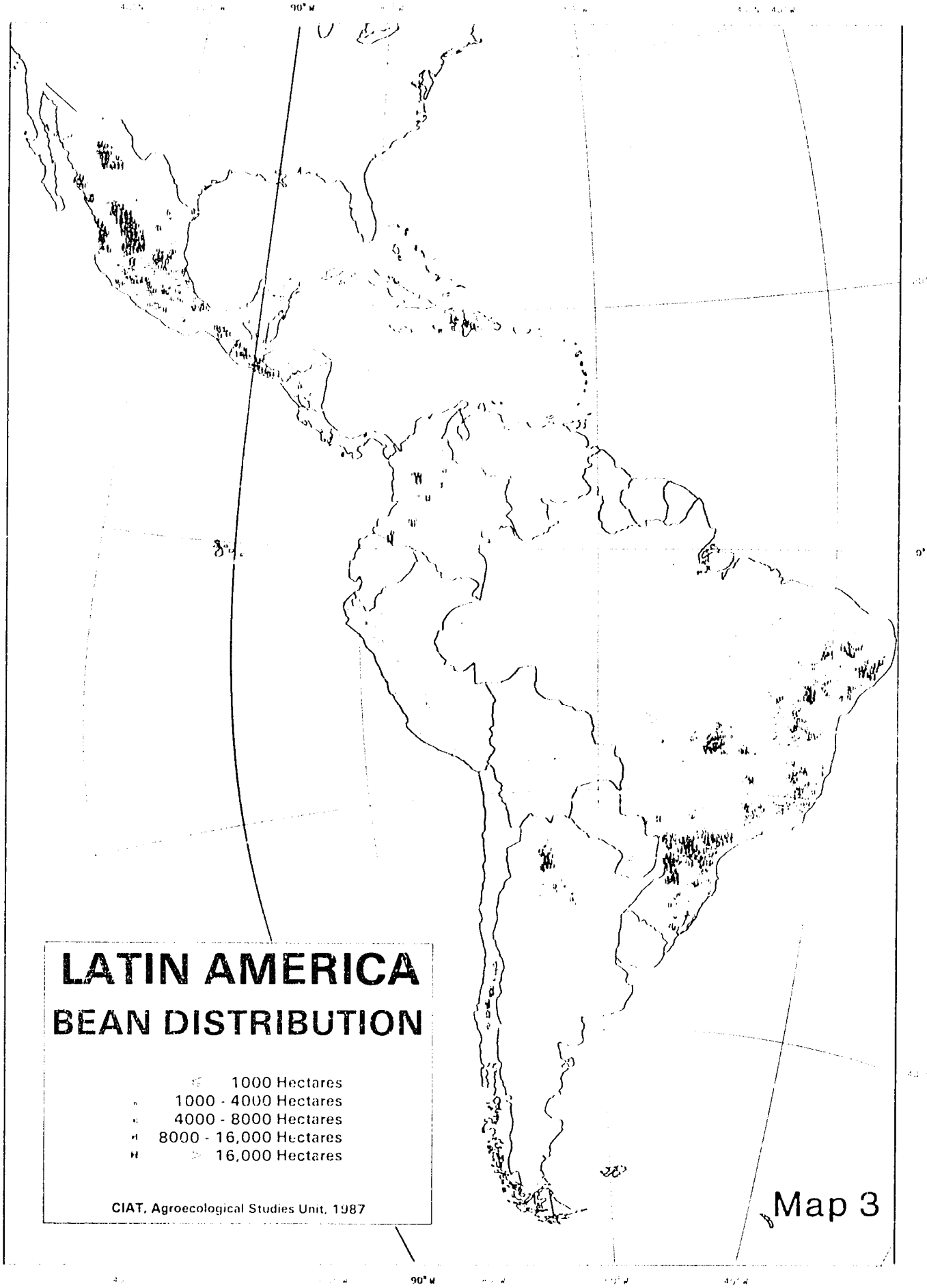


FIGURE 8. BASE SATURATION




LATIN AMERICA
BEAN AREAS
WITH SOIL pH
LOWER THAN 5.3
1000 Hectares
1000 - 4000 Hectares
4000 - 8000 Hectares
8000 - 16,000 Hectares
16,000 Hectares
CIAT, Agroecological Studies Unit, 1987
Map 1


LATIN AMERICA
BEAN AREAS WITH AVAILABLE SOIL PHOSPHORUS LESS THAN 4.5 ppm
≤ 1000 Hectares
1000 - 4000 Hectares
4000 - 8000 Hectares
8000 - 16,000 Hectares
> 16,000 Hectares
CIAT, Agroecological Studies Unit, 1987
Map 2


LATIN AMERICA
BEAN DISTRIBUTION
1000 Hectares
1000 - 4000 Hectares
4000 - 8000 Hectares
8000 - 16,000 Hectares
> 16,000 Hectares
CIAT, Agroecological Studies Unit, 1987
Map 3

C. DEVELOPING METHODS FOR UTILIZING GERMPLASM

1. Biotechnology

The range of genetic variability available for the improvement of *Phaseolus vulgaris* is large. Plant breeding has been successful in utilizing this variability through selection of plants with desired traits after cross fertilization between parental genotypes. There are, however, limitations in the precision and speed with which useful traits can be identified and selected in germplasm collections, parental materials and segregating populations. In addition, sexual exchange of genes between certain *Phaseolus* gene pools is limited due to incompatibility barriers and, in compatible crosses, it is often difficult to separate unwanted genes which may affect crop quality and yield.

In the last two years, collaborative efforts were initiated between the Biotechnology Research Unit (BRU), Bean Program scientists, the Genetic Resources Unit (GRU) and scientists in advanced institutions to develop methodologies for expanding the gene pool accessible for plant breeding. This collaboration included research in the following areas: a) development of biochemical (proteins and isoenzymes) and molecular (DNA-restriction fragment length polymorphisms: RFLPs) markers to characterize gene pools, to track genomic evolution and dispersal of common bean germplasm, to develop linkages with agronomically important traits, and to construct genetic linkage maps; b) recovery of viable plants from intra- and inter-specific *Phaseolus* spp crosses through embryo-rescue culture techniques; c) development of plant regeneration techniques in *Phaseolus* tissue cultures as a prerequisite for exploiting non-sexual methods for the production of genetic variability.

The most important highlights of this work are summarized below.

Biochemical and molecular markers

a. Seed proteins

As part of the IDRC-funded collaborative project between CIAT and the University of Manitoba, Canada, a procedure based on acid polyacrylamide gel electrophoresis (acid PAGE) was developed to characterize common bean germplasm.

Sixty-four accessions grouped into 14 common names were provided by the GRU for electrophoretic analysis. Out of the 14 groups, only 4 displayed the same banding pattern, while 6 groups were separated into two electrophoretic patterns, 1 group into three patterns, 2 into five and 1 group comprising 24 accessions

(Flor de Mayo from Mexico) was separated into nine electrophoretic patterns.

Single seed analyses showed interseed variation in about 25% of the accessions, in contrast to 4% visible variation in seed morphology. In most cases however, variation was limited to one out of ten seeds and referred only to one or two bands. More work is needed to find out the nature of the variation in the acid PAGE patterns of seed proteins.

Analysis of individual seeds collected from different plants of the same variety, and from different pods of the same plant of highly inbred cultivars (ABA, and AB_{57}) showed no differences in electrophoretic patterns. This suggests residual heterozygocity as a possible cause for interseed variation. Therefore, interseed analyses may be necessary prior to cultivar identification.

b. Phaseolin markers

Phaseolin, a high molecular weight protein which represents 40-60% of the storage protein in bean seeds, has been used as a marker for the geographic distribution of common beans in the major centers of diversity. At present, seven electrophoretically distinct phaseolin types have been described: S,T,C,H,A,M and B. These have been related to centers of domestication, e.g. 'S' phaseolin are present in Mexican beans, 'T' in Southern Andes, etc.

Work was initiated this year in collaboration with the GRU to use electrophoretic analysis of phaseolin types to follow the dispersal of common bean cultivars from its center of domestication in the Americas to East Africa. Out of 39 accessions from Kenya, 26 had phaseolin type 'T', 7 showed the 'S' type, and 1 had the 'C' phaseolin type. From 81 Malawian materials analyzed, 58 showed the 'T' phaseolin type, 12 had the 'S' type and 11 had the 'C' phaseolin type (Figure 1A). These preliminary results suggest that most southeastern African materials were possibly introduced from the southern part of the Andes. A few phaseolin types have been found whose electrophoretic pattern differed from the typical 'S', 'C' and 'T' types, suggesting the occurrence of either other molecular forms of phaseolin or new genetic combinations.

Although electrophoretic phaseolin types can be related to the major centers of common bean domestication, they are not sensitive enough to detect variability among accessions having the same phaseolin type. In collaboration with Bean Program breeders varieties with the same phaseolin type were analyzed with the acid PAGE technique. Discrimination between genotypes was possible and furthermore, band polymorphism was detected (Figure 2). Genotypes having clear polymorphism will be used for analysis of protein banding patterns of their progenies.

c. Isoenzyme markers

Isoenzymes can be used to study the relationships among the common bean gene pools and estimate the genetic distance between the gene pools. Based on morphological data (seed size, growth habit) and ecological adaptation, dry beans have been classified into various genepools. Gene transfer between some of the pools is difficult, e.g. transfer of high yielding potential of small seeded to large seeded cultivars. Understanding of those relationships at the isoenzyme level should give insight for future expansion of the available gene pool in *Phaseolus vulgaris*.

In collaboration with Bean Program breeders, work was initiated this year to conduct an electrophoretic survey of isozyme variation among landraces from Peru, Central America, Mexico, Africa, the Middle East region and advanced lines. Out of 12 isoenzymes, 9 were selected due to their polymorphism among materials of different gene pools Figure 1B). Over 200 materials have already been screened and data taken from many loci. Enzyme patterns of F_1 and F_2 progenies of crosses between lines of different gene pools will be evaluated.

d. DNA- restriction fragment length polymorphism (RFLPs) markers

In contrast to morphological markers, molecular markers (isoenzymes and RFLPs) are naturally occurring, are codominant, and their expression (isoenzymes) or presence (RFLPs) is not influenced by the environment and epistatic interactions. The segregation of an infinite number of these markers can be studied in a single progeny, thus allowing the study of the entire genome. Molecular markers can be used to tag genes for qualitative and quantitative traits via linkage analysis and used as effective selection criteria to accelerate the transfer of traits into commercial cultivars.

With the support of US-AID, a collaborative project was initiated this year with scientists (E. Vallejos, project leader) from the University of Florida, Gainesville, to construct a saturation linkage map of DNA markers (RFLPs) for *Phaseolus vulgaris*.

Segregating progenies between two polymorphic genotypes (provided by CIAT) have been produced, and a number of cDNA and genomic clones for detection of RFLPs have been generated. Over 25 cDNA and genomic clones have been hybridized to restriction digests of "Calima" and "XR-235-1". Out of these, 11 have shown polymorphisms between the two lines. The use of those two lines will allow the mapping of the major gene for resistance to *Xanthomonas campestris* pv. *phaseoli* which is present in line "XR-235-1". Furthermore, probing DNAs of an F_2 progeny which was scored for disease resistance has begun.

In vitro culture to recover wild P. vulgaris crosses

Collaborative work with the GRU was carried out to recover viable hybrid plants from various crosses of wild, weedy and aborigeneous P. vulgaris types. Immature embryos (which would normally abort) were excised from young pods after cross-fertilization and stimulated to grow into plants in an artificial, sterile, nutrient medium. Table 1 shows that viable plants can be rescued from otherwise difficult crosses, making such hybrids available for utilization in breeding.

Embryo culture in vitro has also been used to recover P. coccineus accessions with very old seed which otherwise would not germinate. Plants of 12 genotypes have been moved to the field in Popayan by GRU scientists.

Towards a tissue culture cycle in beans

The development of a tissue culture cycle in Phaseolus vulgaris is the first essential step for undertaking many biotechnological approaches with beans.

A tissue culture cycle involves the establishment of a de-differentiated cell or tissue culture, proliferation for a number of cell generations, and the subsequent regeneration of plants.

Thus, a period of essentially de-differentiated cell proliferation is imposed between an explant (initial plant part) and the next plant regeneration.

Induction of de-differentiation can be done readily with beans, but this species has resisted the regeneration phase. It has been recognized that regeneration is a trait under simple genetic control, hence it is reasonable to believe that in the case of P. vulgaris, such a trait may have been lost, or selectively repressed, or mutated throughout crop domestication. Therefore, a logical approach would be to screen the wild relatives of P. vulgaris for plant regeneration under defined culture conditions.

Cotyledonary nodes from germinated mature seeds of several wild relatives of P. vulgaris, were used as primary explants for culture. A granular callus formed on the explants, which upon sub-culture increased in mass; deep green spots formed on the callus which then differentiated into many bud initials. Upon transfer to a different medium, the buds developed into complete plantlets (Figure 3A).

In separate experiments, immature embryos (8-12 days after selfing) of P. vulgaris and P. lunatus were dissected out from pods and cultured in sterile medium. A friable callus formed, and after transfer of the callus to a medium of different composition, somatic embryos differentiated from the callus

(Figure 3B). These are the first efforts of successful plant regeneration in wild P. vulgaris and induction of somatic embryogenesis from P. vulgaris and P. lunatus callus cultures.

The results obtained at CIAT, plus those from other laboratories with which CIAT has established collaborative projects lead us to believe that routine plant regeneration in P. vulgaris is not very far away. These techniques will pave the way to non-sexual production of genetic variability as well as other genetic manipulations in Phaseolus.

Collaborative research

In the last two years, collaborative research projects have been established with other institutions where capabilities for undertaking specific research have been identified. Current collaborative projects include:

1. Project: Electrophoretic characterization of P. vulgaris germplasm .
   Institution: University of Manitoba, Winnipeg, Canada.
   Funding: IDRC
   Period: 1985-1987

2. Project: Tissue culture regeneration in Phaseolus spp.
   Institution: Instituto di Biologia Agraria, Viterbo, Italy.
   Funding: Italian government
   Period: 1987-1990

3. Project: Development of molecular markers in Phaseolus as Breeding tools: Disease Resistance.
   Institution: University of Florida, Gainesville, Fl., USA.
   Funding: US-AID
   Period: 1987-1990

4. Project: Identification of gene pools in P. vulgaris germplasm through biochemical/molecular markers.
   Institution: University of California, Davis, CA. USA.
   Period: 1987-88.

Table 1. Recovery of viable plants from *P. vulgaris* wild and *aborigeneous* crosses by means of immature embryo culture *in vitro*.

Type of cross*	No. of crosses	No plants recovered
1. Wild *P. vulgaris* X *P. vulgaris* var. *aborigeneous*	1	1
2. *P. vulgaris* var. *aborigeneous* X Wild *P. vulgaris*	3	11
3. *P. vulgaris* var. *aborigeneous* X Weedy *P. vulgaris*	1	1
4. Wild *P. vulgaris* X Weedy *P. vulgaris*	1	2
	6	15

* Crosses made and material provided by the GRU.
Germplasm collected in Argentina, Peru, Mexico and Colombia.

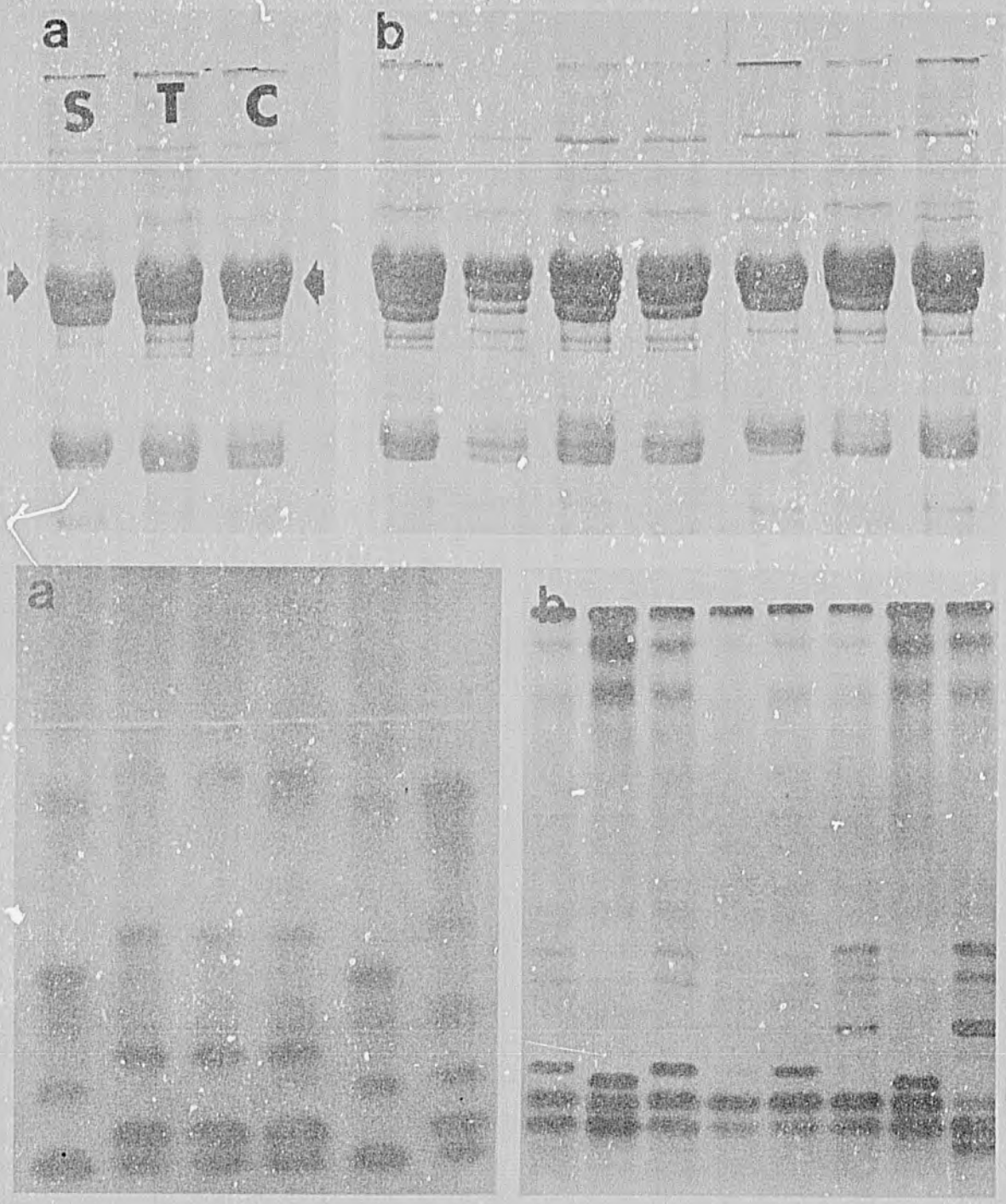


Figure 1. Phaseolin and isoenzyme markers to monitor the dispersal of germplasm and characterize gene pools.

A. Analysis of phaseolin types using basic PAGE: (a) reference phaseolin 'S', 'T', and 'C' patterns (arrows); (b) phaseolin types found in germplasm accessions from Malawi. Note that accessions with phaseolin type 'T' predominate.

B. Electrophoretic isoenzyme variation of material from various genepools: (a) Diaphorase; (b) α, β esterase. Note polymorphis... of isoenzymes shown by many accessions.

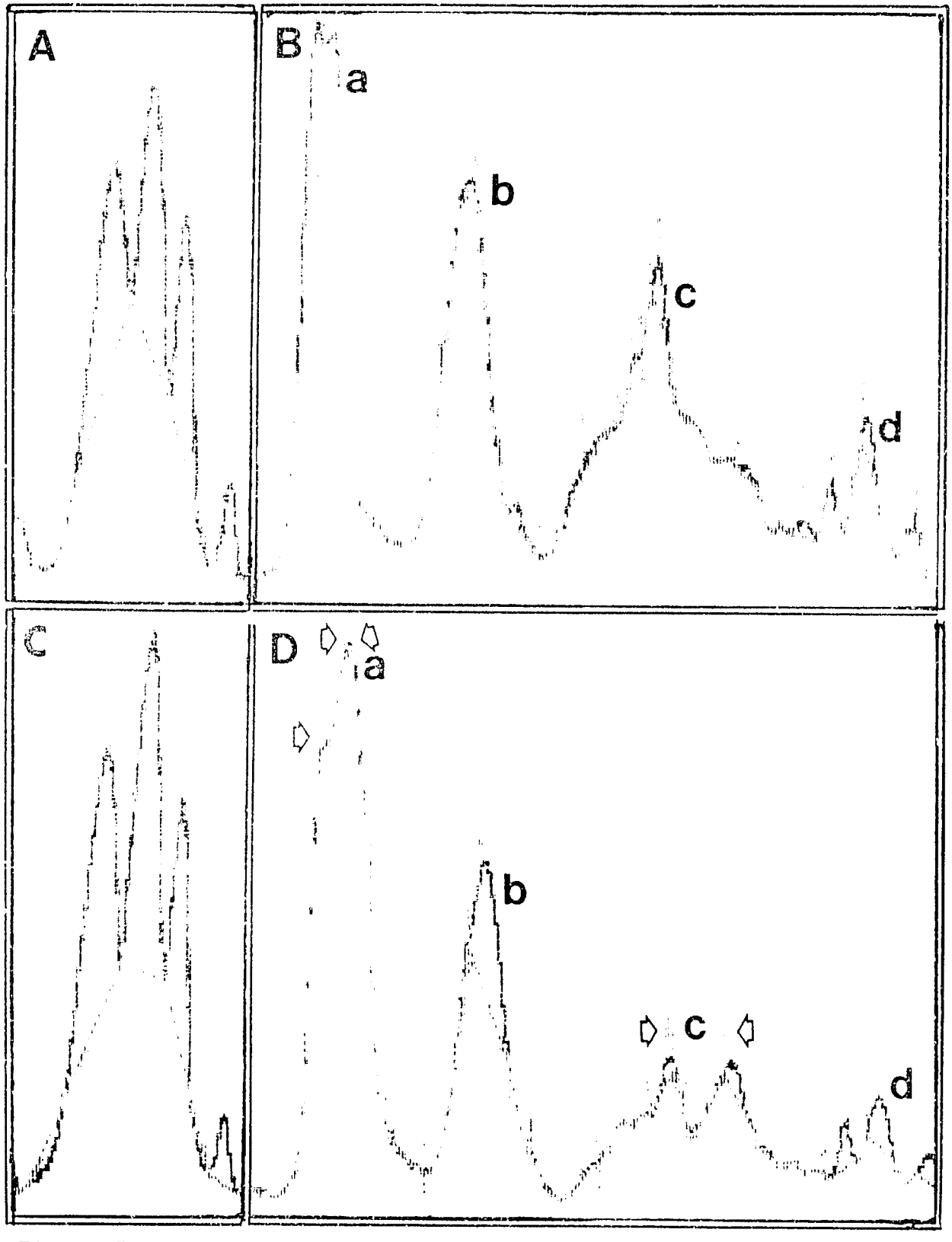


Figure 2. Comparison of electrophoretic patterns of two varieties using basic (A and B) and acid (C and D) PAGE. Although the two varieties have the same phaseolin type (see figures A and C) they differ markedly in their basic PAGE patterns (see peaks in areas a and c in figures B and D). Areas and peaks of graphs were obtained through integration of readings using a computerized densitometer: band migration shown on horizontal axis and band color density (absorbance) shown on vertical axis. A and B = Calima; C and D = Tundama.

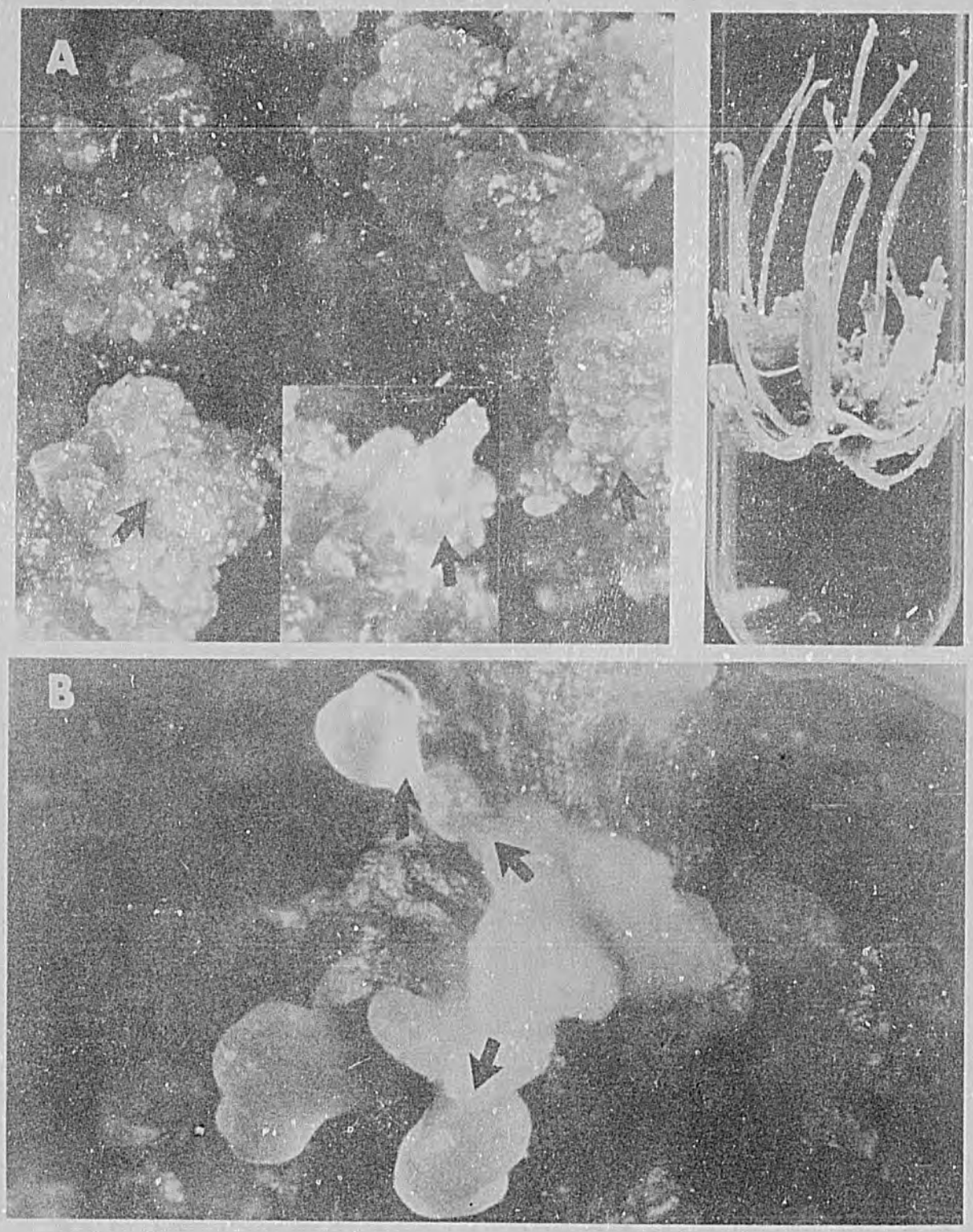


Figure 3. Development of plant regeneration techniques in P. vulgaris. A. Organogenic callus (left) and shoot differentiation from callus (right) in wild relatives of P. vulgaris. Arrows point at bud primordia on callus. B. induction of somatic embryogenesis on callus of P. vulgaris. Arrows point at globular and heart-shaped somatic embryos.

2. Interspecific Hybridization

The main objective of the project between CIAT and Gembloux (Belgium) is the genetic improvement of P. vulgaris through interspecific hybridization. The major donor parents, P. coccineus and P. polyanthus, are species which show many useful characteristics not expressed or poorly expressed in the common bean gene pool. A breeding program with P. vulgaris requires as a prerequisite the seed multiplication and evaluation of the P. coccineus and polyanthus collection held by CIAT (See "Improving other Phaseolus species: P. coccineus").

The P. vulgaris x P. coccineus populations include many highly allogamous materials, due to the floral biology of the scarlet runner bean, and the segregation continues in advanced generations.

The breeding scheme adopted is a method of cumulative selection which involves reselection generation after generation and interbreeding of selected plants. The breeding methodology includes the following steps: selection of the best individual plants for yield and disease resistance, and the favoring of interbreeding of the advanced lines. The ultimate goal is to provide advanced lines to the bean breeders for the VEF.

Screening for beanfly (Ophiomyia phaseoli) resistance

During 1987, 110 F_3 interspecific hybrid lines between P. vulgaris and P. coccineus selected in A.V.R.D.C. (Taiwan) by Dr. Talekar for beanfly resistance were planted in Palmira for multiplication and agronomical selection. F_4 seeds from 307 selected plants were sent back to Taiwan for further evaluation and beanfly resistance selection.

Screening of more advanced generations (F_7 and F_8) was also done in Taiwan. Thirty-nine of 221 lines presented a medium or high level of resistance and were selected. Seeds from these selections were sent to CIAT and have been planted in Palmira for agronomical selection. Results of the screening made in Taiwan are presented in Tables 1 and 2.

Rio Negro 1986 B

In Rio Negro, 18 F_2 populations and 48 F_6 to F_8 populations of interspecific direct hybrids (P. vulgaris x P. coccineus or P. polyanthus) were planted for Ascochyta resistance evaluation. The trial additionally included two F_2 and 12 F_5 complex hybrids (F_2: [(P. coccineus wild form x P. vulgaris) x P. polyanthus] x P. vulgaris; F_5: (P. coccineus wild form x P. vulgaris) x P. coccineus).

Architecture, adaptation and productivity were also observed and 107 plants from 72 populations were selected. In relation to their precocity and resistance to diseases, the most interesting hybrids were: one Mortino x X7 (F_7), three Ecuador 299 x Piloy (F_6), two Guate 467 x Guate 1259 (F_6), one NI 141 x G 35174 (F_8), four San Martin x Piloy (F_7) and one (NI 889 x D 145) x NI 15 (F_5). Seeds of the most advanced generations were given to the breeding program and the earlier progenies were included in further selection trials.

Popayan 1986 B

In Popayan, the plantings of the second semester of 1986 involved F_1 to F_9 direct and complex hybrid populations.

The F_1 progeny includes 22 direct hybrids *P. vulgaris* x *P. polyanthus*, three complex hybrids (*P. purpurascens* x *P. vulgaris*) x *P. polyanthus* and two complex hybrids [(*P. coccineus* wild form x *P. vulgaris*) x *P. polyanthus*] x *P. vulgaris*, made to introduce resistance to Ascochyta into *P. vulgaris*. The direct hybrid plants were selfed to increase the seed production.

In the F_2, 141 plants from 86 direct populations and nine plants from seven complex hybrid populations were selected for Ascochyta resistance. The F_3 seeds were planted in Popayan to be evaluated during the first semester of 1987.

In more advanced progenies, individual selection was made for disease resistance (mainly Ascochyta leaf spot) and for other characters like architecture and adaptation. Some 36 plants from 27 populations were selected in the F_3, as well as 22 plants from 17 populations of the F_7, 10 plants from eight populations of the F_8 and 17 plants from eight populations of the F_9. Seeds have been given to the breeders of the Bean Program to be included in their selection trials.

Popayan 1987 A

During the first semester of 1987, the F_1 progenies included 130 direct hybrid lines *P. vulgaris* x *P. polyanthus* or *P. coccineus* and 44 complex hybrid lines. Table 3 shows the number of lines and objectives for each cross combination.

In the F_2, 20 plants out of 50 *P. vulgaris* x *P. polyanthus* populations were selected for their resistance to *Ascochyta* sp. The F_3 seeds will be planted in Popayan to be evaluated during the second semester of 1987. The more advanced progenies included F_3 and F_4 populations, that were screened mainly for disease resistance, architecture and adaptation. Fifty-two plants from 109 populations in the F_3 and 14 plants from 32 populations in the F_4 were selected and will be planted both in Popayan and Rio Negro for the next selection cycle. They are

made up of both direct and complex hybrids. Details are given in Table 4.

VEF 1987 (Bean Program Nursery)

Three advanced lines of two complex crosses were included in the VEF this year. They are indeterminate climbing types and came from an adaptation trial in Palmira during 1986. They include one [(NI 889 x NI 637) x BAC 24] x NI 663 ([(P. coccineus wild form x P. vulgaris) x P. vulgaris] x P. coccineus) line (pale brown seeds) and two (NI 886 x G 3807) x BAC 24 ((P. coccineus wild form x P. vulgaris) x P. vulgaris) lines (cream with brown spots and yellow seeds, respectively).

EP 1987 (Preliminary trials)

Four of the five direct hybrid P. vulgaris x P. coccineus lines included in the VEF 1986 were selected for their good reaction to common bacterial blight, anthracnose and angular leaf spot. They are being evaluated in the EP during 1987. They include two Aete 1/38 x M 7689A (red and cream seeds) and two ICTA Quetzal x M 7285 lines (black and brown seeds).

Table 1. Distribution of resistance to beanfly of 221 *P. vulgaris* x *P. coccineus* lines for their resistance to beanfly in Taiwan.

Category[1]	No. of lines	% of lines
HS	30	13.5
S	68	31.0
LR	84	38.0
MR	37	16.5
HR	2	1.0
TOTAL	221	100.0

1. HS = high susceptibility; S = susceptibility; LR = low resistance; MR = medium resistance; HR = high resistance.

Table 2. Identification of the best F_7 and F_8 *P. vulgaris* x *P. coccineus* lines selected for beanfly resistance in Taiwan.

Identification	Progeny	No. of lines	Resistance level
Pasto x G 35122	F_7	4	MR
BAT 338 x 46-1	F_7	2	HR
BAT 338 x 46-1	F_7	29	MR
X23-3-66 Cafe x G 35023(A)	F_8	1	MR
78 VEF 1176 x G 35075C(A)	F_7	1	MR
X 28366 Cafe x G 35023(A) 3	F_8	2	MR

Table 3. Number of lines of the F_1 progeny and objectives for each cross combination in Popayan during the first semester of 1987.

Cross combination	No. of lines	Objectives
P. vulgaris x *P. polyanthus*	35	Andean zone
	31	East Africa
	23	Multiple resistance
P. vulgaris x *P. coccineus*	14	Multiple resistance
	23	BGMV resistance
	4	Beanfly resistance
[(*P. coccineus* wild x *P. vulgaris*) x *P. polyanthus*] x *P. vulgaris*	4	Andean zone
	5	East Africa
	14	Ascochyta resistance
(*P. coccineus* wild x *P. vulgaris*) x *P. polyanthus*	5	Multiple resistance
(*P. purpurascens* x *P. vulgaris*) x *P. coccineus*	6	Multiple resistance
(*P. purpurascens* x *P. vulgaris*) x *P. polyanthus*	6	Multiple resistance
(*P. purpurascens* x *P. polyanthus*) x *P. vulgaris*	4	Multiple resistance

Table 4. F_3 and F_4 selected lines during the first semester of 1987 at Popayan.

Cross combinations	Parent identification	Progeny	No.of lines
P. vulgaris x *P. polyanthus*	Kirundo x NI 757	F_3	3
	Urubonobono x NI 757	F_3	15
	Antioquia 8 x NI 757	F_3	3
	BAT 1297 x NI 1015	F_3	14
	ZAV 83102 x NI 757	F_3	1
	A 114 x NI 1015	F_3	13
	Antioquia 8 x NI 1015	F_3	1
(*P. purpurascens* x *P. vulgaris*) x *P. polyanthus*	(NI 552 x ICA-Guali) x NI 757	F_4	5
[(*P. coccineus* wild x *P. vulgaris*) x *P. polyanthus*] x *P. vulgaris*	[(NI 889 x NI 637) x NI 758] x VRA 81043	F_4	2
	[(NI 889 x NI 637) x NI 1015] x NI 1007	F_4	5
	[(NI 889 x NI 637) x NI 1015] x A 114	F_4	2

D. IMPROVING YIELD POTENTIAL

1. Yield Physiology

Germplasm improvement is the objective of the Bean Breeding Program, and is facilitated through a series of independent breeding projects. Research directed toward increasing yield potential in 1987 was carried out via studies on genotypes wth erect architecture combined with intensive agronomic management including use of narrow row spacings. Research in previous seasons indicated that while vegetative growth, particularly before flowering, was greatly enhanced at 0.3 m vs 0.6 m row spacings, yield increases were only in the order of 5% to 10%.

One possible explanation is that with intensive management, bean crops develop excessive leaf area index (LAI). Evaluation of LAI in two trials showed maximum LAIs of 4.7 to 7.5 at 0.3 m row spacings (Table 1), these values considerably exceeding estimated optimal LAI of 4 to 4.5 for bush beans.

Lodging was also suspected as a factor contributing to poor yield performance since previous studies suggested lodging could cause 20% yield reductions, and since severe lodging has occurred in row spacing trials, notwithstanding inclusion of genotypes with more erect architecture. However, in a first attempt to quantify effects of lodging, no difference was found between the control plot with natural lodging, and plots where lodging was prevented through use of various systems of horizontal supports (Table 2).

Combined with previous studies showing no or negative response to split nitrogen applications in crops with 0.3 m row spacings, these results indicate that existing bean cultivars respond to narrow row spacings and high soil fertility by increasing partitioning to leaf growth. While such a response is probably useful for conditions with poor stands, weed competition, or other production constraints, it seems to result in a severe limitation on yield potential under highly favorable agronomic conditions. Future research will test this hypothesis, placing particular emphasis on understanding the nitrogen balance of bean crops.

Complementing this main line of research on yield potential are continuing studies on specialized problems related to yield potential. These include the relation between seed size and yield, efficiency of pollination, and strategies for increasing yields of early maturing cultivars.

Table 1. Maximum leaf area index (LAI) and seed yield of three genotypes grown at 0.3 m and 0.6 m row spacings, in two semesters at CIAT Palmira.

Genotype	LAI		Yield	
	0.3 m	0.6 m	0.3 m	0.6 m
			-------kg/ha-------	
		Semester A		
ICA Pijao	6.7	5.2	2440	2250
BAT 477	4.7	3.9	2540	2250
ICA Linea 24	5.7	4.0	1790	1740
Mean	5.7	4.0	2260	2080
Significance level of effect:				
Genotype	0.01		0.01	
Row spacing	0.01		NS	
Row spacing by genotype	NS		NS	
		Semester B		
BAT 477	7.5	6.2	3380	3010
BAT 881	6.5	5.6	3050	3020
Porrillo Sintetico	6.9	6.5	2920	2870
Mean	7.0	6.1	3120	2970
Significance level of effect:				
Genotype	NS		NS	
Row spacing	0.05		NS	
Row spacing by genotype	NS		NS	

Table 2. Effects of artificial support on yield of cv. ICA Pijao planted at 0.3 m row spacings. Support consisted of polypropylene twine layed in horizontal grids supported at varying heights.

Grid size	Grid height	Seed yield
m^2	m	kg/ha
0.3 x 0.6	0.3	3310
0.3 x 0.3	0.3 and 0.5	3380
0.3 x 0.3	0.5	3200
0.15 x 0.3	0.3	3300
Control (no grid)		3250
$L.S.D._{0.05}$		350

2. Yield Breeding

Morphological, physiological, yield and yield components have often been suggested as selection criteria to breed for high seed yield. In earlier studies selections were made for plant type, leaf, node and pod numbers, and leaf size due to their high positive association with seed yield and due to their relative ease to select. However, contrasting lines thus developed did not significantly outyield the conventional cultivars under any of 16 genotype, density and environment combinations (CIAT Bean Program Annual Report, 1982).

Among apparent physiological traits, total biomass, biological efficiency, leaf area duration, harvest index, and seed yield/day are reported to be highly and positively associated with seed yield. But their usefulness as selection criteria for breeding for higher seed yield has not been demonstrated yet in the common bean.

Within the past several years studies have been underway at CIAT to clarify the role that yield and yield components play in attempts to increase yield potential. Before summarizing the results obtained to date it may be useful to describe different gene pools found in cultivated dry beans and their yield potentials.

Based upon the occurrence and concentration of genetic variation in its cultivated, wild and related species it is generally accepted that Phaseolus beans originated in the Americas. Wild and cultivated common beans are distributed from northern Mexico to the southern tip of the Andes of South America. Among the cultivated types great variation is found for growth habit and other morphological traits, seed characteristics, adaptive features and yield potential. But variation for these traits is not distributed at random. For example, there are at least two principal centers of domestication and diversity; one belonging to Central America and the other to Andean South America. Small and large seeded beans, respectively, belong to these two regions. Based on other morpho-agronomic characteristics, germplasm from each of these two centers can be divided into six different gene pools. A summary of ecological area of adaptation, seed characteristics, crop duration, and existing yield potential of 12 gene pools of common cultivated dry beans is given in Table 1.

Morphologically and genetically, snap beans are related to Andean germplasm and can be grouped into two additional gene pools (determinate bush vs indeterminate semi-climbing and climbing types). From Table 1 it should be clear that in growth habits I and IV, there is apparent lack of any association between seed size and yield potential. But small seeded types II and III of Central American origin have much higher yield potential than their counterparts from Andean South America. Also, F_1 hybrid dwarfism and problems of genetic recombination

between the two groups of germplasm have been reported (CIAT Bean Program Annual Report, 1983). Therefore, it is essential to have a thorough understanding of the genetics of yield, combining ability, and nature of genetic recombination between and within gene pools in order to be able to fully exploit their existing potential for yield breeding. With that in mind studies were initiated for Central American gene pools suitable for sole crop systems.

Results from two separate genetic studies (involving nine-parent complete diallel analyses and the N.C. Design II mating system involving 80 parental materials) indicate that: 1) while in the F_1 both additive and nonadditive gene actions were important, whereas in the F_2 and subsequent generations only additive gene action was responsible for the inheritance of yield and yield components; 2) that narrow-sense heritability of seed yield and pods/plant was low (33-39%), seeds/pod was moderately high (54%), and that of seed weight was very high (8%); 3) that expected genetic gains for yield were positive and high (6%) when seed yield per se and seed weight (7%) were used as selection criteria but correlated response for yield were either negative or nonsignificant when indirect selections were made for pods/plant and seeds/pod--the two traits positively associated with seed yield; 4) that the majority of small seeded commercial cultivars, both traditional and new releases, extensively grown in Latin America and used as donors of desirable resistances for many production limiting factors, possessed negative general combining ability (GCA) for yield, and 5) that their GCA and yield potential could be improved by crossing them to some accessions from semi-arid highlands of Mexico (gene pool 5).

This information was used to design two different selection experiments for yield under high and low stress environments at Quilichao and Popayan. Two hybrid populations involving parents belonging to small seeded gene pools 2 and 3 were utilized at Quilichao. Six crosses were utilized at Popayan; 2 each of low, intermediate, and high yield potential. The first two groups of crosses were from parents belonging to gene pools 2 and 3 and two crosses of high yield potential involved parents belonging to gene pools 3 and 4 on the one hand and those of gene pool 5 on the other. The two stress environments varied for amount of lime and fertilizers applied, as well as disease inoculation vs protected conditions. Mass selections in segregating generations were undertaken to obtain seed yield. The results of the two experiments were similar in that there was no significant difference in the mean performance of lines selected from the high and low stress environments (Tables 2 and 3). Although selection for yield was effective in all crosses in both environments, significantly high yielding lines compared to the highest yielding parent and check cultivar were derived only from the highest yielding cross at Popayan (Tables 4 and 5). Thus, the selection of parents and their knowledge of GCA played a key role in selection for yield. Similar experiments involving gene pools from Andean South America have been initiated. Also,

effect of location, breeding methods, cropping system, plant population, and selection criteria are being investigated for yield breeding.

Table 1. Patterns of variation in cultivated dry beans; proposed gene pools; estimated days to maturity; yield potential.

ORIGIN	CENTRAL AMERICAN						ANDEAN SOUTH AMERICAN					
Seed type	SMALL SEEDED				MEDIUM SEEDED		MEDIUM AND LARGE SEEDED					
Adaptation	(LOWLANDS)				(HIGHLANDS)		(MEDIUM ALTITUDES)				(HIGHLANDS)	
Growth Habit	I	II	III	IV	III	IV	I	II	III Elg.	III Rnd.	IV Det.	IV Ind.
Yield (kg/ha)	3000	4500	5000	6000	5000	6000	3000	3500	4000	4000	5000	6000
Maturity (Days)	70–90	80–110	80–120	120–150	100–120	130–150	70–90	90–120	100	130	210	280
Gene Pool	1	2	3	4	5	6	7	8	9	10	11	12

Table 2. Mean squares from analysis of variance for seed yield, yield components, and days to maturity from dry bean lines selected under low and high stress environments at CIAT-Popayan, Colombia.

Source	d.f.	MEAN SQUARES				
		Yield (kg/ha)	Pod number	Seed number	100-seed weight (g)	Maturity (days)
Year	2	740390*	233234*	9490941*	170.0*	2329.0**
Stress Levels	1	3059290**	1571530**	31178229**	763.0**	625.0**
Crosses (C)	5	591745**	104272**	2010376**	1901.6**	1186.0**
Origin of lines (O)	1	4410	52173**	1046255**	107.0**	74.0**
Lines (C x O)	60	24436**	13968**	319385**	54.4**	195.1**
Parents	4	53403**	14307**	322036**	179.7**	112.0**
Checks	3	4997	32017**	474752**	184.7**	65.3**
Error	384	3096	1887	44791	1.4	1.3

*,** Significant at P = 0.05 and P = 0.01, respectively.

Table 3. Mean squares from analysis of variance for yield, 100-seed weight, and days to maturity for dry bean lines selected under low and high stress environments at CIAT-Quilichao, Colombia.

Source	d.f.	MEAN SQUARES		
		Yield (kg/ha)	100-seed weight (g)	Days to maturity
Year and seasons	3	112813721**	789.27**	939.39**
Stress levels	3	345200143**	973.44**	520.98**
Crosses (C)	1	2368800**	267.96**	283.27**
Source of lines (S)	1	122438	15.23**	19.04*
Lines (C x S)	52	277816**	17.51**	10.95**
Parents	3	884419**	66.88**	22.80**
Checks	3	686776**	114.98**	4.33
Error	392	50215	0.91	2.31

Table 4. Yield, regression coefficient (b), and coefficient of determination (R^2) for dry bean lines selected under low (L) and high (H) stress environments at CIAT-Popayan, Colombia.

Identification	Yield (kg/ha)									
	1984		1985		1986		Mean		b	R^2
	L	H	L	H	L	H	L	H		
A 114 x (Flor de Mayo x AB 136)										
LSL	4782	2924	4155	2878	6560	3835	5166	3212	1.75*	0.87
LSH	4789	3455	4109	3523	6372	4154	5090	3711	1.31	0.84
A 113 x G 1805										
LSL	3898	2342	3336	2958	4825	3339	4020	2880	1.09	0.97
LSH	3579	2211	3243	2603	3682	3004	3501	2606	0.69*	0.91
A 175 x (G 2333 x A 62)										
LSL	3594	1622	3222	2814	4418	3216	3745	2551	1.19	0.96
LSH	3875	2183	3249	2646	4522	3193	3882	2674	1.08	0.97
A 62 x (A 77 x G 13224)										
LSL	3769	2214	2836	2444	3940	2790	3515	2483	0.83	0.85
LSH	3658	2394	3131	2473	4215	3229	3668	2699	0.85	0.91
G 5059 x (G 3393 x A 175)										
LSL	2848	1488	3193	2606	3703	2712	3248	2269	0.88	0.86
LSH	3113	1333	3373	2385	3441	2179	3309	1966	0.92	0.75
A 140 x (G 3038 x G 1274)										
LSL	2222	1101	2364	2151	3528	2407	2705	1886	0.92	0.86
LSH	2365	1044	2908	2662	3782	2584	3018	2097	0.99	0.74

Table 4 continued.

CONTINUE

Identification	Yield (kg/ha)									
	1984		1985		1986		Mean		b	R^2
	L	H	L	H	L	H	L	H		
Parents	3126	1362	2523	2209	3502	2553	3050	2041	0.98	0.96
Checks	3406	2037	3207	2675	3049	2825	3221	2512	0.48*	0.62
Mean	3563	2104	3336	2715	4336	3057				
LSD (.05)	1230	857	1064	854	1509	1022				
CV (%)	18	22	17	16	18	17				

* Significantly different from one.

Table 5. Seed yield, regression coefficient (b), and coefficient of determination (R^2) of dry bean lines selected (LS) under low (L) and high (H) stress environments at CIAT-Quilichao, Colombia.

Identification	Yield (kg/ha)											
	1985		1986 A		1986 B		1987		Mean		b	R^2
	L	H	L	H	L	H	L	H	L	H		
A 286 x (G 5059 x a 80)												
LSL	3532	1279	1713	548	1465	805	1373	650	2021	821	1.05	0.99
LSH	3583	1333	1565	551	1365	777	1398	616	1978	819	1.07	0.99
A 286 x ICA Pijao												
LSL	3216	1274	1611	547	1349	719	1270	566	1862	777	0.94	0.99
LSH	3616	1052	1616	465	1335	683	1164	423	1933	656	1.15	0.99
Parents	3073	1188	1506	475	1207	678	1171	660	1739	750	0.88	0.99
Checks	3277	1381	1588	583	1421	877	1416	588	1925	857	0.93	0.99
Mean	3448	1241	1616	528	1370	750	1300	571				
LSD (.05)	694	605	372	204	343	266	432	466				
CV (%)	10	24	11	19	13	18	17	41				

E. CHARACTER IMPROVEMENT: DEVELOPING SOLUTIONS TO MAJOR PROBLEMS

1. Soil/Nutritional Constraints

a. NITROGEN FIXATION

Nitrogen deficiency limits production in many bean growing areas as indicated by the responses to nitrogenous fertilizers that have been observed, with subsequent recommendations that farmers apply at least minimal doses of this nutrient. Research directed toward increasing nitrogen fixation has emphasized improving both the plant genotype and the Rhizobium strain components of the symbiosis. In addition, agronomic management and soil factors that may limit expression of improved fixation potential are evaluated in on-farm trials.

Breeding for enhanced fixation

The recurrent selection program for improving nitrogen fixation in small seeded indeterminate beans was initiated about ten years ago using materials such as Puebla 152, BAT 332 and BAT 76 as "good-fixing" parents. RIZ lines are selected based on performance for a range of N_2 fixation-associated characters in three field sites and in the glasshouse. For example see Table 1 for selection of RIZ lines from a group of cream-colored materials. Criteria include: nodulation, vigor, total plant N and grain yield, all in low mineral N, Rhizobium-inoculated treatments. Lines very susceptible to rust, bacterial blight, Ascochyta or anthracnose are eliminated.

Results of studies using the ^{15}N isotope dilution method to quantify N_2 fixed by some RIZ lines and early parents indicated that in general the RIZ lines fixed more N_2 (see 1985 and 1986 reports). Some additional RIZ lines and some "favorites" nominated by the breeders have been evaluated using the same method, in two locations over two seasons. In the first semester in CIAT-Palmira no fixation was observed by any of the materials and nodulation was very poor. High nitrogen mineralization rates may have been partly responsible, however very low grain yields in that semester indicate that other factors were also involved. Results from the second semester trials are shown in Tables 2 and 3. Amounts of N_2 fixed ranged from 9 to 51 kgN/ha in 68 days, with less than half of the plant N coming from fixation. The RIZ lines showed no obvious advantage over the materials from other breeding programs. BAT 477 and RIZ 32 fixed large amounts of N_2 and WTE 3 and RIZ 44 were poor at both locations. When these same materials were evaluated by Gudni Hardarson at the IAEA in Austria, WTE 3 was again the poorest and among the best were RIZ 32 and RIZ 68, fixing over 100 kg N/ha. The most striking difference was RIZ 44 which was excellent in Austria and very poor in Colombia.

Although very useful for quantifying N_2 fixation by a few lines, the ^{15}N isotope dilution method is too expensive for routine screening. Nodulation evaluations together with other fixation associated characters, frequently permit differentiation between the best and poorest fixing materials; for example, in the experiments reported in Tables 2 and 3, RIZ 68 and BAT 477 had the best overall nodulation (area under curves of number of red nodules vs. time) in both Palmira and Quilichao. RIZ 32 was particularly good in nodulating early which may have accounted for its good fixation. Using nodulation as the evaluation criterion, WTE 3 and RIZ 53 would have been considered poorest in fixation. RIZ 53 suffered from a virus disease in Quilichao but in Palmira was one of the best for fixation, although it nodulated poorly. From the acetylene reduction data it was noted that specific nodule activity was particularly high in RIZ 53, a characteristic previously observed in RIZ 30.

With the identification of materials good for specific N_2-fixation associated characters, the present strategy for improving fixation in small seeded indeterminate bush beans is to work towards combining the traits. In 1987 genotypes good for each of the following characters were crossed: early nodulation, late nodule senescence, maximum nodule mass, nitrogen harvest index, vegetative vigor, specific nodule activity and yield potential. Obviously a priority area is the evaluation of more germplasm in detail to identify better parents with these desirable traits. Preliminary indications are promising as materials superior to RIZ lines and other "good fixing" checks have already been identified for at least some of the above characters.

As reported in 1986 (Annual Report) a breeding program to improve fixation in medium to large seeded materials with promise for Africa has been initiated. Germplasm evaluation for the identification of parental lines included the measuring of nodulation, plant nitrogen and grain yield of 12 varieties under low and high mineral nitrogen availability. Some of the materials were repeated from last year and the results were similar; Ancash and Tostado nodulated well while Natal Sugar and Kabanima were poor. See Table 4 for relative nodulation values of the materials in the two nitrogen treatments. Two new well-nodulating varieties were identified: Canadian Wonder Moshi and Masai Red. GLP-24 had fairly late nodule senescence and nodulation of the Tanzanian variety T-3 was significantly less sensitive to mineral nitrogen, a desirable character particularly in mixed cropping systems where the non-legume is fertilized. Plant nitrogen and grain yield of these varieties are shown in Table 5. The nitrogen response index (NRI) was negative for some materials thus the high mineral nitrogen treatment did not serve as a good indicator of plant potential; however it was interesting to note that in general it was the poorly nodulating varieties that responded to mineral nitrogen. There were significant ($P = 0.05$) linear correlations between seed yield in the low N treatment and both "total" nodule number and nodule

number at 56 days (r = 0.602 and r = 0.695 respectively). There was no relation between nitrogen yield in the low and in the high N treatments (r = 0.094); however, as has been observed in previous trials, the change in genotype ranking between the two treatments was not notable with respect to grain yield (r = 0.667).

The backcross program to increase fixation in well-adapted but poorly-nodulating varieties such as Mutiki 2 and Rubona 5 includes selection for early nodulation in the F_2 and F_3 generations of BC(1) and BC(2) populations, then selections are multiplied for replicated field evaluations under low and high mineral N availability. In 1987 selections were made from BC(1)F_3, BC(2)F_2 and BC(2)F_3 populations of the Mutiki 2 x RIZ 29 cross; also from F_2 and BC(1)F_2 populations of six other "African" materials crossed with RIZ 23. In addition to the backcross program, crosses have been made between varieties with different good fixation traits; e.g. Canadian Wonder Moshi (good early nodulation), Tostado (many nodules at flowering) and Naivasha (late nodule senescence).

Nodulation mutants

Ineffective or non-nodulating mutants of beans are needed for ^{15}N and difference method evaluations of N_2 fixation, as well as for more fundamental genetic and physiological studies on fixation. The cause for poor seed set by the two promising non-nodulating mutants NOD 109 and NOD 125 (described in the 1986 report) was found to be very low pollen viability (about 2%). It is hoped that the non-nod character can be isolated in the progeny of the backcrosses. NOD 238 is another interesting mutant that has consistently shown inefecctive nodulation (a number of *Rhizobium* strains have now been tested).

Several thousand seeds of the varieties Huetar and Talamanca were gamma-irradiated with doses from 5 to 20 krads and treated with several concentrations of EMS to 0.075% for 2 h. The seeds were planted in the field, but even at the highest doses mutation rates were low. Several hundred M_2 plants of each variety were evaluated for mutations in nodulation but none were promising. Hopefully the basic work on refining mutation methods for beans being done in collaboration with the University of Napoli in Italy will help in this area.

Rhizobium strain collection and testing

Work on the bacterial component of the symbiosis is focused in three main areas: maintenance and characterization of the strain collection; screening for effective and competitive strains; and ecological studies on nodulation by inoculated *Rhizobium*.

A set of 100 strains from the collection was used to develop a system of characterization for *Rhizobium leguminosarum* biovar

phaseoli. Simple and inexpensive methods were sought; those that can be used by national program collaborators to identify variability and to ensure purity and maintenance of tested strains. Some morphological, physiological and serological categories are defined. The clonal morphology characters include growth rate, gum production, colony shape, appearance, acid production, and texture when grown using specific plating and incubation conditions. Physiological parameters include growth rates on media of different pH levels from 4.5 to 6.8, growth at different temperatures and tolerance to high salt (NaCl) concentrations. The strains are tested for reaction against eight antisera using immunodiffusion or ELISA. This information together with results of infectivity tests in Leonard jars and effectiveness studies in soil conditions will be coded in the new catalogue that is being prepared. A photograph of the strain grown on yeast mannitol agar for 16 days at 20°C will be filed.

The inability of inoculant Rhizobium strains to survive and compete against the abundant and often ineffective native soil populations severely limits improvement of the bean-rhizobium symbiosis. Two years ago a greenhouse strain screening program was initiated using plant growth response to inoculation in soil as the indicator of an effective and competitive strain. This work continued in 1987 with 30 strains being tested in two soils. Some refinements have been made in the method: the addition of 0.4% cassava flour was shown to be more effective than leaching for lowering mineral nitrogen; and the pot size and watering regime have been changed to facilitate maintenance of soil humidity late in the growth cycle.

In order to study Rhizobium inoculant strain survival and competition it is necessary to be able to identify, rapidly and effectively, the strain present in the nodules. The serological method ELISA has been used successfully with some other legume-rhizobium systems, and this year work was done in setting up the method for competition studies of R. leguminosarum biovar. phaseoli. A preliminary study was done (in Leonard jars) in which two bean genotypes (BAT 76 and Frijolica 03.2) were inoculated with varying concentrations of two Rhizobium strains (CIAT 632 and CIAT 652). After 40 days the proportion of nodules formed by each of the strains was determined using ELISA. The results are shown in Table 6 and it can be concluded that strain 652 was more competitive than 632 in these controlled conditions, however there was an interaction between strain and genotype (CIAT 632 did compete better with Frijolica 03.2 than with BAT 76). A surprisingly large number of nodules contained both strains; to determine whether this double occupancy occurs to the same extent in a soil environment awaits further study. The plant response to inoculation in a soil environment is shown in Figure 1. Although the nodules were not typed in this experiment the better performance of strain 652 is consistent with the notion of it being more competitive. Inoculation trials are being conducted on farms in several areas and the competitiveness of these two strains is being evaluated. This information should

help in understanding the variable inoculation responses observed on farms (see On Farm Agronomy section, Latin America).

Table 1. Selection of RIZ lines for increased potential to fix N_2 (best materials in each category are underlined).

Lines	Nodulation V_4 [1/]			Nodulation R6			Vigor Score R6			Grain yield (low N) [3/]			Grain Yield (high N)	N-yield [4/]	Seed Quality [5/]	
	C	S	P [2/]	C	S	P	C	S	P	C	S	P	P	GH		
879-	8	13	30	5	82	48	4	4	4	10	7	8	10	249	2	
884-	12	20	32	17	157	77	4	3	1	15	13	12	13	409	2	RIZ 101
41-14-	12	14	46	2	105	167	4	4	4	17	10	8	13	372	1	
45-8-	13	7	26	1	145	47	4	4	4	11	14	11	16	408	2	RIZ 102
45-1-9-	2	14	17	1	103	84	5	5	3	16	17	14	17	347	3	RIZ 103
45-9-2-	5	12	34	3	124	181	4	3	3	13	10	14	14	433	2	
40-16-	18	25	35	5	88	55	3	5	5	14	11	12	16	324	2	RIZ 104
45-1-7-3	6	13	25	15	122	61	4	5	3	16	12	13	15	358	1	
41-17-4-	11	28	29	3	98	56	4	4	2	10	7	10	14	332	2	
41-3-	34	16	23	14	167	122	4	4	3	14	11	11	12	285	1	
40-13-	10	8	34	9	158	85	5	5	4	14	14	10	16	375	1	
45-9-4-	21	19	32	15	122	70	4	5	3	12	14	11	13	330	1	
45-1-7-1	4	24	31	7	62	62	4	6	5	14	8	14	18	371	2	
41-17-1-	12	24	54	4	90	130	3	4	2	12	9	14	12	332	1	
RIZ 29	12	12	36	23	135	88	4	4	3	15	13	12	13	382	2	
RIZ 34	7	19	51	14	147	126	4	4	4	11	14	10	13	-	2	

1/ Number of red nodules/plant

2/ CIAT-Palmira (C), Santander de Quilichao (S), Popayan (P), Glasshouse (GH)

3/ g/plant

4/ mg/plant, sand culture

5/ 3-acceptable, 1-very poor

Table 2. Nitrogen fixation by nine bean genotypes grown in CIAT-Palmira.

Genotype	Mean atom % ^{15}N excess	N fixed kg/ha	% N from fixation
BAT 477	0.074	51	49
RIZ 32	0.082	50	43
RIZ 53	0.089	39	37
BAT 1554	0.089	36	39
RIZ 68	0.080	36	50
RIZ 30	0.087	31	40
DOR 41	0.091	27	37
RIZ 44	0.097	23	33
WTE 3	0.118	18	19
SORGHUM	0.145		
SE	0.0108	7.3	8.3

Table 3. Nitrogen fixation by nine bean genotypes grown in Santander de Quilichao.

Genotype	Total N kg/ha	Mean atom % ^{15}N excess	N fixed kg/ha	% N from fixation
BAT 477	100	0.247	41	40
RIZ 68	93	0.250	37	40
RIZ 32	101	0.276	35	33
DOR 41	92	0.282	29	32
RIZ 30	71	0.250	29	39
BAT 1554	72	0.259	27	37
RIZ 44	71	0.273	24	34
WTE 3	54	0.291	18	30
RIZ 53	36	0.315	9	24
SE	11	0.0147	6.7	3.6
SORGHUM	57	0.412		
SE	14.6	0.0360		

Table 4. "Total" nodule number (area under curves of red nodule number[1/] vs. time) of 12 genotypes in soil with low and high mineral nitrogen availability (Popayan 1987A).

GENOTYPE	LOW N	HIGH N
Ancash 66	15.00	9.10
Tostado	14.95	8.33
Canadian Wonder Moshi	9.90	4.87
Masai Red	8.13	4.38
GLP-24	7.97	4.95
Canadian Wonder Mbeya	6.83	3.88
RIZ 29	6.15	4.43
T-3	5.89	5.13
Rubona 5	5.42	4.19
Natal Sugar	4.30	3.49
T-23	4.11	2.60
Kabanima	4.04	3.18

[1/]There was little variation in nodule size within a treatment, but the size of the nodules in the high N treatment was about half that of the low N treatment.

Table 5. Plant nitrogen (low N treatment) and nitrogen response index at R-7 and the grain yield at R-9 of 12 genotypes (Popayan 1987A).

GENOTYPE	TOTAL N (g/plant)	NRI %	GRAIN (g/plant)
C. W. Mbeya	0.524	-45	10.41
Ancash 66	0.408	22	12.48
RIZ-29	0.404	-19	10.51
Masai Red	0.390	4	10.01
Tostado	0.382	-9	11.53
Rubona 5	0.347	36	10.43
T-3	0.341	21	9.57
Natal Sugar	0.325	28	9.16
GLP-24	0.314	23	9.58
C. W. Moshi	0.313	-12	8.54
Kabanima	0.266	26	8.50
T-23	0.231	35	6.53
SE	0.047	12.1	0.60
P 0.05	S	S	S

Table 6. Competitiveness of two *Rhizobium* strains in the formation of nodules on BAT 76 and Frijolica 03.2

Inoculation treatment	# of nodules reacting with the 2 antisera[1/]			
No. of Cells x 10^8	BAT 76		FRIJOLICA	
632:652	632	652	632	652
5.0 : 0	24	0	24	0
4.99: 0.01	12	21	21	16
4.0 : 1.0	7	23	23	24
2.5 : 2.5	8	23	9	17
1.0 : 4.0	12	23	8	21
0.01: 4.99	2	24	10	23

[1/] 48 nodules (12 x 4 reps) per treatment were tested

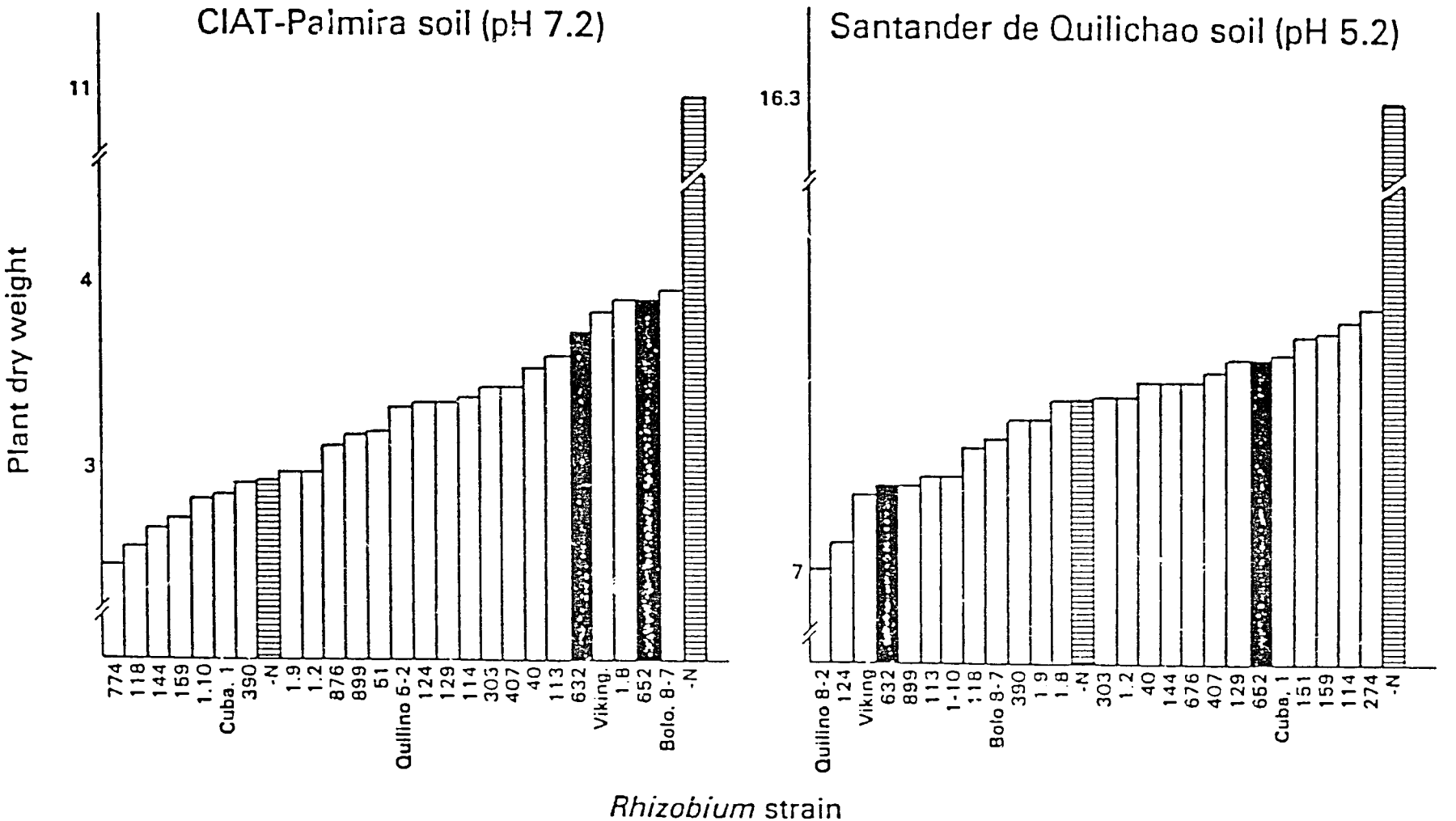


Figure 1. Growth of BAT 76 in 2 soils inoculated with 25 different Rhizobium strains.

b. LOW SOIL PHOSPHORUS AND ACID SOILS

Low soil phosphorus is probably the most widespread limitation of crop production in the tropics. Differences in tolerance to low soil P were recognized early by CIAT's Bean Team (CIAT Annual Report, 1976). Cultivars adopted and utilized in Brazil, particularly Carioca and Rio Tibagi, proved to be relatively tolerant in screening carried out in CIAT's research station at Santander de Quilichao.

The existence of genetic differences and the good performance of cultivars already in use implied two things: that it would be necessary at least to maintain the level of tolerance already available in commercial cultivars; and that it might be possible to increase tolerance by actively breeding for this trait. Either goal implies a conscious effort to measure yield under conditions of low P, since yield is the only criterion available by which to judge tolerance.

Although a breeding project was established to increase tolerance, progress has been negligible, one of the principal problems still being the lack of an adequate selection criterion which can be used in segregating populations and early generation lines. While selection with confidence in segregating populations is not yet possible, the program continues to screen advanced lines to identify superior materials to be incorporated into the breeding program.

Tables 1 and 2 show the genotypes of growth habits II and III respectively, from two planting seasons, which were superior to the respective check varieties, Rio Tibagi and Carioca, under phosphorus stress conditions (12 kg P/ha applied as supertriple phosphate in band). The data from 1986 A were presented previously but are included here for comparison. It can be seen that the advantage of the selected lines relative to the checks was wider under phosphorus stress than without stress, indicating that their superiority is due to more than merely local adaptation. A study of the pedigrees of these lines suggests that their tolerance is derived from germplasm from Mexico, Costa Rica, Brazil and possibly other countries. Other more preliminary data (based on a single season's plantings and therefore not presented here) suggests that several Central American land races likewise have a degree of tolerance to low phosphorus, as has been suggested to us by agronomists in the region. The diverse origins of tolerant germplasm offer the hope of genetic diversity of tolerance genes, and hence genetic advance.

Another important development in the phosphorus project was the establishment of an International Phosphorus Yield Trial, including the best genotypes from the Colombian-based program and

the best from the Brazilian-based program. This trial consisting of 49 genotypes, will be planted initially at several Colombian sites and at CNPAF, Brazil, to try to determine what correlation exists between results across sites.

The program continued to evaluate tolerance to toxicities of acid soils (particularly aluminum) as in years past. In Tables 3 and 4 data are presented for genotypes of growth habit II and III which yielded as well or better than the check varieties in two planting seasons. While many genotypes did repeat in the two seasons, their relationship as % of the checks was not consistent over seasons. In the first season, most of the type II selected genotypes yielded relatively better under stress, suggesting superior tolerance. The situation in the second season was not so clear.

Table 1. Yield (kg/ha and % check), with and without P stress, of genotypes of type II growth habit that outyielded the check variety in two seasons of planting under stress.

	1986 A				1986 B			
	Without stress	% check	With stress	% check	Without stress	% check	With stress	% check
BAT 1432	3066	(109)	1574	(156)	2609	(129)	1366	(168)
NAG 1	3458	(123)	1339	(133)	2488	(123)	1275	(156)
XAN 78	3153	(112)	1275	(127)	2603	(129)	1207	(148)
G 4454	2923	(104)	1204	(120)	2339	(116)	1161	(142)
BAT 1467	3228	(115)	1205	(120)	2325	(115)	947	(116)
NAG 183	3715	(132)	1176	(117)	2547	(126)	1108	(136)
A 283	3182	(113)	1105	(110)	2692	(133)	1337	(164)
NAG 161	3464	(123)	1203	(119)	2174	(107)	1150	(141)
BAT 76*	2407	(85)	803	(80)	1873	(93)	548	(67)
G 4495*	3029	(108)	463	(46)	2369	(118)	543	(67)
Rio Tibagi (Check)	3806		1003		2015		813	
LSD	41		48		32		40	

* Contrasting materials sensitive to low P.

Table 2. Yield (kg/ha and % check), with and without P stress, of genotypes of type III growth habit that outyielded the check variety in two seasons of planting under stress.

	1986 A				1986 B			
	Without stress	% check	With stress	% check	Without stress	% check	With stress	% check
BAT 271	2979	(98)	1409	(146)	1661	(109)	755	(116)
G 11893	2392	(79)	1204	(124)	1155	(75)	726	(111)
RAB 404	2867	(94)	1359	(140)	1899	(124)	668	(102)
NAG 195	2828	(93)	1257	(130)	1798	(118)	689	(06)
RAO 33*	2368	(78)	464	(48)	1288	(84)	374	(57)
Carioca (Check)	3024		965		1523		650	
LSD	80		22		72		18	

* Material sensitive to low P.

Table 3. Yield (kg/ha and % check) of genotypes of type II growth habit which were superior to the check under stress of soil acidity in two planting seasons in Santander de Quilichao.

	1986 A				1986 B			
	Without stress	% check	With stress	% check	Without stress	% check	With stress	% check
G 4000	2713	(96)	1435	(140)	2005	(100)	844	(111)
G 4454	2923	(104)	1373	(134)	2339	(116)	807	(106)
G 4495	3029	(108)	1413	(138)	2369	(118)	1183	(155)
BAT 1432	3066	(109)	1206	(118)	2609	(129)	820	(107)
BAT 1467	3228	(115)	1422	(139)	2325	(115)	851	(112)
BAT 1647	3395	(121)	1614	(158)	2511	(125)	994	(131)
DOR 227	3198	(114)	1464	(143)	2188	(109)	1086	(142)
NAG 11	3733	(133)	1839	(180)	2671	(133)	804	(106)
NAG 45	3137	(112)	1681	(164)	2233	(111)	1047	(138)
NAG 51	3387	(121)	1426	(139)	2509	(125)	980	(129)
NAG 160	3176	(113)	1537	(150)	2465	(122)	912	(120)
NAG 163	3230	(115)	1361	(133)	2691	(134)	966	(127)
NAG 171	3081	(110)	1331	(130)	1812	(89)	979	(129)
NAG 176	2767	(99)	1258	(123)	2409	(120)	822	(108)
RAB 353	3110	(111)	1292	(126)	2190	(109)	875	(115)
RAB 381	3025	(108)	1274	(125)	2004	(99)	762	(100)
XAN 78	3153	(112)	1350	(132)	2603	(129)	775	(102)
XAN 151	3501	(125)	1523	(149)	2603	(129)	845	(111)
Rio Tibagi (Check)	2806		1023		2015		760	
LSD	41		52		32		53	

Table 4. Yield (kg/ha and % check) of genotypes of type III growth habit which were superior to the check under stress of soil acidity in two planting seasons in Santander de Quilichao.

	1986 A				1986 B			
	Without stress	% check	With stress	% check	Without stress	% check	With stress	% check
FEB 17	3194	(106)	602	(334)	2151	(141)	1753	(158)
RAB 429	2501	(83)	434	(241)	1849	(121)	1379	(125)
RAB 404	2867	(95)	503	(279)	1899	(125)	1283	(116)
RAB 48	2572	(85)	485	(269)	932	(61)	1215	(109)
BAT 271	2979	(99)	400	(222)	1661	(109)	1168	(105)
G 18244	2031	(67)	465	(258)	1292	(85)	1240	(112)
Carioca (Check)	3024		180		1523		1105	
LSD	80		51		72		74	

2. Fungal Pathogens

Introduction

The principal research activities of the pathology section of the Bean Program relate to the management of diseases caused by fungal and bacterial pathogens through an integrated disease management strategy. This strategy emphasizes breeding for disease resistance with cultural practices.

Research efforts concentrate on the most economically important and widespread bean diseases. These are: anthracnose, angular leaf spot, and rust (caused by fungal pathogens), and common bacterial blight (caused by a bacterium). Other diseases that are economically important but have limited spread in certain specific bean growing regions are also researched but with less emphasis. These are: web blight and Ascochyta blight (caused by fungi) and halo blight (a bacterial disease). Some efforts are also dedicated to root rots that are quite widespread but having an economic importance limited to very specific areas.

Evaluations of reactions to the principal bean pathogens are routinely conducted within (1) the Bean Program germplasm bank, (2) advanced uniform nurseries and breeding progenies, as well as in (3) specific bean pathology nurseries such as the international bean disease resistance nurseries. Lines from these sources are methodically exposed to one or more pathogens in several locations or environments where these pathogens may occur naturally, or they are artificially inoculated. The evaluation of breeding progenies are conducted in collaboration with the breeding sections of the program in specific locations according to the diseases.

Rust and common bacterial blight reactions are evaluated at CIAT-Palmira; angular leaf spot, common bacterial blight and charcoal rot are evaluated in Santander de Quilichao; anthracnose, Ascochyta blight, and Rhizoctonia and Fusarium root rots are evaluated in Popayan; and web blight is evaluated in the Colombian coffee zone. The halo blight evaluations are conducted in collaboration with the National Vegetable Research Station in Wellesbourne, England and also under field conditions in several locations in Africa. Similar evaluations for web blight are conducted in several Central American locations.

With advanced nurseries and segregating progenies, the principal objective of these evaluations continues to be the identification and selection of germplasm with resistance to the most important bean pathogens present in a given target area; or, the identification of germplasm with broad resistance to a given pathogen or multiple resistance to several pathogens (Table 1). With the international bean disease nurseries, additional objectives are the identification of bean germplasm with

resistance to the spectrum of the pathogenic potential inherent in a given pathogen population; to monitor the pathogen populations and to identify different disease resistance mechanisms that can be utilized against bean pathogens. The international bean disease nurseries are evaluated primarily in Latin America and Africa, in close collaboration with scientists from national programs, although most of the nurseries are also evaluated elsewhere throughout the world.

Breeding for disease resistance is the principal strategy for control of most diseases. For diseases caused by highly variable pathogens, a large number of different resistance sources are used to broaden the genetic base. In addition, studies are conducted to monitor the existing pathogenic variation. With diseases where breeding for disease resistance is difficult, cultural practices are studied. In general, the disease management strategies emphasized and researched are compatible with the limited economic capacity of small bean producers.

a. ANGULAR LEAF SPOT

Pathology

Angular leaf spot (ALS) of beans is caused by *Phaeoisiaropsis griseola*. The disease is economically important in many bean growing areas of Latin America, particularly in the northeast of Brazil. In Africa, ALS is very widespread but is most important in the Great Lakes area where it is endemic.

Since the reaction of many bean lines or varieties to the ALS pathogen vary considerably from one location to another, the main research activities related to ALS have included the study Pathogenic variation of the ALS fungus in Latin America and Africa and the identification of ALS resistance sources. Pathogenic variation studies have been conducted in close collaboration with Michigan State University, (MSU-CIAT-UNDP angular leaf spot project). Partial results were reported previously (See Bean Program Annual Report, 1985).

For the pathogenic variation studies, thirty-two isolates of ALS fungus were taken from nine countries in Latin America, and twenty-seven from seven African countries. These were inoculated on a set of 21 bean lines under greenhouse conditions in Michigan. The results for 17 isolates of the ALS pathogen from Latin America reported in 1985, showed that this fungus has very broad variability in pathogenicity and virulence. Pathogenicity varied among isolates from different countries as well as among isolates of the same country and location of origin. Some isolates caused disease on all 21 bean cultivars while others caused disease in only a few. Variations in virulence, and percentage of disease caused by isolates on the infected cultivars, was also observed. Similarly the number of lesions and the lesion size induced by each of the isolates on the host cultivars varied considerably.

The disease reactions of the 21 cultivars of each of the 17 isolates of the ALS pathogen expressed in terms of disease severity, number of lesions, lesion, and incubation period, varied considerably. No cultivar was resistant or susceptible to all isolates. The lowest disease severity developed in cultivars A 339, A 212, BAT 76, BAT 1647, A 235 and Caraota 260. There was also a large variation among the bean cultivars in the number and size of lesions they developed. A significant positive correlation was found between average disease severity and the average number and size of lesions.

The results obtained here do confirm previous reported field results of the broad resistance of A 235, BAT 76, A 339 and BAT 1647 to ALS in Latin America. The susceptible reaction of BAT 332 was consistent with that reported from Brazil and more recently from Quilichao, Colombia. The resistant reaction for the same cultivar in Popayan, Colombia was also confirmed in these studies. The cultivar was susceptible to all Brazilian isolates and resistant to isolates from Popayan.

The pathogenicity of forty-two isolates of P. griseola from Latin America and Africa was studied by comparing the reactions of a set of eight cultivars to all isolates (Table 2). The isolates were divided into fourteen pathogenicity groups. Four pathogenicity groups contained isolates from both Latin America and African locations while the other ten groups contained isolates from only one or the other continent. Based on these results, pathogenicity groups were proposed (Table 3 and 4). To facilitate interpretations of results, isolates that induced susceptible or intermediate reaction were classified as susceptible. No cultivar was resistant to all pathogenicity groups; however BAT 1647 was resistant to eleven of the fourteen and A 339 was highly resistant to most Latin American isolates while being susceptible to several from Africa.

It is interesting that research conducted at Michigan State University (as part of the same MSU-CIAT-UNDP angular leaf spot project) to study the amount of isozyme variation present in the populations of Latin American and African isolates of P. griseola, showed two isozyme patterns present for each of four enzymes: esterase, catalase, Cucine aminopetidase, and adenylate kimase. All African isolates exhibited both, pattern 1 and pattern 2. Pattern 1 for each enzyme was associated with large seeded bean types while pattern 2 was associated with small seeded bean types. These results suggest a coevolution of the fungus isolates having pattern 1 with large seeded bean types found in the Andean zone of South America and Africa, while the pathogen isolates having isozyme pattern 2 coevolved with small seeded bean types found in many bean growing regions of Latin America.

Breeding

Although thousands of germplasm bank accessions have bee screened for resistance to ALS, the number of resistan accessions is few, and the level of resistance is relatively low No material showing complete immunity under field conditions ha been identified. This fungus is much more difficult to work wit (especially in field conditions) than the anthracnose, CBB, o rust pathogens. Consequently, progress in breeding is slow. A present, the inheritance of a dozen different sources o resistance is being studied in the greenhouses of CIAT-Palmira Commercial bean types of black, cream and cream striped color showing resistance to ALS have been developed, and curren research is directed toward other grain types as well as towar combining two or more sources of resistance into commo desireable genetic backgrounds.

b. ANTHRACNOSE

Pathology

Bean anthracnose, caused by Colletotrichum lindemuthianum i probably the most economically important bean disease worldwide The causal agent is known to have an extensive pathogeni variation that accounts for the change in anthracnose reaction o many bean varieties from one location to another.

In the last few years, in order to make the breeding fo anthracnose resistance more efficient, a number of studies abou the extent of the pathogenic variation of the population of C lindemuthianum from different bean producing areas has bee conducted. These studies in all cases have been done in clos collaboration with scientists from national programs. This year two studies were conducted in collaboration with the pathologis and breeder from the state of Santa Catarina, Brazil. In on pathology study, 36 isolates of the anthracnose fungus fro different regions of Santa Catarina were inoculated on the set o 14 differential bean varieties used previously to conduct C lindemuthianum pathogenic studies (Table 5). In addition, th following bean varieties were also inoculated: Aguille Verc Imuna, BO22, Costa Rica, and Phaseolus aborigeneous (the last tw used extensively by Brazilian scientists). For comparison, al these bean anthracnose differential varieties were als inoculated with Brazilian races: Alpha Brazil; Ba 2; Teta; Zeta Delta; Lambda; Kappa; and, with races Epsilon Kenya and C-236 from Europe and Guatemala, respectively.

The methodology evaluation system followed that use previously (see annual reports 1981, 1982, 1983, 1986). Based o the reaction of the 14 differential varieties, the 36 C lindemuthianum isolates can be classified in 12 differen pathotypes; however 14 isolates belonged to pathotype 1, and 1 isolates belonged to pathotype 2 (Table 5).

Once the pathogenic variation of the C. lindemuthianum isolates from Santa Catarina was established, a number of bean lines known for their anthracnose resistance under field and greenhouse conditions were inoculated with individual isolates. Many of these have been previously evaluated as resistant in southern Brazil. A total of 21 bean lines had a resistant reaction to the nine individual isolates used as well as to the mixture (Table 6). These beans lines with very broad anthracnose resistance are utilized as sources of resistance for Brazil. Some lines, such as G 2333, G 2338, AB 136, G 9032, etc. have been previously reported as having very broad anthracnose resistance.

Breeding

Several years ago the first 10,000 accessions from the CIAT germplasm bank were systematically screened against isolates from Colombia, Brazil, Mexico and Europe. Over 150 different sources of resistance were identified from this initial screening, and about two dozen of them carried resistance against all available races. Also, three different mechanisms of resistance, a set of differentials, and an international nursery (IBAT) were formed. But the search for new, different and better sources of germplasm is still continuing. The past two years has seen the screening of over 21,000 currently available germplasm bank accessions. The three mechanisms of resistance are: (1) adult plant resistance (inoculated seedlings are susceptible), (2) field tolerance (high seed yield in spite of heavy disease pressure in the field), and, (3) an immunity to pathogen races at all stages of plant growth. Work is in progress to study the genetics of these mechanisms. Also, breeding work in progress includes: (1) transferring BCMV resistance into desirable sources of resistance; (2) combining different sources of resistance together; (3) transferring resistance genes into commercial bean types. Thus far, emphasis has been given to the latter aspect, and, as a result, all commercial bean types of small seeded cream and cream striped, and medium seeded pinto, bayo, and ojo de cabra developed at CIAT now carry resistance to anthracnose under Popayan conditions. It is hoped that in the immediate future bred lines combining two or more sources of anthracnose resistance will be available.

c. ASCOCHYTA BLIGHT

Pathology

This is a disease of economic importance in the highlands of Latin America and Africa where cool, humid conditions prevail. Under these conditions the disease can be very severe. In the past the disease was ascribed to Ascochyta boltshauseri or to A. phaseolorum; however, A. phaseolorum has been proved to be

identical with Phoma exigua, or P. exigua var. exigua, a weak pathogen that cannot cause the severe symptoms associated with Ascochyta blight in Latin America and Africa. The current accepted name for the Ascochyta blight causal agent is Phoma exigua var. diversispora (A. boltshauseri), a pathogen that can induce the typical and very severe foliar blight and node and stem necrosis associated with Ascochyta blight. During the First African Bean Pathology Workshop recently held, it was agreed the new pathogen name should be used. It was also suggested that the common name of the disease should be Phoma blight rather than Ascochyta blight.

The main research activity with this disease has been the evaluation of bean germplasm in uniform or segregating nurseries as well as accessions from the germplasm bank with the purpose of identifying lines with at least intermediate levels of resistance that can be utilized as varieties or in the crossing block. Since 1985, several evaluations in Popayan, repeated in Guatemala, Peru and Rwanda have facilitated the selection of several bush and climbing beans lines with which to form the International Ascochyta Blight Nursery (IBABN). This nursery has been distributed to collaborating national programs since 1986.

Breeding

The IBABN consisted of 13 bush bean lines and 14 climbing bean lines which represent the best sources of resistance available at that time. High levels of resistance to Ascochyta blight have not been identified in P. vulgaris germplasm. Included in the nursery were susceptible checks as well as the local control variety. The purpose of this nursery is: 1) to provide resistant germplasm to national programs which can be utilized in their breeding programs or as varieties if they meet local agronomic and consumer requirements, and 2) to monitor the possible existence of pathogenic variation in the different bean growing areas within Latin America and Africa, to determine whether races or different strains of the pathogen may exist. Results of nurseries grown in Rwanda and Colombia suggest that pathogen variability may be minimal in these two areas (Tables 7 and 8) and screening for resistance to Ascochyta blight in Popayan, Colombia may identify bean genotypes suitable for Rwanda.

Among the bush bean lines in the IBABN, G 4603, BAT 1569 and G 17098 showed the highest level of resistance to Ascochyta blight, and for climbing beans, G 12582, G 10747 and VRA 81051 were resistant in both countries. The Phaseolus coccineus subsp. polyanthus check, G 35182 (Cuate 1076) continued to show the highest levels of resistance to Ascochyta. Other lines with high levels of resistance are G 10889, G 6040, VNA 81006, VNA 81014, EMP 31, VRA 81013.

Crosses are being made among the best entries in the IBABN as part of a recurrent selection program to increase overall

levels of resistance to Ascochyta blight. Interspecific hybridization between P. vulgaris and P. coccineus are also being conducted to transfer the high levels of resistance found in P. coccineus to common bean genotypes. More information on this is available in the Interspecific Hybridization chapter.

d. WEB BLIGHT

Pathology

Control of the imperfect phase of the web-blight (WB) fungus, Rhizoctonia solani, (sexual stage: Thanatephorus cucumeris) is best achieved by integration of cultural practices, chemical control, and varietal resistance.

Although cultural practices are the most effective, genetic variability is real and exploitable. Furthermore, in some situations cultural practices may not be practical. For example, in some areas a mulch can increase slug problems. Planting in beds implies more expense in field preparation. In such cases varietal resistance, albeit incomplete, may contribute relatively more to disease control.

A series of trials were conducted to evaluate seed transmission of T. cucumeris in plots of Huasteco and Mexico 27 under moderate-severe WB attack, with and without protection from foliar applications of benomyl. Seed was harvested, dissected into three principal parts (seed coat, cotyledon, embryo) and assayed for the presence of T. cucumeris and other seedborne pathogens. Seed from fungicide-treated plots showed no transmission whereas non-treated plots had a 6.3% recovery of T. cucumeris. The pathogen was recovered from both Huasteco and Mexico 27 at a rate of 3.0%. Absence of fungicide resulted in a 50% yield loss. Thanatephorus cucumeris was found exclusively in the seed coat; other pathogens such as Fusarium, Alternaria, Phomopsis, and Aspergillus spp. were present in all the seed parts. Seed from fungicide-treated plots had better yield and fewer microflora than seed from non-treated plots but upon replanting did not produce better stands or yields in the second generation.

The effect of herbicides on the growth of T. cucumeris in vitro and on WB development in the field was studied in a series of experiments. At doses of 33-99 ppm, dinoseb completely inhibited the growth of T. cucumeris in culture plates; inhibition by paraquat was an average 91%. Round-up had the least in vitro pathogen toxicity. In a field trial comparing six herbicides applied at preemergence, dinoseb-treated plots had the least WB and the highest yields. In subsequent field trials, dinoseb alone was evaluated at doses ranging from 1-13 kg a.i./ha. There was no linear dose effect on WB development; the lower doses (1-4 kg a.i./ha) produced higher yields and less disease. Similar trials conducted with paraquat

at 3.4 kg a.i./ha seemed to give the best results under severe l pressure. A final trial was conducted to evaluate previo post-emergent herbicide treatments under severe WB pressur Results were mixed but the post-emergent treatment of Basagran Fusilade (applied 21 days after) offered best yield and lowe rate of WB infection. Generally, post-emergent treatmen outperformed pre-emergent treatments under high disease pressur

Breeding

Differences in reaction to the web-blight fungus were not as early as 1974. The first crosses to increase resistance we realized in 1980, and in 1984 we reported results with bred lin from cross number ht 7716, which demonstrated a 51% to 93% yie increase over the resistant check, Porrillo 70. In 1986 anoth bred line, ht 7719 became the first variety develop specifically for web blight resistance, released under the na Chirripó in Costa Rica. Other varieties previously releas (Talamanca = Icacol 10103 and Huasteco = Dor 60) also h resistant reactions but were not bred specifically for w blight.

In the International Web Blight Workshop held in Costa Ri in November, 1986, it was decided that 1987 should be dedicat to evaluating populations and lines already available in the w blight project. Specifically, it was decided that yield shoul be measured and used as a selection criterion. Therefore, t Elite Web Blight Nursery was created to measure yield in statistical design.

In parallel fashion the Costa Rican National bean progr formed the National Web Blight Nursery which is also a yie nursery with statistical design.

In the September plantings of this year, improved agronom (more uniform drainage and bed preparation) created much mo uniform disease conditions, hence genetic differences could b distinguished with confidence. Although yield data from thi semester were not available at the time this report was writte it was evident based on symptoms that advance had been made Observations confirmed those of previous semesters.

Superior materials included XAN 222 and XAN 226, progeny c XAN 112 and Porrillo derived materials; apparently XAN 11 contributed more distinct gen s for resistance than thos available in Porrillo. Among red seeded lines RAB 377 wa excellent, better even than the blacks, having resistance derive from Porrillo, Turrialba 1, and a Nicaraguan land race Orgulloso. CENTA Izalco, a land race from El Salvador, als produced excellent progeny. Orgulloso and CENTA Izalco have n apparent relationship to other sources of resistance, and it i hoped that genetic gain will continue by recombining genes amon sources.

All the best lines are derived from sources previously recognized as superior, however, selection of resistant progeny in populations and progeny rows has been hindered by non-genetic variability within the nursery. This year's experience has demonstrated the value of both improved agronomy and larger plot size to distinguish genetic effects. Likewise, the incorporation of yield testing into the selection scheme is an important development in the web-blight project.

Table 1. Selected bean lines from advanced uniform nurseries having multiple disease resistance under field conditions in Palmira, Colombia.

Bean line	Color	Nursery	Disease reaction[1]			
			Rust	CBB	ANT	ALS
BAT 1462	7MK	VEF 81	R	I	R	R
PAD 25	6J	VEF 83	I	I	R	R
PAD 38	7M	VEF 84	I	I	R	R
PAD 40	7M	VEF 85	R	R	I	R
AND 370	6M	VEF 85	R	I	R	R
ICA 15141	6M	VEF 85	R	I	R	R
ICA 15255	6M	VEF 85	R	I	R	R
PAD 51	7M	VEF 85	I	R	R	I
BAT 1430	6T	VEF 80	I	I	R	R
BAT 1264	4	VEF 80	I	I	R	R
BAT 1275	6MK	VEF 80	I	I	R	R
BAT 93	2	VEF 80	R	R	R	I

[1]Disease evaluation based on a 1-9 scale where 1,2 and 3 ar considered resistant; 4,5 and 6 intermediate and 7,8 and susceptible. 1= no visible symptoms of disease and 9= severel diseased.

Table 2. Pathogenicity groups in isolates of *Phaeoisariopsis griseola* from Latin America and Africa based on disease reaction of 8 bean cultivars.

Pathogenicity group and isolate			Disease reaction on host cultivar[a]							
			a	b	c	d	e	f	g	h
1	A	Colombia 1	S	S	S	S	S	S	S	S
	B	Guatemala 1	S	S	S	S	S	S	S	S
	C	Tanzania 2	S	S	S	S	S	S	S	S
2	A	Uganda 1	S	S	I	S	S	S	R	I
	B	Uganda 2	S	S	I	S	S	S	R	S
	C	Zaire 2	S	S	I	S	S	S	R	S
3	A	Mexico 1	S	S	S	S	S	S	R	R
	B	Guatemala 2	S	S	S	S	S	S	R	R
4	A	Kenya 2	S	S	S	S	R	S	S	R
5	A	Brazil 1	S	S	S	R	S	R	R	I
	B	Brazil 3	S	S	S	R	S	R	R	S
	C	Argentina 1	S	S	S	R	S	R	R	S
6	A	Rwanda 3	S	S	R	S	S	S	R	R
	B	Burundi 3	S	S	R	S	S	S	R	R
7	A	Tanzania 1	S	I	S	S	R	R	S	R
	B	Kenya 1	S	I	I	S	R	R	S	R
	C	Uganda 3	S	S	I	S	R	R	I	R
	D	Rwanda 1	S	S	S	S	R	R	S	R
	E	Burundi 1	S	S	S	S	R	R	S	R
	F	Burundi 2	S	I	S	S	R	R	S	R
	G	Zaire 1	S	S	S	S	R	R	S	R
8	A	Colombia 2	S	S	R	S	R	S	R	R
9	A	Costa Rica 1	S	S	R	S	S	R	R	R

(Continuation Table 2)

	B	Rwanda 2	S	S	R	S	S	R	R	R
10	A	Brazil 2	S	S	S	R	R	R	R	R
	B	Brazil 4	S	S	S	R	R	R	R	R
11	A	Tanzania 3	S	S	R	R	R	R	S	R
	B	Malawi 2	S	S	R	R	R	R	S	R
12	A	Malawi 5	S	R	S	R	R	R	S	R
	B	Malawi 9	S	R	S	R	R	R	S	R
13	A	Colombia 3	S	R	R	R	S	R	R	R
	B	Colombia 4	S	R	R	R	S	R	R	R
	C	Malawi 3	S	R	R	R	I	R	R	R
14	A	Malawi 4	S	R	R	R	R	R	R	R
	B	Malawi 7	S	R	R	R	R	R	R	R
	C	Malawi 10	S	R	R	R	R	R	R	R
	D	Tanzania 4	S	R	R	R	R	R	R	R
	E	Kenya 2	S	R	R	R	R	R	R	R
	F	Nicaragua 1	S	R	R	R	R	R	R	R
	G	Argentina 2	S	R	R	R	R	R	R	R
	H	Argentina 3	S	R	R	R	R	R	R	R
	I	Argentina 4	S	R	R	R	R	R	R	R

[a] S = Susceptible; more than 4% leaf area covered by *P. griseola* lesions.

I = Intermediate; 1-4% leaf area covered by lesions.

R = Resistant; less than 1% leaf area covered by lesions.

a = Montcalm b = Seafarer c = BAT 332 d = Pompadour Checa e = G 5686

f = Cornell 49242 g = A339 h = BAT 1647.

Table 3. Proposed pathogenicity groups in *Phaeoisariopsis griseola*[a] based on reaction of 8 bean cultivars.

	Pathogenicity group													
Host cultivar	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Montcalm	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Seafarer	S	S	S	S	S	S	S	S	S	S	S	R	R	R
BAT 332	S	S	S	S	S	R	S	R	R	S	R	S	R	R
Pompadour Checa	S	S	S	S	R	S	S	S	S	R	R	R	R	R
G 5686	S	S	S	R	S	S	R	R	S	R	R	R	S	R
Cornell 49242	S	S	S	S	R	S	R	S	R	R	R	R	R	R
A 339	S	R	R	S	R	R	S	R	R	R	S	S	R	R
BAT 1647	S	S	R	R	S	R	R	R	R	R	R	R	R	R

[a] S= Susceptible; 1% or more leaf area covered by *P. griseola* lesions
R = Resistant; less than 1% leaf area covered by lesions.

Table 4. Disease severity in 8 bean cultivars inoculated with 42 isolates of *Phaeoisariopsis griseola*[a].

Pathogenicity group and isolate			Disease Severity[a]							
			a	b	c	d	e	f	g	h
1	A	Colombia 1	48	33	50	50	23	50	43	50
	B	Guatemala 1	40	22	40	35	40	40	14	18
	C	Tanzania 2	50	50	38	50	50	50	16	40
2	A	Uganda 1	50	13	5	50	33	50		5
	B	Uganda 2	50	12	3	50	50	43		14
	C	Zaire 2	50	50	4	50	50	50		15
3	A	Mexico 1	40	50	50	50	25	5		
	B	Guatemala 2	6	20	40	25	16	33		
4	A	Kenya 2	50	11	15	50		17	36	
5	A	Brazil 1	40	40	43		18			3
	B	Brazil 3	40	50	43		20			25
	C	Argentina 1	45	10	42		30			25
6	A	Rwanda 3	40	40		34	30	45		
	B	Burundi 3	42	33		27	39	50		
7	A	Tanzania 1	50	4	8	50			15	
	B	Kenya 1	50	5	1	13			10	
	C	Uganda 3	50	16	4	50			6	
	D	Rwanda 1	50	50	15	50			16	
	E	Burundi 1	50	30	16	8			7	
	F	Burundi 2	50	4	9	7			11	
	G	Zaire 1	50	10	16	50			9	
8	A	Colombia 2	25	40		27		30		
9	A	Costa Rica 1	40	25		40	8			
	B	Rwanda 2	50	50		50	50			
10	A	Brazil 2	6	29	1					

(Continue)

(Continuation Table 4)

	B	Brazil 4	18	25	39		
11	A	Tanzania 3	50	25			50
	B	Malawi 2	50	38			19
12	A	Malawi 5	50		6		8
	B	Malawi 9	50		9		11
13	A	Colombia 3	50			43	
	B	Colombia 4	50			47	
	C	Malawi 3	50			5	
14	A	Malawi 4	39				
	B	Malawi 7	50				
	C	Malawi 10	31				
	D	Tanzania 4	43				
	E	Kenya 2	30				
	F	Nicaragua 1	32				
	G	Argentina 2	40				
	H	Argentina 3	40				
	I	Argentina 4	50				

[a] Disease severity expressed as percentage of leaf area covered by ALS lesions. Maximum disease severity = 50%, minimum disease severity (blank) = 0%.

a= Montcalm b= Seafarer c= BAT 332 d= Pompadour Checa e= G 5686
f= Cornell g= A 339 h= BAT 1647.

Table 5. Reaction of bean differential varieties to a group of Colletotrichum lindemuthianum isolates from Santa Catarina, Brazil.

	ANTHRACNOSE REACTION[1]													
DIFFERENTIAL VARIETY	CL68 BR	CL65 BR	CL57 BR	CL59 BR	EC21b BR	EC51a BR	CL56 BR	CL75 BR	EC22b BR	CL78 BR	CL76 BR	EC43b BR	ALPHA BR[2]	KAPPA[2]
MICHELITE	S	S	S	S	S	S	S	S	S	S	S	S	S	S
M.D.R.K.	R	R	R	R	R	R	R	S	S	S	S	S	R	S
PERRY MARROW	R	R	R	R	R	R	R	R	R	R	S	S	R	S
COR.49242	S	S	S	S	S	S	S	S	S	S	S	S	S	S
WIDUSA	S	R	R	S	S	S	S	S	S	S	S	S	S	S
KABOON	R	R	R	R	R	R	R	R	R	R	R	R	R	R
SANILAC	R	R	R	R	R	S	S	S	R	R	S	S	R	S
EMERSON 847	R	R	S	S	R	R	R	R	R	R	S	R	–	–
TO	R	R	R	R	R	R	R	R	R	R	R	R	R	R
TU	R	R	R	R	R	R	R	R	R	R	R	R	R	R
PI 207262	R	R	R	R	R	R	R	R	R	R	R	R	R	R
AB 136	R	R	R	R	R	R	R	R	R	R	R	R	R	R
A 475	R	R	R	R	S	R	S	R	R	S	R	S	R	R
G 2338	R	R	R	R	R	R	R	R	R	R	R	R	R	R
PRINCOR	R	R	R	S	R	R	R	R	R	R	R	R	R	S
G 2333	R	R	R	R	R	R	R	R	R	R	R	R	R	R

[1] Reaction base on 1-9 scale where 1 = no visible disease symptoms and 9= very severe symptoms. For this study 1, 2 and 3 are considered as R and the rest as S.

[2] These isolates were used as checks.

NOTE:

The isolates were classified into groups as follows:

Isolate Cl-68-BR: VII, 8, P, p. Also included in this group were isolates EC-21a-BR, EC-22a-BR, EC-35a-BR, CL-59-BR, CL-60-BR, CL-64-BR, CL-66-BR, CL-69-BR, CL-73-BR AND CL-75-BR.

Isolate CL-65-BR: VII, 16,P,p Also included in this group were isolates CL-57-BR, CL-58-BR, CL-62-61-BR, CL-62-BR, CL-63-BR, CL-65-BR.

Isolate CL-57-BR: VII,15, P, p
Isolate CL-59-BR: VII, 8, P, p
Isolate EC-21b-BR: VII, 8, P, p
Isolate EC-21a-BR: VII, 6, P, p
Isolate CL-56-BR: III, 6, P, h
Isolate CL-75-BR: III, 8, P, p
Isolate EC-22-BR: III, 8, P, p
Isolate CL-69-BR: III, 8, P, h
Isolate CL-76-BR: I, 5, P, p
Isolate EC-43b-BR: I, 6, P, h

Table 6. Reaction of selected bean accessions with resistance to Colletotrichum lindemuthianum under field conditions and to individual races of the pathogen under greenhouse conditions.

	Field[1]	GREENHOUSE[1]									
	#EVAL[2]	X[3]	AL-BR	EP-K	T	L	C-236	K	D	Z	AB-2
A 62	4	R	R	R	R	R	R	R	R	R	R
A 227	11	R	R	R	R	R	R	R	R	R	R
A 255	5	R	R	R	R	R	R	R	R	R	R
A 260	1	R	R	R	R	R	R	R	R	R	R
A 317	4	R	R	R	R	R	R	R	R	R	R
A 319	5	R	R	R	R	R	R	R	R	R	R
A 320	14	R	R	R	R	R	R	R	R	R	R
A 321	9	R	R	R	R	R	R	R	R	R	R
A 322	9	R	R	R	R	R	R	R	R	R	R
A 373	8	R	R	R	R	R	R	R	R	R	R
A 375	5	R	R	R	R	R	R	R	R	R	R
A 381	13	R	R	R	R	R	R	R	R	R	R
G 4032	7	R	R	R	R	R	R	R	R	R	R
G 3991	7	R	R	R	R	R	R	R	R	R	R
XAN 57	1	R	R	R	R	R	R	R	R	R	R
XAN 148			R	R	R	R	R	R	R	R	R
TU	6	R	R	R	R	R	R	R	R	R	R
PI 207262			R	R	R	R	R	R	R	R	R
AB 136	12	R	R	R	R	R	R	R	R	R	R
G2333	11	R	R	R	R	R	R	R	R	R	R
62338	9	R	R	R	R	R	R	R	R	R	R

[1] Reaction in the field and greenhouse based on a 1-9 scale where 1 = no visible disease symptoms and 9= very severe symptoms.

[2] Evaluation conducted in Popayan, Colombia; La Selva, Colombia; Tepatitlan, Mexico; Irati,Brazil; Chiapata, Zambia; Goiania,Brazil; Salta,Argentina.

[3] Mixture of nine isolates (AL-Br, EP-K, T, L, C-236, K, D, Z and AB-2)

Table 7. International Bean Ascochyta Blight Nursery (IBABN-Bush beans) evaluated for reaction to *Phoma exigua* var. *diversispora* in Colombia and Rwanda.

Identification	Popayan	Rwerere Rwanda	Ascochyta Rating
Local Check[1]	7.0[2]	5.0	S
BAT 477 (S check)	6.5	5.2	S
CATU	5.3	3.8	I
BAN 6	5.3	3.7	I
EMP 117	5.0	4.7	I
PAI 119	4.3	2.9	R
A 182	4.2	3.4	R
BAT 795	4.2	3.0	R
BAT 1225	3.5	4.2	R
BAT 1416	3.3	3.8	R
G 17098	3.3	3.0	R
BAT 1569	3.3	3.0	R
G 4603	3.3	2.7	R

[1] Local checks: Popayan, Colombia = Diacol Calima
Rwerere, Rwanda = Shikashika

[2] Average of three rating periods on a 1-9 scale, where 1 = no visible disease symptoms and 9 = very susceptible.

Table 8. International Bean Ascochyta Blight Nursery (IBABN-climbing beans) evaluated for reaction to *Phoma exigua* var. *diversispora* in Colombia and Rwanda.

Identification	Popayan	Rwerere Rwanda	Ascochyta Rating
AND 244 (S check)	8.0[1]	4.7	S
AFR 223	5.3	3.5	I
VRA 81058	5.3	4.1	I
ASC 6	4.7	3.5	R
VRA 81058	4.7	3.4	R
G 12307	4.5	3.1	R
ZAV 21	4.3	4.0	R
ZAV 91	3.8	2.8	R
ASC 1	3.8	2.8	R
ASC 4	3.6	3.3	R
VRA 81051	3.5	2.4	R
G 10747	3.1	3.3	R
G 12582	2.8	2.8	R
G 35182[2] (Guate 1076)	1.6	1.8	R

[1] Average of three rating periods on a 1-9 scale, where 1 = immune and 9 = very susceptible.

[2] Resistance check - *Phaseolus coccineus* subsp *polyanthus*

3. Bacterial Pathogens

a. COMMON BACTERIAL BLIGHT

Pathology

Common bacterial blight (CBB) continues to be a very important disease in many bean producing areas of Brazil, Argentina, Central America, the Caribbean and in some regions of Africa. Many of the traditional and newly introduced varieties in these areas are susceptible to CBB and often the seed used for planting comes from fields that have severe CBB symptoms. These two factors, in addition to climatic conditions conducive to CBB epidemics, may account for the apparent current increase of this disease in several bean producing regions.

In 1979 the pathology and breeding sections of the program began most of the work in breeding for CBB resistance in beans. The number of lines with either resistant or intermediate reaction to the CBB pathogen was below 20% in the 1979 VEF nursery, and about 50% in 1986. Despite this decrease in the number of susceptible lines generated by the breeding projects at CIAT, the relative number of lines with resistant reaction remains low.

However, there are now several CIAT generated lines from the CBB project that have tropical adaptation and excellent levels of CBB resistance (Table 1). Among these, line XAN 112 is worth mentioning because it has been extensively evaluated as resistant to CBB in many countries (Argentina, Brazil, Colombia, Cuba, Guatemala, France, USA etc). XAN 112 shows excellent levels of CBB resistance in fields where other lines are severely diseased, and it has an upright architecture, good earliness, and shows resistance to other pathogens.

During 1987, routine evaluations of CIAT uniform nurseries under field conditions, as well as pathology nurseries, permitted selection of lines with CBB resistance. Further evaluations were made to choose possible parental sources of CBB resistance or possible candidates for the International Bacterial Blight Nursery (Table 2). Similarly, several evaluations were conducted under greenhouse conditions in close collaboration with the breeding program. In some cases, the main objective was to incorporate CBB resistance into widely grown susceptible varieties such as A 295 (EMGOPA-OURO in Brazil), DOR 41 (widely grown in Guatemala and Argentina) etc. In other cases, the main objective was the elimination of highly susceptible lines.

Breeding

The project to develop and utilize resistance to the common blight pathogen, Xanthomonas campestris pv. phaseoli is one of the oldest in CIAT, yet one which has yet to result in a resistant commercial variety.

Resistant sources reported in the literature, PI 207262 and Great Northern varieties derived from P. acutifolius, were incorporated into the first crosses made in the Bean Program. Although inoculation methods were developed here and selection criteria existed, poor adaptation of the sources and their resistant progeny was a recurrent problem, as was an apparent linkage of one or some of the resistance genes to the gene for brilliant seed. The first moderately well-adapted lines with black opaque seed were produced in 1981, these including XANs 87, 93, and 112. However, it soon became evident that resistance was also related, probably by genetic linkage, to undesirable purplish tone of black seed. These lines therefore became parental material for yet another generation of breeding, which produced, by backcrossing, a new series of resistant black-seeded lines, improved for grain type and adaptation. The best of these from the first and second cycles of backcrossing are at present in preliminary yield trials in Cuba, and have yielded as much as 23% more than the check variety. In the past, CBB resistant lines from these sources have not displayed the rusticity and stability that is expected in black seeded varieties, and it remains to be seen if these new lines represent an improvement in this respect.

Recovery of resistance in small red varieties has likewise been slow due to apparent problems of linkage of resistance to undesirable color, but we believe that a few recombinant types are now available.

In 1981 a CBB sub-project was initiated to evaluate interspecific P. vulgaris x P. acutifolius crosses obtained from the University of California-Riverside. This effort produced totally self-fertile, highly resistant lines XAN 159, 160 and 161, all with growth habit type I (derived from the vulgaris parent, Masterpiece, a snap bean). Backcrosses were initiated with several important cultivars, the most successful of these being with Pompadour Checa, which has medium sized grain and also a type I habit. It has been possible to recover the plant type, adaptation, grain size, form, and mottling of Pompadour, although most selections of high resistance have undesirable purple grain. It is hoped that these selections have also recovered the pod resistance of XAN 159, which is even more urgent in type I types than is foliar resistance, but this is yet to be confirmed. It is possible that the selection of the vulgaris parent in the original interspecific cross affected the utility of the derived lines for improving different vulgaris germplasm since XAN 159 combined better with Pompadour than with small seeded indeterminates. A few indeterminate lines derived from XAN 159

are also being used to improve small seeded vulgaris, but problems of adaptation continue to slow progress with these sources.

Conscious that almost all the resistance in small seeded advanced lines was derived from only two sources (PI 207262 and Great Northern cultivars), an attempt was made during 1987 to find new sources in a screening of germplasm accessions. More than 12,000 accessions were planted, inoculated manually using the surgical blades method of inoculation (Bean Program Annual Report, 1981) and a suspension of bacteria (5×10^8 CF4/ml), and evaluated in the first semester of 1987. Selected accessions were reevaluated in the second semester, the best of which appear in Table 3. Most accessions with a higher degree of foliar resistance (grades 3 and 4) were type Is. Of the indeterminate small seeded types, all were inferior to resistant check XAN 112 in both adaptation and resistance. To date, the best small seeded germplasm accession continues to be G 4399, Tamaulipas 9-8, which was identified in 1980. It is indeed curious that resistance in small seeded P. vulgaris is so rare when in P. acutifolius a moderate to high level of resistance is almost the rule.

A more productive line of research to find sources of CBB resistance for small seeded types, has been breeding for transgressive segregation among lines of intermediate resistance.

Some of these lines have been identified in the VEF testing scheme, presumably as chance combinations of minor genes unidentified individually (BAT 1500, BAT 1192). Others are lines developed within the CBB project from sources which are themselves intermediate (Sel 813 from G 8255, Taletes). Still others are lines of good adaptation which did not recover the full complement of resistance genes from poorly adapted parents. Combinations among intermediates produced F_3 families at least as good as XAN 112 in both resistance and adaptation. XAN 236 was a particularly good source for black seeded types, and the facility with which its resistance was transmitted suggested simple inheritance. Its parent, XAN 91 (progeny of G 4399) has been incorporated widely into crosses, as well as DOR 308 (a small seeded line derived from ICA L-23).

b. HALO BLIGHT

Pathology

A collaborative project between CIAT and the National Vegetable Research Station, Wellesbourne, England was continued in 1987. Studies were conducted at NVRS on the occurrence and distribution in Africa and Latin America of pathogenic variants of the halo blight of Phaseolus beans pathogen, Pseudomonas syringae pv. phaseolicola. The main emphasis during 1986 and 1987

was on the characterization of isolates from eastern and central Africa.

To date, approximately 700 isolates of Pseudomonas spp. have been obtained and 610 of these have been identified by bacteriophage and serological methods as Pss or a closely related pathovar. (Table 4). Pseudomonas syringae pv. glycinea is a pathogen of soybeans. The characterization of the Pss isolates into races was based on the reaction of a preliminary series of differential cultivars (Table 5). Of the 610 isolates provisionally identified as pv. phaseolicola, or as being similar, 240 isolates belonged to race 3 and all of them originated in Africa. Race 1 (110 isolates) and race 2 (234 isolates), although widely distributed in some African countries, were also found worldwide. Race 4 (26 isolates) which is able to attack only a limited number of Phaseolus vulgaris cultivars was isolated mainly from soybean, Glycine max, in close proximity to P. vulgaris in Africa. From comparative tests, it is now considered probable that the pathogen previously identified as pv. phaseolicola race 4 is synonymous with Pseudomonas syringae pv. glycinea.

The geographic distribution of the pv. phaseolicola races is shown in Table 6 and the host range distribution of the races is shown in Table 7. The wide host range of pv. phaseolicola should provide additional sources of infection of P. vulgaris, in addition to the primary method of disease transmission through infected seed. Additionally, in Africa the often brief time between successive crops could allow disease carry-over in crop debris.

From resistance screening of accessions of P. vulgaris a more extensive range of differential cultivars has been selected. Tests with these cultivars (Table 8) indicate sub-divisions within the previously described races 1, 2 and 3. For example, certain cultivars will separate race 1 isolates from different hosts (e.g. Phaseolus coccineus and Lablab purpureus). Similarly, other cultivars will distinguish between isolates of race 3 from different geographic areas (e.g. Tanzania and Rwanda) while other cultivars will separate race 2 isolates from Tanzania and the USA. These sub-divisions within races 1,2 and 3 suggests that pv phaseolicola may contain at least six races in addition to the so called race 4 Pseudomonas syringae pv. glycinea). It now seems likely that the race structure of pv phaseolicola has a degree of complexity similar to that already established for Pseudomonas syringae pv pisi which has six races, and pv glycinea with eight races.

In preliminary studies of the inheritance of resistance, it was shown that specific resistance to races 1 and 3 (as previously defined) is controlled by different dominant genes. Race non-specific resistance is controlled by recessive genes or polygenes. Further crosses have been made at CIAT for a more

detailed study of the inheritance of resistance in various important cultivars including resistance to race 4.

Cultivars with known resistance characteristics, both race-specific and race non-specific, were grown at two sites in Africa with expected race 3 infection, and one site in the USA with expected race 2 infection. Cultivars with resistance to race 3 generally showed little disease at the African sites, but were susceptible at the USA site. A number of cultivars with race non-specific resistance were highly resistant at all sites. The navy bean cv Edmund developed at Wellesbourne was completely resistant. This cultivar has two resistance genes, a recessive gene for race non-specific resistance and a dominant gene for race 3 resistance. The combination of these two genes appears to have an additive effect. It is suggested that the use of this gene combination would provide an ideal solution to the African situation. Table 9 shows a list of some of the bean lines with non-specific resistance and lines with resistance to either race 1, race 3 or both.

Table 1. Selected bean lines generated at CIAT and evaluated under field conditions several times as resistant to the common bacterial blight pathogen.

Xanthomonas campestris pv. *phaseoli*

A 193	RAB 123	XAN 154	XAN 189
A 297	XAN 30	XAN 155	XAN 190
BAT 93	XAN 87	XAN 156	XAN 191
BAT 1212	XAN 91	XAN 157	XAN 199
BAT 1500	XAN 93	XAN 158	XAN 201
BAT 1769	XAN 112	XAN 159	XAN 203
NAG 50	XAN 124	XAN 160	XAN 204
PAD 3	XAN 132	XAN 161	XAN 205
RAB 9	XAN 137	XAN 165	XAN 208
RAB 101	XAN 153	XAN 166	XAN 212

Table 2. Selected bean lines from advanced uniform nurseries with high levels of resistance to the common blight pathogen under field conditions in Palmira, Colombia.

Nursery	No. Entries Selected	Identification
EP 86	3	ICA 15418, 15409, 15412
VEF 86–EP87	26	XAN 205, 208; AFR 243; AND 618, 623; A623, 652, 678, 683, 716; AFR 314, 317, 322; AND 416, 662, 665; FEB 136, 141; BRU 25; NAG 185; PAC 18.
VEF 87	19	XAN 218, 219; AMA3, 16, 28; CAL 22, 55, 69, 71; HAB 239, 242, 243, 292; LRK 1; WAF 82, 96, 97, 238; ZIRCON.
Others	10	XAN 170, 173; AND 260; PAD 6; ZAA 96; SEL 846, 847, 855; NAG 173, 174.

[1] Selected lines had a disease evaluation of 4 or less, where: 1 is free of visible disease symptoms, and 9 is severely diseased.

Table 3. Bean accessions from a group of 12,000 entries that were artificially inoculated under field conditions in Palmira, Colombia during two semesters, and showing the highest levels of common bacterial blight resistance.

No G	Identification	Color	Size	Habit	CBB reaction[2]
4081	Dark Red Kidney 023	RD	L	1	3
4079	Light Red Kidney 03	PK	L	1	3
3954	WIS HBR72	WH	S	1	4
6708	MSU 305	WH	S	1	4
5688	Tregi Fullgreen	BR	S	1	1
6617	Pompadour Mocana	RD	M	1	4
6415	Mecosta 003	PK	L	1	4
7040	Galinho	YE	M	1	5
2932	Yanco	WH	S	1	5
6595	Glamis	BR	M	1	1
7157	68-1369	BR	S	1	5
5377	9/3/1	CR	M	1	5
5705	Corbett Refugee	BL	S	1	5
5373	Diacol Calima	RD	L	1	1
6618	Pompadour Rocio	RD	S	1	5
6381	Kidney Light Red 003	PK	L	1	5
6414	Manitou	PK	L	1	5
5492	0633	WH	S	1	6
6619	Bush Blue Lake	WH	S	1	6
5753	Brown Beauty	BR	L	1	6
5496	Beautiful	BR	M	1	6
5485	Tenderlong	CR	M	1	6
5744	Redlands Autumn Crop	CR	M	1	6
5621	Diacol Calima	RD	L	1	6
6647	Pamarejo	RD	L	1	6
6637	X	RD	M	1	6
3916	36 Retinto Alta Dulce-13	PU	S	2	5
5731	Mateigao Preto No. 20	BL	M	2	5
5716	Linea 31	BL	S	2	5
1291	Facultad	RD	M	2	5
5164	Amendoim	PK	L	2	2
7077	Mulungu	PK	L	2	5
11300	Habilla	PK	M	2	5
5746	Redlands Green Leaf C	BR	S	2	6
5871	Tropero	CR	S	2	6
5906	10233-M(3)-11PM-12-4-M(6)	PU	S	2	6
5685		BL	S	2	6
5909	Negro Cahabon	BL	S	2	6

No G	Identification	Color	Size	Habit	CBB reaction[2]
5911	Negro	BL	S	2	6
6097	Mexico 9=Variedad 37-4	BL	S	2	6
5733	Miss Kelly	PK	M	2	6
6700	MSU 183	WH	S	3	3
5476	Jules	WH	S	3	4
5477	GN No. 1 Sel. 27	WH	M	3	4
4528	Anc 2=Facultad	RD	M	3	4
1181		CR	M	3	5
3439	Zacatecas 81	CR	M	3	5
6378	GN Nebraska No. 1	WH	M	3	6
2281		BR	M	3	6
3266	Aguascalientes 65	BR	L	3	6
4311	Puebla 435	CR	M	3	6
4314	Zacatecas 5-A	CR	L	3	6
3694	Honduras 46	PU	S	3	6
2899	Mrondo	BL	S	3	6
5910	Burros	OT	M	3	6
6800	Nicaragua 42	RED	S	3	6
6772	Colima 9	CR	S	4	4
1320	Tlalnepantla	YE	S		5
706	Barbunya	CR	L	4	5
7368	Ancash 110	PU	M	4	5
5734	Mountaineer	WH	S	4	6
5504	Bojnourd	CR	M	4	6
6306	Ecuador 218	BL	S	4	6

1. YE = Yellow CR = Cream OT = Others S = Small
   WH = White PU = Purple RD = Red M = Medium
   BR = Brown BL = Black PK = Pink L = Large

2. Evaluation scale 1-9; where 1 is free of visible CBB symptoms and 9 is severely diseased.

Table 4. Preliminary laboratory classification into pathovars of *Pseudomonas* isolates obtained from *Phaseolus* Spp and other leguminous crops.

Phage reaction[1]		Serological reaction[2]		
Phaseolicola phage	*syringae* phage	heat-labile antigen	heat-stable antigen	Provisional identification
+	+	+	+	pv. *phaseolicola*
+	-	+	+	
-	+	+	+	pv. *glycinea*
-	+	+	-	
-	-	+	-	*Pseudomonas* Spp
-	-	-	-	

[1]Lysis

[2]agglutination

Table 5. Race identification in *Pseudomonas syringae* pv *phaseolicola*, the pathogen of halo blight of beans.

Differential Cultivars	Reaction to race 1	2	3	4[c]
Canadian Wonder	+[a]	+	+	+
Red Mexican	-	+	+	-
Tendergreen	+	+	-[b]	-
PI 105 414	-	-	-	-

[a] + = susceptible; - = resistant

[b] very strong hypersensitive reaction

[c] probably *Pseudomonas syringae* pv *glycinea*

Table 6. Geographic distribution of the races of *Pseudomonas syringae* pv *phaseolicola* (610 isolates)

Geographic area		Number of isolates of race 1	2	3	4*
Africa	...Burundi			64	
	Ethiopia	13	1	4	3
	Kenya	27	19	4	
	Rwanda	8		112	7
	Tanzania	10	93	18	1
	Uganda			18	
	Zaire		3	20	9
	Zambia	6	12		
America	...Colombia	1	9		
	Mexico		13		
	Peru	5	5		
	United States		8		1
other areas	...Australia		2		
	Bulgaria		10		
	France		4		
	Mauritius		32		
	New Zealand		5		5

(Continue)

Table 6. (continued) Geographic distribution of the races of *Pseudomonas syringae* pv *phaseolicola* (610 isolates)

Geographic area		Number of isolates of race 1	2	3	4*
	North Yemen		4		
	Sweden		1		
	United Kingdom	21	12		
	Totals	110	234	240	26

* race 4 probably *Pseudomonas syringae* pv *glycinea*

Table 7. Host range distribution of *Pseudomonas syringae* pv *phaseolicola* races (610 isolates).

Host (Common name)	Number of isolates of race			
	1	2	3	4
Phaseolus vulgaris (Bean)	36	218	225	
Phaseolus coccineus (Runner bean)	21	4	6	
Phaseolus acutifolius (Tepary bean)	7			
Phaseolus lunatus (Lima bean)			2	
Phaseolus spp.	3	1		
Cajanus cajan (Pigeon pea)	3	4		
Lablab purpureus (Hyacinth bean)	12	5		
Desmodium sp.	10		7	
Neonotonia wightii(P. Montana)	8			
Pueraria montana	2			
Macroptilium atropurpureus (Sinatro)	2			
Vigna angularis (Adzuki bean)	3			
Vigna radiata (Mung bean)	1			2
Glycine max (Soybean)				24
Unidentified leguminous weed	4			
	110	234	240	26

* race 4 probably *Pseudomonas syringae* pv. *glycinea*.

Table 8. Further differentiation of the three races of *Pseudomonas syringae* pv. *phaseolicola* using a more extensive range of differential cultivars.

		Race 1		Race 2		Race 3	
	Isolate...	1281A	1375A	882	1299A	1301A	1302A
	Origin ..	UK	KYA	USA	TZA	TZA	RWA
Differential cultivars	Host	*P.coccineus*	*Lablab*	*P.vulgaris*	*P.vulgaris*	*P.vulgaris*	*P.vulgaris*
Canadian Wonder		+[a]	+	+	+	+	+
Red Mexican UI3		-	-	+	+	+	+
Tendergreen		+	+	+	+	-	-
Guatemala 196B		-	-	+	+	-	-
Bayo Madero		-	-	+	+	+	-
Sangretoro		+	-	+	+	-	+
A43 ZAA 12		+	-	-	+	-	-
A52 ZAA 54		+	-	+	+	+	+
A53 ZAA 55		+	-	+	+	-	-

[a] + = susceptible; - = resistant

Table 9. Selected bean accessions with resistance to the halo blight pathogen.

Race non-specific resistance	race 1	race 3	race 1-3
Gloriabamba(G2829)	Amarillo Enredo(G2331)	BAT 1215	BAT 590
Pajuro (G11766)	Bayo Zacatecas	BAT 1220	BAT 1281
Nariño 20 (G12666)	Guatemala 1246(G10813)	BAT 1251	V 8010
Poroto (G12592)	Guatemala 1382(G10889)	APN 18	VRA 81022
Palomo (G12669)	Calabozo (G12720)	FMP 60	CUAT.196-B(G5960)
Great Northern 1 Sel. 27(G3954)	Bola Roja (G11818)	FMP 81	Bayo madero
Wisc. HPR72 (G5477)	Pintado (G11761)	ICA linea 23(G14013)	G790
Jules (G5476)	Liborino L-7 (G916)	Norinbee (G14645)	

4. Viral Pathogens

The objectives of bean virus research at CIAT are:

1. Identification and characterization of plant viruses that affect beans in production areas assisted by the Bean Program.

2. Assessment of the economic impact and epidemiologic potential of the viral diseases of beans.

3. Identification and selection of bean germplasm resistant or tolerant to bean viruses of economic importance.

4. Screening of improved segregating and advanced bean germplasm for its reaction to selected pathogenic viruses.

Strategies employed to reach these objectives include:

1. Create the necessary laboratory infrastructure to conduct applied research on tropical bean viruses.

2. Train and assist national program scientists in the identification of viruses that affect bean production.

3. Develop suitable germplasm screening methodologies for bean viruses.

4. Assist breeders in the identification and selection of agronomically superior bean genotypes resistant or tolerant to economically important bean viruses.

Research and training

The Bean Program was the first of the Center's Commodity Programs to initiate research in plant virology. This year, following over a decade of intensive research in this area, CIAT inaugurated one of the most modern plant virus laboratories in Latin America, containing the necessary equipment to meet the Center's and Bean Program's needs: 1) to accurately detect and identify virus diseases of beans; 2) produce diagnostic materials; 3) help identify resistant germplasm; and 4) monitor the distribution and epidemiology of the viruses that affect bean production in target areas.

Bean Virology has trained national program scientists from Argentina, Chile, Brazil, Bolivia, Peru, Ecuador, Colombia, Costa Rica, Nicaragua, El Salvador, Guatemala, Mexico, Cuba, Dominican Republic, as well as scientists from some European and African countries. Bean Virology constantly supplies these collaborators with diagnostic materials, such as antisera and differential

cultivars, and visits most Latin American countries, whenever possible, to maintain a close interaction within this research network.

Viral diseases of beans

Table 1 shows the main virus diseases of *Phaseolus vulgaris* in Latin America; their causal agents; vectors; epidemiology; economic importance; and geographical distribution. Of these diseases, bean common mosaic, bean yellow mosaic, bean severe mosaic, bean southern mosaic, bean dwarf mosaic, and bean golden mosaic, are the most important bean production constraints caused by viruses in Latin America. The yield losses shown in Table 1 are based on experimental results and/or observations of total yield losses, which often occur with diseases such as bean severe mosaic, bean dwarf mosaic, and bean golden mosaic. Some of these diseases are geographically restricted, but others, such as bean common and bean southern mosaic, are widely distributed due to the transmission of the causal viruses in some of the seeds produced by infected plants. Another interesting observation is the high incidence of beetle-borne viruses in Central America, probably due to the more frequent association of beans and maize (a good host for the beetle vectors of these viruses). The distribution of whitefly-transmitted viruses may also depend on the presence of other crops, which act as hosts for the whitefly (*Bemisia tabaci*) vector of bean dwarf and bean golden mosaic viruses. However, both the vector and, consequently, the disease, are more prevalent in warm and dry environments or periods of the year.

Due to the economic importance and epidemiologic potential of bean common, bean yellow, bean dwarf, and bean golden mosaic viruses, the Bean Program decided to concentrate research efforts on these four major viruses, with emphasis on the development of resistant or tolerant germplasm.

a. BEAN COMMON MOSAIC VIRUS

The first screening methodology was developed in 1978 for bean common mosaic, undoubtedly the most important virus disease of the common bean in the world. The first step was the selection of the bean common mosaic virus (BCMV) strains (pathogenic variants) needed to identify the recessive and dominant genes known to exist in *Phaseolus vulgaris*. Due to the large volume of individual plants screened in the beginning of the project (over 2,000 plants per work day), a combination of three BCMV strains (Fla, NY 15 and NL 4), was used to inoculate F_3/F_4 plants in order to eliminate mosaic-susceptible (recessive) genotypes. Homozygous mosaic-resistant F_4 lines were finally challenged with a different BCMV strain, NL 3, capable of detecting the dominant (I) gene which confers resistance to BCMV in *P. vulgaris*. The expression of hypersensitivity in plants inoculated with BCMV-NL 3, is definite proof for the existence of dominant resistance against mosaic-inducing strains of BCMV,

found predominantly in Latin America. The monogenic dominant resistance to BCMV has been highly stable and effective in Latin America for over two decades.

However, the existence of BCMV strains capable of inducing systemic necrosis (known as blackroot) in bean genotypes possessing dominant monogenic resistance, led to the implementation of a modified screening methodology designed to identify genotypes possessing a combination of the dominant gene and recessive genes, previously shown to protect genotypes possessing dominant monogenic resistance alone, against necrosis-inducing strains of BCMV. The modification (Figure 1) involved the selection of BCMV strains NL 3 and NL 4, to detect the following: 1) the dominant gene alone (systemic necrosis induced by BCMV-NL 3); 2) the dominant gene protected by recessive genes (local necrotic lesions induced by BCMV NL 3, or symptomless plants); and 3) recessive genes alone (mosaic induced by BCMV NL 4, except in plants possessing the recessive gene bc 3, which remain symptomless).

Following this methodology, Bean Virology continued the screening of diverse bean germplasm this year. As can be appreciated in Table 2, the screening of early segregating materials remains the main thrust (67%) of the BMCV project, followed by the evaluation of advanced lines (17.3%), used primarily as a confirmatory test. In 1987, the number of segregating lines (approximately 860), sent to Bean Virology by some national programs, increased 58% in relation to last year's figure (500), indicating a greater capacity in national programs to handle early generations.

The blackroot resistance project is still maintained at a relatively moderate but increasing level. For instance, the recently implemented African blackroot project produced 63 F_3 homozygous resistant lines and an equal number of segregating materials, from individual F_3 selections and backcrosses. This backcrossing project, initiated two years ago to improve BCMV-susceptible landraces known to exhibit grain color-BCMV susceptibility linkage problems, continued with a total of 4,360 plants individually tested and seed-increased under screenhouse conditions.

In the case of Latin America, the Chilean blackroot project initiated six years ago, continued to generate mosaic- and blackroot-resistant lines. This year, we received 357 black- and white-seeded lines, 43 of which were homozygous-resistant to all strains of BCMV, and 13 more were segregating multiple-resistant and blackroot-susceptible plants. All of these lines have excellent agronomic characteristics and, together with 28 lines identified last year in the same project, constitute very valuable germplasm for bean production areas with existing or potential blackroot problems.

The collaborative project between IVT, Wageningen, and CIAT for the incorporation of I, bc2.2 and bc3 genes for resistance to mosaic-and necrosis-inducing strains of BCMV, into tropically-adapted germplasm, ended this year with the final evaluation and selection of 23 F_4bc3 populations (Table 3). These materials are to enter CIAT's VEF 88 and crossing blocks, as sources of resistance to BCMV and to be evaluated for their adaptation to tropical conditions and other resistance factors.

Whitefly-Transmitted Bean Viruses: Bean Golden Mosaic and Bean Dwarf Mosaic

As announced last year, there was a major shift in Bean Virology's research priorities, from heavy concentration on bean common mosaic to bean diseases caused by whitefly-transmitted viruses. This change in research priorities is the result of the successful implementation of efficient BCMV-screening methodologies, and the shift in research focus in response to the increasing spread and economic importance of bean diseases caused by viruses transmitted by the whitefly Bemisia tabaci. These plant viruses, known as geminiviruses, are highly virulent pathogens capable of causing total yield losses. Two of these viral pathogens, bean dwarf mosaic and bean golden mosaic viruses, have reached epidemic proportions in important bean growing areas of Central America, South America, and the Caribbean, severely limiting bean production in over a million hectares.

b. BEAN GOLDEN MOSAIC VIRUS

Last year, we reported on the implementation of mechanical inoculation techniques for bean golden mosaic virus (BGMV), which allowed us to evaluate the most widely used sources of BGMV resistance or tolerance, specifically for their reaction to the virus, thus, excluding a possible interaction with insect vector resistance mechanisms present in some bean genotypes. The results obtained in this study led to the identification of previously unnoticed plant defense mechanisms, and favorable genotypic recombinations (possibly transgressive segregation), both of which are currently being exploited in the BGMV breeding project. The various defense mechanisms identified so far are: 1) disease escape due to earliness or superior plant vigor, 2) tolerance, defined as the ability of a genotype to yield acceptably despite the existence of systemic infection, and 3) low mosaic and dwarfing symptom expression.

Potential new sources of resistance

A total of 1,660 germplasm accessions were evaluated in 1986-1987, under various growing conditions in Guatemala, Mexico, Argentina and Brazil. Based on the results obtained in these four locations, a final selection of 188 accessions was made to be more critically evaluated in key locations of Argentina,

Brazil, El Salvador, Guatemala, the Gulf and Pacific Coasts of Mexico, and the Dominican Republic. These evaluations are expected to be completed next year, but we already have preliminary results obtained in Guatemala. As shown in Table 4, 40 new sources of BGMV resistance were selected in Guatemala. These selections contrast in quantity and variety with the few (2-5) previously available black seeded sources of BGMV resistance. Besides these 40 germplasm accessions, another group of 31 germplasm accessions was also selected in Guatemala as 'intermediate' in symptom expression. It is expected that more accessions will be selected in other test areas.

Experimental crosses with selected new sources of BGMV resistance

As reported last year, we have identified valuable defense mechanisms in diverse bean genotypes possessing different grain types and agronomic characteristics. Three of these selected genotypes: Great Northern 164557 (white seeded); Pinto 114 (brown mottled cream seeded); and Red Mexican 35 (dark red seeded) were selected as both male and female parents to be crossed with the most widely used source of BGMV resistance: Porrillo Sintetico. This black seeded genotype has indeed proved an excellent parent in the BGMV project and, although it can be severely affected by the virus, it withstands moderate BGMV attacks under field conditions. Porrillo Sintetico also appears to have some resistance against the whitefly vector of BGMV. The six crosses between P. Sintetico and Great Northern 164557, Pinto 114 and Red Mexican 35 (including reciprocal crosses) were made under screenhouse conditions, where the plants remained until F_1 seed was produced. The F_1 populations were planted this year in Monjas, Guatemala together with the F_1/F_2 populations generated by Bean Breeding I. The results of a preliminary evaluation carried out approximately seven weeks after planting, indicated that there was adequate genetic variability, good agronomic characteristics and, moreover, excellent levels of BGMV resistance in all of these experimental F_1 populations, relative to the performance of the resistant and susceptible checks planted in the same field.

In conclusion, we are dealing with an unusually devastating virus, capable of infecting every one of the thousands of bean germplasm accessions and cultivars tested to date. BGMV usually attacks plants very early, causing severe plant stunting, loss of photosynthetic activity, flower abortion, and pod and seed malformation. Understandably, these symptoms often result in 100% yield losses or, in the best of cases, cause substantial economic losses which have already led to the abandonment of traditional bean growing regions. Consequently, we are not searching for immune bean genotypes; the well-documented success obtained with the black seeded BGMV-tolerant lines developed in Central America, clearly shows that bean golden mosaic can be economically managed with an adequate level of virus tolerance. The emphasis of the BGMV research currently carried out at CIAT is on the development of BGMV-resistant or tolerant bean

genotypes possessing grain colors other than black. To achieve this goal, we have identified different genotypes which possess specific BGMV-resistant traits. Thus, we have genotypes which exhibit either vigorous growth or virus/insect resistance traits which often lead to disease escape. We also have genotypes which do not show the characteristic golden mosaic or noticeable yellowing symptoms when infected by BGMV. Also, there are genotypes which do not suffer significant growth reduction when attacked by the virus. Furthermore, we have identified several accessions which do not suffer noticeable flower abortion despite the viral infection, and some of these genotypes produce normal pods and seed. The next step requires a well-planned crossing project to combine these traits and incorporate them into commercially acceptable cultivars. The existence of highly BGMV-tolerant experimental lines, such as A 429, bred for projects other than BGMV but which coincidentally originated from some of the genotype combinations proposed here, constitute experimental evidence supporting the breeding objectives pursued by the current BGMV project. Table 5 summarizes these research findings and lists some of the grain types which can be used in future crossing projects.

Breeding for resistance to BGMV

Apart from success with the Azufrado class in Mexico, little progress had been registered in non-black genotypes of truly commercial types, although non-black resistant lines have over the years accumulated levels of resistance equal to or better than the original black varieties. These non-black resistant lines include DOR 364, a dark red of excellent agronomic characteristics; DOR 365, with a grain similar to Carioca; A 429, with Pinto grain type, which in turn produced a series of lines with grain similar to the light pink Rosinha class. Increased resistance has also been recovered in blacks, and Cuba Cueto 25-9, also black but with no known relationship to other blacks, presented a moderate degree of resistance. The current germplasm screening revealed resistance and tolerance in two major groups, basically: 1) materials of medium grain size and type III growth habit, from the gene pool represented by Pintos and Great Northerns, and 2) large seeded types which principally presented the type of reaction frequently selected in Sinaloa, that of heavy symptoms and good pod load.

In summary, we have at present an unprecedented amount of genetic variability for resistance to BGMV, much of it in non-black genotypes. Future breeding efforts should focus on utilizing this diversity in the areas where as of yet little progress has been made: in small seeded genotypes for Brazil, and in medium sized red mottled types for the Caribbean. With this purpose crosses were planned with scientists of CNPAF, Brazil, and realized in CIAT, to seek even higher levels of resistance capable of withstanding disease pressure in Brazil. Populations were preselected for grain type, and it was observed that even in crosses involving only resistant genotypes, it was possible to

recover commercial or near-commercial grain type of the following classes: cream, bico de ouro, carioca, rosinha, as well as black.

The use of the medium sized type III genotypes of the Pinto gene pool may present special problems. Past experience with crosses between such genotypes and those of small seed suggests that progress is usually slow in introducing traits from one gene pool to another. Nevertheless, notable exceptions to this rule have occurred in populations involving Carioca, also a type III but with relatively smaller grain. Besides being an important commercial variety in need of BGMV resistance, Carioca may serve as a bridge between the two gene pools involved.

Improvement of the Caribbean types should most logically be favored by the germplasm of large grain size, since it will not be necessary to deal with problems of crossing among gene pools. As of yet, however, the germplasm has not been evaluated in the Dominican Republic or any other Caribbean site. Evidence with greenhouse inoculations suggests that the Dominican isolate is especially aggressive. Indeed, susceptible Dominican variety Pompadour is occasionally tolerant in the field in Guatemala and is even better in Sinaloa. It remains to be seen how much of the tolerance selected in Guatemala will maintain itself in the Dominican Republic. Meanwhile, we continue to pursue resistance with lines developed previously such as DOR 302, DOR 257, etc.

Evaluation and selection of BGMV-resistant/tolerant germplasm under field conditions

In the past, bean germplasm was evaluated for bean golden mosaic on a 1-5 or 1-9 rating scale, according to the degree of symptom (mosaic or yellowing) expression. However, production losses do not always correlate with the intensity or severity of mosaic symptoms exhibited by a genotype. Currently, while the 1-9 scale is still used to rate the intensity of the mosaic symptoms induced by BGMV in a given genotype, the ultimate selection criterion is pod load or reproductive adaptation, also rated on a 1-9 scale (1 being excellent, and 9 very poor). A comparison between these two selection criteria was made by Ing. Rafael Salinas, bean breeder of the Mexican National Program, in Los Mochis, Sinaloa. The results of this study, conducted with two different 'Azufrado' (yellow seeded) families, showed average yield gains of 26.5% in F_3 and 21.5% in F_4 when the selection criterion was yield, in comparison to average yield gains of 17.5% in F_3 and 15.0% in F_4 when the selection was based on symptom expression alone. This study clearly demonstrates the importance of evaluating the differential response of bean genotypes to the various symptoms (mosaic, dwarfing, flower abortion, pod/seed distortion) induced by BGMV. This evaluation scheme can be easily followed by adopting letter codes such as M = intense golden mosaic symptoms; m = intermediate mosaic symptoms; D = severe dwarfing; d= intermediate dwarfing; while the absence of selected letters would mean little or no expression of the symptom evaluated. These letter codes can be

extended to evaluate flower and pod setting or other plant responses of interest. This evaluation is not meant to be distributed but serves as a codified description of the way bean genotypes respond to BGMV. These evaluation concepts have been thoroughly discussed and readily accepted among national program investigators involved in the BGMV cooperative project.

Molecular virology research

The outstanding advancement of science in the fields of genetic engineering, molecular biology, and immunology, has given us access to highly advanced but practical technology of considerable potential in the area of applied research. Plant Virology has been particularly benefitted by the recent technological advances in the fields of immunology (development of monoclonal antibodies), genetic engineering (development of complementary DNA probes), and molecular biology (sequencing of viral nucleic acids). As a practical example, one of the most frequently asked questions about bean golden mosaic virus (BGMV), is whether this virus possesses enough pathogenic variability to limit the deployment of resistant genes to BGMV-affected areas where these genes may not exist. For most viruses, the identification/detection of pathogenic variants (strains), can be accomplished through the use of differential cultivars or using conventional polyclonal (unfractionated antisera which contain a mixture of antibodies) antiserum. In the case of BGMV, however, the virus can infect all bean genotypes tested so far and, more unfortunately, there is a close serological relationship not only among geographical isolates of BGMV but also between BGMV and other geminiviruses transmitted by B. tabaci, in quite different plant species.

Consequently, in order to answer the question on pathogenic variability of BGMV, we began this year to explore the practical applicability of the new techniques available. First, we looked into the possibility of using monoclonal antibodies (produced by clones of hybrid cells which secrete highly specific antibodies) against a serologically-related whitefly-borne virus, cassava African mosaic virus (ACMV) (tests kindly performed by Dr. B.D. Harrison of the Scottish Crop Research Institute) and, also, against a strain of BGMV (monoclonal cultures produced at the Plant Pathology Department, University of Florida, by Dr. E. Hiebert and Mrs. G. Wisler). The results of the first test with monoclonal antibodies to ACMV and BGMV isolates from Mexico and Guatemala, are shown in Table 6. As can be concluded from these results, the SCR 18 monoclonal antibody to ACMV, differentiated between the Mexican and Guatemalan isolates of BGMV, and, consequently, these isolates can now be recognized as distinct strains of BGMV. The SCR 18 monoclonal ACMV antibody also differentiated between the Guatemalan isolate of BGMV and bean dwarf mosaic virus (formerly bean chlorotic mottle virus), and showed a serological relationship between BGMV-Guatemala and Rhynchosia mosaic virus from Colombia. Finally, the SCR 17 monoclonal recognizes all the whitefly-transmitted geminiviruses

tested while SCR 11 is specific for African cassava mosaic virus (Table 6).

The monoclonal antibodies produced at the University of Florida will be tested at CIAT in December of this year, against eight different BGMV isolates, and four other geminiviruses (pathogenic to beans) recently isolated from local weed reservoirs.

The second approach involves the comparison of BGMV isolates by sequencing of their DNA-1 and DNA-2 genomes, taking advantage of the cooperative CRSP-P XII project established between the Plant Pathology Department of the University of Wisconsin and Brazil (CNPAF). This project, led by Drs. D. Maxwell, R. Gilbertson, and P. Ahlquist in Wisconsin, and J. Faria in Brazil, seeks to compare a Brazilian isolate of BGMV with BGMV isolates from other countries. So far, the project has been successful in sequencing a Brazilian isolate of BGMV and in demonstrating significant differences in nucleotide sequence between this isolate and the original BGMV isolate collected in Puerto Rico by Dr. R.M. Goodman. CIAT has recently made available the Guatemalan isolate of BGMV to conduct similar comparative studies in Wisconsin and hopefully at CIAT next year, and to expand the number of BGMV isolates sequenced.

The third technique, is the nucleic acid hybridization test, using DNA-1 and DNA-2 probes radioactively labelled with P32. For this purpose, a special laboratory, equipped to handle radioactive materials, had already been set up as part of the new Central Virology Laboratory. The next step was to obtain the DNA-1 and DNA-2 clones, which have already arrived (kindly provided by Dr. R.M. Goodman). We expect to implement this technique this year to start comparing the BGMV isolates available in 1988.

c. BEAN DWARF MOSAIC VIRUS

Bean Dwarf Mosaic Virus (BDMV), formerly called Bean Chlorotic Mottle Virus, was renamed this year for various reasons. First, the virus was isolated for the first time, and was partially characterized as a whitefly-transmitted member of the geminivirus group. Secondly, the main symptoms induced by this virus, are mosaic and dwarfing; and, third, the original name given to this disease (first described in Brazil) was 'dwarf mosaic'.

As mentioned before, bean dwarf mosaic was first described in Brazil as a minor disease of Phaseolus vulgaris. This disease, however, is widely distributed in Latin America, being closely associated with the presence of the whitefly Bemisia tabaci and malvaceous weed species in affected bean fields. As reported in past years, this disease reached epidemic proportions in northwestern Argentina, in the late 70's, coinciding with the expansion of soybeans in the same region (soybean is a suitable

host for the whitefly B. tabaci). The disease also reached a high incidence in the Pacific Coast of Mexico, interfering with the evaluation of bean germplasm for its reaction to BGMV. Yield losses in Argentina alone surpassed 20,000 tons in a single year.

Given the economic importance of this disease, and its close relationship with bean golden mosaic, the causal agent was isolated and partially characterized at CIAT. This study demonstrated that the virus is a member of the geminivirus group, transmitted by the whitefly Bemisia tabaci. BDMV is serologically related to BGMV (golden mosaic) but as shown previously in Table 6, these two bean geminiviruses can be serologically differentiated using monoclonal antibodies.

Of particular interest was the investigation on the pathogenicity spectrum of BDMV in the differential cultivars used routinely for other bean viruses (originally tested for bean common mosaic virus by Dr. E. Drijfhout, IVT, Wageningen, The Netherlands). Table 7 shows the results of the pathogenicity tests carried out both by mechanical inoculation and using the whitefly vector, B. tabaci. As can be concluded from these results, there were some genotypes which could not be infected by BDMV, unlike the case of BGMV which infects all of these genotypes. It is interesting to observe that the BDMV-resistant genotypes are also the most difficult to infect with BGMV in mechanical inoculation tests and, furthermore, that these resistant genotypes had been previously selected as potential sources of golden mosaic resistance. Also, these results agree with previous field evaluations of similar bean genotypes.

d. BEAN YELLOW MOSAIC VIRUS

Bean yellow mosaic is a relatively restricted but important viral disease of beans in Latin America. The disease is found primarily in Chile and Uruguay. As reported in previous years, this disease is one of the major production constraints in Chile, due to the recent appearance of a new pathogenic variant of the virus (BYMV), capable of infecting bean genotypes used as sources of resistance to control the previously known strains of BYMV in Chile. This disease is also important in the United States, Europe, Northern Africa, West Asia and China.

Considering the restricted distribution of this disease and the absence of virulent strains of this virus in Colombia, Bean Virology sought the cooperation of the Institute of Applied Plant Virology, in Torino, Italy. The resulting cooperative project, entitled "Characterization of the Main Yellow Mosaic Virus Isolates that Limit Bean Production in Northern Africa, West Africa and China", is now officially in progress, with Drs. O. Lovisolo and V. Lisa as principal investigators in Italy. Considering the importance of continuing the bean yellow mosaic research in Latin America, the initial cooperative studies carried out in Chile by national program scientists and CIAT, have now been transferred to Italy.

Table 1. Main virus diseases of the common bean (*Phaseolus vulgaris*) in Latin America: general characteristics, economic importance, and geographical distribution.

Disease	Virus	Vector	Seed transmission	Epidemiology	Yield Crosses	Geographical Distribution
Bean Common Mosaic	BCMV[1]	Aphids	Yes	Endemic	20–50%	All countries
Bean Yellow Mosaic	BYMV	Aphids	No	Epidemic	10–50%	Chile, Uruguay
Soybean Mosaic	SMV	Aphids	Yes	Epidemic	10–30%	Argentina, Brazil, Colombia
Cucumber Mosaic	CMV	Aphids	Yes	Epidemic	Unknown	Colombia
Bean Mild Mosaic	BMMV	Beetles	Yes	Endemic	Unknown	El Salvador, Colombia
Bean Severe Mosaic	QPMV	Beetles	No	Epidemic	10–100%	Central America, Venezuela
Bean Southern Mosaic	BSMV	Beetles	Yes	Endemic	20–56%	All countries
Bean Rugose Mosaic	BRMV	Beetles	No	Epidemic	20–60%	Costa Rica, El Salvador, Guatemala
Bean Dwarf Mosaic	BDMV	Whitefly	No	Endemic + Epidemic	5–100%	Widely distributed; epidemic in Argentina, Mexico
Bean Golden Mosaic	BGMV	Whitefly	No	Endemic/ Epidemic	5–100%	Argentina, Brazil, Central America and the Caribbean

[1] BCMV = Bean Common Mosaic Virus; BYMV = Bean Yellow Mosaic Virus; SMV = Soybean Mosaic Virus; CMV = Cucumber Mosaic Virus; BMMV = Bean Mild Mosaic Virus; QPMV = Quail Pea Mosaic Virus; BSMV = Bean Southern Mosaic Virus; BRMV = Bean Rugose Mosaic Virus; BDMV = Bean Dwarf Mosaic Virus; BGMV = Bean Golden Mosaic Virus.

Table 2. Bean germplasm screened in 1987 for its reaction to bean common mosaic virus.

Materials evaluated	No. Plants Evaluated	% Total Materials Evaluated
Progeny Tests	122,940	67%
Backcrossing Project	4,360	2.4%
Blackroot Resistance Project	5,765	3.1%
Special Projects	5,578	3.0%
Advanced Selections	3,270	1.8%
Germplasm from National Programs	12,960	7.2%
Bean Program Nurseries	28,360	15.5%
	183,223	100.0%

Table 3. F_4bc3 materials from the IVT-CIAT collaborative project which contain I, bc2.2 and bc3 genes for resistance to BCMV mosaic and necrosis strains.

Cross F_4bc3	IVT Stock No.	Population No.	Seed Color
IVT 831575 x PAN 29	861149	1	Navy
IVT 831575 x PAN 29	861150	2	Navy
IVT 831607 x RAB 71	861151	1	Small red brilliant
IVT 831607 x RAB 71	861152	2	Small red brilliant
IVT 831607 x RAB 71	861153	3	Small red brilliant
IVT 831607 x RAB 71	861154	1	Small black brilliant
IVT 831607 x RAB 71	861155	2	Small black brilliant
IVT 831607 x RAB 71	861156	3	Small black brilliant
IVT 831629 x BAT 1554	861157	1	Med. black opaque
IVT 831629 x BAT 1554	861158	2	Med. black opaque
IVT 831629 x BAT 1554	861159	3	Med. black opaque
IVT 831629 x BAT 1554	861160	1	Pinto
IVT 831657 x BAT 1412	861161	1	Med. red mottled kidney
IVT 831657 x BAT 1412	861162	2	Med. red mottled kidney
IVT 831653 x Blanco INIA	870001	1	Med. white
IVT 831654 x CAN 20	870002	1	Yellow
IVT 831654 x CAN 20	870003	2	Yellow
IVT 831654 x CAN 21	870004	1	Yellow
IVT 831657 x PAI 112	870005	1	Small red mottled
IVT 831657 x PAI 112	870006	2	Small red mottled
IVT 831657 x PAI 112	870007	3	Small red mottled
IVT 831657 x PAI 112	870008	4	Small red mottled
IVT 831657 x PAI 112	870009	5	Small red mottled

Table 4. Final selection of germplasm accessions and grain types selected in Monjas, Guatemala as potential sources of bean sources of bean golden mosaic resistance.

Number of germplasm accessions selected	Grain Type	Seed Color	
		CP*	CS
12	Red Cranberry	2	6
3	Purple Cranberry	2	7
6	Pinto	2	4
1	Red Mottled	6	2
4	Light Red	5	
9	Dark Red	6	
1	Purple	7	
4	White	1	

* CP = Primary seed color; CS = Secondary seed color.

Table 5. Main symptoms induced by Bean Golden Mosaic Virus in *Phaseolus vulgaris*, and bean genotypes exhibiting specific low-symptom-expression.

Main BGMV Symptoms	Resistant Genotypes*
Mosaic (Yellowing)	Pinto, Great Northern
Plant Dwarfing (Stunting)	Red Kidney, Cranberry, Canario
Flower Abortion	Cranberry, Red Kidney
Pod/Seed Distortion	Redlands Greenleaf, Exotic Genotypes

* Not all genotypes cited present the same reaction. For specific information please contact CIAT's Bean Virology Section.

Table 5. Serological relationship between four whitefly-transmitted geminiviruses of *Phaseolus vulgaris* as determined with monoclonal antibodies to African cassava mosaic virus.[1]

Geminivirus	Monoclonal Antibody		
	SCR 11	SCR 17	SCR 18
BGMV-GUA[2]	0	++[3]	+++
BGMV-MEX	0	++	0
BDMV-COL	0	++	0
RhMV-COL	0	++	++
Healthy Bean	0	0	0
ACMV	+++	+++	+++

[1]Tests performed by Dr. B.D. Harrison, Scottish Crop Research Institute.

[2]BGMV = Bean golden mosaic virus; GUA = Guatemala; MEX = Mexico; BDMV = Bean dwarf mosaic virus; COL = Colombia; RhMV = Rhynchosia mosaic virus; ACMV = African cassava mosaic virus.

[3]+ = positive reaction according to magnitude (relatedness); 0 = negative reaction.

Table 7. Reaction of selected bean cvs. to BDMV-Col.

	Inoculation	
	Mechanical	*B. tabaci*
Dubbele Witte	+	+
Stringless Green Refugee	+	
Redlands Greenleaf-C	+	
Puregold Wax	+	
Imuna	+	
Redlands Greenleaf-B	+	
Great Northern 123	+	
Sanilac	-	+
Michelite	-	+
Red Mexican 34	-	-
Pinto 114	-	-
Monroe	-	+
Great Northern 31	-	-
Red Mexican 35	-	-
Widusa	+	
Black Turtle Soup	-	-
Jubila	+	
Topcrop	+	+
Improved Tendergreen	+	
Amanda	+	

+ = Bean Dwarf Mosaic Symptoms; - = Symtomless; Blank spaces = not tested.

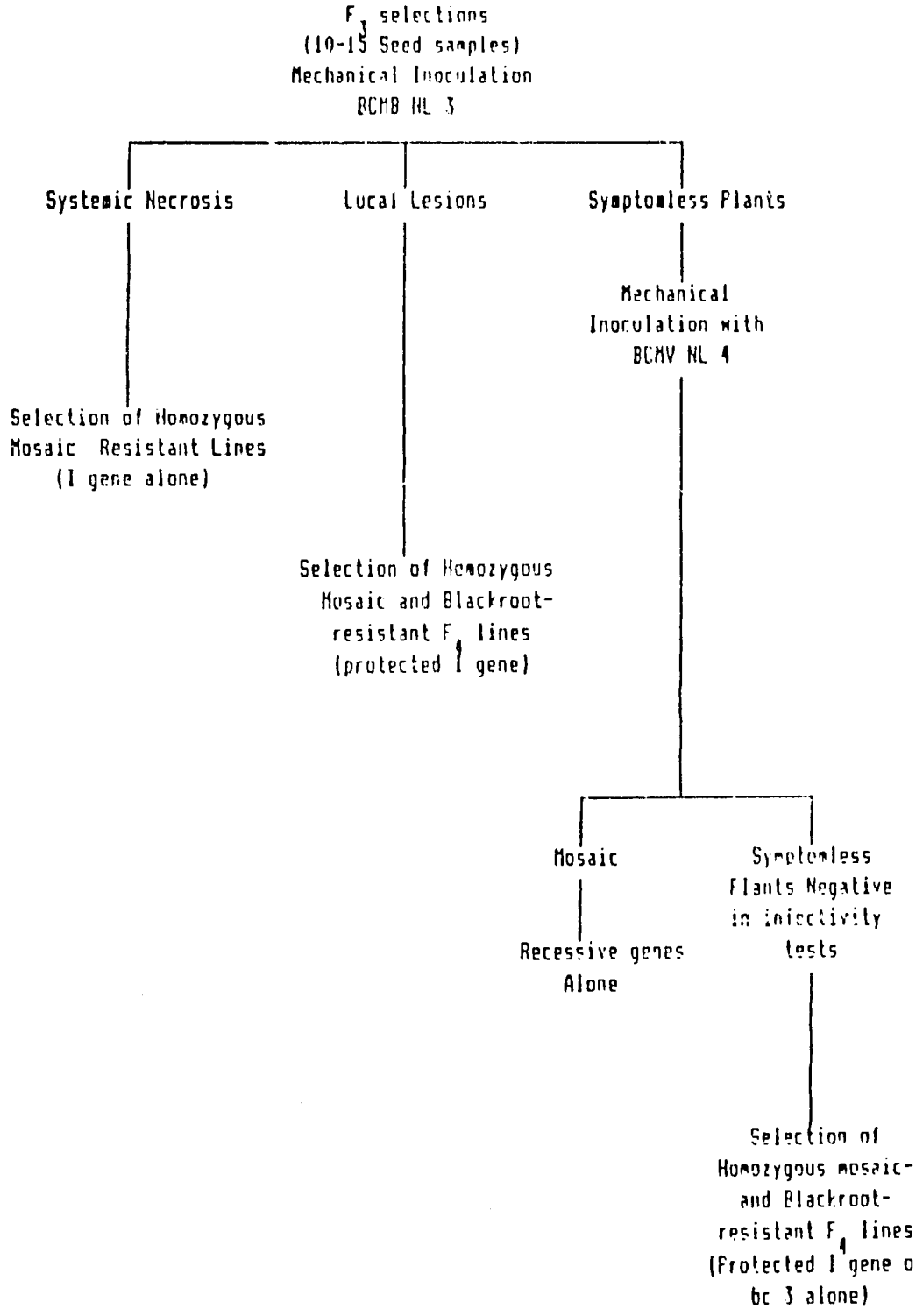


Figure 1. Current screening methodology implemented at CIAT to select mosaic-and black-root-resistant bean genotypes.

5. Invertebrate Pests

Breeding for resistance to leafhoppers, bruchids, and pod weevil continued to be the main priority of the Bean Program's Entomology Section in 1987. Studies on the biology, ecology and possible varietal preferences of the whitefly were continued. Significant progress was made in relation to the understanding of the mechanisms of resistance to bruchids and on techniques for selection of resistant materials in segregating populations. The Apion network in Central America was expanded and strengthened. For the first time the mechanisms of resistance to A. godmani were studied. Progress in breeding for resistance to this insect was also made and several resistant and well adapted lines were identified.

a. BRUCHIDS

Screening for resistance

High levels of resistance to the Mexican bean weevil (Zabrotes subfasciatus) were reconfirmed in accessions G 12947, G 12950, and G 12951. These materials will be included as parents in future crossing blocks. The search for sources of resistance to bruchids was expanded to other species within the genus Phaseolus. Out of 40 accessions evaluated, only one P. xanthotrichus material was resistant to the Mexican bean weevil and to the bean weevil (Acanthoscelides obtectus). In addition, 21 cultivated African varieties that had been reported as resistant to bruchids in Rwanda were reevaluated at CIAT. All were found to be highly susceptible to the Mexican bean weevil and to the bean weevil.

Mechanisms and factors responsible for resistance

To determine mortality levels and the stage in the life cycle affected by antibiosis, both species of bruchids were reared on the highly resistant wild accession G 12954, and the cultivated check, Diacol Calima. Daily dissection and measurement of the larvae revealed that the life cycles of both the Mexican bean weevil and the bean weevil reared on G 12954 were staggered and significantly delayed (Figure 1). Thus, 24 days after infestation, 100% of Z. subfasciatus individuals on Calima had pupated, while 63.4% of the population on G 12954 had not even become second instar larvae. Similarly, 90% of the A. obtectus population reared on Calima had pupated, while 40% of the individuals on G 12954 were still first instar larvae. Mortality levels for the Mexican bean weevil and the bean weevil reared on the resistant accessions were 72.4 and 42.6%, respectively. Up to 97% of the mortality occurred at the first instar larval stage, which explains the low levels of emergence obtained in resistant varieties. This is important as it directly affects population growth rates and resulting damage levels.

A very important development was the successful rearing of the bruchids on 'artificial' seeds. Briefly, beans are soaked, the testae are removed and the flour is dried and milled. The flour is then reconstituted in molds, lyophilized and then hydrated at room temperature. The 'artificial' seeds thus obtained are then coated with gelatin and infested as if they were intact. Chemicals or flour of different varieties can be added and their effect tested. Size, texture and color are standardized so that factors intrinsic to the seed can be bioassayed. Table 1 shows that resistance and susceptibility reactions for both bruchids were consistent even though numeric values for days to adult emergence and percentage emergence differed. Figure 2 shows that as flour of resistant accessions was added to a Calima background in increasing proportions, there was a significant prolongation of the life cycle of both insects as the percentage of resistant variety in the diet was increased.

It has been reported that arcelin, a lectin-like protein, confers resistance to the Mexican bean weevil (CIAT, 1986 Annual Report). Several tests, conducted throughout the year, reconfirmed this theory. Thus, high levels of resistance to the Mexican bean weevil were found in wild bean varieties selected for the different types of arcelin previously identified by means of electrophoresis (Table 2). When 67 lines selected at the University of Wisconsin were tested for resistance to the Mexican bean weevil, four lines positive for the presence of arcelin 1 were resistant. One line initially reported as devoid of arcelin was resistant. The rest were susceptible. Evaluation for resistance to the bean weevil is pending.

Further and more definitive proof of the importance of arcelin in conferring resistance to Z. subfasciatus was obtained when the Mexican bean weevil was reared on artificial seeds to which purified arcelin 1 was added at three different levels. At the lowest level tested arcelin had no significant effect on larvae. As the concentration increased, the life cycle was significantly prolonged and the percentage emergence was reduced. The dosage response as measured by life cycle duration was nearly linear over the range of arcelin levels tested (Figure 3). For percentage emergence, a significant dosage response was observed at the highest arcelin level, indicating that high levels may be needed to affect this parameter (Figure 3). The LC_{50} for arcelin was 6.5%.The importance of arcelin as a resistance factor was confirmed when the insect was reared on 'artificial' seeds prepared with flour of SARC-1, a Sanilac backcross-derived line homozygous for the presence of arcelin 1 obtained at the University of Wisconsin (Table 3).

Breeding for resistance

The confirmation of arcelin as the factor responsible for resistance to Z. subfasciatus but not to A. obtectus introduced important changes in the breeding scheme, in particular in relation to the selection of resistant materials in segregating

populations. Each species of bruchids is being handled separately. Selection for Z. subfasciatus is based on the presence or absence of arcelin as detected by means of serological tests (Ouchterlony plates, ELISA tests) or electrophoresis. In the absence of a quick screening technique for the carbohydrate claimed by the University of Durham to be responsible for resistance to A. obtectus, selection for this species in segregating populations is based on individual seed feeding tests coupled with individual plant selections made in the field for agronomic and seed size characteristics. Tables 4 and 5 illustrate some of the selections currently being reevaluated for resistance to the Mexican bean weevil and the bean weevil, respectively.

b. BEAN POD WEEVIL (APION)

Biological studies

The life cycle of the pod weevil, Apion godmani, was studied under field conditions in Danli, Honduras. The duration of the different stages was as follows: egg, 9 days; larva, 19 days; pupa, 10.5 days; for a total of 38.5 days and one generation per cropping season. There seems to be a close phenological relationship between the appearance of the first colonizing adults and flowering time. In other experiments, early plantings were found to be more heavily attacked than late plantings. This is important as manipulation of planting dates is one of the techniques recommended to obtain high insect populations in screening nurseries.

Studies on possible mechanisms of resistance to the pod weevil were conducted at two locations in Honduras. For simplicity, the results of one location are discussed in this report. Oviposition rates on resistant and susceptible varieties did not differ significantly (Figure 4). When larval populations were sampled daily, up to 54% larval mortality was found in the resistant variety APN 83. As a result, total larval populations on the susceptible check, Desarrural, were consistently higher than in the resistant variety (Figure 4). Pending reconfirmation, these preliminary results suggest that antibiosis could be the mechanism responsible for resistance to the pod weevil.

Screening for resistance to A. godamni was reinitiated. High levels of resistance were reconfirmed for the following germplasm accessions: G 03295, G 13614, G 07090, G 06990, G 03324, G 03313, G 06130, G 09885, G 07032, G 03578, G 04397, and G 08142.

Excellent progress has been made in terms of breeding for resistance to the pod weevil. Thirteen APN bush bean lines with acceptable levels of resistance, good adaptation and seed color were selected in Honduras (Table 6). For the first time, climbing bean lines were selected for resistance and adaptation among

materials in the 1986 International Apion Nursery (Table 7) and from the 1987 International Apion Nursery (Table 8).

C. EMPOASCA KRAEMERI

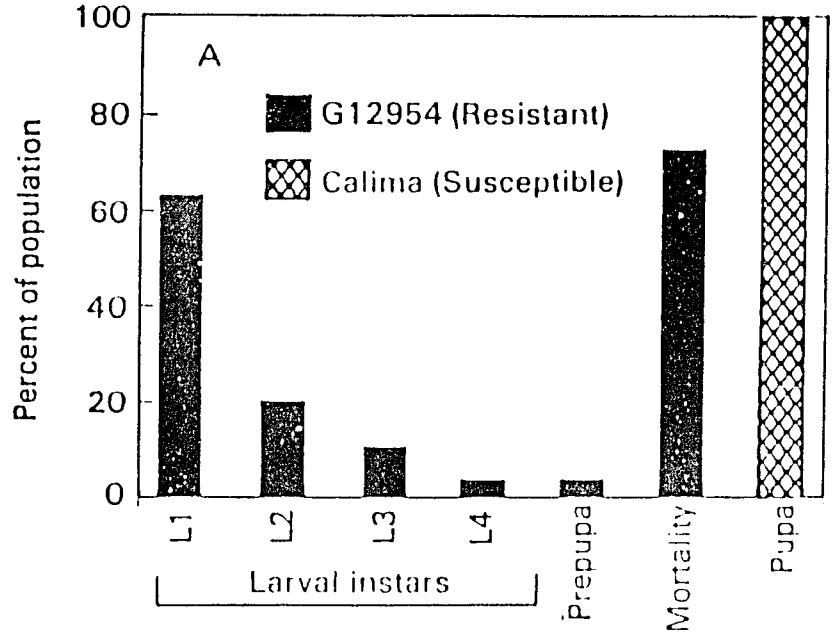
The report on leafhopper resistance covers the first semester of 1987 as second semester trials are still to be harvested. Emphasis was placed upon the evaluation of early segregating populations of red and white seeded materials, two groups particularly difficult to improve for leafhopper resistance. Several of the white and red populations significantly outyielded the checks, EMP 175 and BAT 41, respectively, under high leafhopper infestation (Table 9). Absolute protected yields were not high due to severe temperature conditions during the growing season.

As reported previously (CIAT, 1986 Annual Report), superior determinate bush bean lines had, for the first time, been identified. These improved lines were yield-tested again in 1987. As shown in Table 10, most of the lines significantly outyielded the commercial checks. A new cycle of recurrent selection was inititated with these superior genotypes.

The search for new sources of resistance among germplasm accessions included the evaluation of 2,247 materials. No sources were found among snap beans or wild beans. Two dry bean varieties were classified as highly resistant. In addition to germplasm accessions, 38 *Phaseolus vulgaris* x *P. acutifolius* hybrid lines were evaluated. None was resistant.

d. WHITEFLY

Studies on host-plant relationships and varietal preferences of the whitefly, *Bemisia tabaci*, continued in 1987. Several experiments confirmed that adults prefer to oviposit on cotyledonal leaves and that optimum sampling time for pupal populations is 30-35 days after planting. Optimum plot size for routine evaluations of whitefly populations on different genotypes was evaluated. One-row, 3-m long plots did not significantly differ from 4-row, 3-m long plots. As reported in 1986, optimum sample size to compare varietal differences in terms of pupal populations was again 10 cotyledonal leaves per 3-m row plot. Once the experimental and sampling techniques were refined, the screening for possible varietal differences among selected, previously studied genotypes continued under greenhouse and field conditions. Results will be reported in 1988.



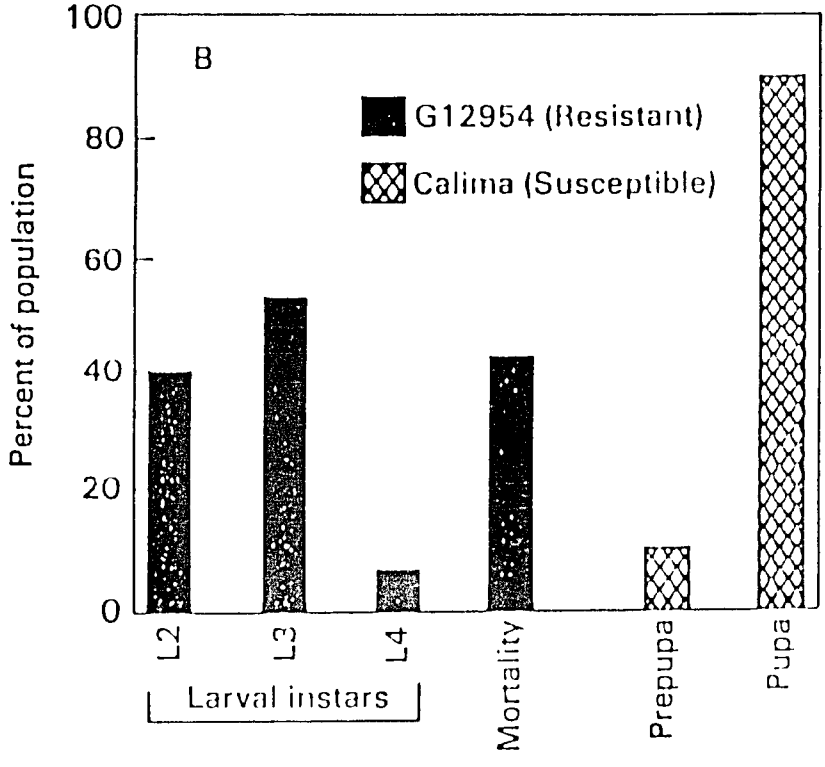


Figure 1. Distribution of life stages and mortality of (A) *Z. subfasciatus* and (B) *A. obtectus* 24 and 29 days, respectively, after infestation of two bean varieties.

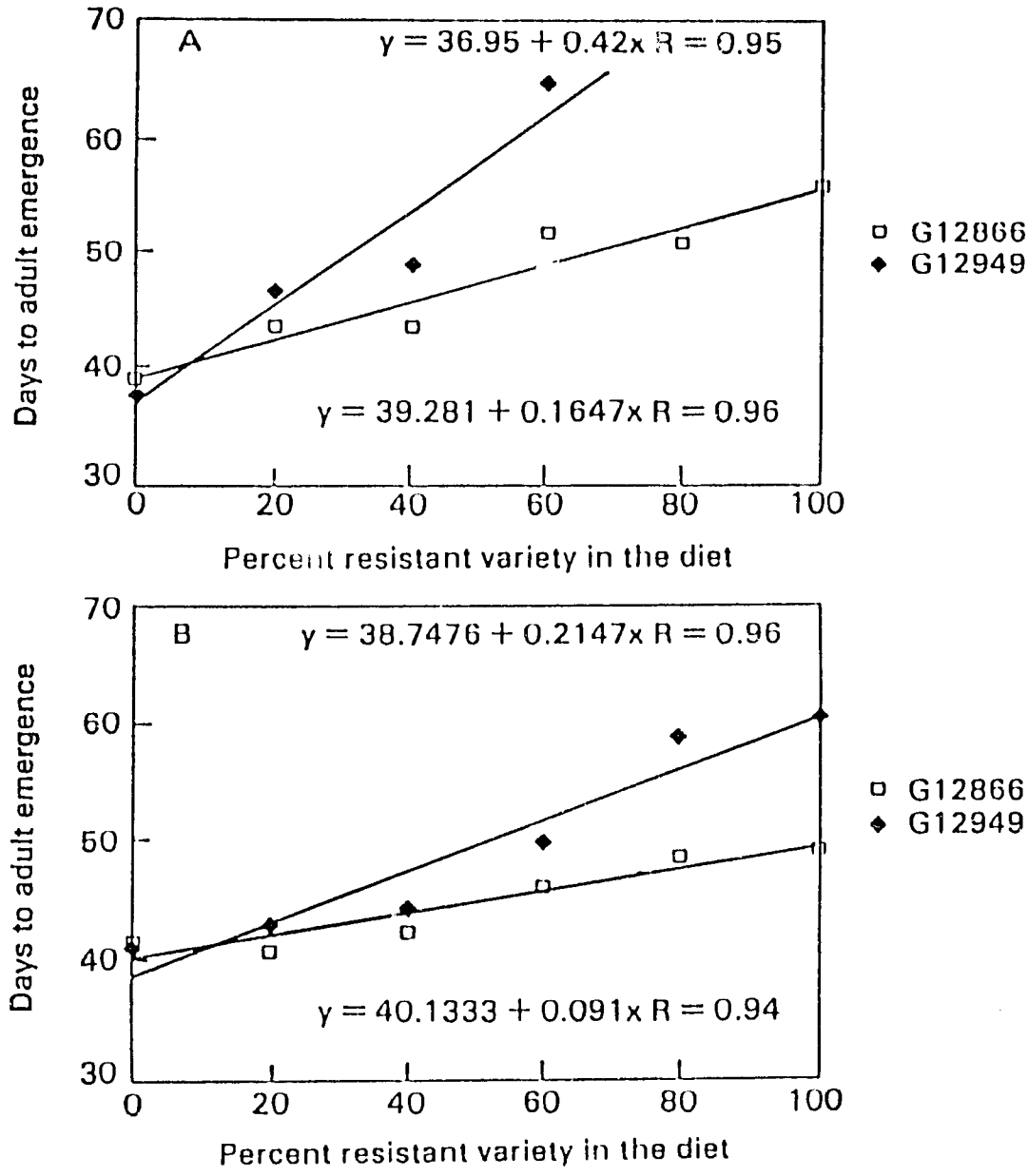


Figure 2. The regression of percent resistant variety in the diet on life cycle duration of (A) the Mexican bean weevil and (B) the bean weevil.

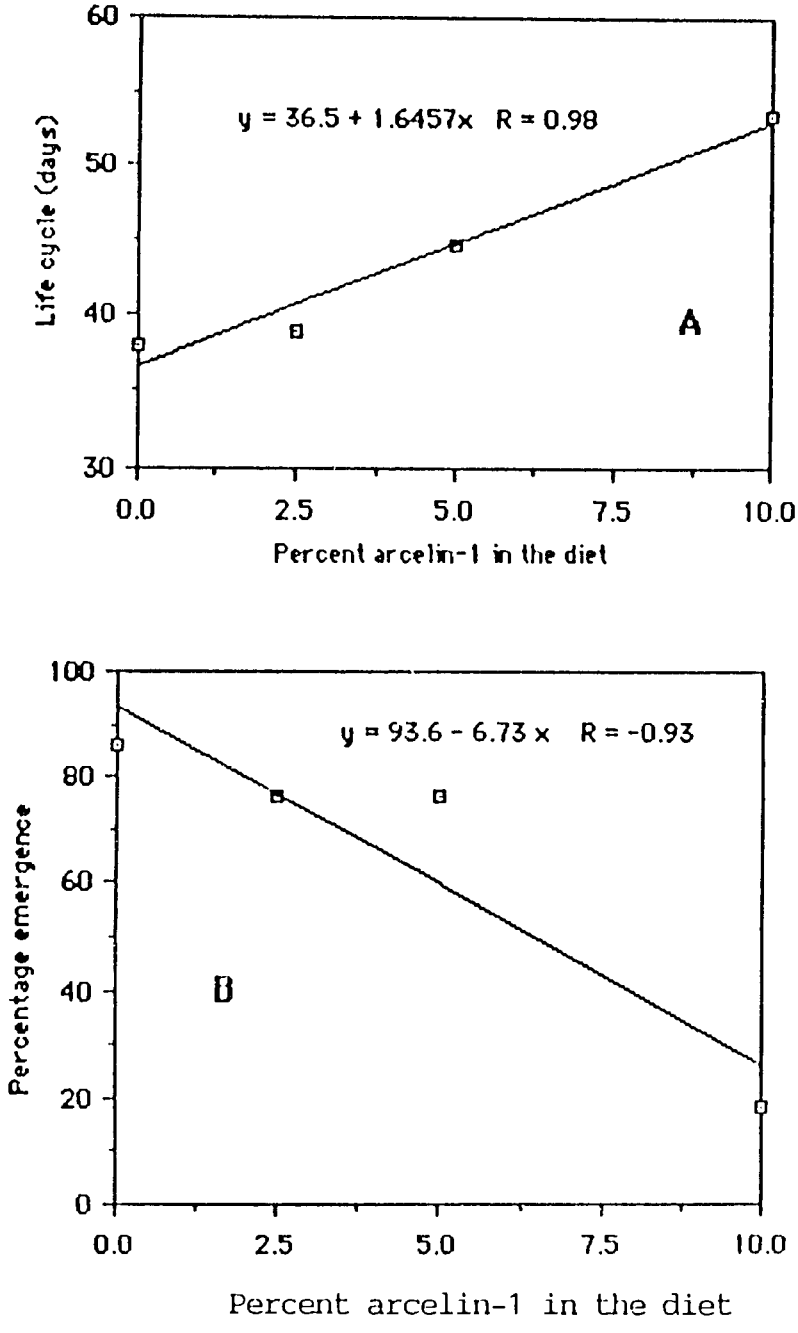


Figure 3. The regression of percent arcelin-1 in the diet on (A) life cycle duration and (B) percent emergence of the Mexican bean weevil.

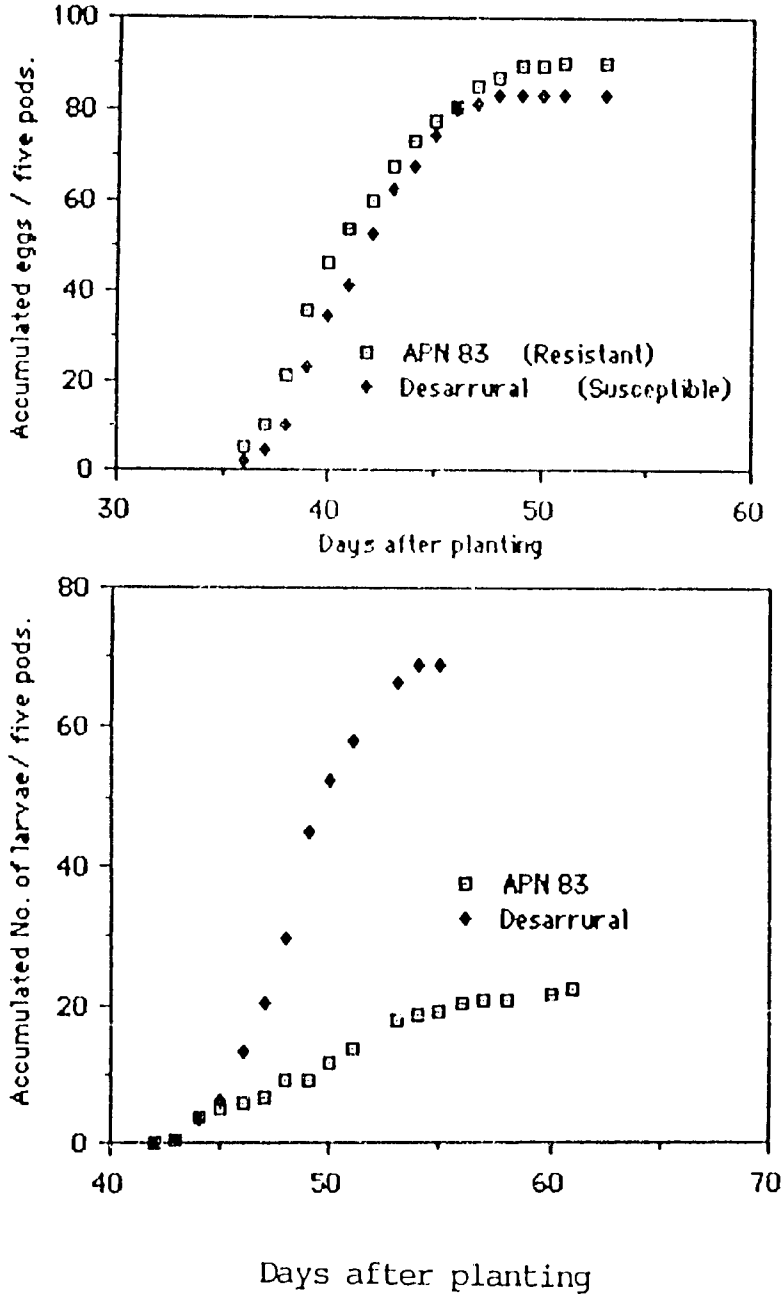


Figure 4. Egg and larval populations of Apion godmani on two bean varieties. El Barro, Honduras 1987. Means of four reps.

Table 1. Development of *Z. subfasciatus* and *A. obtectus* on 'artificial' and intact dry bean seeds of a resistant (G 12954) and a susceptible (Calima) bean variety.

Technique	Variety	Percentage emergence	Days to adult emergence	Weight/adult (9x10-3)
Z. subfasciatus				
Artificial seed	G 12954	1.3b	64.0a	-
	Calima	61.9a	40.5b	-
Intact seed	G 12954	20.6b	59.3a	0.7
	Calima	86.5a	33.7b	1.4
A. obtectus				
Artificial seed	G 12954	1.0b	74.0a	1.3b
	Calima	40.2a	38.3b	2.5a
Intact seed	G 12954	7.2b	55.1a	1.0b
	Calima	40.6a	36.2b	2.4a

a) Means within a column followed by the same letter are not significantly different at the 5% level (P 0.05; Duncan's [1955] multiple range test). Each species analyzed separately.

Table 2. Levels of resistance to *Z. subfasciatus* in wild bean varieties selected for the presence of four arcelin variants. Means of five replicates.

Accession	Percentage emergence	Life cycle (days)	Weight/adult (g $X10^{-3}$)	Rating
G 12882-Arc1	11.5c	48.9c	0.8c	Resistant
G 12866-Arc2	11.7c	48.5c	0.9b	Resistant
G 12922-Arc3	81.7b	42.3d	0.8c	Intermediate
G 12949-Arc4	5.4d	70.1a	0.5d	Resistant
G 12952 (check)	10.4c	64.5b	0.5d	Resistant
Calima (Susc.check)	96.1a	32.9c	1.3a	Susceptible

Means followed by the same letter are not significantly different at the 5% level (Duncan's multiple range test).

Table 3. Biology of the Mexican bean weevil on 'artificial' and intact seeds of four varieties.

Technique	Variety	Rating	Percentage emergence[a]	Days to adult emergence
Artificial seed	Calima	Susceptible	87.7b	37.9b
	L 12-56	Susceptible	74.7c	38.4b
	Sanilac	Susceptible	86.1bc	37.8b
	SARC 1	Resistant	18.4d	53.7a
Intact seed	Calima	Susceptible	93.0abc	31.5b
	L 12-56	Susceptible	100.0a	32.1b
	Sanilac	Susceptible	95.9ab	31.3b
	SARC 1	Resistant	7.3d	50.7a

[a]Means within a column followed by the same letter are not significantly different at the 5% level (P=0.05; Duncan's [1955] multiple range test).

Table 4. Some of the best individual seed selections for resistance to *Z. subfasciatus*.

CROSSES	GENERATION	LIFE CYCLE (DAYS)
Backcrosses		
BAT 477 X (BAT 477X G 13016)	F_1	52.5
Catu X (Catu X G 13029)	F_1	76.0
859446-67 X (859446-67 X XAN 105)	F_1	55.0
EMP 175 X (EMP 175 X G 12866)	F_1	49.0
Triplecrosses		
XAN 105 X (EMP 175 X G 12866)	F_1	44.0
A 114 X (EMP 175 X G 12866)	F_1	43.0
Simple crosses		
G 12952 X A 484)	F_2	44.8
Checks		
G 12952 (Resistant)	-	48.0
Calima (Susceptible)	-	32.2

Table 5. Some of the best F_4 individual plant selections made for resistance to *A. obtectus*.

CROSS	PERCENTAGE EMERGENCE	LIFE CYCLE (DAYS)
GG 41B-1-1 (G 12952 X G 4435)	38.9	54.4
GG 41B-7-1	16.7	64.0
GG 48B-4-5 (G 12952 X A 484)	26.6	42.2
GG 48B-5-4	33.3	44.7
GG 52A-2-11 (G 12891 X A 83)	42.0	46.5
Calima (susceptible check)	63.3	37.1
G 12952 (resistant check)	4.7	54.7

Table 6. Adaptation, percentage pods damaged and percentage seeds damaged in 13 bush bean lines selected for resistance to A. godmani in Danli, Honduras, 1987 A. Means of three replications.

Line	Parents	Adaptation (1-9 scale)	% pods damaged	% seeds damaged
APN 96	RAB 56XG 3578	7	23.3	5.9
97	"	5	14.4	4.2
98	"	6	12.2	3.6
99	"	5	10.0	2.7
100	RAB 56XG 8142	4	28.9	7.7
101	"	6	22.2	6.1
102	"	6	12.2	2.2
103	"	6	17.9	4.3
104	"	7	13.3	4.6
105	"	4	20.0	8.3
106	"	6	15.5	4.9
107	RAO 30XG 13614	5	15.6	4.6
108	"	5	9.5	2.3
APN 84[1)]	--	2	12.2	3.9
88[1)]	--	5	13.3	3.3
93[1)]	--	3	5.5	1.4
79[1)]	--	5	4.4	1.1
Zamorano[2)]	--	6	50.0	19.5
Ranges (68 materials)		2-8	0-56.7	0-22.8

1) Improved checks

2) Susceptible check

Table 7. Adaptation, percentage pods damaged and percentage seeds damaged in 10 lines selected from the 1986 Apion International Climbing Bean Nursery. Danli, Honduras. Means of three replications.

Material	Adaptation (1-9 scale)	% pods damaged	% seeds damaged
RCAG 12485-10-CM-CM	5	13.3	2.5
12508-21-CM-CM	3	40.0	11.8
12513- 3-CM-CM	2	33.3	9.7
- 6-CM-CM	5	21.3	10.0
-20-CM-CM	4	6.7	1.6
-25-CM-CM	5	26.5	8.5
-26-CM-CM	2	20.1	4.9
-28-CM-CM	5	12.4	3.1
-31-CM-CM	5	16.7	4.1
-39-CM-CM	3	22.2	6.4
Zamorano[1)]	3	81.1	45.4
Rojo de Seda[1)]	3	91.1	50.7
Desarrural[1)]	5	85.6	55.8
Ranges (30 materials)	2-9	6.7-91.1	1.6-55.8

[1)] Commercial susceptible checks

PARENTS: RCAG 12485 : RAB56 X G 13602

RCAG 12508 : BAT38 X G 13602

RCAG 12513 : BAT56 X G 13614

Table 8. Adaptation, percentage pods damaged and percentage seeds damaged in 11 materials selected from the 1987 Apion International Climbing Bean Nursery. Danli, Honduras. Means of three replications.

Material	Adaptation (1-9 scale)	% pods damaged	% seeds damaged
RCAH 14123-1-CM-CM	5	5.8	1.4
-4-CM-CM	3	5.5	1.1
-7-CM-CM	4	3.3	0.9
-11-CM-CM	5	3.3	1.5
RCAH 14124-6-CM-CM	7	3.3	1.8
RCAS 14126-1-CM-CM	4	1.1	0.2
-2-CM-CM	3	2.2	0.5
-3-CM-CM	4	2.2	0.5
-7-CM-CM	2	3.3	0.8
-8-CM-CM	5	1.1	0.2
RCAS 14134-14-CM-CM	6	2.3	0.5
Zamorano[1)]	5	64.4	23.0
Ranges (25 materials)	2-9	1.1-64.4	0.2-23.0

1) Susceptible check

PARENTS: RCAH 14123: RAB 34XG 13614
RCAH 14124: RAB 49XG 13614
RCAS 14126: RAB 11XG 13614

Table 9. Best F_3 populations from the X cycle of recurrent selection for leafhopper resistance. Means of three replications.

Population	Color	Yield (kg/ha)		Porcentage yield reduction
		Nonprotected	Protected	
ER 13815-CM(V)	1	896	984	8.9
13816-CM(V)	1	866	964	10.2
13817-CM(V)	1	870	1027	15.3
13861-CM(V)	1	967	1024	5.6
13870-CM(V)	1	1085	1296	16.3
13844-CM(V)	6	931	1134	17.9
13848-CM(V)	6	756	894	15.4
EMP 175[1)]	1	702	1058	33.6
BAT 41[1)]	6	675	1325	49.0
LSD 5%		287	393	-
C.V.		20.6	20.1	-

1) Checks

Table 10. Best determinate bush bean lines from a recurrent selection cycle for leafhopper resistance. Means of three replications.

Line	Color	100-seed weight (g)	Nonprotected yield (kg/ha) 1986B	1987*A	Mean % yield reduction
EMP 177	6M	29	1114	385	29.8
EMP 178	6M	34	1102	596	35.5
EMP 179	7M	25	903	600	39.9
EMP 182	6M	33	807	495	39.9
EMP 184	7M	34	776	399	53.9
EMP 185	7M	30	749	488	50.4
EMP 186	6M	26	718	383	52.9
Checks:					
ICA P 11	6M	35	459	89	67.1
BAT 1366	6M	32	404	203	66.8
Linea 24	6M	39	365	114	75.7
A 36	6M	30	-	200	63.2
LSD 5%			254	177	-
C.V.			22.6	25.6	-

6. Adaptation

a. DROUGHT

Over 60% of bean production regions are affected by drought, and water stress is probably the largest individual factor causing low yields in beans. Although it is recognized that there will always exist severe physiological limits to bean production under drought stress, there exist several possible avenues for improving adaptation of beans to drought conditions. Research at CIAT has focused on three classes of mechanisms giving higher yields under drought. These are:

1. Drought escape through inherent earliness or a response of accelerated maturity.

2. Drought avoidance based on greater soil moisture extraction, or moisture conservation.

3. True drought tolerance, defined as the ability to withstand greater tissue water deficits.

Recognizing that these mechanisms are not mutually exclusive, and that their relative importance will vary with local conditions, attempts are also being made to analyze their integrated effects in relation to soil and climate conditions.

Drought escape

Previous studies at CIAT showed that drought yields and days to maturity of different genotypes were frequently negatively correlated, confirming that drought escape is an important adaptation in beans. This is consistent with beans being a short season annual crop adapted to growing on residual soil moisture. Unfortunately, precisely what level of earliness should be sought for a given environment will depend on the stress regime and the balance farmers may seek between reducing risk with earliness and sacrificing yield potential.

A possible alternative to seeking a specific level of earliness would be to develop cultivars which vary their maturation rate depending on the stress regime in a given season. Evidence for such mechanisms is suggested by comparisons of days to maturity and yields of 72 genotypes grown under stress and irrigated conditions in three semesters differing in rainfall distribution (Table 1). In semester A, with severe stress after 35 days, days to maturity and drought yield were negatively correlated, but a stronger relation with yield was found for the difference between days to maturity under irrigated and stress conditions, with drought plots showing a mean acceleration of maturity of 10 days. In contrast, for semester C, where stress was received by rains after 35 days, later maturing cultivars

gave higher yields, and materials showing a delay in maturity under drought gave higher yields. In semester A, the four genotypes of growth habit I were among the materials showing the least ability to adjust growth cycle under stress, suggesting that this may partially explain their generally poor drought adaptation.

Drought avoidance

An initial study on the importance of increased soil moisture extraction through greater root growth had demonstrated that while this mechanism was effective in the fertile soils at Palmira, it was not functional in the acid soils of Quilichao where root growth was concentrated in upper soil layers. To verify this observation for a wider range of genotypes, root growth under drought stress was analyzed for 10 small to medium seeded genotypes of indeterminate growth habits. At Palmira, root length density was correlated with yield (Figure 1), but at Quilichao no relation was detected. However, root growth at the two sites did show a significant correlation (Figure 2). These results confirm the importance of root growth under certain soil conditions, and furthermore suggested that cultivar differences in root growth may show similar patterns in contrasting soil environments.

While root length density was not correlated with yield at Quilichao, this finding did not exclude the possibility that other aspects of root function control differences in drought performance in the soils at Quilichao. Using reciprocal grafting of two genotypes of contrasting drought response, the relative effect of shoot and root characteristics on drought response was evaluated. The results indicated an overwhelming effect of root genotype at Quilichao (Table 2). This suggests that other characteristics of the root system besides root growth may be important in determining performance under drought.

Two previous grafting studies at Palmira had similarly supported the importance of root growth, but since they had only involved two genotypes, an additional study was conducted using four genotypes. Results again supported the effect of root systems on drought tolerance (Table 3).

Characteristics which favor conservation of water can also result in drought avoidance. Traditional measures of water loss are very cumbersome since they usually reflect events over time spans of less than a day (often only minutes), and are difficult to relate to photosynthetic activity. Recently, work in several C_3 crops has indicated that tissue carbon isotope composition is closely related to water use efficiency (WUE defined as the ratio of assimilation to transpiration). Because of discrimination against $^{13}CO_2$ vs $^{12}CO_2$ in diffusion processes and fixation by RuDP carboxylase, relatively less ^{13}C is fixed when there is no

limitation on gas exchange (e.g. when stomata are open and transpiration is unrestricted). Thus, if tissues are formed under conditions of high transpiration in relation to assimilation, ^{13}C concentration will be relatively low. Expressing ^{13}C concentration in parts per thousand depletion relative to a standard representing the relative concentration of the two isotopes in atmospheric CO_2, increasingly negative values of ^{13}C to ^{12}C ratios indicate lower WUE.

Measured in 10 bean genotypes grown at Palmira and Quilichao, leaf carbon isotope ratios indicated that greater biomass production and seed yield were associated with low WUE (Figure 3) at Palmira, but that at Quilichao, an intermediate level of WUE resulted in greater growth and yield (Figure 4). These results suggest that as a short season crop, beans achieve greater growth under drought by exploiting available soil moisture rather than conserving it and maintaining high WUE. At Palmira, where a deep rooting genotype can maintain transpiration for a relatively long period, low WUE is desirable. For conditions where soil moisture availability is more limited, such as at Quilichao, an intermediate level is desirable since excessive transpiration in early growth could exhaust soil water for subsequent growth.

Future work on drought avoidance will emphasize two main areas. One is to develop a rapid system for screening for differences in root growth. The second is to understand effects of physical and chemical characteristics of soil on root growth.

Drought tolerance

True drought tolerance does not appear to have been detected in beans. Studies at CIAT, Durango, Mexico (in collaboration with researchers at INIFAP), and Goiania, Brazil (with researchers at CNPAF) have all indicated that even under severe stress beans do not reach water potentials below -1.5 MPa. Slight genetic differences in tissue water potentials are probably due to differences in root growth rather than ability to withstand stress. The failure to detect major effects of shoot genotype on yield in drought studies would also argue against differences in tolerance to desiccation unless they are either only expressed in root tissues, or are regulated by root tissues.

Integration of mechanisms

Many lines of evidence indicate that no single drought adaptation will prove useful across environments, and furthermore, that desirable levels of earliness or root growth will vary with environment. The immediate practical implication is that breeding for drought tolerance should be directed to specific drought environments. A second implication is that there is a need for developing techniques for estimating

integrated effects of adaptation such as earliness and deep roots in relation to different climatic and edaphic conditions. To evaluate such effects, BEANGRO, a crop growth simulation model, being developed by researchers at the University of Florida through support from IBSNAT, is being used to simulate crop growth of different genotypes grown under drought stress at CIAT. The model is currently in final stages of testing prior to formal release.

To test the relative importance of earliness for planting dates corresponding to peak periods of stress vs periods with varying levels of stress, BEANGRO was run for May 21 (drought) and September 26 (variable stress) planting dates with parameters for BAT 477 and a hypothetical cultivar identical to BAT 477 except flowering and maturing approximately 10% earlier. As expected, the early maturing genotype was superior for the drought planting date, although the advantage was by no means constant over the 8 years of test data (Table 4).

Assuming that BEANGRO continues to show promise for such work, emphasis will be placed on using the model to examine drought stress in regions contrasting strongly with those available at CIAT. Priority regions are north central Mexico and northeast Brazil.

Table 1. Acceleration of maturity under drought stress for 72 genotypes grown in three semesters varying in distribution of precipitation.

	Semester		
	A	B	C
Mean yield (kg/ha)			
Drought	1650	1080	600
Irrigation	2660	2550	1340
Acceleration of maturity[1] (days)	10.0	0.3	-0.1
Correlation with drought yield			
Days to maturity under drought	-0.39**	-0.15	0.30*
Acceleration of maturity	0.49**	0.05	-0.24*
Precipitation (mm)			
0-35 days	61.4	6.6	81.4
36-70 days	21.2	27.4	157.9

[1] Calculated as the difference between days to maturity under irrigated and stress conditions.

*,** Significant at the p = 0.05 and p = 0.01 levels, respectively.

Table 2. Relative effect of root and shoot genotype on drought response at Quilichao as assessed using reciprocally grafted plants derived from BAT 477 and BAT 1224.

Root genotype	Yield for shoot genotype			
	Grafted		Control	
	BAT 477	BAT 1224	BAT 477	BAT 1224
	kg/ha			
BAT 477	500	610	610	-
BAT 1224	810	1000	-	1170

Significance of effect:	Probability
Root	0.01
Shoot	NS
Root x shoot	NS
Graft	0.05

Table 3. Relative effect of root and shoot genotype on drought response at Palmira using reciprocally grafted plants derived from four bean genotypes.

Root genotype	Yield for shoot genotype			
	G 4495	BAT 1224	BAT 477	G 17722
	kg/ha			
Grafted:				
G 4495	430	570	490	510
BAT 1224	530	570	630	570
BAT 477	530	550	470	380
G 17722	690	810	710	540
Ungrafted:				
G 4495	380			
BAT 1224		560		
BAT 477			510	
G 17722				670

Significance of effect:	Probability
Root	0.01
Shoot	NS
Root x shoot	NS
Graft	NS

Table 4. Yields over eight years at Palmira for normal and early maturing BAT 477 planted in dry and variable season planting dates (May 21 and Sept. 26, respectively) as predicted by BEANGRO simulation. Precipitation is for 65 day period after planting.

	Dry season			Variable season		
	Yield			Yield		
Year	Normal	Early	Precip.	Normal	Early	Precip.
	------kg/ha-----		mm	-----kg/ha----		mm
1979	280	20	144	3240	3170	184
1980	490	820	111	1150	1360	189
1981	690	1000	135	3900	3370	273
1982	10	50	88	3250	2710	252
1983	440	370	83	1390	590	152
1984	2020	2060	162	3580	3040	280
1985	0	50	36	2340	1530	203
1986	680	920	166	3450	3160	309
Mean	580	660	116	2790	2370	230

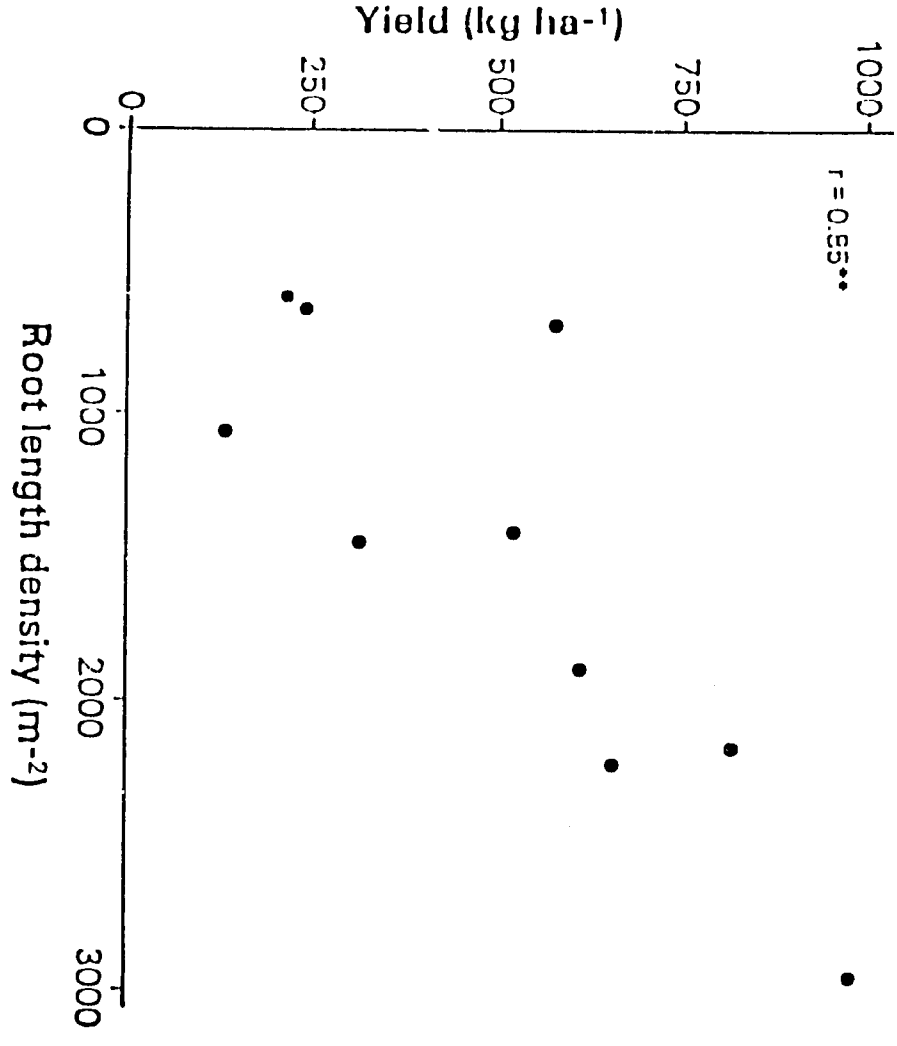


Figure 1. Comparison of root length density and seed yield of 10 genotypes grown under drought stress at CIAT-Palmira.

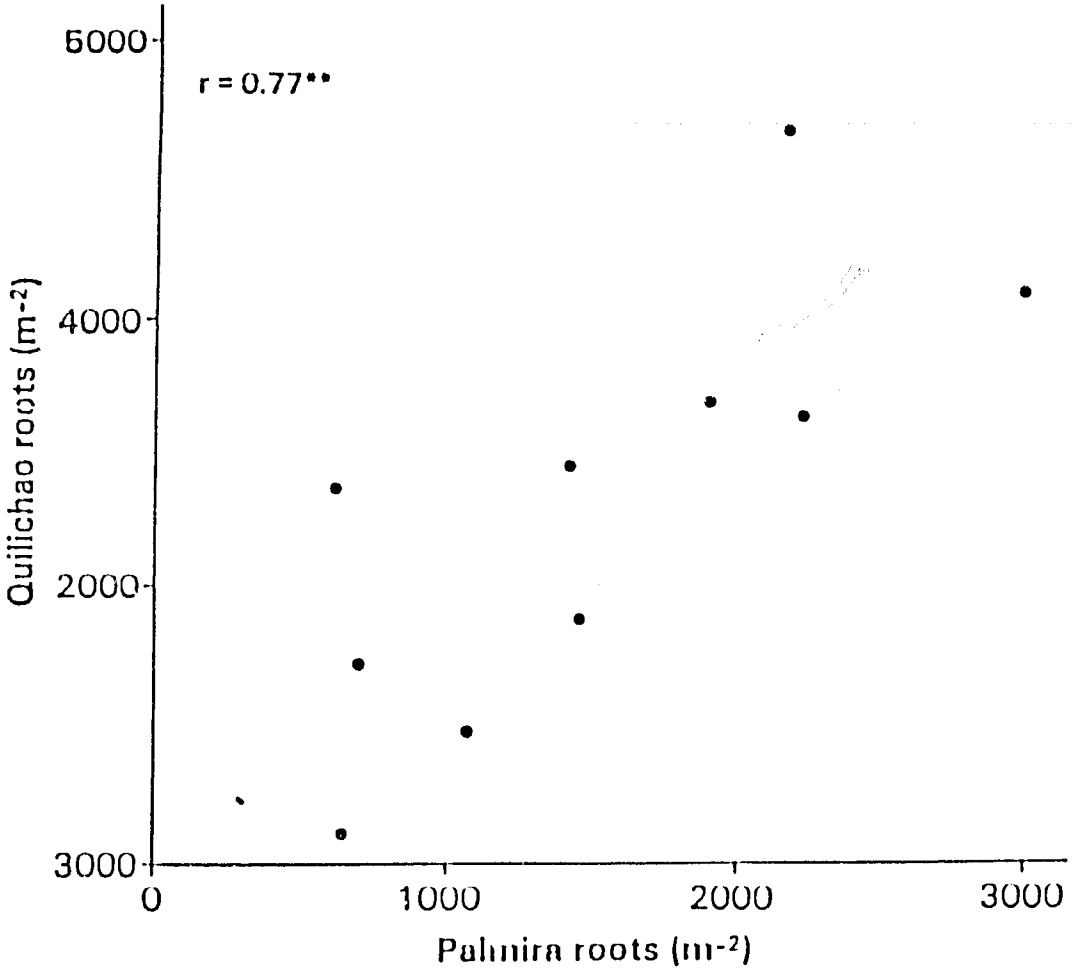


Figure 2. Comparison of root length density of 10 genotypes grown under drought stress at CIAT-Palmira and CIAT-Quilichao.

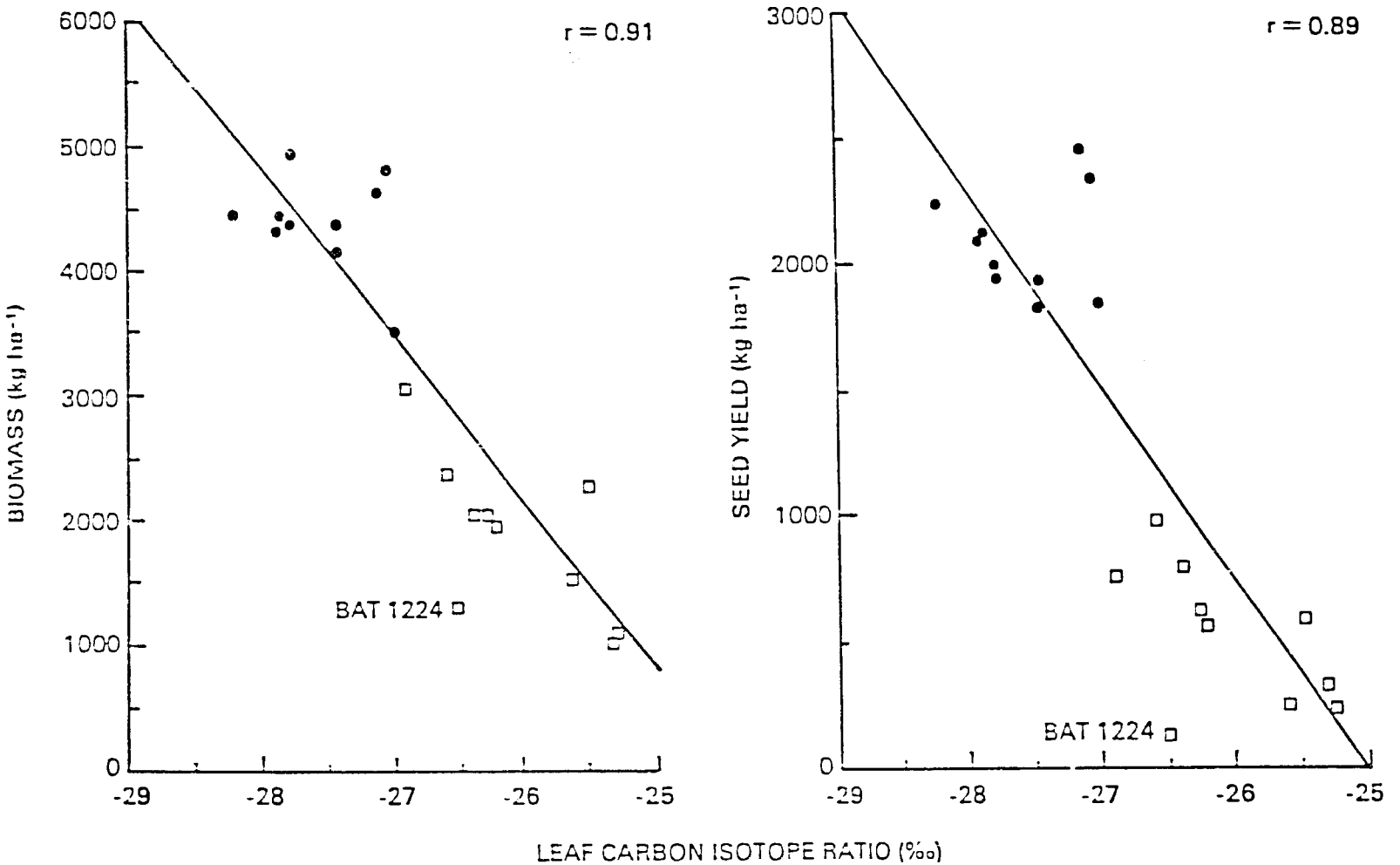


Figure 3. Linear correlations between aboveground biomass (left) and seed yield in kg/ha (right) and leaf carbon isotope ratio for irrigated (closed symbols) and nonirrigated (open symbols) bean lines at Palmira.

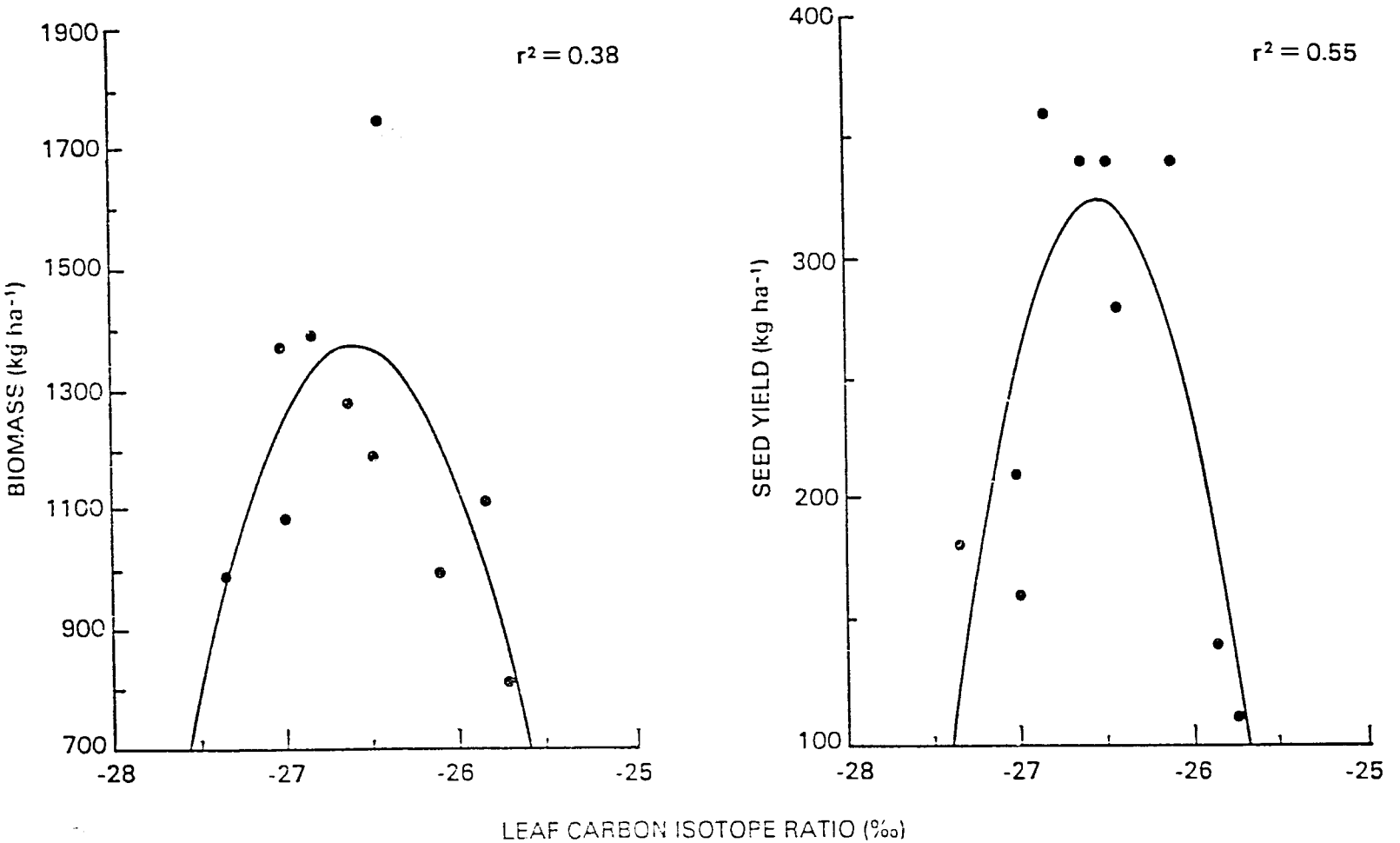


Figure 4. Relationship between aboveground biomass (left) and seed yield (right) and leaf carbon isotope ration for nonirrigated lines at Quilichao.

b. TEMPERATURE AND PHOTOPERIOD

Routine screening of photoperiod response was continued in the first semester of 1987 but was halted in the second semester to permit relocation of the facilities to a site allowing a 50% increase in screening capacity. This improved facility should prove of particular value for characterizing germplasm from Africa and western Asia.

One limitation to studies of photoperiod and temperature data has been the failure to determine whether "poor adaptation" involves both developmental and growth effects, or is essentially a developmental problem mediated by photoperiod-temperature response. A study was therefore undertaken to separate growth and developmental effects of photoperiod-temperature regime. Sixty-four genotypes representing a full range of seed types, growth habits, and genetic origins were grown at Palmira, Popayan, Rio Negro (in collaboration with ICA), and Davis, California (in collaboration with U.C. Davis). At each site, biomass (sampled at a single date corresponding to onset of podfill in the earliest maturing cultivars) and seed yield were determined.

For preliminary analyses, genotypes were tabulated by photoperiod response (scored at CIAT on a 1 to 8 scale, but summarized as neutral, intermediate, or sensitive) vs biomass or seed yield categories (defined as low, medium, or high) (Table 1). None of the 3 x 3 tables for biomass showed a significant interaction between photoperiod response and biomass, suggesting that photoperiod response and initial growth are independent processes. As expected, at the high latitude site, photoperiod sensitive cultivars yielded poorly, while at the Colombian sites, no photoperiod effect was noted.

These results thus demonstrate that temperature effects on developmental and growth processes may be manipulated independently. For example, it should be possible to breed highland adapted genotypes which are less photoperiod sensitive, but maintain their yield potential.

Table 1. Comparison of photoperiod response vs biomass at onset of podfill and seed yield for 64 genotypes grown at four locations.

Photoperiod response class	Genotypes within categories					
	Biomass			Yield		
	Low	Medium	High	Low	Medium	High
			Palmira			
Neutral	6	5	5	2	8	6
Intermediate	11	6	8	4	12	9
Sensitive	5	7	10	9	5	7
Chi^2, d.f.		2.6, 4			0.1, 2	
			Popayan			
Neutral	7	6	3	6	5	5
Intermediate	7	9	9	9	8	8
Sensitive	7	4	10	7	5	8
Chi^2, d.f.		1.1, 2			0.5, 4	
			Rio Negro			
Neutral	4	9	3	5	6	5
Intermediate	10	6	9	9	7	9
Sensitive	9	5	8	6	7	5
Chi^2, d.f.		6.0, 4			0.7, 4	
			Davis			
Neutral	6	7	3	1	6	9
Intermediate	11	7	7	4	14	7
Sensitive	10	7	5	13	8	1
Chi^2, d.f.		1.3, 4			9.3**, 1	

** Significant at the p = 0.01 level.

c. MATURITY

Under relatively warm tropical and subtropical environments most of the dry bush bean cultivars mature in less than 90 days. However, there is a growing demand for earlier maturing (less than 70 days) cultivars (1) in areas where food shortages make earlier harvests desireable; (2) in areas where moisture stress is severe at the end of the 90 day growing season; or (3) to accomodate a short growing season between major crops (e.g. the sowing of a third crop under irrigation in the winter season in central Brazil).

Dozens of different sources of early maturity have been identified--these are either determinate type I (medium and large seeded beans from the Andean South American gene pools), or indeterminate type II (small and medium seeded accessions of Central American origin). All parental sources are, however, susceptible to bean common mosaic virus and other diseases. Incorporating resistance to diseases into early maturing parents and transferring this trait to desireable bean cultivars is one aspect of any earliness breeding project.

Earliness also implies certain limitations on the yielding capacity of the crop, so an early maturity project must also strive to increase crop efficiency by maximizing yield.

The objectives of a project for early maturity are: to define models of maximizing yield in early genotypes; to define selection parameters for genotypes to fit the models; and, to test the models and selection parameters in a breeding program.

In 1986 we reported the results of a growth analysis including genotypes varying from 56-74 days to maturity (DM). Although plant size and DM were highly correlated with yield, under favorable conditions several early genotypes did attain an optimal leaf area index (LAI) of 3.8-4, even at standard plant densities of 160×10^3 pl/ha. This suggests that yield in these conditions was not limited so much by plant size as by time available to utilize leaf area. On the basis of these results, we formulated the following model whereby yield might be maximized in early genotypes by: (1) attaining optimal LAI rapidly through, perhaps, larger seed size which might contribute to more rapid initial growth; (2) early flowering, to bring the vegetative period to a more rapid close, thus avoiding excess leaf area; (3) an extended pod-filling period (PFP; flowering to maturity) to take better advantage of leaf area produced. Extension of the PFP should result in better filled, higher yielding pods, thus the parameters of yield per pod (Y/P) and PFP are assumed to be highly correlated, and were indeed proved to be in the growth analysis study.

To test this model, parental material (including early genotypes) was selected for long PFP on the basis of flowering and maturity data.

To obtain a general idea of the effectiveness of selection, crosses were made among these; F_2 populations were mass selected for

well-filled pods; and Y/P was calculated for the bulked selections for each population. Large differences were found for Y/P, with greater values being associated with type III parents.

In the present F_3 breeding cycle, single plant selections will be made for analysis as F_4 families for the following parameters: PFP, Y/P, and yield per day. Some 700 advanced lines from the earliness project were planted this semester and are being analyzed by these same criteria.

In conjunction with this project, heritability of Y/P is being studied.

d. PLANT ARCHITECTURE

Morphological traits such as branching pattern, stem strength, fruiting pattern, leaf size, number of nodes, and internode length have been used in breeding programs to develop contrasting plant types.

An important objective is to develop plant architecture of a suitable type to withstand or facilitate mechanized farming. The increased cost of rural labor has enhanced interest in mechanization even in small, poor farming communities.

Plant types best suited for mechanization are upright determinate type I and indeterminate type II. In addition to good lodging resistance, these types provide synchronous maturity, are shatter resistant, and have a minimum of 10-15 cm clearance from lower pod tips to ground.

The first cycle of architecture breeding developed lines of both type I (A 57, A 124, A 132) and type II (A 25, A 54, A 55, A 156, A 170, A 240). These upright types were, however, found to be lower yielding than traditional cultivars of similar growth habit such as Brazil 2, ICA Pijao, Rio Tibagi, NEP 2, and others. The second cycle of breeding will therefore concentrate on the development of yield potential in upright plant types.

7. Nutritional Quality

The nutritional quality laboratory monitors materials produced in the EP as well as conducting research in specific areas. Work on EP materials concentrates on defining each of the characteristics encountered within routine parameters of evaluation, e.g. cooking time; absorption of water; and, quantities of solids in the broth and total protein. Research in specific areas was focused this year on the relationship of tannins in beans to acceptability characteristics such as post-storage seed hardness and darkening, as well as nutritional aspects such as protein and starch digestibility, and the bioavailability of iron.

Analysis of materials evaluated in the laboratory 1982-1986

In general, the mean values for each agronomic group are stable with variations around the mean. Materials from group 25 have shown average cooking times slightly higher than all the others; and grains from group 30 and group 85 show somewhat higher crude protein levels. Table 1 shows group analyses.

Studies of methods to measure cooking time

In a collaborative project with INCAP, 14 indirect and direct methods of measuring cooking time were compared. Comparisons were accomplished using four Mattson cookers, the cooking index, sensing techniques, tests with trained panelists, and texture measurements done with OTMS analyzed with an ESRI program. The best method to measure cooking time was found to be a Mattson cooker with 90 gram weight rods, having rounded tips of 1 mm diameter. This cooker gave the shortest cooking time, with high sensitivity and specificity, and, in addition, the results from this cooker gave the best correlation with all the other methods tested.

Studies on cooking times

Materials used in last year's study on water absorption, were employed again this year in a study on factors controlling cooking times. Results from the former study indicated that water absorption is essentially controlled by physical factors within the seed. Data from the new study indicate that cooking time is essentially controlled by starch chemistry. It can be inferred that these differences are due to granule structure and tests are currently being implemented to verify this.

Study on the relationship of tannin content and seed color

Using the traditional vanillin method, 155 materials divided into eight testa color groups were evaluated to see how tannin level is related to testa color. The data showed that the mean values tend to show an association, however the extremely wide

range of values indicates that it is not possible to prove a relationship with any color group other than whites. With all other colors, it is possible to show materials having the same tannin content and a range of catechin (Table 2).

Study on methods to evaluate tannin levels

A comparison of two methods (the vanillin method and Dr. Lehel Telek's 'procyanidins' method) showed a need to develop a new method that combined the specificity of Dr. Telek's method with the ease and sensitivity of the vanillin method. We therefore developed a method to (1) increase the specificity of the vanillin method by the use of PVP (poly-vinil-poly-pirrolidona), (2) while preserving sensitivity using initial readings as catechin equivalents fitted to previously developed callibration curves to tannins. Figure 1 shows a graphic representation of this method.

Study on the relationship of certain tannin characteristics with seed color

Since seed color has not previously been reported to be associated with tannin levels, it has been very interesting to discover and document an association between the molecular weight of the tannins (as measured by absorbance rates in solution) and seed color. Among newly harvested seed, red materials have the highest molecular weight, while white materials have the slightest (Figure 2). These studies also revealed that red materials, in general, have the worst post-storage hardness, a characteristic apparently associated with polyphenols molecular weight. In addition, it was discovered that yellow and cream colored seed darken the most rapidly, a characteristic associated with the same phenomenon.

Study on the degree of polymerization and seed hardness

This study aimed to document and understand the association between hardening and a changing degree of polimerization in the polyphenols. Figure 3 shows the reduction in quantity of soluble tannins in a typical material, being concommitant with reduction in water absorption. This on-going study will also look at color changes associated with this process.

Table 1. Group analyses of beans conducted in the nutritional laboratory 1982-1986.

Group # 10 - Small seeded black bush bean

YEAR	82	84	85	86
VARIABLES:				
NTC	31.0	9.0	32.0	35.0
MTC (min.)	21.8	23.8	26.0	22.7
SDTC	3.1	3.3	1.2	2.0
NABS (%)	31.0	9.0	32.0	35.0
MABS	102.8	96.2	99.0	103.7
SDABS	9.4	4.8	2.0	2.3
NPC (%)	31.0	9.0	32.0	35.0
MPC	23.0	22.8	21.6	24.0
SDPC	1.1	1.6	1.1	1.1

Group # 20 - Small seeded red bush bean

YEAR	82	84	85	86
VARIABLES:				
NTC	34.0	45.0	45.0	33.0
MTC (min.)	17.4	25.1	25.8	21.8
SDTC	2.7	4.2	5.9	3.8
NABS (%)	34.0		46.0	33.0
MABS	95.4		92.7	98.5
SDABS	12.0		18.5	7.3
NPC (%)	34.0	60.0	46.0	33.0
MPC	23.2	23.6	27.8	25.7
SDPC	1.5	1.7	1.9	1.4

Group # 25 - Large seeded red bush bean

YEAR	82	84	85	86
VARIABLES:				
NTC	53.0	135.0	73.0	136.0
MTC (min.)	21.8	27.2	27.1	25.7
SDTC	4.2	6.1	5.3	4.4
NABS (%)	53.0	146.0	76.0	136.0
MABS	96.5	92.6	102.3	108.5
SDABS	16.1	22.2	16.3	8.5
NPC (%)	53.0	146.0	76.0	136.0
MPC	21.3	23.4	27.1	23.6
SDPC	1.7	2.3	1.9	1.4

Group # 30 - Small seeded white bush bean

YEAR	82	84	85	86
VARIABLES:				
NTC	11.0	32.0	37.0	44.0
MTC (min.)	19.6	23.9	29.4	22.5
SDTC	2.6	4.1	4.5	2.4
NABS (%)	11.0	32.0	37.0	44.0
MABS	90.2	94.0	94.0	99.2
SDABS	8.5	5.7	3.4	5.4
NPC (%)	11.0	32.0	37.0	44.0
MPC	24.2	25.8	28.7	25.1
SDPC	1.0	2.0	2.0	1.4

Group # 35 - Medium-large seeded white bush bean

YEAR	82	84	85	86
VARIABLES:				
NTC	13.0	10.0	7.0	
MTC (min.)	23.8	22.4	35.3	
SDTC	4.9	6.1	14.6	
NABS (%)	13.0	10.0	7.0	
MABS	101.1	97.2	105.7	
SDABS	7.7	13.0	7.8	
NPC (%)	13.0	12.0	7.0	
MPC	23.3	24.1	27.0	
SDPC	1.9	2.1	2.5	

Group # 40 - Coastal and Pacific bush bean

YEAR VARIABLES:	82	84	85	86
NTC	23.0	20.0	28.0	21.0
MTC (min.)	19.7	24.8	28.8	22.7
SDTC	4.6	7.9	3.7	3.6
NABS (%)	23.0	20.0	28.0	21.0
MABS	101.1	99.4	101.3	106.0
SDABS	8.4	4.2	4.8	5.3
NPC (%)	23.0	25.0	28.0	21.0
MPC	23.7	25.8	23.3	24.2
SDPC	2.1	1.8	2.0	1.4

Group 45 - Bush Bean from the Mexican Plateau

YEAR VARIABLES:	82	84	85	86
NTC	18.0	13.0	4.0	
MTC (min.)	21.2	25.2	29.3	
SDTC	5.2	5.0	2.5	
NABS (%)	18.0	13.0	4.0	
MABS	101.8	96.3	96.5	
SDABS	9.9	8.6	3.8	
NPC (%)	18.0	13.0	4.0	
MPC	23.9	25.6	23.6	
SDPC	2.2	2.5	1.6	

Group # 50 - Brazilian bush bean

YEAR VARIABLES:	82	84	85	86
NTC	56.0	16.0	24.0	14.0
MTC (min.)	20.7	27.5	26.1	24.4
SDTC	2.9	6.8	3.9	3.0
NABS (%)	56.0	16.0	24.0	14.0
MABS	98.8	86.5	98.9	102.1
SDABS	8.0	7.2	6.6	11.9
NPC (%)	56.0	16.0	24.0	14.0
MPC	22.5	25.5	23.5	26.0
SDPC	1.7	2.5	1.4	1.8

Group # 60 - Hot temperature black climbing bean

YEAR VARIABLES:	82	84	85	86
NTC	2.0	5.0		
MTC (min.)	27.0	23.4		
SDTC	4.2	2.9		
NABS (%)	2.0	5.0		
MABS	101.3	90.7		
SDABS	5.7	5.0		
NPC (%)	2.0	5.0		
MPC	24.6	23.9		
SDPC	1.4	1.9		

Group # 65 - Temperate-cold temperature black climbing-bean

YEAR VARIABLES:	82	84	85	86
NTC	7.0			3.0
MTC (min.)	18.6			30.3
SDTC	2.9			1.2
NABS (%)	7.0			3.0
MABS	101.1			96.6
SDABS	3.0			4.3
NPC (%)	7.0			3.0
MPC	26.4			24.0
SDPC	1.6			0.2

Group # 70 - Hot temperature red climbing bean

YEAR	82	84	85	86
VARIABLES:				
NTC	16.0	24.0	27.0	62.0
MTC (min.)	27.9	26.5	28.7	23.7
SDTC	4.2	4.6	5.0	4.1
NABS (%)	16.0	24.0	27.0	62.0
MABS	100.6	83.6	96.2	102.2
SDABS	6.1	7.9	10.1	6.4
NPC (%)	16.0	24.0	27.0	62.0
MPC	23.7	21.7	24.4	26.1
SDPC	2.1	1.5	1.8	1.4

Group # 75 - Temperate-cold temperature red climbing bean

YEAR	82	84	85	86
VARIABLES:				
NTC	22.0			
MTC (min.)	20.9			
SDTC	2.4			
NABS (%)	22.0			
MABS	101.7			
SDABS	9.6			
NPC (%)	22.0			
MPC	26.9			
SDPC	2.8			

Group # 80 - Hot temperature climbing beans (other colors)

YEAR	82	84	85	86
VARIABLES:				
NTC	8.0	32.0		
MTC (min.)	27.0	26.3		
SDTC	3.5	7.9		
NABS (%)	8.0	32.0		
MABS	97.7	87.1		
SDABS	5.8	25.2		
NPC (%)	8.0	33.0		
MPC	23.5	22.6		
SDPC	2.0	1.6		

Group # 85 - Cold temperature climbing beans (other colors)

YEAR	82	84	85	86
VARIABLES:				
NTC	7.0	15.0	20.0	48.0
MTC (min.)	19.6	23.7	31.5	25.3
SDTC	2.8	7.9	5.5	4.4
NABS (%)	7.0	15.0	21.0	50.0
MABS	101.5	92.7	88.8	92.0
SDABS	8.0	5.1	20.2	22.5
NPC (%)	7.0	15.0	21.0	50.0
MPC	26.6	25.2	24.1	25.6
SDPC	2.4	2.7	1.2	2.1

N = sample number, M = mean value, SD = standard deviation
TC = cooking time; ABS = water absorption and PC = andeprotein

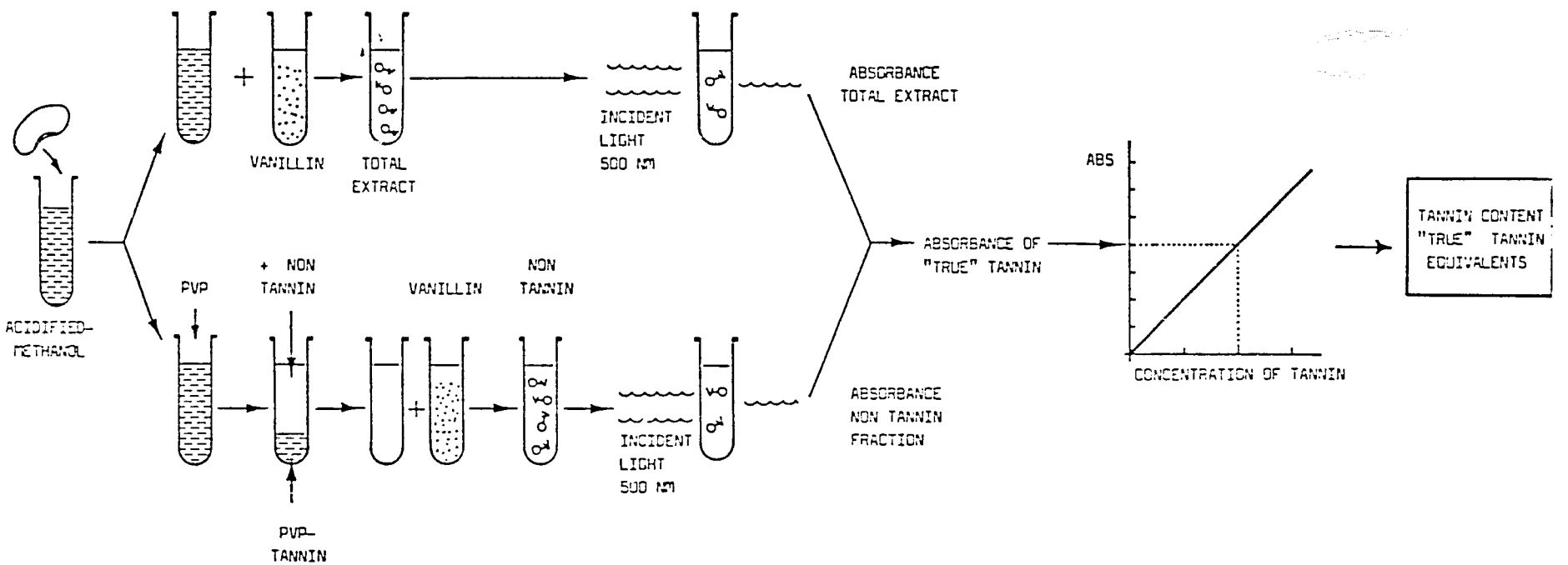
Table 2. Descriptive statistics of tannin content in common beans (*Phaseolus vulgaris*) by testa color.

Testa color	Sample size	Mean of[a] catechin equivalents[b]	Standard Deviation	Range Minimum	Range Maximum
White	28	0.34 [g]	0.15	0.17	0.77
Cream-Beige	26	8.45 [d]	3.83	0.34	17.94
Yellow	5	6.51 [f]	4.39	2.87	12.10
Brown-Maroon	5	8.03 [e]	1.82	6.31	10.00
Pink	16	8.25 [d,e]	1.89	4.74	11.57
Red	26	14.00 [a]	6.70	5.87	30.20
Purple	5	11.17 [b]	4.84	4.13	16.17
Black	44	10.01 [c]	2.84	2.33	16.10

a. Means with the same letter are not significantly different at the 5% probability level by Duncan's Multiple Range Test.

b. Catechin equivalents in mg/g of grain flour.

Figure 1. CIAT 's method for tannin determination.



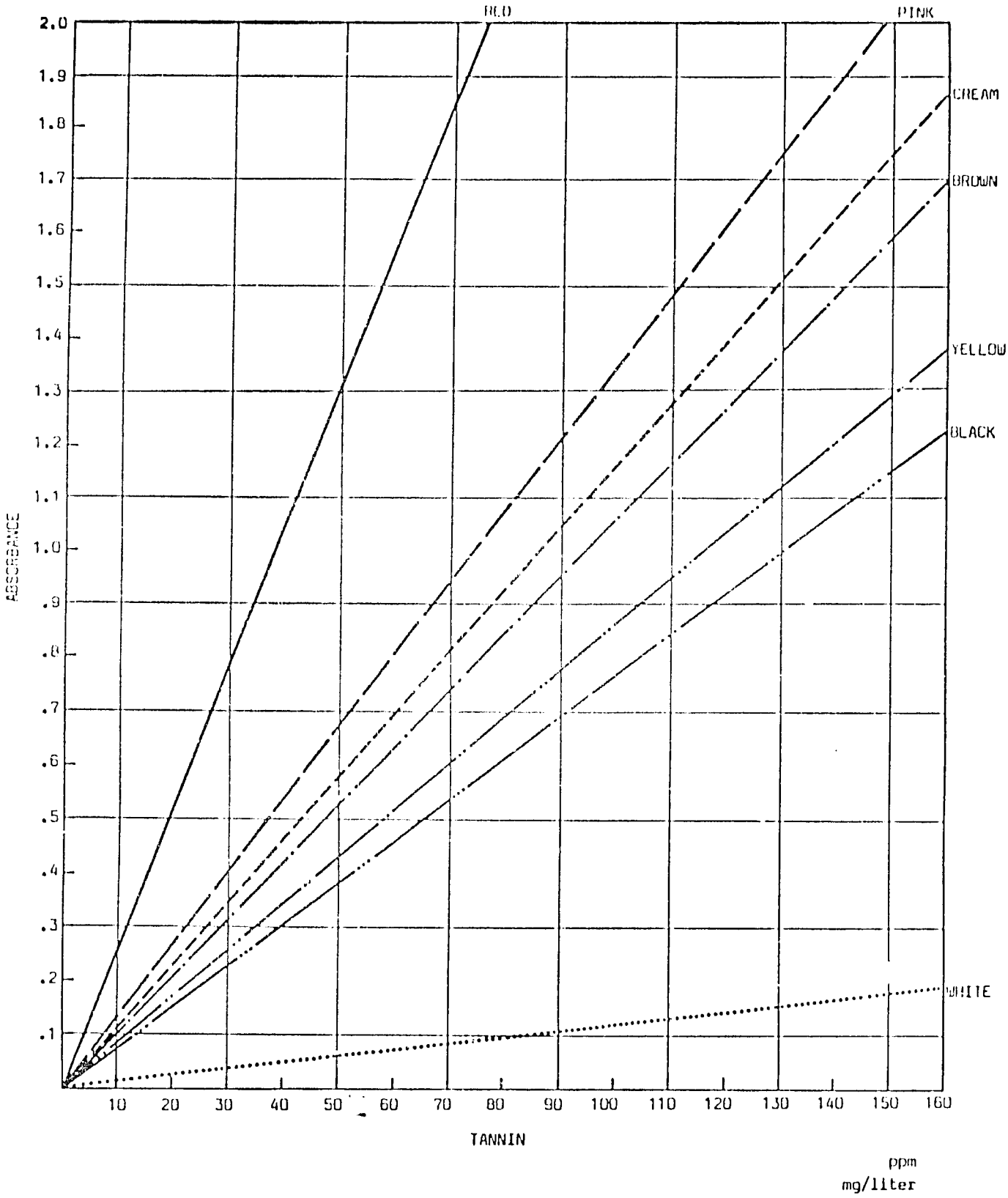
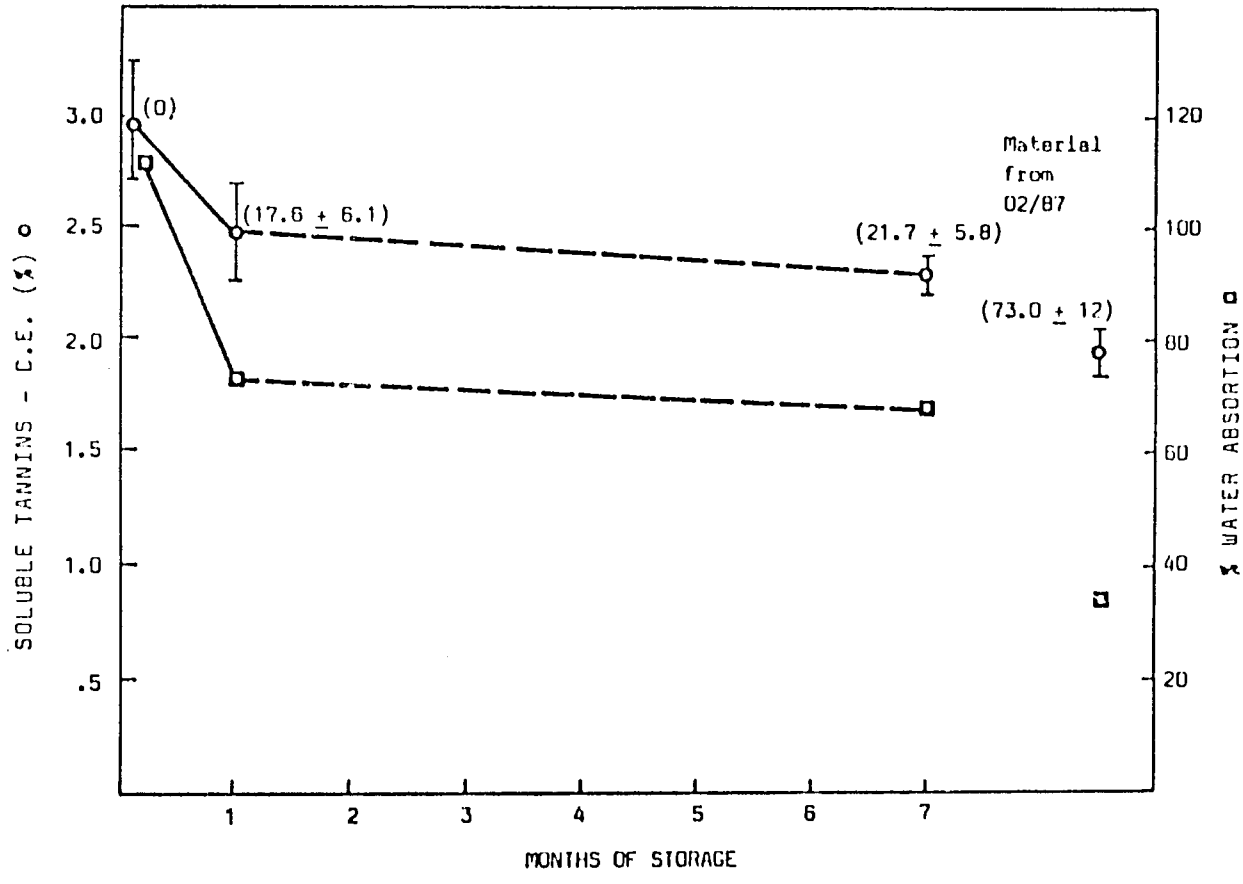


Figure 2.. Absorbtivity of tannin extracts by bean colors.

Figure 3. Relationship between soluble tannins and water absorption in PAI-29 during hardening development.



8. Character Deployment

a. BLACK BEANS

In the last year, black bean crosses were executed and/or populations shipped to the following countries to satisfy specific tolerance or other traits needed by country : Guatemala (Apion, BGMV, earliness, low phosphorus); Brazil (antaracnose, common blight, low phosphorus); Mexico (yield potential, drought, BGMV); Costa Rica (anthracnose); Cuba (drought).

Other crosses for black bean improvement emphasized: (1) utilization of alternative sources of common blight resistance, and in combination with architecture, anthracnose and/or rust resistance; (2) incorporation of sources of low phosphorus and drought tolerance into the mainstream breeding program; and,(3) earliness.

The single most significant advance in the black bean breeding program this year, was the development of more alternative sources of resistance for common bacterial blight (see Common Bacterial Blight under Chapter 5, Character Improvement).

Apart from the breeding activities per se, a study of genotype x environment interaction has been initiated with a set of genotypes already tested in the national yield testing network of Brazil. These will be planted in several sites in Colombia to measure correlations of these with Brazilian sites.

b. SMALL RED AND PINK/LIGHT PURPLE BEANS

Although small red beans and pink/purple beans are cultivated in geographically distant areas (Central America and central Brazil, respectively) they are very similar in regards to plant habit, grain size, disease susceptibilities and genetic control of grain color. Thus, improvement of these color classes can often be combined into a common program. For example, when BCMV resistance was finally obtained in small reds, it was easy to transfer this characteristic to pink/purple beans. It is hoped that progress in small reds in common blight resistance, BGMV resistance, plant architecture etc., will likewise transfer easily to pinks and purples.

In the small reds the most significant advance in 1987 was the purification of dominant BCMV resistance in a number of Central American land races, and the subsequent utilization of these in crosses delivered to national program breeders in several countries. In a Central American breeders' workshop held in January of this year, it was agreed to give highest priority to Apion resistance. The best new Apion selections with commercial red seed color were crossed to the BCMV-resistant land

races and F_2 populations were shipped to Nicaragua, Honduras, and El Salvador in August. Unfortunately, severe drought did not permit advance in this project in the August-September plantings.

Some commercial pink and purple cultivars were also obtained in the BCMV backcross program, and are now ready to enter crosses for broader purposes. Apart from the purification of BCMV resistance, the most significant advance in this class was the segregation of commercial types in crosses among BGMV-resistant parents. While truly commercial types were few in number and do not therefore offer much hope of an immediate solution, there is a significant indication that the resistance sources are now genetically close to commercial type with regards to color. BGMV is unquestionably the most serious problem in the areas of Brazil where these colors are preferred.

c. WHITE BEANS

Beginning breeding strategies for white beans were directed toward large cylindrical (Alubia, Horos, Cannaline, Fabada) and large kidney-shaped (Baladi) beans. Recently, breeding has been initiated for small navy (Panamito, Arroz, pea beans), medium flat Great Northern (Dermason), and medium and large round types (Marrow, Bolita, Caballeros). The first cycle of breeding has yet to be completed in this new breeding project, but over 300 different cross combinations have already been made. From the first group of crosses, 73 medium and large cylindrical, and 200 white kidney and other lines have been developed, all with resistance to BCMV. Of these, ABA 2, WAF 9, and WAF 18 look promising in some countries. Serious limiting factors to white bean breeding in Colombia include virus diseases and adaptation to higher altitudes.

d. YELLOW AND BEIGE BEANS

Very little active work is carried out in CIAT on the selection of the yellow and beige classes, for two reasons. First, the correlation with principal target areas (the Pacific coasts of Mexico and Peru) is believed to be poor. Secondly, the local selection programs in each area are capable, and active in genetic improvement.

The Bean Breeding Program responds to requests from these programs for crosses and populations. The CIAT program also serves the Mexican program by collecting germplasm or lines from within the Bean Program, which are of interest to evaluate as potential parents (e.g. large grained types of type II growth habit; germplasm for BGMV evaluation).

In CIAT-Palmira, we are assisting with the incorporation of BCMV resistance into important local materials. There now exist good yellow medium sized grain combined with dominant I gene. Cultivars will also be incorporated into the BCMV recessive gene project. Also, a marked effect of date of planting on genotypes

of this class has been noted in the past, so a date of planting experiment is currently underway in an attempt to quantify this effect.

e. SMALL SEEDED CREAM AND CREAM STRIPED BEANS

From the first cycle of breeding one cultivar each of cream (A 295 as EMGOPA Ouro) and cream striped (A 247 as Rio Doce) seed type was released in Brazil. A few lines are also being multiplied for eventual release in Zambia and other African countries. For the second cycle of breeding approximately one thousand crosses were made, over 300 of which were planned jointly by national program breeders. From all these crosses nearly 10,000 F_6 lines were derived in 1987. These were evaluated in fields at Popayan, Quilichao, and Palmira for reactions to anthracnose, angular leaf spot, common bacterial blight, maturity and seed yield. In addition, lines derived from crosses involving one or more BGMV susceptible parents were screened for the virus in screenhouses at CIAT-Palmira by the virology group. By the end of 1988 we hope to finish this second cycle of breeding, developing lines that carry resistance to all four diseases mentioned here. Also, for the first time we should have a desirable range in maturity in finished lines.

f. MEDIUM SEEDED BAYO AND PINTO BEANS

Except for Pinto, all other commercial bean types (e.g. Flor de Mayo, Ojo de Cabra, Bayo, Garbancillo, Rosita, etc.) in this group are grown exclusively in the Mexican highlands. Humid highland bean cultivars are mostly type IV climbers and those grown in semi-arid regions are of type III growth habit. Lack of adaptation of Mexican germplasm under Colombian environments and vice versa has been the principal bottleneck thus far. Nonetheless, from the first cycle of breeding over one hundred lines were made available to the Mexican programs of which A 417 (Pinto) and MAM 13 (Bayo) have been selected as promising materials there. From [illegible] 800 hybrid populations of the second cycle of breeding several thousand single plant selections, all resistant to anthracnose, were made at Popayan in the first planting season of 1987. These currently are being progeny-tested at the same site. The survivals will be seed increased for further evaluations and yield tests in the following years. In addition to the problem of adaptation, it has been difficult to recover suitable commercial seed type characteristics (size, color, brilliance, etc.) in this group. As a result, necessary modifications in the crossing strategy have to be implemented in the next cycles of breeding. Access to evaluation and selection sites in the Mexican highlands for segregating materials will greatly maximize the chances of developing superior lines and help in the breeding process.

F. SNAP BEANS

1. Economic Potential of Snap Beans

In March 1987 the CIAT Bean Program started a study of the importance of snap beans in the developing world in order to orient future CIAT research in snap bean improvements. Initial emphasis has been on the collection and analysis of secondary data as well as case studies.

Preliminary findings of the case studies conducted in collaboration with national program in Taiwan, the Philippines, Indonesia, Brazil, Colombia, Costa Rica and Rwanda show that most snap bean growers have limited access to land. In Taiwan, for example, areas planted are measured by tenths of the hectare. A farmer who would have 0.4 hectares in snap beans would be a large producer in this country. Most snap bean growers have irrigation facilities. This allows precise planning of production and consequently better control of marketing. Snap beans are most often grown in areas with privileged urban market access. In highland countries, land availability does not form a constraint to snap bean production.

In countries with little highlands, like Indonesia and the Philippines, snap beans encounter heavy competition by other crops that need similar climates. If the value added of these crops is higher, as in the case of flowers, snap beans might be pushed out of production.

Bibliographic survey

In collaboration with CIAT's Communication and Information Service Unit, a bibliographic search on snap beans was started. Existing information within CIAT's documentation center has been reassessed, and a preliminary bibliography on snap beans was produced. More than 140 institutes in the world have been asked whether they have articles available, and a computer search has been undertaken.

Econometric analysis of snap bean marketing and consumption

For Brazil and Colombia detailed high-quality data on marketing and consumption were obtained and analyzed. Marketing margins are normally very high, more than 50% of the final price to the consumer. Neither in Brazil or in Colombia, could seasonal supply and price patterns be distinguished. Prices fluctuate through the year, but in a very irregular way. The year round availability, the absence of specific periods with low prices and others with high prices decrease the feasibility of processing (canning or freezing) as a storage mechanism.

For those countries where data were available, snap beans are an expensive vegetable. Price elasticities of 0.4 (short run, Brazil) and 0.8 (long run, Colombia) were found. The long run price elasticity for Colombia suggests that reductions of acquisition costs made possible through research, would lead to strong consumption increases. For this research to be effective it should not only emphasize production costs but also marketing costs.

Snap bean consumption is very income dependent. In Indonesia, Brazil and Colombia, consumption levels in the highest economic stratum are eight times higher than in the lowest stratum (see Table 1 for Colombia). Urban consumption levels are two and a half times higher than for rural consumption. This suggests rapid demand growth in the process of development. Snap bean production has to grow at a rate of about 4 to 5% per year to keep prices constant.

Data from Bogota, Colombia suggest that most consumers are well aware of the nutritive value of snap beans. Even poor consumers express the importance of snap beans for vitamin and mineral supply. Present snap bean price levels in most countries limit the dietary contribution of the product. Most people eat snap beans to vary their diet, but if prices were to fall, the product might gain importance as a high quality food source. At present price levels however, attention to snap beans would mainly be justified because of its income potential to the small producer.

Table 1: Snap bean consumption in Colombia, by income group and urbanization degree (1981).

Income Stratum	Urban	Rural	Average
I	1146	313	697
II	1973	667	1358
III	3318	1766	2768
IV	3992	2049	3546
V	5570	1869	5058
Average	3521	1057	2662

Source: DRI-PAN Food Budget Survey, 1981, Bogota.

2. Snap Bean Improvement

The Bean Breeding III program at CIAT is responsible for developing snap bean varieties for tropical regions with resistance to the major diseases limiting their production. The commercial varieties planted throughout Latin America and Afric in most cases, were not developed for tropical environments and as a result are highly susceptible to diseases such as rust (*Uromyces phaseoli*), BCMV, anthracnose (*Colletotrichum lindemuthianum*), common bacterial blight (*Xanthomonas phaseoli*) and are susceptible to root rots and other factors as well that influence poor germination.

In Latin America an estimated 600,000 ha are planted in snap beans each year. Snap bean consumers (predominantly urban) enrich their diets with this source of protein, vitamins, and minerals. The major advantages of growing the snap bean crop are: snap beans can easily be grown in rotation with other vegetables because of their short vegetative period; snap beans provide a higher than average source of income to small farmers; and, snap beans can be consumed in either their fresh or dry seed state.

The majority of the third world countries do not have quarantine restrictions on commercial snap bean varieties introduced from the United States or Europe which specify adaptation requirements or minimal levels of resistance to tropical bean diseases. Nor do most national agricultural research programs in the tropics have snap bean breeding programs. Consequently, poorly adapted, highly susceptible snap bean varieties are being grown in large areas and excessive quantities of pesticides are being applied in many regions without government restrictions. For these reasons, CIAT began a snap bean varietal improvement program to address the needs of the small snap bean farmer in the tropics. The strategy used by CIAT in developing snap beans for the tropics is based on our collective experiences and results in breeding dry beans. In many instances production constraints are similar for the two crops.

In 1982, 250 snap bean germplasm accessions were evaluated at CIAT, and of these 21 accessions showed good adaptation and acceptable pod characteristics, but were susceptible to diseases (Tables 1 and 2). Later, commercial varieties and advanced lines were provided to CIAT by Dr. Matt J. Silbernagel, U.S. Department of Agriculture, Prosser, Washington, which were resistant to rust and of excellent pod quality under tropical conditions, but showed problems with germination associated with white colored seed which, in general, are more delicate than colored seed.

Resistance to diseases such as BCMV and anthracnose was obtained from CIAT's dry bean lines utilizing a backcross breeding program to recover the snap bean type of pod. For resistance to other diseases with more complex patterns of

inheritance, a recurrent selection program has been employed using the pedigree method for advancing generations.

The first advanced snap bean lines from CIAT's breeding program entered the VEF in 1985 (Table 3). The best of these lines were used to form a Regional Snap Bean Yield Nursery and 30 trials have been sent out to different organizations within Colombia. One climbing snap bean line, BAB 229, is presently being grown and marketed by farmers in the Cauca Department. Its high level of resistance to rust, anthracnose, and BCMV enable the farmers to drastically reduce their pesticide applications as compared to the highly susceptible imported variety Blue Lake. The VEF and selected lines from the VEF nurseries have been dispatched to 14 countries. Several temperate climate countries have commented on the ability of CIAT lines to tolerate high summer temperatures, whereas European lines are quite sensitive and tend to abort their flowers and young pods.

In May 1987, the first international workshop on snap beans was held for 5 days at CIAT with participants from Argentina, Brazil, Colombia, Ecuador, Spain, the United States, Guatemala and Peru. The objective of this meeting was to establish an international network of snap bean scientists and to promote future research and varietal development. Each participant presented a summary of the snap bean research being carried out in their country, and future plans for the decentralization of snap bean breeding from CIAT to the national programs was discussed.

The major objectives of future collaborative activities between CIAT and national programs are as follows:

1. Increase yield potential in snap bean varieties presently in production.
2. Breed and select for varieties with multiple disease and insect resistance and acceptable pod characteristics.
3. Breed and select for varieties with wide adaptation and short vegetative periods.
4. Look for varieties that can be used as either snap beans or dry beans.
5. Study the inheritance of different characters in order to improve overall pod quality (i.e. pod color, size, curvature, form, presence of fiber, etc).

Plant characteristics to be improved in the breeding programs:

1. Germination
2. Vegetative period
3. Pod quality - varies with country
4. Disease and insect resistance
5. Wide adaptation
6. Plant architecture
7. Drought and low fertility tolerance

Sources of desirable traits to use in breeding by national programs:

1. Germplasm bank
2. Breeding nurseries
3. Introduced varieties

Characters to be evaluated:

General	Specific
1. Germination	1. Pod color
2. Days to flowering	2. Pod size
3. Growth habit	3. Pod curvature
4. Diseases	4. Transverse section of pod
5. Plant vigor	5. Presence of fiber in pods
6. Pod load	6. Overall pod quality
7. Days to harvest	7. Consumer acceptability
8. Yield	

Proceedings from the Snap Bean Workshop are being published for distribution to the participating scientists and other interested institutions.

Table 1. Climbing snap bean germplasm adapted to tropical conditions.

No. CIAT	Identification	Origin	Proc.	Growth habit	Rust[1]	BCMV	CBB[2]
G 1040		MEX	USA	4A	I	R	S
G 3736	Alabama 1	USA	VNZ	4A	S	R	S
G 5734	Mountaineer	USA	USA	4A	I	S	R
G 7605	Habichuela 2-2-3-V	-	IGU	4A	S	R	I
G 7647	Ever Beanning St.	-	GDR	4A	S	S	S
G 8105	Haricot Arames	FRC	UTK	4A	S	S	S
G 8776	Genuine Cornfield	USA	PER	4A	I	R	S
G 8992	String Blue Lake P.	USA	-	4A	S	R	S
G 9069	Burpees Green P.S.	USA	JPN	4A	S	S	I
G 10053	Witte Stok Boon D.	NLD	NLD	4A	S	R	I
G 10054	Witte Boon D.P.	NLD	NLD	4A	S	S	I
G 10208	Pole Orange Brown	PTC	PTC	3B	I	S	S
G 10219	Pole Deep Red Mottled	PTC	PTC	3B	I	S	S
G 10278	Dorwas Pole Brown S	PTC	PTC	4A	I	S	S
G 12742	M7323-3-1-1 Bulk C.	MEX	USA	4A	S	S	S
G 13450	Courone De Are	-	JPN	4A	S	S	S

* Selection from 250 materials

[1] Field evaluations where R = resistant, I = intermediate, S = susceptible

[2] Common Bacterial Blight

Table 2. Bush snap bean germplasm adapted to the tropics.

No. CIAT	Identification	Origin	Proc.	Growth habit	Rust[1]	BCMV	CBB[2]
G 3737	Asgrow Valentine	USA	VNZ	I	R	R	I
G 3742	Brock Marvel	USA	VNZ	I	R	S	I
G 6628	Tempo	USA	USA	I	S	R	I
G 6629	Tender Crop	USA	USA	I	I	S	R
G 6631	Wonder Green	USA	USA	I	I	S	I

* Selection from 46 materials

1 Field evaluations where R = resistant, I = intermediate, S = susceptible
2 Common Bacterial Blight

Table 3. Advanced snap bean breeding lines from CIAT entering the VEF

Year	No. of lines
1985	236
1987	100
1988	120

G. IMPROVING OTHER PHASEOLUS SPECIES

1. P. coccineus

The seed of P. coccineus and P. polyanthus continued to be increased in 1987 according to the methodology described in previous reports, with the aim of preserving the genetic integrity of each population. Multiplication is carried out in the open field at Rio Negro with racemes protected by paper bags, and in meshcages at Popayan.

In 1987, 103 accessions of both species were planted in Popayan, and in Rio Negro 120 accessions are currently being multiplied to obtain open pollinated seed for further evaluation and distribution. Seeds from controlled pollination are obtained by hand pollination between plants of the same accession or by selfing, and are used to maintain the accession.

Preliminary evaluations are made during multiplication on morphological characteristics in order to produce a catalogue.

P. coccineus and P. polyanthus evaluation for Ascochyta resistance at Rio Negro 1986 B

Some 30 accessions of the species polyanthus and 30 accessions of the species coccineus were evaluated in Rio Negro during the second semester of 1986 for their reaction to Ascochyta and other fungal diseases. The accessions were planted as a trial with two replicates in sole crop with stakes using the P. vulgaris cultivars E 1056, G 06040 and Cargamanto as susceptible, tolerant and local checks, respectively.

The results confirm the observations made during former trials. The species polyanthus has a very good resistance reaction to Ascochyta sp., presenting no lesions or lesions limited to the primary leaves. Different reactions were observed among the various populations of the species coccineus. Some of them were resistant with lesions limited to the primary leaves and others were susceptible. The best accessions were one population from Costa Rica (G 35369) and nine populations from Mexico (G 35370, G 35393, G 35394, G 35402, G 35413, G 35489, G 35497, G 35509, G 35510).

The reactions to anthracnose, angular leaf spot, rust and powdery mildew were also observed. Results are summarized in Table 1.

High yields were obtained in the species polyanthus, with a general mean for the 30 accessions of 4051 kg/ha (standard deviation: 1465), and a maximum of 6596 kg/ha (G 35545). P. coccineus had a lower production, with a general mean of 2253 kg/ha (standard deviation: 1147), and a maximum of 5086 kg/ha (G 35392).

Other evaluations

In mid-1986, three P. polyanthus accessions were sent to Dr. Talekar at A.V.R.D.C. (The Asian Vegetable Reseach and Development Center, Taiwan), to be screened for beanfly resistance in the field along with beanfly-resistant P. coccineus and suceptible P. vulgaris. They were evaluated for beanfly resistance at 30 days from emergence using a randomized complete block design with three replicates, and the plant mortality was also recorded. The results are shown in Table 2. These P. polyanthus are not as resistant to beanflies as the P. coccineus accession G 35023.

Results of the International Bean Yield and Adaptation Nursery (IBYAN) for P. polyanthus

The main objective of the nursery is to promote the productivity of P. polyanthus and P. coccineus.

Other objectives are to evaluate, under various environmental conditions, the yield and adaptation of promising accessions of P. polyanthus, to compare the accessions with the best local varieties (climbing P. vulgaris and P. coccineus) and to show the value of using the species directly, rather than only as a source of interesting characteristics for the improvement of the common bean by interspecific hybridization.

The trial includes 12 entries: 10 P. polyanthus accessions selected at Rio Negro for disease resistance and productivity, and two local varieties planted as checks (P. vulgaris and/or P. coccineus, acc ding to the region) with three replications in a randomized des .

In Colombia, the trial was planted in Popayan during the first semester of 1986 and in Rio Negro (Antioquia) and Pasto (Narino) during the second semester of 1986. The trial was realized in sole crop with stakes as support. It was also planted in Ecuador, Peru, Guatemala and some African countries (Rwanda, Kenya, Tanzania). Table 3 shows results for the three locations in Colombia, and for Ecuador and Peru. Results from Guatemala have not been received yet, nor for Africa.

In Colombia, the low production in Popayan can be explained by the very dry weather during 1986 A. For the same reason no diseases were observed. The best yielding accessions were G 35349 and G 35337. Absence of diseases also occurred in Pasto during 1986 B and no disease evaluation could be made. The production was better than in Popayan with G 35182 and G 35531 as best accessions. Nevertheless, no single P. polyanthus yielded better than the common bean checks E 605 and Mortino. In Rio Negro, the strong weed competition affected production, particularly for the P. vulgaris checks. In P. polyanthus, G 35182 and G 35403 showed the best production. While the Cargamanto check was susceptible to Ascochyta leaf spot, anthracnose and powdery mildew, P. polyanthus did not show any Ascochyta sp. lesion and showed only a little anthracnose attack.

In Ecuador, the trial was realized at the INIAP station of Santa Catalina, at an altitude of 2760 m. Dry weather prevailed at this site, and no disease was observed. On the other hand, the very strong maize used provided high competition for the beans and reduced their production. The best accessions of P. polyanthus were G 35564 and G 35349, with production being lower for P. polyanthus than for P. vulgaris. It would be interesting to repeat the trial next year.

In Peru, the trial was planted in the Chota zone of Cajamarca department at an altitude of 2000 m. Partial results are shown in Table 3. G 15330 yielded the best and was better than both checks. No Ascochyta or anthracnose lesions were observed in P. polyanthus, while both checks were susceptible to Ascochyta and the P. vulgaris "caballero" presented lesions of anthracnose. The trial is going to be repeated next year with the best accessions.

The demand for P. polyanthus is increasing and seeds have been distributed to some Colombian farmers in order to popularize the crop.

P. coccineus also has been included in the trials, using the same experimental design as for P. polyanthus. Ten P. coccineus accessions selected for productivity and earliness and two P. vulgaris checks have been planted in Rio Negro and Pasto in 1987 B.

Table 1. Reaction of 30 *P. coccineus* and 30 *P. polyanthus* introductions to some foliar diseases at Rio Negro during the second semester of 1986.

Disease	*P. coccineus* No. of introductions showing few symptoms	*P. coccineus* No. of introductions susceptible	*P. polyanthus* No. of introductions showing few symptoms	*P. polyanthus* No. of introductions susceptible
Anthracnose	28	2	30	0
Angular leaf spot	30	0	30	0
Rust	30	0	29	1
Powdery mildew	30	0	30	0

Table 2. Beanfly infestation of various *Phaseolus* accessions at A.V.R.D.C. (Taiwan)

Entries[1]	Percent damaged	No. P & L[2] per 20 plants	Percent plant mortality
G 35023	47	0.67	20
G 35045	39	2.00	19
G 35047	65	6.00	30
G 35050	40	3.67	17
Local	90	11.00	31

1. G 35023 = *P. coccineus*, Resistant check.
   G 35045, G 35047, G 35050 = *P. polyanthus*
   Local = *P. vulgaris*, Susceptible check.

2. No. P & L/20 plant = number of pupae and larvae per 20 plants.

Table 3. Bean production results of the international Bean Yield and Adaptation Nursery (kg/ha).

CIAT number	Sole Crop			Asso. with maize	
	Popayan	Rio Negro	Pasto	Ecuador	Peru
P. polyanthus					
G 35182	81	2,784	3,304	131	271
G 35336	301	1,371	2,241	361	695
G 35337	486	1,279	2,623	319	
G 35349	505	2,219	1,551	479	588
G 35403	144	2,376	1,712	267	
G 35420	299	1,537	3,098	338	
G 35434	124	2,119	2,301	392	
G 35436	275	2,026	2,548	406	489
G 35531	97	2,165	3,192	274	483
G 35564	223	1,315	2,524	551	
P. vulgaris					
G 10885	426				
G 06040	1,189				
G 12488		108			
Cargamanto		381			
E 605			3,542	1,285	
Mortino			4,397		
E 794				998	
Gloriabamba					631
Caballero					451
Mean *P. polyanthus*	253	1,919	2,509	352	505
Standard deviation	144	488	559	111	140

2. P. lunatus

As part of the collaboration between CIAT and the Faculty of Gembloux (Belgium) a new research project was begun in May 1986 on the P. lunatus (lima bean) collection held by CIAT.

The first priority was to increase the entire collection of 2794 samples, and multiplication was started in two meshhouses in Palmira with previously unmultiplied accessions as well as with some increased accessions which had only produced a few seeds. The number of accessions sown for the seed increase during the first year represents 14.2% of the entire CIAT collection (see Table 1).

The low germination of accessions in the two meshhouses in Palmira was due to their age--they had been received by CIAT between 1970 and 1979. The field in Popayan includes some accessions collected in 1985 in Peru and Colombia and showed corresponding good seed germination. Accessions which will not flower in the conditions of Palmira are multiplied in Popayan, with most of the seed increase in Popayan taking place in the field for want of a meshhouse. The goal is to have 200 seeds from meshhouse multiplication or 4000 seeds from field multiplication in stock in short and long term storage.

During this initial seed increase, samples are pre-evaluated for morphological characteristics like coloration of hypocotyls, stems, primordial leaves, flowers (keels, standards), pods and seeds; dimensions of leaves, pods and seeds; the date of flowering, and the growth habit. There is great variation among these characters and research has been broadened to complete passport data. Correlation will then be possible of the characterization data and the passport data.

Problems encountered during the first year of the project include:

-- Some accessions segregate (see Table 1) and this slows down the seed increase because the number of plants with a particular original characteristic decreases.

-- For some accessions (see Table 1) - which are always "Big Lima" and principally shrubby - a very variable percentage of seed germination occurs in the pods even before maturity. To clarify this problem a hygro-thermograph was placed in the meshhouse during one month. After irrigation, temperature decreased (32°C to 23°C), but relative humidity increased (30 to 100%) and remained higher than 85% for 6 to 10 hours. Rlative humidity seems to be a limiting factor in the germination of Big Lima types.

-- Pests in the meshhouse are principally mites which are resistant to many different acaricides. This problem is not currently totally controllable.

The second priority is to evaluate the percentage of outcrossing in lima beans and to subsequently find a methodology to increase the seeds in the field with no or very little (less than 1%) percentage of outcrossing.

Tests were made at the different sites (Dagua, Palmira, Popayan) where future seed increase would be possible. In Palmira and Dagua two different accessions of both Sieva and Big Lima were planted at increasing distances (1 m to 12 m) between the dominant parent and the recessives. Both accessions of Sieva have a lower percentage of outcrossing than the Big Lima (the second Big Lima had poor germination and the outcrossing is not consistent (see Table 2). We have noted that the dehiscence of the stamen in Sieva flowers occurs immediately before flowering, so that insects like honey bees cannot pollinate these flowers. A second trial has been sown to refine and confirm the first results.

There is some site influence on field crossing. In Palmira there is an obvious difference between Sieva which had been sown in a field surrounded by plots with insect control and Big Lima which was surrounded by plots with no insect control.

An increase of the distance between dominant and recessives reduces the outcrossing rate. The numerous thrips found in a flower bud seem to pollinate only in the vicinity of one row. Other pollinators also visit one row and its vicinity, but if they are disturbed (for example by the wind), they can transport the pollen greater distances.

A trial is planned to investigate ways of reducing this outcrossing, with barriers such as king grass or a climbing legume, or by bagging the racemes during flowering. Future control is very important to allow the increase of more seed of more accessions while conservirg the original genotype.

Dagua

Thirty-six climbing accessions have been evaluated in Dagua in very heterogeneous soil.

Accessions vary in days to flowering (34 days - C 25108; to 81 - G 25173); days to first mature pod (89 days - G 25575; to 137 - G 25247); yield threshing (54% - G 25108; to 81% C 25411); percentage of pod set (61% - C 25150; to 97% - G 25135) and an estimation of the yield (0.6 t/ha - Big Lima G 25804; to 6.2 t/ha - Potato G 25190).

A new trial was sown in July 1987 with 99 climbing accessions of different origins and altitudes in a completely randomized design with 16 replicates of one control accession.

Full results are not yet available, but preliminary indications are that germination and the first phase of growth are crucial for lima beans. High soil humidity is crucial to good development of the root system. Later, irrigation can be spaced every 3 to 4 weeks. This observation can be a factor explaining the 2-4 weeks later flowering in the second trial; the first trial had been sown during the rainy season in December.

Days to flowering ranges from 47 days (G 25288) to 123 (G 25408A - from higher altitudes).

The number of nodes to insertion of the first raceme increase with the number of days to flowering and thus production of the earlier flowering accessions are mainly concentrated at the base and are more prone to moisture damage.

The major diseases and pests are anthracnose, Macrophomina, leafworms, leafminers, leafhoppers, red spider mites and pod borers. There are differences in susceptibilities. Macrophomina may cause plant death when the climatic conditions are too dry.

Palmira

A trial is underway in Palmira using the same accessions to compare behavior, disease problems, and yield with those from Dagua, and to see which plant characteristics are influenced by the environment.

Seed-borne virus

After many inoculations in 200 accessions of lima beans and retroinoculation on P. vulgaris (double white), only very weak virus symptoms have been observed. Despite the absence of BCMV symptoms on P. lunatus, it is important to test if it can be transmitted by seeds in order to prevent its spreading. This will be done in collaboration with the CIAT virus-pathology program.

Catalogue of accessions

Two data bases including passport and collection information have been established and we have now 650 accessions (23% of CIAT's collection) in these. Information parallels that in the P. vulgaris data base. Seed color characterization is particularly difficult in P. lunatus because some accessions show 3 different colors and an additional hilum color. A more accurate definition of seed size and shape may allow a reclassification of some accessions which are now classified intermediate as Potato-Sieva or Sieva-Big Lima.

Table 1. *P. lunatus* seed increase in Palmira and in Popayan during the first year.

Sites	Number of accessions				Percent accessions	
	sowed	increased	in multi-plication	no germi-nation	segrega-tion	with seed germination
Palmira meshhouse						
1	182	91	49	42	25.7	6.7
2	123	in harvest		12	17.1	10.8
Popayan field	91	3	84	4	0.0	0.0

Table 2. Percentage of outcrossing in lima bean in terms of the cultigroup and the sites.

Sites	Sieva				Big Lima			
	G 25139		G 25143		G 25121		G 25124	
	No. plants obser.	% cros-sing	plants obser.	% cros-sing	plants obser.	% cros-sing	plants obser.	% cros-sing
Dagua	1,041	2.4	1,222	1.7	1,412	7.4	53	0
Palmira	1,081	0	889	0	226	7.5	52	0

H. ON-FARM AGRONOMY

1. Latin America

The objective of on-farm agronomy activities of the Bean Program in Latin America is to guide scientists working in technology development (whether in national programs or in CIAT) in setting priorities through feedback from farm surveys and trials, and to increase the chance of effective technology transfer by adaptive on-farm trials (i.e. feed-forward).

On-farm research (OFR) is considered the most effective way of achieving these objectives. As practiced by CIAT (and many other institutions), OFR has the following characteristics:

a) it starts from understanding farmers' circumstances, needs and objectives

b) it emphasizes a strong link between continuing diagnosis and experimental trials on-farm

c) it seeks a synthesis of researchers' and farmers' knowledge

d) in view of farmers' documented adoption behavior, it usually works on stepwise change within farmers' existing cropping systems (although groups of stepwise changes can sometimes represent a change of cropping systems - see below the example on intensifying the cropping cycle in Ipiales, Colombia)

e) its activities are often based within or around the activities of a commodity program, since this seems at present a more effective way of ensuring the occasional participation of many disciplines on-farm and of obtaining strong links between experimental station and farm activities

f) its methodologies are not commodity-specific, but to be effective need technologies available for testing in particular commodities.

CIAT considers that OFR should principally be the responsibility of national research and extension programs. The Bean Program has therefore developed since 1982 an OFR activity which:

a) adapts and develops OFR methodology through work in specific, varied areas and systems which include beans, with major CIAT participation

b) demonstrates that OFR is an effective technique

c) trains national research and extension personnel in OFR techniques

d) provides follow-up and consultancy for those active in OFR, especially those previously trained and,

e) initiates and supports network links between personnel active in OFR, whether members of national or international institutes.

Progress made in achieving these objectives between 1982 and 1987 is summarized below.

Progress in methodology adaptation and development

Methodologies for OFR were adapted to the case of beans, based on experiences of international centers such as CIMMYT, CIP and IRRI and of national centers such as ICTA Guatemala, ICA Colombia and INIA (now INIFAP) Mexico. In addition, the help of five invited experts in OFR working in Latin America, Africa and Asia was sought during a workshop on Bean Program OFR in December 1983.

Over the years, a series of stages based on objectives has been found useful for surveys and for trials. Steps have also been described for planning and analyzing trials on the basis of diagnostic information. Such stages and steps are a useful guide to OFR practitioners, but we have also learned the value of their flexible application. Thanks to the contributions from a number of collaborating national programs, a diverse body of experience is now available to guide practitioners.

Methodology adaptation was originally carried out with ICA support in five areas of Colombia (Ipiales, Funes and El Tambo, Nariño; San Vicente and El Carmen, Antioquia). At present work in San Vicente, El Carmen and Funes has passed completely to the hands of ICA personnel. Ipiales and El Tambo continue as collaborative projects between CIAT and ICA to develop ideas further (Ipiales principally on farmer participation and as a base for training courses; El Tambo for studies of selection of advanced bean lines and segregating generations on-farm and as a principal genetic selection site in Colombian network activities). A new work area (Restrepo/Darien, in Valle department) has been added, where beans are a more marginal crop, with support from the Comite de Cafeteros del Valle. Work in this area was initiated with a diagnosis conducted by the 1987 CIAT-based OFR course.

An important recent influence in methodology for OFR has been the work of the Farmer Participation Project of CIAT, whose ideas have greatly contributed to work in Ipiales and Restrepo/Darien.

Bean Program work on OFR methodology has also, over a number of years, analyzed the question of where varietal selection and the identification of cultural practices suitable for farmers' conditions should be conducted. Data presented in the on-farm research section of the 1985 Bean Program Annual Report, showed the great differences in the ranking of advanced lines between farms and the nearby experimental stations which serve them. Recent analyses of two years'data from eastern Antioquia show that the differences in ranking of lines between farms or years in the same area are smaller than those between station and farms. Additionally, although differences in mean yield between farms are large, similar precision in yield measurement is obtained with three replications on different farms and with three replications side-by-side on an experimental station. This confirms that it is preferable and possible to select advanced lines on two or three representative farms rather than on-station.

Other work in progress in El Tambo, Nariño is exploring the possibility and desirability of handling segregating generations of beans on-farm, probably alternated with selection on-station, in order to produce materials better adapted to farmers' conditions.

Data presented in the 1986 Annual Report showed the large differences in results between station and farms in experiments on cultural practices, even when a field of low fertility was chosen on the station. Fertilizer doses and application methods, plant population and spatial arrangement, and even preferred fungicides for foliar or soil treatment were different between Obonuco experimental station and the farms of Ipiales. These data underline the importance of conducting OFR in the target areas of technologies. Where a technology is intended for several target areas, careful identification of representative target areas for technology development, and of representative farms within them, should be possible.

An example of technology development on-farm is provided by the work on Rhizobium inoculation in farms of Ipiales and El Tambo conducted by the microbiology and OFR sections. In El Tambo, for example, early results suggest that maize benefits when beans are inoculated. In 1985, maize responded dramatically to increased N fertilization, but in doing so, depressed bean yield. When inoculated, beans did not suffer this decline, but maize yields increased, even though no N had been applied (Table 1). In the second year, the results were less clear. Maize yield was low due to end-of-season drought. Neither maize nor beans responded to N application or inoculation alone, but both responded to inoculation combined with N application.

The importance of OFR methodologies to the CIAT Bean Program itself can be illustrated in another way. In 1984, there were two senior-staff on-farm agronomists (based in Cali and Guatemala); by the end of 1987, four more had been added in

Africa and another was expected to be added to staff in Latin America.

Progress in OFR training and follow-up

Most of the Bean Program's actions on OFR in Latin America now revolve around training and its related activities (i.e. follow-up and the preparation of documents on OFR procedures).

Two methods for OFR training were tested between 1984 and 1987 with Ford Foundation financial support, and are now in use in the Bean Program. They are CIAT-based training and in-country training. CIAT-based training now consists of an eight-week practical course in which participants execute the different meeting-room and field activities of OFR with real examples from different areas of Colombia. They later receive follow-up to support the application of OFR methodologies in their own countries. In-country training is conducted in a three-phase course spread over 15-18 months in a bean-growing area of a country. Participants from different areas of the country meet to learn OFR techniques in the area. Between phases they return to their own areas to put into practice the techniques. They return to the next phase to report their experiences and discuss their results with the whole group.

Eighty-eight researchers and extensionists have now been trained in courses of 5 weeks or more with follow-up: 25 in an in-country course with INIPA (now INIAA) in Peru and a total of 69 in four annual CIAT-based courses (six Peruvian scientists attended both types of course) (Appendix 1). A high proportion of participants has continued active in OFR (Appendix 1), particularly from those trained in 1986 and 1987 when the quality of selection of candidates, teaching and follow-up had been refined through experience.

Both models of OFR training have advantages. In-country courses allow participants to learn in the situation of their own country and intensive follow-up is possible because of the multiple phases. Follow-up is more difficult and costly in CIAT-based training, but there is more chance for discussion between countries and "cross-fertilization" of ideas. Methodologies taught in Bean Program OFR courses are now being used by former participants, on other crops such as potatoes, maize and sugar cane. In at least two cases, those trained at CIAT now hold directorial positions in their institute and are pressing for OFR to be applied to many crops in their area.

The production and identification of documents to support training is an important activity. A complete set of written materials, some still in advanced draft, now exists for use in courses. The set includes previous publications by CIMMYT, new working documents prepared by CIAT and two joint publications in preparation between CIAT and CIMMYT.

Now that the ideas being communicated have been set down, an intended future activity is the development of training materials to communicate the concepts in a more didactic manner, especially for those who cannot attend courses in person.

At present, major support is being given by the OFR team from Cali headquarters to support and consult in Colombia (12 areas active in OFR on beans), Peru (18 areas active) and Mexico (5 areas active with CIAT support). Within each of these countries, informal support between OFR practitioners is developing. For 1988, the commencement of a three-phase in-country course is planned in Santa Catarina state, Brazil, with attendance of participants from other states too.

Progress in OFR network development

Within about 5 years we expect in Latin America that interchange between national programs on OFR will became at least as important as contacts between IARCs and national programs. CIAT, CIMMYT and CIP will act as catalysts to contacts between national centers and provide back-up support through OFR training, ideas and technologies to a collegiate group of national research and extension programs active in OFR.

As an early step in the development of such a network, CIAT organized in February 1987 a 10-day workshop on On-Farm Research in Beans in Latin America with 29 participants from 10 countries, as well as members of CIAT, CIMMYT and CIP. Participants found the event useful and requested CIAT to take logistic and financial responsibility for a similar event late in 1988, preferably in one of the participating countries. Gradual evolution was suggested, so as to include more personnel working on other crops, without losing the communication established among the group members.

In workshop discussions, greater availability of high quality information on OFR, and the opportunity to publish it, were regarded as crucial to improving exchange between OFR workers. At present work is often published in fragments, with excessive detail (or too little detail) in institutional annual reports.

The Bean Program is trying to meet this need in a number of ways:

a) The proceedings of the workshop have been compiled and distributed as a working document.

b) Working documents are being prepared for all the areas in which CIAT-ICA OFR work was conducted between 1982 and 1986. Those for Ipiales and San Vicente are shortly to be distributed; those for Funes, El Tambo and El Carmen are in preparation.

c) INIFAP staff in the two longer-established OFR projects on beans in Mexico have prepared (La Fraylesca, Chiapas) or are preparing (Tepatitlan, Jalisco) reports for publication about the diagnosis, planning and experimentation (and the link between them) during their first year's work on OFR.

d) Summary documents have been prepared by INIPA (now INIAA), Peru with CIAT support, on the results of diagnosis, the problems identified and the first year's trials in the 24 areas covered by the INIPA-CIAT on-farm research course. These documents are serving to orient the INIAA Legumes Program.

Network contacts between IARCs are also important to harmonize ideas when appropriate, and to learn from each other. Two such efforts within Latin America were already mentioned: the preparation of OFR publications with CIMMYT and the participation with CIMMYT and CIP in the OFR workshop. CIMMYT and CIAT are also working together in OFR on maize and beans when possible. In La Fraylesca, Chiapas, Mexico, CIMMYT and CIAT are supporting the integration of maize and bean OFR in work conducted by INIFAP. In Ipiales, Colombia, CIMMYT maize scientists provide support to CIAT-ICA OFR on the maize-bean association. CIAT has also participated actively in inter-IARC conferences (at Nairobi in 1984 and Hyderabad in 1986) on OFR and farming systems research (FSR), and has established itself as a center where FSR is conducted within commodity programs.

Progress in the identification of technologies for specific areas

The identification of technologies for specific areas is a spin-off from methodology adaptation in Colombia and, more important, an indication that OFR on beans in national programs is functioning effectively. This summary covers the three countries in which CIAT-HQ support in OFR has been most active.

In the CIAT-ICA work areas initiated in 1982 (in 1978 in the case of El Carmen) some adoption of technology by farmers is now apparent.

Seed of the climbing bean Frijolica 0-3.2 which was released in June 1985 for Ipiales, Nariño and whose adoption had been held back by low bean prices and the resulting larger discount for a new variety, has been maintained by farmers. Now that the price situation is more normal and the variety is better known, higher sales and larger areas planted are being reported.

The variety Frijolica LS-3.3, released in August 1985, is starting to be adopted by farmers in San Vicente, Antioquia. In parts of Funes, Nariño, the line Ancash 66 (not released so far because of its limited adaptation) is being grown and marketed by a number of farmers.

In these areas, other suitable technological components have also been identified through OFR. Adoption of these has been slower so far, for reasons we hope to understand better in the 1987/88 season. However, in El Carmen and San Vicente, farmers have already adopted closer spacing of maize plants, higher bean density, and the use of benomyl in disease control mixtures. In Ipiales and Funes, farmers' doses of fertilizer application have risen, possibly due to the influence of research results.

Stepwise OFR does not always produce small changes, as the following example from Ipiales shows. In the maize-climbing bean association it proved possible to increase the net benefit per year by shortening both maize and bean cycles from 8.5 to 6.5 months and including a crop of barley (Table 2). This system was highly appreciated by farmers, is in ten verification trials this year and is likely to be adopted. Not only is an extra crop produced, but maize and beans are harvested earlier, giving farmers a greater feeling of security. The correct combination of maize and beans was identified only in the fourth year of work on-farm. Before this, both maize and bean cultivars which were sufficiently early to maturity and well adapted were known, but they dominated the other crop unduly. Not all farmers found time to plant the barley crop after beans or maize-beans, so some refinement of the cropping system is still needed.

OFR collaborators in Peru and Mexico started OFR trials on beans in 1986 or 1987, so it is early to expect results. However in Peru the following progress can already be reported as a direct result of OFR.

a) The "Gloriabamba" variety is being widely adopted in Cajamarca department and is spreading to other areas of the highlands.

b) Farmers in some parts of Cajamarca and Junin are reported to be changing from broadcast planting to higher density row-planting arrangements.

c) In Cusco, "Blanco Salkantay" climbing beans are being adopted for a novel relay planting with maize.

d) Other new varieties are in verification trials in two other areas of the highlands and in four areas of the coast.

e) Other technologies in verification are: chemical nematode and root rot control in two areas; more economic densities in two areas; Rhizobium inoculation in parts of Cajamarca department.

In the only area of bean OFR in Mexico where the first year's results are so far available, the INIFAP scientist in La Fraylesca showed in verification trials that the new variety Negro Huasteco 81 was superior to the local cultivar Veracruzano

whether or not the other successful components (40kg/ha N and use of Tamaron instead of Foley insecticide) were employed.

In view of the quality of execution by national programs of present OFR projects on beans, we fully expect more examples like these to mount up in the next two years.

Appendix 1. OFR TRAINING IN THE CIAT BEAN PROGRAM 1984 - 1987

Country	No. Scientists trained in complete OFR courses[1]			No. presently active in OFR programs with	
	Total	Research	Extension	Frequent CIAT Support	Occasional CIAT Support
Argentina	1	1	0	0	1
Bolivia	1	1	0	0	1
Brazil	4	2	2	3	1
Colombia	23	9	14	19	3
Costa Rica	6	2	4	3	1
Dominican Republic	2	0	2	0	0
Ecuador	4	4	0	0	2
El Salvador	5	3	2	1	1
Guatemala	5	3	2	1	3
Honduras	1	1	0	0	0
Mexico	6	6	0	5	0
Nicaragua	1	0	1	1	0
Peru	25	11	14	18	0
Paraguay	4	0	4	0	4
TOTAL	88	43	45	51	17

1 Courses of at least 5-weeks formal teaching.

Table 1. Response to inoculation and nitrogen application in maize-bean row intercropping. El Tambo, Nariño, Colombia.

Inoculation[a]	Nitrogen[b]	Yield (kg/ha)			
		1985 (mean 4 cultivars) One farm		1986 (mean 2 cultivars) Three farms	
	(kg/ha)	Beans	Maize	Beans	Maize
No	0	509	1171	436	749
No	19.3	361	2879	489	697
Yes	0	568	1802	417	737
Yes	19.3	-	-	526	1113
LSD P = 0.10		116	485	85	227

a Mixture of three adapted strains.

b All treatments also received 20 kg/ha P and 9.3 kg/ha K.

Table 2. Summary of results from an intensification trial on four farms, Ipiales 1986–7. (Farmers made different decisions on planting the second barley crop. Costs and benefits were calculated separately for each farm).

Maize cultivar	Bean cultivar	Barley	Yield (kg/ha) Maize	Beans	Barley	Costs that vary[1]	Mean Net benefit	Rank of net benefit on 4 farms A	B	C	D
						thousand pesos/ha					
None	Antioquia 8-II	After beans	——	999	4168	70.6 ABC/22.9 D	357	3	1*	1*	8
Pool 5	L 32983 (M4)	After beans	2017	369	2986[2]	59.5 AB/11.7 CD	355	1*	2*	6*	2*
Pool 5	Antioquia 8-II	After beans	1382	698	2986[2]	74.3 AB/26.4 CD	310	2	3	7	7
Pool 7	TIB 3042	None planned	1619	640	——	13.3	231	4*	6*	5*	4
None	Antioquia 8-II	Before beans	——	773	2134	70.7	224	7	4	2	5
Morocho Blanco	Frijolica 0-3.2	None planned	1558	471	——	16.6	216	8	7	3*	3
None	TIB 33411	Before beans	——	704	2134	70.1	212	5	5	4	6
Morocho Blanco	Mortiño	None planned	1604	143	——	13.6	171	6	8	8	1*
	LSD(10%)		314	172	——						

* Economically efficient treatments.

1 Farmer A planted barley after beans in the first three treatments and farmer B planted wheat; farmer found there was only time for barley in the first treatment; farmer D decided not to plant.

2. The two farmers who harvested these barley treatments both mixed these two plots.

2. Central America

A number of shorter courses on OFR in Central America grew out of models provided by OFR work in Latin America. Phases were shorter and there were some problems with selection of candidates and follow-up. Even so, OFR on beans is established in some areas of El Salvador, Nicaragua, Costa Rica and Honduras as a result of these courses and of a CIAT-based course which trained key personnel in those countries.

El Salvador. In the first season plantings 24 plots were installed in Region IV and 35 in Region III to evaluate the performance of Centa Izalco and RAB 204. These lines have consistently out-yielded farmer lines by 20%, or more.

The first phase of a course on the production and promotion of new bean varieties was held during the third week of August. As 31 technicians from Region I participated in this course, the area of influence of the on-farm work was extended by conducting a diagnostic of the region. The first variety trials were also established in the area to evaluate bush types (RAB 276, RAB 310, RAB 311, RAB 282, RAB 204, and the local check), and climbing types (LV 104, RCWI-22, VRB 81064, ES-1361, and the local check). Three technicians from Region III also participated and reinforced the group from San Vincente in establishing 37 technology transfer plots (Centa Izalco and RAB 204). Although the data are yet to be analyzed, evidently they performed quite well since they were well-accepted by farmers for their obvious advantages, such as overall health, yield and good quality.

The first phase of a course on artesanal bean seed production was presented for farmers and extension workers during the fourth week of August. Participants received seed of RAB 204 and Cental Izalco to begin local seed production. The Project is backstopping CENTA in their support of this effort to replace local varieties that are severely affected by CBB, anthracnose, and common mosaic.

Guatemala. In eight on-farm trials in El Peten (alt. 300-500 m) ICTA Tamazulapa yielded between 650 and 1600 kg/ha, with a mean of 1050 kg/ha, while the predominant farmer varieties, Mono and Chapin, never exceeded 200 kg/ha. Yields of ICTA Tamazulapa in commercial plantings of cooperatives surpassed those already mentioned, with the most common being around 1200 kg/ha, and other commercial varieties yielding around 600 kg/ha.

Three hundred pounds each of seed of ICTA Ostua and ICTA Tamazulapa were given to the regional agricultural cooperative to establish 80 plots in El Peten. In the cool season planting 40 plots of each variety were established. Most farmers who planted

Ostua expressed their satisfaction with yield, the number of pods, the number of seeds per pod, and grain size, all of which were superior to the local cultivar. Formal data will be presented at the end of the season.

There was considerable activity by the artesanal seed production group in the regions of Quesada and Artescatempa in the southwest in the form of field days and exchange of experimental results. In the Department of Santa Rosa 150 lbs of ICTA Ostua seed were delivered to DIGESA to be introduced into this important production area. Unfortunately, all the second season plantings were affected by drought. However, in the first season plantings, Ostua gave yields of around 1155 kg/ha, surpassing local checks by about 29%. The local checks were improved varieties in 30% of the cases, permitting a comparison of the production systems in the region.

Honduras. In the first season plantings (which permitted evaluation of beans under very adverse conditions), Catrachita (RAB 205) was superior to commercial varieties for diseases (common mosaic, anthracnose, Mustia, and/or CBB, depending on the zone). El Zamorano was later in maturity and photoperiod sensitive, as well as being more susceptible to the diseases. El Danli 46 was very affected by Mustia and common mosaic, and Desarrural was severely affected by anthracnose.

Empoasca control trials received no treatments because heavy rains reduced insect populations. Chemical control trials for Apion were established, and results were very promising in Siguatepeque and Sta. Rosa de Copan where a pyrethroid (Arrivo) with low human toxicity gave good control. The plots treated with this product gave higher yields than those treated with organophosphates, which have very high human toxicity. Decis and Arrivo are proposed to be included in on-farm evaluations next year for control of Apion and Empoasca, since data are available on the control of the latter pest from the the Secretariat of Natural Resources in the central west region.

Release of RAB 205 under the name of Catrachita was supported by its excellent performance in on-farm trials in most of the major bean growing regions of the country, with yields between 1160 and 1950 kg/ha.

RAB 50 maintains its high acceptability by farmers who originally planted it in on-farm trials in the region of El Paraiso. Its superior adaptation to the region, yield stability, and its overall health are particularly appealing. Since it is so similar to its sister line RAB 205, it may serve as a replacement should RAB 205 fail.

Nicaragua. Recently the Directorate of Basic Feed Grains, of MIDINRA, has given high priority to on-farm research in order to make available technology in the form of improved varieties to farmers previously excluded from technological innovations.

Furthermore, it is felt that their input would be invaluable in judging whether to retain or eliminate lines. The Directorate of Research and the national bean program both have adequate resources for the execution of on-farm trials, and are seeking the support of CIAT in training. The bean program already has materials released under the names of Revolution 79, 81, 82, 83, 84, and most recently, selections from crosses between CIAT lines and Orgulloso. Other lines which should be tested, perhaps by means of an on-farm research course, are: RAB 210, BAT 1631, RAB 211, RAB 204, RAB 213, and XAN 107.

Costa Rica. HT 7719 (Porrillo Sintetico, BAT 76) was multiplied for seed and released as "Chirripo". ICTA 883-2-M (ICTA 81-8-D83) was planted in demonstration plots, showing superior performance to Talamanca which had problems with anthracnose.

Dominican Republic. It has not been possible to include farmers in early evaluation of materials, delaying the development of on-farm trials in the Dominican Republic. However, a course presented this year contains the tool which should permit the participants to begin and encourage this kind of work. In addition to PC 50 and BAT 1412, the Bean Program has BAT 1274, XAN 42, and this year will put out demonstration plots of ZAA 84064 and DAP 34.

Cuba. Drought damaged plantings this year, but Sibomei (NAG 20), Centa Tazumal (BAT 58), Brunca (BAT 304), BAT 832, and BAT 518 continued to perform well at the commercial level. These lines may replace ICA Pijao in areas affected by rust, and also replace ICA 23 (red mottle), BAT 482 (white), and A 336 (cream).

3. Irrigated Systems - Brazil

There has been great demand recently for information on, and seed for, planting beans under partially inundated land. In Brazil, this kind of land is known as Varzeas. The Brazilian government has created several government entities to investigate problems inherent in irrigated bean crops; has promoted the preparation of land for a huge irrigation project; has indicated that roughly 1 million hectares of land will be under irrigation within the next five years; and, in general, has shown great enthusiasm for research on beans under inundation. Research was begun last year in a collaborative effort between CIAT and CNPAF scientists, and preliminary results were obtained this year.

The main problem of bean production under irrigation systems is temporary inundation since perfect land leveling is impossible. Furthermore, beans do not tolerate excess water even for short periods of time. Another type of constraint for bean production under sub-irrigation systems is the depth of the water table. Sub-irrigation keeps the superficies of the terrain dry. In areas where soil-borne disease, such as web blight, are production constraints, this type of irrigation permits bean production. Regulating the water table is important especially at the initial growth phase since the plant will suffer from water stress if the water table is too deep or the roots may suffer from lack of oxygen and from the subsequent plant reactions due to inundated soils (such as production of ethylene gas) when the water table is too shallow. Certain hormones may increase (abscesic acid, auxin) or decrease (gibberellin, cytokinin) due to excess water.

To understand the effect of excess water on the bean plant, a series of experiments was conducted at CNPAF with the following objectives:

1. to determine the critical period in the bean cycle when the plant is most affected by excess water;

2. to measure the effect the duration of inundation has on yield;

3. to determine optimum water table depth and,

4. to look for genetic variations in *Phaseolus vulgaris* with tolerance to excess water.

The experiment was conducted in pots with 6 kg of varzeas soil that was fertilized and limed to obtain optimum growth. Inundation was performed by slowly pouring the water from the pot side to avoid air pockets building in the pot. Water was maintained at 2 cm above the surface during the treatment. Draining the excess water from the pot was done by piercing the bottom of the pot. Water flow was controlled so that all pots

had, more or less, the same velocity of drainage. The pots, after treatment, did not receive water until they showed the first signs of wilting at mid-day.

To determine the critical period of inundation in the bean cycle, the pots were inundated for 48 hours at the following stages:

Inundation of the pod lasted for 48 hours at:

1. first trifoliate formation (V3)
2. third trifoliate formation (V4)
3. preflowering (R5)
4. full bloom (R6)
5. pod formation (R7)
6. pod filling stage (R8)

Critical duration of the inundations was measured by applying seven inundation periods (0, 6, 12, 24, 36, 48 and 72 hours) were applied at third trifoliate (V4) and at full bloom (R6). Each pot contained four plants. Rio Doce (A 247) was used as the test plant. Plants received full plant protection during the experiment.

Results: critical period of excess water

Bean yield was reduced by application for 48 hours of excess water at all stages of growth except for the third trifoliate stage (Figure 1). Yield losses increased when the inundation occurred later in the growth stages. From full bloom onward, yield losses reached about 70% (Figure 2). Epinasty occurred after 24 hours of inundation. Plants treated with inundation occurring prior to flowering recovered well, but when inundation occurred after flowering, recovery was poor and was reflected in yield losses.

In practice, irrigation should be performed before flowering commences and, after flowering, irrigation should be performed with great care since excess water significantly reduces yield.

Results: duration of inundation

Bean yield (g/plant) was reduced by different durations of inundation and the yield reductions increased with increasing times of inundation. Inundation of 72 hours at the flowering stage produced almost nothing (Figures 3 and 4). Yield losses in

percentage for inundation occurring during the third trifoliate and flowering stages are shown in Figures 5 and 6. Yield losses were lower than 70% when inundation occurred during the third trifoliate stage at any duration. However, during the flowering stage, any inundation occurring for more than 24 hours, resulted in significant yield losses with reductions of more than 50%. Yield analysis is shown in Tables 1 and 2 for the inundation occurring during the third trifoliate and flowering stage, respectively. Inundation during the trifoliate stage at all durations reduced the number of pods/plant. The extractable root weight was reduced when inundation occurred for more than 24 hours whereas the 100 gram weight, seed number/pod, and harvest index were not significantly different than the checks. Inundation during the flowering stage significantly reduced the 100 gram weight, pods/plant, and extractable root weight when inundation occurred for longer than 24 hours. Growth analysis, taken two weeks after treatment's end, confirmed the yield reductions (Table 3 and 4). In general, inundation mostly affected yield and the number of pods/plant. Hundred grain weight was affected only when the duration of inundation occurred for longer than 24 hours. Grain number/pod and root weight were the least sensitive parameters. These results suggest that irrigation should be carefully executed during the flowering period and that inundation for periods longer than 24 hours must be immediately drained. The genetic variation test for tolerance to inundation will start next semester.

Depth of water table

Pot experiments were carried out in Eternit boxes where water could be adjusted according to the desired level. Pot preparation was equal to the previous pot experiments. The water table was maintained through siphoning excess water out of the boxes. Three levels of water tables were applied: 25, 20, and 15 cm from the soil surface. Two phosphorus levels (2 and 6 g of triple superphosphate) were also included to represent about 150 and 750 ppm phosphorus.

Results: Different depths of water table

Bean yield was reduced by different depths of the water table which were kept constant during the whole crop cycle. Reductions were higher at high phosphorus levels than at low phosphorus levels (Figure 7). Yield losses were greatest when the water table was only 13 cm below the soil surface (Figure 8). Yield analysis (Table 5) showed that pod number was significantly affected by water table depths whereas other yield parameters did not change significantly. Growth analysis (Table 6) showed that all growth parameters did not significantly change but that increasing water tables tended to decrease the dry weight of all plant parts. These results all suggest that a careful water table control is required when sub-irrigating the bean field. During germination, a shallow water table is required so that

moisture can reach the seed layer. When the root starts to grow, the water table should be continuously dropped to a certain depth so that the bean plant will be guaranteed to have water. Generalizations are difficult when physical properties are different. Fortunately, all regions with sub-irrigation systems have, more or less, the same soil, textures, and structures.

Future research will continue looking at genetic variation in beans tolerant to temporal inundation with field testing in key regions. Sub-irrigation and high temperature yield experiments will be executed in the key regions.

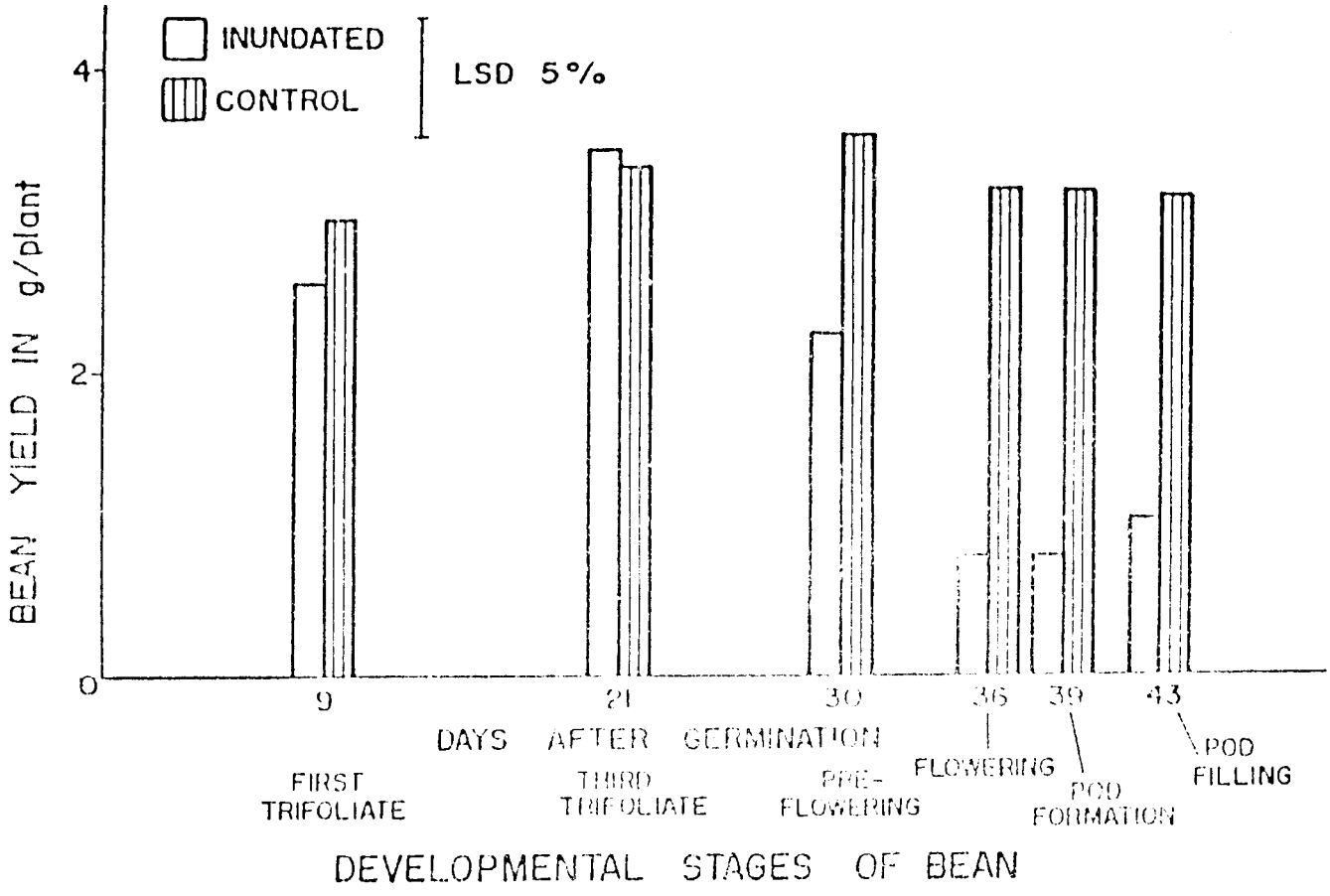


Figure 1. Bean yield as affected by 48 hrs inundation at different stages of growth.

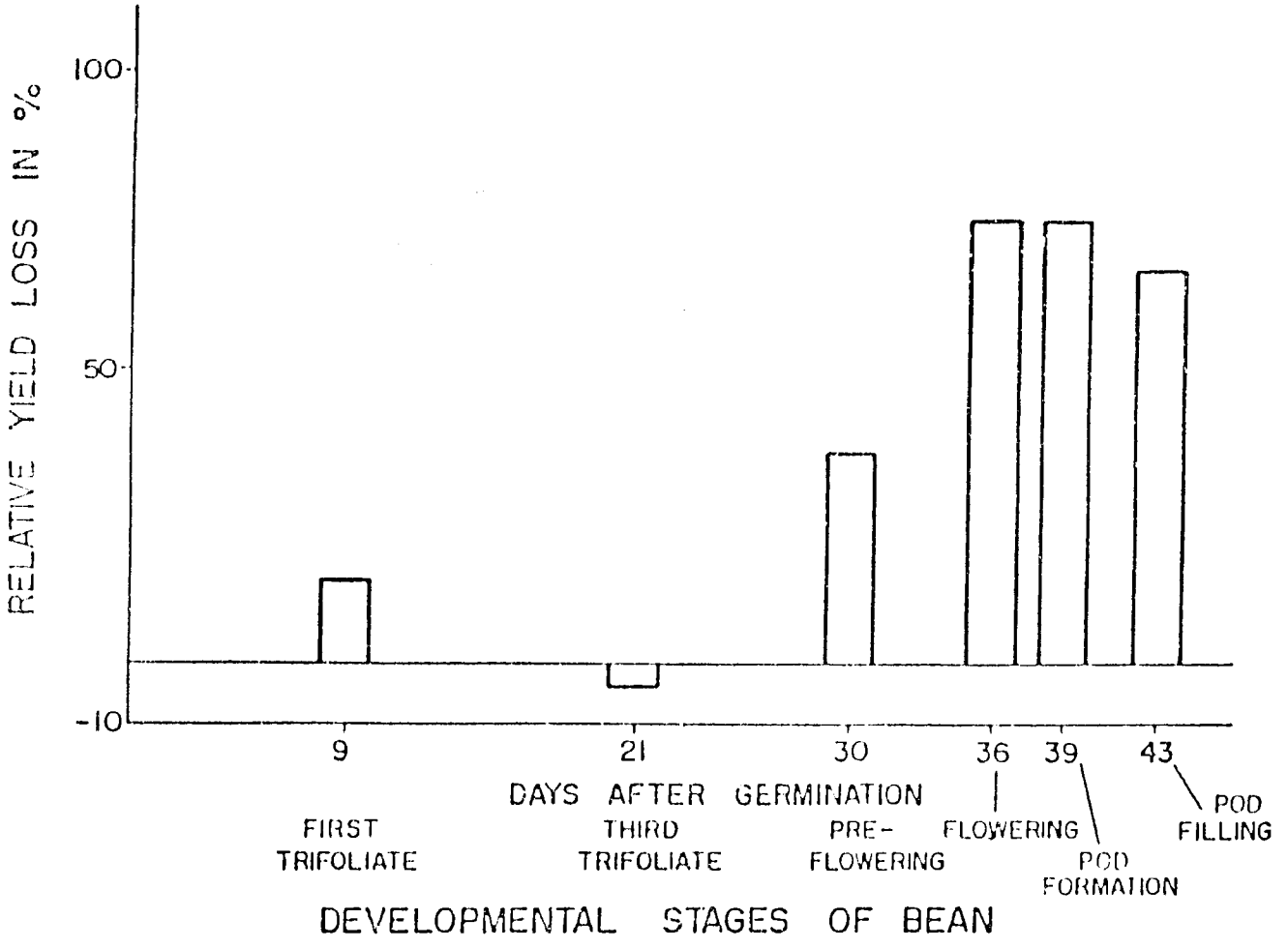


Figure 2. Relative yield loss in % as affected by 48 hrs inundation at different stages of growth.

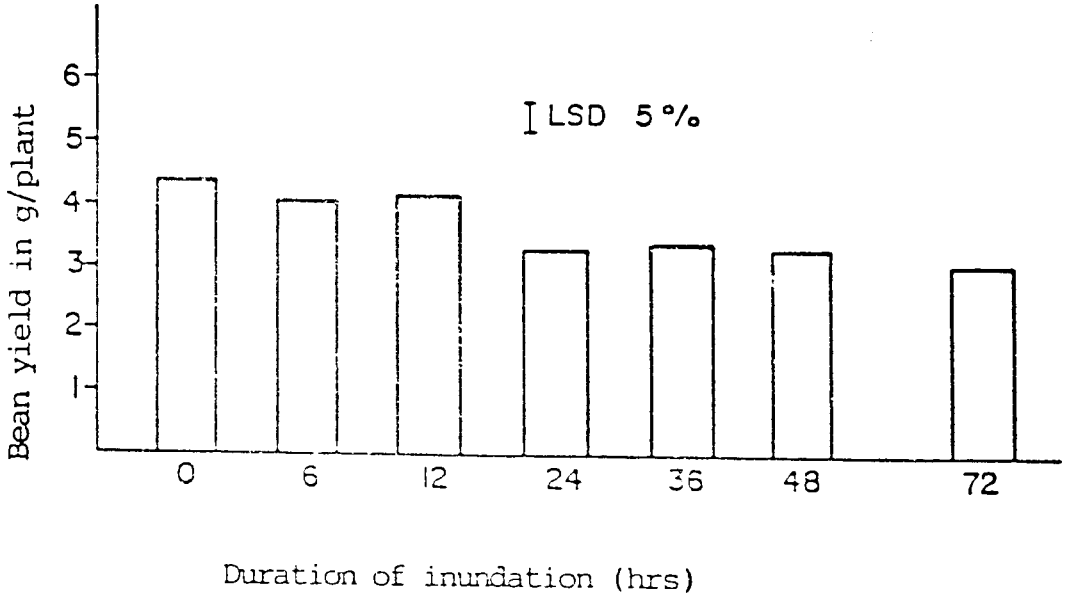


Figure 3. Bean yield as affected by different periods of inundation during the third trifoliate stage.

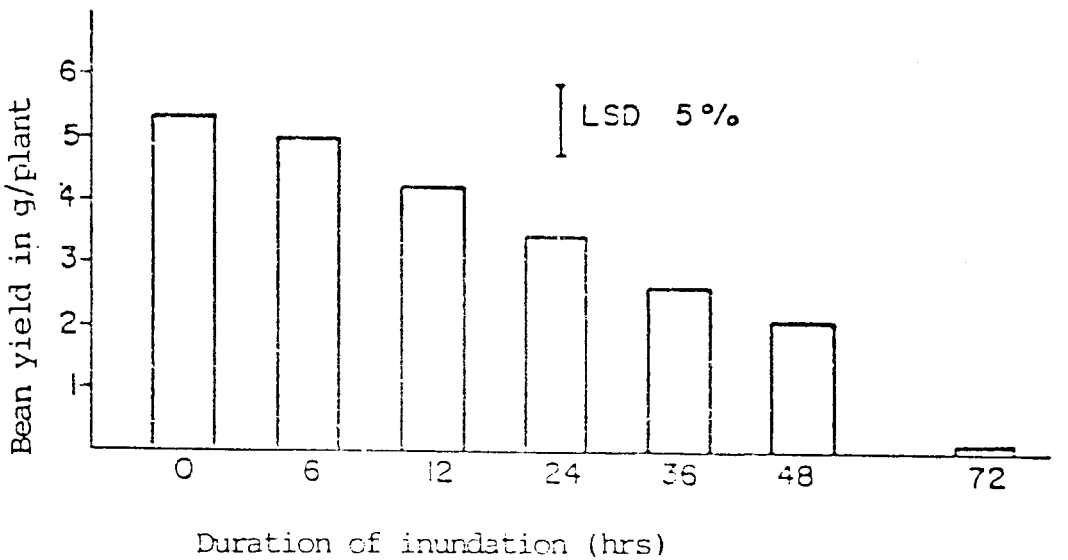


Figure 4. Bean yield as affected by different periods of inundation during the flowering stage.

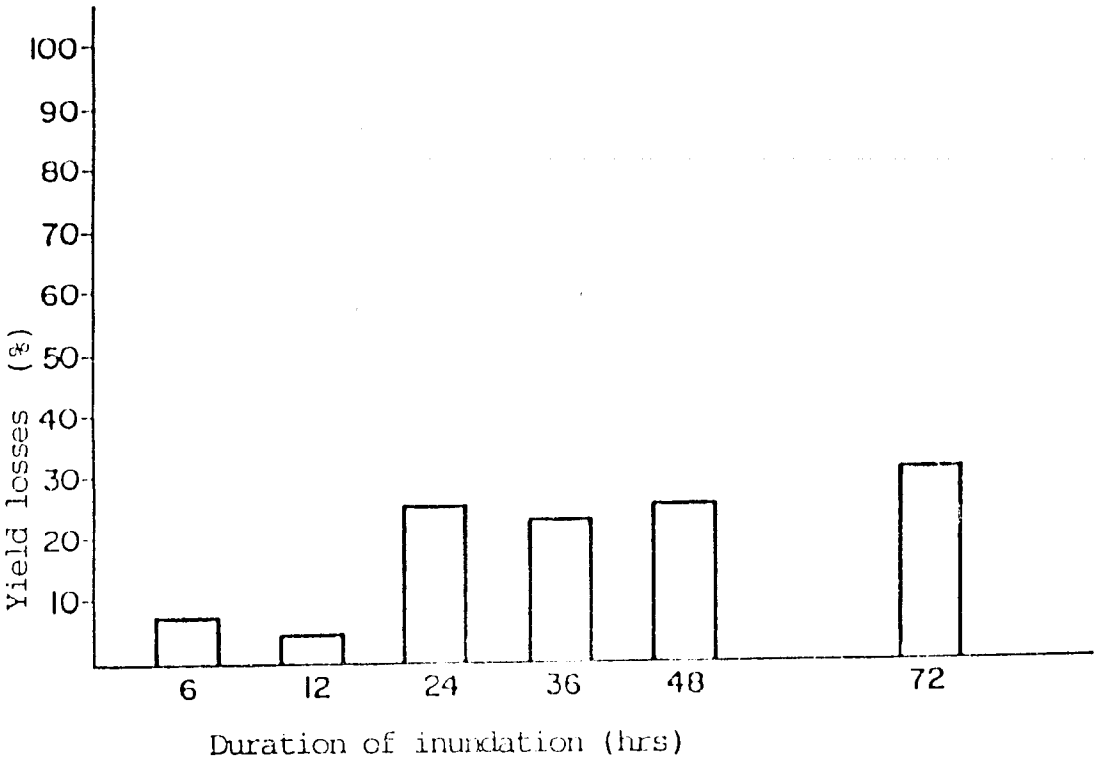


Figure 5. Yield losses (in %) due to different periods of inundation occurring during the third trifoliate stage.

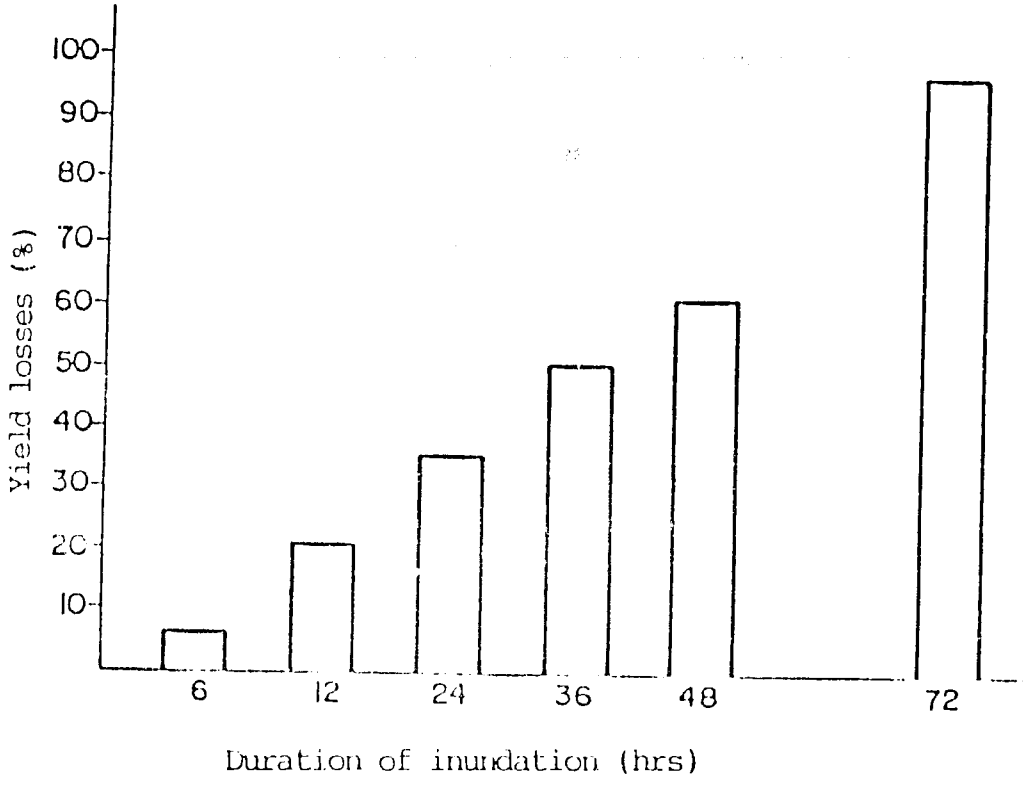


Figure 6. Yield losses (in %) due to different periods of inundation occurring during the flowering stage.

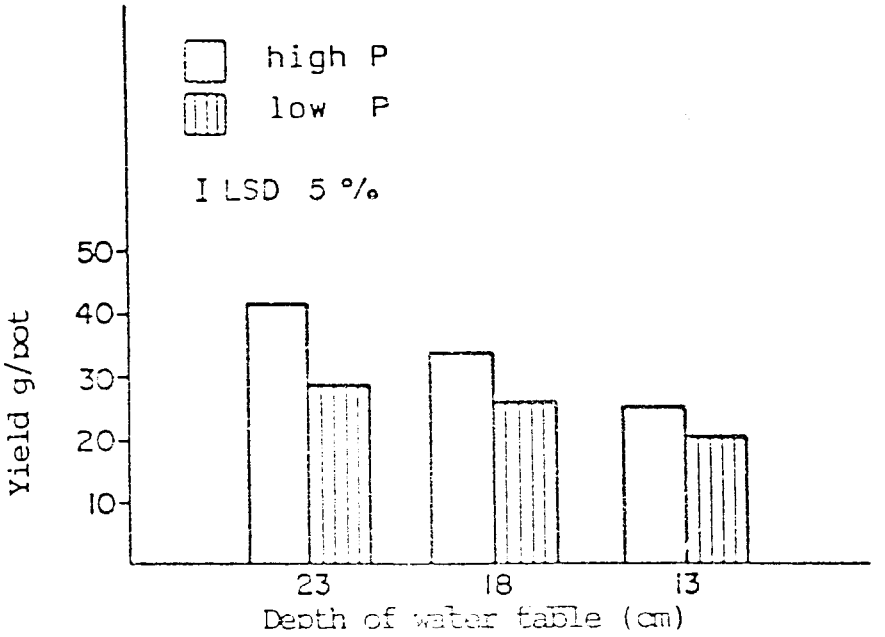


Figure 7. Different depths of water table effects on bean yield when beans are grown with high an low phosphorus levels.

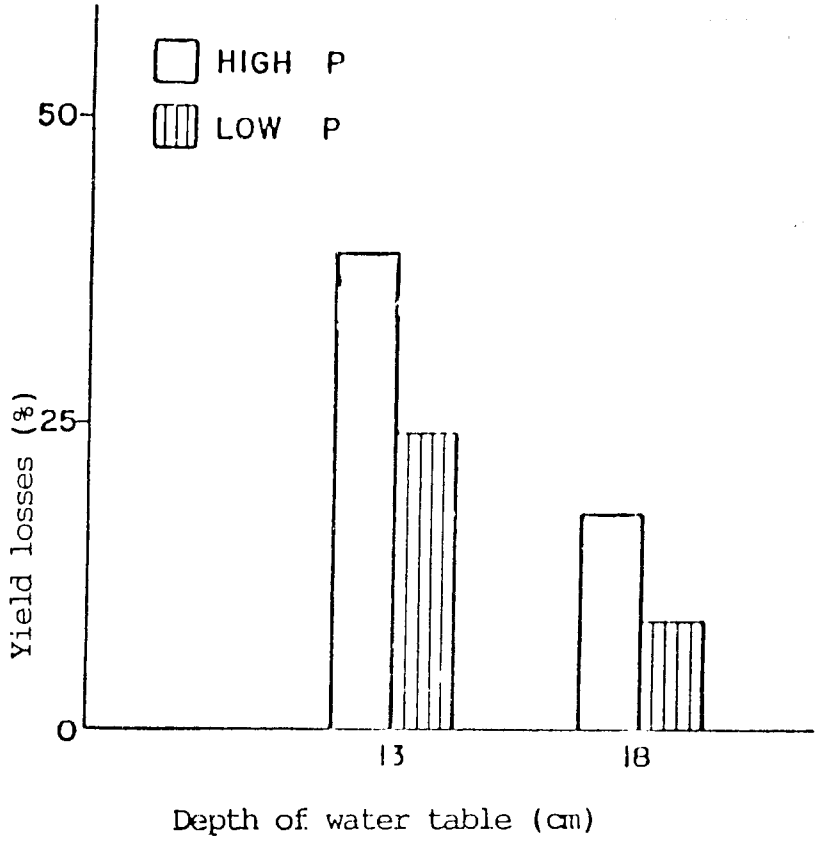


Figure 8. Bean yield losses as determined by differing water table depths, with high and low P inputs.

Table 1. Yield and yield components of bean as affected by different durations of inundation occurring during the first trifoliate stage.

TREATMENT (HRS)	YIELD g/PLANT	100 GRAIN WEIGHT (g)	PODS/ PLANT	SEED NUMBER/ POD	EXTRACTABLE ROOT (g/PLANT)	HARVEST INDEX
0	4.3	13.3	7.3	4.7	1.5	0.47
6	4.0	15.3	5.3	5.0	1.6	0.50
12	4.1	14.8	5.7	4.7	1.8	0.52
24	3.2	12.7	5.0	4.3	1.3	0.46
36	3.3	15.4	5.3	4.3	1.1	0.50
48	3.2	15.4	5.3	4.0	1.2	0.50
72	3.0	15.3	4.3	4.3	0.7	0.47
LSD (5%)	0.5	2.0	0.9	0.9	0.2	0.06
CV (%)	8.5	7.6	9.6	11.1	10.2	6.4

Table 2. Yield and yield components of bean as affected by different durations of inundation occurring during the flowering station..

TREATMENT (HRS)	YIELD g/PLANT	100 GRAIN WEIGHT (g)	PODS/ PLANT	SEED NUMBER/ POD	EXTRACTABLE ROOT (g/PLANT)	HARVEST INDEX
0	5.3	17.1	7.3	4.7	1.5	0.51
6	5.0	14.7	6.3	4.7	1.7	0.51
12	4.2	14.5	6.3	4.3	1.4	0.48
24	3.4	12.2	6.3	4.0	1.3	0.38
36	2.6	10.8	5.0	4.3	1.0	0.33
48	2.1	10.9	4.0	5.0	1.1	0.29
72	0.1	0.3	1.7	0.7	1.0	0.01
LSD (5%)	1.2	4.5	1.9	1.6	0.4	0.17
CV (%)	20.9	21.8	19.9	22.2	19.2	26.0

Table 3. Growth parameters of bean plant as affected by different durations of inundation occurring during the third trifoliate stage. Sampling taken two weeks after end of treatment.

TREATMENT (HRS)	PLANT HEIGHT (cm)		LEAF AREA (cm2/PLANT)		DRY WEIGHT g/PLANT									
					LEAVES		PETIOLES		STEM		TOTAL AERIAL PART		ROOT	
	IN *	CHECK	IN *	CHECK	IN *	CHECK	IN *	CHECK	IN *	CHECK	IN *	CHECK	IN *	CHECK
6	43.3	50.3	547	618	2.09	2.24	0.48	0.56	0.87	0.95	3.44	3.75	0.96	0.89
12	43.3	50.3	364	618	1.67	2.24	0.36	0.56	0.70	0.95	2.73	3.75	0.78	0.89
24	40.3	63.7	268	546	1.22	2.46	0.26	0.71	0.61	1.07	2.10	4.24	0.67	0.93
36	34.3	63.7	230	546	1.11	2.46	0.23	0.71	0.51	1.07	1.80	4.24	0.51	0.93
48	26.7	55.0	184	544	1.00	2.59	0.23	0.82	0.52	1.17	1.75	4.57	0.51	0.90
72	26.0	55.0	110	544	0.77	2.59	0.14	0.82	0.44	1.17	1.39	4.57	0.37	0.90
LSD (5%) INUND.	5.1		83		0.22		0.07		0.08		0.27		0.10	
LSD (5%) DURATION	3.0		48		0.13		0.04		0.05		0.32		0.06	
CV (%)	9.3		16		10.36		11.74		8.33		8.38		10.80	

*IN = INUNDATION

Table 4. Growth parameters of bean plant as affected by different durations of inundations occurring durir_ the flowering stage. Data taken two weeks after end of treatment.

TREATMENT (HRS)	PLANT HEIGHT (cm)		LEAF AREA (cm2/PLANT)		DRY WEIGHT (g/plant) LEAVES		PETIOLES		STEM		POD		TOTAL AERIAL PART		ROOT	
	IN *	CHECK	IN *	CHECK	IN *	CHECK	IN *	CHECK	IN *	CHECK	IN *	CHECK	IN *	CHECK	IN *	CHECK
6	109.3	115.3	836	1010	4.05	4.15	1.65	1.54	2.61	2.55	2.40	2.93	10.80	11.22	1.41	1.80
12	101.3	115.3	892	1010	3.92	4.15	1.64	1.54	2.64	2.55	2.80	2.93	11.06	11.22	1.33	1.80
24	107.0	106.3	916	941	3.84	4.14	1.63	1.66	2.60	2.47	2.89	3.03	11.01	11.37	1.32	1.85
36	97.3	106.3	616	941	2.75	4.14	1.36	1.66	2.48	2.47	1.87	3.03	8.50	11.37	0.98	1.85
48	97.7	117.7	541	862	2.02	3.86	1.12	1.56	2.23	2.57	1.92	4.01	7.35	12.05	1.00	2.00
72	101.3	117.7	126	862	0.85	3.86	0.95	1.56	1.94	2.57	0.30	4.01	3.99	12.05	0.80	2.00
LSD (5%) INUND.	9.5		97		0.29		0.10		0.20		0.53		0.15		0.19	
LSD (5%) DURATION	5.5		56		0.17		0.06		0.11		0.31		0.54		0.11	
CV (%)	7.4		10		7.02		6.15		6.80		16.56		4.45		10.35	

*IN = INUNDATED

Table 5. The effect of different depths of water table and phosphorus levels on yield and yield components.

DEPTH OF WATER TABLE	PHOSPHORUS LEVEL	GRAIN YIELD g/pi	100 GRAIN WEIGHT	POD/ PLANT	GRAIN/ POD	ROOT DRY WEIGHT	HARVEST INDEX
23		8.39	21.09	9.2	4.3	3.52	0.56
18	HIGH PHOSPHORUS*	6.89	23.96	7.9	3.7	3.12	0.55
13		4.75	25.97	5.1	3.8	2.38	0.49
23		5.73	22.67	6.6	3.8	2.30	0.58
18	LOW PHOSPHORUS**	5.23	23.64	5.4	4.1	1.89	0.60
13		4.33	24.23	4.8	3.7	1.71	0.60
LSD (5%)		0.80	2.17	1.6	0.6	0.54	0.34
CV (%)		8.82	5.97	16.0	10.6	14.22	0.31

* 6 g TRIPLE SUPERPHOSPHATE/POT
** 2 g TRIPLE SUPERPHOSPHATE/POT

Table 6. The effect of different depths of water table and phosphorus levels on bean growth parameters at the third trifoliate (V4), flowering (R6), and pod filling stage (R8).

DEPTH OF WATER LEVEL (cm)	PHOSPHORUS LEVEL	PLANT HEIGHT (cm)	LEAF (cm 2/ PL)	DRY WEIGHT (g/plant) LEAF	PETIOLE	STEM	POD	TOTAL ABOVE PART
	THIRD TRIFOLIATE STAGE							
23		14.4	270	0.93	0.17	0.24	-	1.34
18	HIGH PHOSPHORUS*	17.8	436	1.40	0.26	0.31	-	1.97
13		18.1	428	1.40	0.26	0.32	-	2.00
23		19.1	242	0.77	0.16	0.20	-	1.13
18	LOW PHOSPHORUS**	19.8	278	0.84	0.19	0.22	-	1.25
13		21.5	222	0.69	0.15	0.19	-	1.03
LSD (5%)		1.5	61	0.21	0.05	0.06	-	0.31
CV (%)		5.3	13	13.32	16.55	16.60	-	13.75
	FLOWERING							
23		36.2	1570	4.36	1.42	2.75	-	8.53
18	HIGH PHOSPHORUS*	42.3	1493	4.31	1.29	2.68	-	8.27
13		35.8	1114	3.22	0.94	2.38	-	6.54
23		28.7	1032	2.73	0.79	1.28	-	4.80
18	LOW PHOSPHORUS**	32.8	888	2.05	0.67	1.18	-	3.91
13		27.9	745	1.95	0.53	0.95	-	3.43
LSD (5%)		4.2	209	0.53	0.18	0.44	-	1.06
CV (%)		8.0	12	11.15	12.24	15.20	-	11.66
	POD FILLING STAGE							
23		69.8	1084	3.48	1.18	4.06	3.91	12.84
18	HIGH PHOSPHORUS*	72.8	1190	3.80	1.38	4.79	3.91	14.28
13		67.0	711	2.34	1.08	4.26	3.82	11.75
23		51.6	447	1.70	0.90	2.47	2.32	7.47
18	LOW PHOSPHORUS**	46.0	395	1.44	0.53	1.97	1.85	5.89
13		45.2	299	1.17	0.46	1.91	1.62	5.24
LSD (5%)		11.6	487	1.48	0.40	0.49	1.38	2.86
CV (%)		12.8	46	41.26	28.34	9.88	30.84	19.42

* 6 g SUPERPHOSPHATE/POT

** 2 g TRIPLE SUPERPHOSPHATE/POT

I. ECONOMICS AND SOCIAL SCIENCE

1. Latin America

The Bean Economics section provides socio-economic guidelines for technology development and release. These guidelines concern strategic decisions within the program (e.g. breeding versus agronomy) as well as decisions within specific research sections. Additionally the section measures the degree of success obtained with new technology. To do so the Bean Economics section concentrates its research efforts around three basic activities:

- Documenting developments in dry bean production and consumption in the third world.

- Diagnosing the bean sector of different countries. The section tries to define target zones for research on the basis of the importance of bean production, the ability to conduct research on specific bean production problems, and the potential impact of successful research. The section also works on the specific diagnosis of bean production problems within regions and on the establishment of more efficient feedback from farmer to researcher.

- Monitoring the release and measuring the impact of successfully new technology. By studying the success of new technology, the section hopes to be able to define future research objectives as well as to provide suggestions for improved release strategies.

Research is highly decentralized since guidelines for research in specific areas of Latin America can only be developed on the spot. Over the last three years the section has maintained two researchers in Central America and has undertaken considerable efforts in Peru and Brazil, where in-country researchers are planned for the near future.

The research capacity of headquarters is used to document developments in bean production and consumption in the third world, to develop methodologies that can be applied in the target regions, to assist outposted researchers in specific problems (e.g. consumer acceptance) and to process the data which are obtained in the various countries/regions. Issues in the Bean Economics and Social Science section currently receiving attention are:

- The measurement of impact of new technology in target areas. A conservative estimate was 23 million dollars per year (1985).

- Consumer acceptance of new technology. Prerelease evaluations of varieties by consumers form part of the research process.

- Equity-versus-overall-impact. Bean technology can be directed towards small farmers, instead of large farmers, but often at the cost of a reduction of consumer benefits. As Latin America is highly urbanized, these costs weigh heavily in balancing total benefits of technology.

- Appropriate varietal release strategies. Awareness of market conditions, interinstitutional collaboration and policy coordination combined with factors of seed availability, extension, market and credit support, and publicity are all interrelated in the search for improved release strategies that will enhance the impact potential of new varieties.

- Cultural practices research. The benefits of certain varieties can be augmented by understanding their relationship to cultural practices, as when disease resistant varieties cause a decrease in chemical control practices. Cultural practices also help to amplify the target area of a new variety and therefore its potential impact.

- Snap bean potential. The economic potential of snap beans in the developing world is being researched.

Production studies

After the conclusion of adoption studies in primary target zones of Guatemala and Costa Rica, attention has shifted to the study of other regions. These studies have a mixed diagnostic/evaluative nature, which describe and prioritize research problems, while simultaneously measuring the penetration of materials released for other zones into these areas.

GUATEMALA

A diagnostic survey was executed in the Northeastern part of Guatemala, in the department of El Peten. This recently colonized region has heavy rainfall and temperatures are towards the upper limits for bean production, while soils are shallow, infertile and susceptible to erosion. Some 43,000 hectares of beans are planted in the region. Most colonizers come from the southeastern part of the country, a traditional bean production area. To a large extent, these colonizers have copied bean production technology from the southeast to El Peten. Consequently varieties that were introduced for the southeast are also found in El Peten. In an acceptability study more than half of the farmers liked the architecture, yield potential and disease resistance of the variety ICTA-Tamazulapa.

Excessive rainfall is the major constraint for the introduction of varieties that were developed for other parts of the country. Some farmers considered that ICTA-Tamazulapa was not sufficiently tolerant to high rainfall. Due to the high humidity, seed storage through the year is very difficult. The present practice is to purchase seed from truck drivers that come driving from the south. Seed availability is determined by harvests in other parts of the country and by the contacts with these truck drivers. Improving seed distribution would have a large impact on bean production in the region.

In contrast to southeastern Guatemala, production in El Peten is mainly taking place in the "tapado" system. After broadcasting the seed in the fallow, the fallow is chopped down. The bean plants emerge after a while from the chopped down fallow. In the existing conditions, this "tapado" system forms an efficient and ecologically balanced system of bean production, as erosion of the shallow soils is avoided, organic matter is improved, and a minimum amount of minerals is lost by chopping the fallow. As shown in Table 1, production costs in the "tapado system" are lower than in production systems with formal land preparation and weeding ("postura" system). In both systems profitability is high, which indicates that bean production in El Peten will probably continue to expand.

COSTA RICA

In Costa Rica costs of production were analyzed for different production systems. Traditionally most beans were grown in the "tapado" system, but as the consequence of the introduction of improved varieties, plantings in systems with more formal land preparation and weeding ("espeque") have increased. Lately, beans have been produced in a semi-mechanized system (Table 2). In this system land is prepared by tractor, fumigations are done by hand or by tractor, a manual weeding might take place, and harvesting is done manually.

The rise of the semi-mechanized system might be explained by the high internal bean price in Costa Rica. Presently beans bring around US$600 per ton, while cotton production or cattle holding are becoming rapidly less attractive because of disease and marketing problems.

Through the availability of improved varieties and the existence of attractive support prices, Costa Rica has become a surplus producer of beans. By decreasing the support price of beans the government could transfer part of the benefits of improved bean production technology to the consumer. Presently the government of Costa Rica is slowly decreasing the support price and also considering other means to reduce bean surpluses.

At a full cost basis, semi-mechanized production is most efficient, by producing beans at a cost of US$0.40 per kilogram (Table 3). Both "tapado" and "espeque" systems have production costs that are around 10% higher. The production costs in the

semi-mechanized systems are low because yield levels are considerably higher than in the other two systems. Table 3 shows that yields double from "tapado" to "espeque" system, and are again 30% higher in the semi-mechanized system. Through the higher yields the semi-mechanized system compensates for its high production costs per hectare.

Table 3 also shows that cost structures are very different for the three systems. Whereas in the "tapado" and "espeque" system, labor is the most important cost element, machinery costs are more important in the semi-mechanized system. Both in the "espeque" and the semi-mechanized system, input costs are the second most important component. In the tapado systems input costs are very limited and land costs (often an imputed, not a real cost) becomes the second most important cost element.

The difference in cost structure has consequences for the impact of possible price reductions. Land costs and labor costs do not incur spending to the farmer if land and labor are his own. If land costs are assumed zero it is not any longer the semi-mechanized system which has the best income/costs ratio, but the "tapado" system. If labor costs are also assumed zero, the income/costs ratio for the semi-mechanized system would also be considerably worse than for the "espeque" system.

This suggests that the semi-mechanized system is least capable of accepting price reductions. If the government of Costa Rica would slowly reduce bean support prices the relative importance of the "tapado" system might well increase, as semi-mechanized production is reduced.

PERU

Within the framework of a three stage on-farm research course a diagnostic study of bean production throughout Peru was realized. Data collection was undertaken by INIAA-course participants, while data processing and analysis was undertaken in a joint CIAT/INIAA effort. The results of the study were used for three purposes: on-farm experiments were planned and executed; data were discussed at the national legume program meeting of INIAA; a research plan on the economics of bean production in Peru was developed with INIAA's Agro-Economics program.

The outcomes of this nation-wide diagnosis strongly suggest that bean production improvement needs a different focus in Coast and "Sierra" (mountainous) regions. As indicated in Table 4 the differences not only involve present germplasm and production problems, but also marketing arrangements, seed availability and input use.

In the Peruvian coast most production takes place in intensive monoculture, highly protected with chemical inputs. Farmers are very market oriented, as can be appreciated from the number purchasing seed and obtaining credit or the low percentage

of farmers that produce for home consumption only. The high spraying frequencies to protect the market value of the crop are of doubtful effectiveness. Yield levels are appropriate and the main focus of bean improvement in this area must be on cost reduction.

In the highlands, beans are grown by a completely different type of farmer. This farmer is often isolated from the market, plants small areas and considers beans as a crop for home consumption with a possible marketable surplus in good years. The potential for improved varieties appears more eminent in this area. The impact of such varieties will depend strongly on the improvement of seed distribution, credit availability and bean marketing mechanisms.

COLOMBIA

Participatory research

Simple participative research methods, based to some extent on the methodologies developed in CIAT's participative research program are in use. The aim of these activities is to improve the understanding of farmers' technological needs, and to increase feedback from farmers to researchers. This activity is highly complementary with the work of the On-Farm Research section.

In Colombia promising dry bean and snap bean lines were evaluated in participatory experiments. These experiments emphasized traditional agronomic management, to the extent that farmers could plant in the way they liked most. Farmers were visited every fifteen days, and mutual evaluations of varietal performance were undertaken, and farmer-applied treatments were recorded. In the case of snap beans, yields were not measured by weighing, but by farmer opinion of yield.

These experiments do not pretend to obtain detailed data on the performance of new lines, but provide information on the characteristics that farmers keep in mind when evaluating new varieties. This might help the program to develop better "farmer" adapted technology while suggesting optimum release strategies.

In the first semester five experiments were planted in Dagua, Valle del Cauca, in which 35 snap bean varieties were evaluated. This number proved to be high and consequently in the second semester the number of lines was reduced. In the second semester 10 snap bean trials with 10 varieties each and 9 bean trials with either four lines (six experiments) or seven lines (three experiments) were planted.

Commercial acceptability turned out to be the determining criteria in farmer's evaluations. Seed was collected and stored until the next plantings from highly marketable varieties.

Rust resistance and yield were both appreciated by farmers, but observed resistance did not lead farmers to change their spraying practices. Rapid and vigorous plant establishment was another factor of importance. Some new lines germinated badly and were discarded for that reason.

A constraint in the organization of these experiments was the difficulty in adapting cultural practices (such as chemical treatments) to the new varieties, which did not demand them. It is hoped that by combining farmers' and researchers' experiences in experimenting with cultural practices, the advantage of improved varieties can be more fully appreciated by farmers. In the next year varietal evaluations will be followed by cultural practices experiments, to understand whether this could change perceptions and requests of farmers with respect to improved bean germplasm.

Bean farm characterization

In eastern Antioquia a survey was held to characterize bean production within the farm context. The survey not only included production parameters but also household and consumption parameters. The survey tries to interpret the impact of technology in a household context.

To first classification of bean farms was made with a factor analysis. For the 213 farms included in the survey, six variables explained 70% of the differences in 19 original characteristics. The variables concerned were identified as: market access, production capacity, education level, labor availability, household size and credit use. The effect of the first three on some farm characteristics will be discussed here. Market access turns out to be an important production determining factor (Table 5). Area planted in beans, as well as production intensity, increases with improved market access. However in the group with the best market access, beans are less important again and more intensive crops such as fruits and vegetables dominate production systems. Market access also has an effect on the degree to which women participate in income generating activities. Both on-and off-farm labor increases with market access. However market access does not clearly influence nutrition levels.

The educational standard of the family influences the intensity of bean production. Intensive bean production was found more often among educated families. Education also has a marked positive effect on off-farm female employment. Improved education improves the income gaining capacity of the family by allowing the use of more intensive production methods and by increasing the chances of off-farm employment. The improved education also expresses itself in better nutrition.

The farm's production capacity has a clear positive influence on the area of beans planted, but does not correlate with production intensity. Female off-farm labor is negatively

related with production capacity. In farms with sufficient resources the need for the women to work off-farm is strongly reduced. Production capacity influences in a highly positive way the nutritional quality. Whereas the caloric availability is too low in the stratum with least productive capacity, it is more than sufficient in the group with most production capacity. It should also be noted that protein availability is more than sufficient in all groups.

Eastern Antioquia is a well-developed zone with good infrastructure. However, farmers having good market access continue to rely to a very large extent on home consumption. Farmers' concepts with regards to home bean consumption will remain an important adoption criterion even though farmers produce mainly for the market.

Production capacity correlates negatively with off-farm female labor. This suggests that the improvement of the productive capacity of small farmers through new bean technology might lead to decreased participation of women in the labor market. The extra time that the woman will spend in the household will form a big social benefit for many families.

Acceptability studies: Colombia, Peru, the Dominican Republic and Honduras.

During the last four years consumer acceptability studies were conducted in four countries. These studies were initially oriented towards methodology development and afterwards towards the consumer validation of new varieties.

Preferences in all countries are strongly focused to grain types available in the market (see Table 6). This is mostly true for wealthy consumers who purchase those beans they like most. Poor consumers often do not purchase the beans that they prefer, but those beans that are cheapest. It is questionable to what extent preferences have defined supply or supply has defined preferences. It appears that the steady availability of non-preferred bean types can change consumer attitudes, as shown by the case of imported pintos in the Dominican Republic or imported small red grain types in Colombia. With regard to the release of new varieties, the question is whether the discount that is needed to get access to consumers, is compensated for by lower production costs. If so, poor consumers will normally be the first to start purchasing new varieties.

Bean acceptability depends on dry grain appearance before cooking, cooking characteristics, and eating characteristics. In Honduras and the Dominican Republic, consumers prefer short cooking time and will search for fresh looking grain types. Seeds that stay hard after cooking depreciate strongly the preference for a certain bean type. In Colombia the color of the broth and the water absorption capacity influence acceptability.

Differences in acceptability criteria are strongly determined by cooking habits. Because Honduras or Dominican consumers do not soak beans, the hard to cook phenomenon is an important quality consideration in these countries. Because many Colombians use pressure cookers, cooking time is less important. Because Honduran consumers often grind beans, they prefer a thin, soft skin. Table 6 shows the interaction of cooking habits and quality preferences for those countries where consumer acceptability studies were done.

Table 1. Production cost parameters for "tapado" system and "postura" system, El Peten, Guatemala, 1986

	"Tapado" system	"Postura" system
Yield (kg/ha)	666	742
Total production costs (US$/ha)	97.50	131.60
% Labor costs	57	69
% Seed costs	30	21
% Land costs	13	10
Production costs (US$ per kg)	0.15	0.18
Income/costs	2.30	1.91

Source: Internal data, Bean Economics.

Table 2. The importance of different bean production systems, Costa Rica

Year	"Tapado" (%)	"Espeque" (%)	Semi-mechanized (%)	Total area/ha
80/81	80	18	2	23,681
86/87	49	38	13	57,989

Source: Consejo Nacional de Producción, San José, Costa Rica

Table 3. A comparison of production costs for the "tapado", "espeque" and "semi-mechanized" systems, Costa Rica 1986/1987.

	Tapado	Espeque	Semi-Mechanized
Yield (kg/ha)	513	1039	1380
Production costs	224.43	446.3	555.2
% Machinery costs	-----	-----	33.7
% Labor costs	52.3	43.0	16.3
% Input costs	10.4	33.3	28.2
% Land costs	33.8	17.0	15.3
% Interests	3.5	6.5	6.5
Production costs per kg	0.44	0.43	0.40
Gross income/costs	1.40	1.43	1.52
Income/costs (land costs =0)	2.23	1.81	1.79
Income/costs (land + labor costs = 0)	10.60	3.76	2.71

Table 4. Average characteristics of bean production in Coast and Sierra, Peru.

	Coast	Sierra
Percentage of National Bean Production	46	34
% Area on missed cropping	13	81
Yield (kg/ha)	1321	400
% Farmers that purchases seed in commercial outlets	46	4
Predominant seed types	medium bright yellow medium cream yellow	White small whites
Predominant growth habit	III, I	IV, I
Area planted with beans/ farm (ha)	4.1	1.2
Rotation crop	Rice	
Principal diseases	Rust	Anthracnosis Rust Powdery mildew
Principal insects	Leafminers	Leaf eaters (Diabrotica)
Insecticide/fungicide use (%)	100	35
Home consumption only (%)	0	30
Credit use (%)	72	3

Source: Diagnóstico de la Producción de Frijol-Perú, 1985-1986, N. de Londoño y H. de la Cruz, mimeograph, September 1987.

Table 5. The effect of market access, education level and farm production capacity on: bean production intensity; on-and off-farm female labor; and nutrition.

	Market Access				Education Standards			Production capacity			
	I	II	III	IV	I	II	III	I	II	III	IV
Area in beans (ha)	0.33	0.42	0.74	0.60	0.38	0.56	0.53	0.1	0.3	0.6	1.0
% in intensive production	0	14	58	25	26	21	39	33	33	33	30
On-farm female labor (hours/year)	614	73	41	107	39	114	60	42	54	105	82
Off-farm female labor (hours/year)	24	40	226	188	16	8	336	278	60	78	62
Energy intake (kcal/cap/day/) (on-farm)	1986	2136	1911	1962	1888	1900	2213	1505	1918	1860	2718
Protein intake (grms/cap/day)	93	115	102	109	94	98	122	82	106	95	135

Table 6. Bean acceptability parameters for different countries.

	Colombia	Dominican Republic	Honduras	Peru
Preferred grain size	large	small-medium	small	large-medium
Preferred grain form	round	oval/round	oval/round	oval
Color	cream mottled dark mottled	red mottled	red	yellow
Low income purchased grain size	medium	medium	small	small
Low income purchased color	red mottled	cream mottled	red	white
Pressure cooker [1]	++	—	-	—
Importance of cooking time [2)]	—	++	+	n. a.
Soaking [1)]	++	—	—	++
Hard seed phenomenon [2)]	—	+	+	n. a.
Grinding [1)]	—	++	+	++
Coat thickness	indifferent	thin	thin	thin

Note: Cooking habits are underlined

1) ++ = frequent
+ = often
- = sometimes
— = seldom
n.a. = not available

2) ++ = very important
+ = important
- = not important
— = very unimportant

Table 7: Snap bean consumption in Colombia, 1981 by income group and urbanization degree.

Income Stratum	Urban	Rural	Average
I	1146	313	697
II	1973	667	1358
III	3318	1766	2768
IV	3992	2049	3546
V	5570	1869	5058
Average	3521	1057	2662

Source: DRI-PAN Food Budget Survey, 1981, Bogotá.

A. UNIFORM NURSERIES

In its relationships with national programs the Bean Program germplasm flow operates at three levels:

1. The individual scientist's interactions with colleagues in each country. Flow of germplasm is involved in this relationship, although the material does not necessarily have commercial characteristics since it is intended primarily for use in specific projects. In addition, resistances for certain stresses are only considered when they have specific significance to the project under study.

2. The regional program level. This involves a close relationship between national programs of a certain geographical area coordinated by CIAT to complement the bean research carried out by each individual country. Types of nurseries and standards on reaction to stresses are fixed regionally.

3. The bean program level. This level involves attempts to coordinate relationships between two or more national programs from different regions or among individual scientists. The germplasm flow at this level has the following characteristics:
   - Only advanced lines having commercial grain characteristics are distributed.
   - The yield trials for international distribution do not include any susceptible material to any of these diseases: BCMV, angular leaf spot, rust, anthracnose or common bacterial blight.
   - No susceptible material for the five above mentioned diseases is included in the Observational Trials distributed internationally if any of these diseases are prevalent in the trial region.

In order to guarantee that the germplasm distributed fulfills these requirements, CIAT's Bean Program uses a three-stage evaluation system consisting of an equal number of uniform nurseries known as the VEF, EP and IBYAN.

First stage: The Bean Team Nursery (VEF)

This objectives of this nursery, begun in 1978, are:

a. To demonstrate the relative potential and deficiencies of advanced selections from all sources having commercial grain characteristics.
b. To enable selection of candidates for national or international nurseries.
c. To enable selection of parents for subsequent germplasm improvement.

Nursery management:

Entries are submitted at the beginning of the year and evaluated for a year in Colombia for reaction to diseases and insects. Yield, growth habit, grain characteristics and growth duration is also recorded. At the end of the year a detailed record of the evaluations is published and seed of all entries is ready for international distribution upon request. The whole nursery is kept in reserve for two years but only non-susceptible materials for any of the five diseases under evaluation are kept for the second stage (EP).

Results of the 1987 VEF (Semester A):

Table 1 shows the number of entries that exhibited a resistant or intermediate (R/I) reaction to the following diseases: bean common mosaic virus (BCMV), common bacterial blight (CBB), angular leaf spot (ALS), anthracnose (ANT) and rust. Furthermore, since CBB and BCMV are the two most common seed-transmitted diseases present in the main bean producing areas, results are shown on a number of materials with R/I reaction to CBB and resistant to BCMV.

The 1987 results are a confirmation of the increasing trend in the production of disease resistant bean lines to the five most common bean diseases. Results from previous years show that there are now enough sources of combined disease resistance to satisfy specific regional needs (Table 2).

Second stage: Preliminary Yield Trials (EP)

After the VEF is completed all non-susceptible materials are selected for a following phase (EP) which should corroborate the disease reaction of the selected entries and provide an estimate of their yield potential.

The objectives of this nursery are similar to those of the VEF with the obvious advantage that data accumulated from the previous VEF plus yield data should facilitate better selection.

Nursery management:

For the 1987 EP no entries were selected from the VEF if they showed susceptible reaction for CBB and BCMV. As a routine procedure all EP entries are subjected to the same kind of evaluation as in the VEF, except that in the EP, yield potential is estimated through replicated trials where materials are grouped according to plant and grain characteristics.

Results of the 1987 EP (Semester A):

From 1282 entries tested in the 1986 VEF, 380 were selected for further evaluation in EP nurseries; with the exception of climbing beans, only materials resistant to BCMV and either R or I to CBB were selected. Table 3 shows the effectiveness of selection based on two

very important diseases and the manner in which an important number of resistant materials is being built up.

Yield evaluations were conducted at CIAT-Palmira and Popayan. Materials were arranged in 12 trials according to their grain and plant characteristics. Complete data on the year round evaluation of the EP is published every year. The following summary of results shows the net superiority of the materials derived from the increased yield potential project; not only did they clearly outyield the checks in the experiments in which they were included, they also showed yield levels unmatched by the best lines and checks in other EP experiments conducted in the same season, location and experimental site (Tables 4, 5).

A summary of the results from previous years is presented in Table 6. Yield evaluation of 1257 lines corresponding to EP trials from years 1984 to 1986 identified 317 lines as high yielders: i.e. these lines outyielded the corresponding check variety in any one of the testing sites at any time. Out of these, 158 lines (13% of the lines tested) were of specific adaptation to Palmira; 117 (9% of the lines tested) were of specific adaptation to Popayan and 42 (3% of the lines tested) showed general adaptation to both testing sites. Table 7 shows the average yield increment over the checks of the high yielders; lines with general adaptation showed greater yield potential than those with specific environmental adaptation. Table 8 shows the mean yield of high-yielding lines, discriminated by their adaptation conditions. Table 9 describes disease resistance attributes of the 317 high yielders.

Third stage: International Bean Yield and Adaptation Nursery (IBYAN)

Entries for the uniform replicated yield trials are chosen from the EP. Up to 1986 entries were selected considering overall performance comprised of a combination of good yield, resistance to BCMV, grain with commercial characteristics, and any other outstanding quality. Starting in 1988 all advanced lines to be included in the IBYAN should show R or I reaction to CBB and anthracnose in VEF and EP evaluations and be resistant to BCMV. Due to these changes in the selection of materials, plus the fact that in this year the experimental lines began to be grouped into market classes, the distribution of the IBYAN was kept to a minimun during 1987 to avoid overlapping of trials with entries selected and classified under different standards.

Best entries based on results of trials conducted at Palmira and Popayan are shown on Table 10. Statistical data from IBYAN trials from 1976-1985 given in Table 11, show that, historically, approximately 25 to 42% of the trials include an experimental line that significantly outyielded the local check. This situation occurred least often in the black seeded bean trials, and most often in the small red seeded bean trials. Approximately 60 to 90% of the lines (according to seed color), significantly outyielded the control on at least one occasion. The cream color seeds were the ones showing this performance with least frequency and the red seeded beans showed the

highest frequency. Upon the examination of the performance across-sites on a per-case basis, we see that in 5.6% of cases the black seeded varieties significantly outyielded the check.

Complete results of IBYAN trials are reported annually in an special publication.

Table 1. Reaction to diseases of 1987 VEF entries.

Grain color	Total	R/I to all diseases[1]		R/I to CBB R to BCMV		Market Class
White	258	29	(11.2%)	116	(45%)	Alubia, Navy, Panamito, GN, WK
Small/Med Red	59	3	(10.3%)	6	(20.7%)	Red Mexican, Mex 80, Zamorano, etc.
Large Red	40	2	(5%)	3	(7.5%)	DRK, Radical, Sangretoro
Red Mottled	123	44	(35.8%)	80	(65%)	Calima, Gualí, Tundama, Pompadour
Pink	24	2	(8.3%)	7	(29.2%)	LRK, Rosinha
Pink Mottled	18	9	(50%)	14	(77.8%)	Andino, Flor de Mayo
Cream and Beige	15	1	(6.7%)	1	(6.67%)	Bayo Bolón, Bayo Titán, Mulatinho
Cream Mottled	61	7	(11.5%)	18	(29.5%)	Cranberry, Cargamanto, Llanogrande
Cream Striped	30	3	(10%)	3	(10%)	Carioca, Ojo de Cabra, Pinto
Yellow	33	0	(0%)	2	(6.1%)	Canario, Liborino
Black	33	13	(39.4%)	26	(78.8%)	Negro
Other	137	15	(10.9%)	124	(90.5%)	Snapbean and other classes
	801	128	(16%)	400	(49.9%)	

[1] BCMV-CBB-ALS-ANT-Rust.

Table 2. Number of bean lines with resistance to 5 of the most important diseases evaluated in VEF nurseries from 1979-1986.

Diseases	Number of lines	Reaction			
		R		R/I	
BCMV	6730	4980	(74%)	-	
ANT	7093	2581	(36%)	4818	(68%)
RUST	7165	2507	(35%)	5046	(70%)
ALS	7017	1171	(17%)	5281	(75%)
CBB	7165	71	(1%)	2271	(32%)
RUST-ALS-BCMV	6749			2669	(40%)
RUST-ANT-BCMV	6749			2199	(33%)
ANT-ALS-CBB	6749			1796	(27%)
RUST-ALS-CBB	6749			1488	(22%)
ANT-ALS-CBB	6749			1290	(19%)
RUST-CBB-BCMV	6749			1102	(16%)
RUST-ALS-ANT-CBB-BCMV	6749			617	(9.4%)

R = Resistant
I = Intermediate

Table 3. Reaction to diseases of 1987 EP entries.

Type	Total	R/I to all diseases[1]		R/I to CBB R to BCMV	
Bush - Black	27	8	(29.6%)	27	(100%)
Small Red	31	18	(58.1%)	31	(100%)
Red Mottled	87	59	(67.8%)	74	(85.1%)
Small/Med White	21	7	(33.3%)	17	(81%)
Mex. & Braz. Types	139	127	(91.4%)	134	(96.4%)
Climbing	75	25	(33.3%)	26	(34.7%)
87 EP	380	244	(64.2%)	309	(81.3%)
1979-86 EP	1957	197	(10.1%)		

[1] BCMV-CBB-ALS-ANT-Rust

Table 4. Average yield (kg/ha) of bush lines evaluated in Palmira, Colombia. 1987 EP-Semester A.

Trial[1]	Line	kg/ha	% relationship with best check: In trial	% relationship with best check: In site[2]	Best Check	kg/ha	Mean	LSD	CV
EP trials with lines from high yield project									
50 A (n = 49)	A 605	4431	158	158	IPA 7419	2803	2522	82.9	14.2
40 A (n = 36)	A 673	4157	214	148	Ojo de Cabra	1945	2786	152.4	20.1
40 B (n = 36)	A 752	4005	286	143	Bayo Titán	1401	2616	133.5	18.7
50 B (n = 25	FEB 127	3330	164	119	Carioca 80	2036	2238	132.0	17.8
Other EP trials									
20 B (n = 20)	AND 382	2649	129	94	A 21	2056	1726	107.5	16.6
25 A (n = 25)	AND 632	2612	106	93	BAT 1297	2454	1853	106.2	17.3
10 (n = 30)	XAN 108	2559	115	91	ICA Pijao	2220	1782	95.7	14.1
20 A (n = 16)	AFR 251	2299	99	82	A 21	2320	1743	129.3	17.5
30 (n = 25)	PAC 18	1970	92	70	78-0374	2139	1326	86.5	19.7
25 C (n = 20)	AND 625	1800	101	64	BAT 1297	1777	1353	111.4	17.3
25 D (n = 20)	AFR 314	1639	87	58	BAT 1297	1892	1123	104.0	24.1
25 B (n = 12)	AFR 285	1380	164	49	Calima	868	957	113.0	15.9

1 50 = Cream, Brazilian type, 40 = Mexican highland types, 20 = Red, small seeded, 25 = Red mottled, large seeded, 10 = Black, small seeded, 30 = White, medium and small seeded.

2 IPA 7419 = 100%

Table 5. Average yield (kg/ha) of bush lines evaluated in Popayan, Colombia. 1987 EP-Semester A.

Trial[1]	Line	kg/ha	% relationship with best check: In trial	In site[2]	Best Check	kg/ha	Mean	LSD	CV
EP trials with lines from high yield project									
50 A (n = 49)	FEB 85	4322	131	1.09	IPA 7419	3295	3210	92.9	12.5
50 B (n = 25)	FEB 131	4017	110	1.02	Carioca 80	3663	3333	92.6	8.4
Other EP trials									
25 A (n = 25)	Africa 244	3651	117	0.92	BAT 1297	3118	2892	115.0	12.0
30 (n = 25)	PAN 166	3629	92	0.92	Ex Rico 23	3955	2554	119.2	14.1
25 D (n = 20)	AFR 314	3279	87	0.83	BAT 1297	3784	2246	89.7	24.1
20 B (n = 20)	RAB 365	3150	101	0.80	A 21	3119	2232	119.2	14.2
20 A (n = 16)	AND 682	2963	101	0.75	A 21	2937	2598	159.7	14.5
10 (n = 30)	XAN 206	2783	99	0.70	ICA Pijao	2812	2132	137.0	16.8
25 B (n = 12)	AND 660	2701	113	0.68	Línea 24	2392	2362	138.7	7.9
25 C (n = 20)	RIZ 73	2513	103	0.64	BAT 1297	2449	2139	142.5	17.4

[1] 50 = Cream, Brazilian type. 25 = Red mottled, 30 = White, medium and small seeded, 20 = Red, small-seeded, 10 = Black, small seeded.

[2] Ex Rico 23 = 100%

Table 6. High yield potential lines produced on each bean type. (Totals over the three years). EP 1984-1986.

Bean Types	Number of lines tested	No. of lines superior at: CIAT	Popayan	Both	Total	%
Bush						
Red Mottled	396	53	32	2	87	(22)
Small Red	141	45	17	5	67	(48)
Pacific Coasts	72	4	23	6	33	(46)
Small White	110	23	5	4	32	(29)
Mexican Types	22	10	-	3	13	(59)
Brazilian Types	57	3	1	-	4	(7)
Medium White	18	3	1	-	4	(22)
Small Black	114	-	3	-	3	(3)
Climbing						
Warm temperatures[1]	155	17	24	22	63	(41)
Cold temperatures[1]	172	-	11	-	11	(6)
Total	1257	158	117	42	317	
%	100%	13%	9%	3%	25%	

[1] Evaluated at "La Selva" Experimental Station (2400 m.s.n.m. approx.)

Table 7. High yield potential lines: Mean increment in yield over the checks. EP 1984-1986.

Superior at:	No. of lines	Mean yield (kg/ha)	Mean increament over the checks (kg/ha)
CIAT only	158	2334	724
Popayan	117	2433	793
Both sites	42	CIAT: 2731	1515
		Pop: 3327	1342
Total	317		

Table 8. High yield potential lines: Yield per bean type. EP 1984-1986.

Bean Types	No. of lines	Yield, when superior at:			
				Both	
		CIAT	Popayan	CIAT	Popayan
Bush					
Red Mottled	87	2370	1949	2536	2372
Small Red	67	2222	2364	2219	2705
Pacific Coasts	33	2016	2100	2016	1873
Small White	32	2904	1923	3074	2625
Mexican Types	13	2096	-	2419	2724
Brazilian Types	4	3657	3134	-	-
Medium White	4	2391	1423	-	-
Small Black	3	-	2789	-	-
Climbing					
Warm temperatures	63	1715	2126	3789	4162
Cold temperatures[1]	11	-	5479[1]	-	-
Total	317	2334	2433	3123	3327

[1] Evaluated at "La Selva".

Table 9. Disease resistance attributes of high yield potential lines.

Attribute		No. of lines	%
	High Yield potential	317	100
R to	CMV	269	85
R-I to	Anthracnose	229	72
	Rust	189	60
	ALS	167	53
	R-Ant-CMV	125	39
	Ant-ALS-CMV	108	34
	R-ALS-CMV	102	32
	BB	68	21
	R-BB-CMV	36	11
	R-BB-ALS	36	11
	Ant-BB-ALS	28	9
	All diseases	19	6

Table 10. Yield (kg/ha) of most outstanding bush lines in 1987 IBYAN trials tested in Palmira and Popayan. Semester A.

Trial	Line	kg/ha	Best check = 100%	Mean	LSD	CV	Site
Black (n = 20)	NAG 46	3626	113	3046	397	7.9	Popayan
Small Red (n = 16)	XAN 194	2459	125	1946	653	20.1	Palmira
Red Mottled (n = 24)	ICA 15384	3174	118	2580	484	11.4	Popayan
Red Mottled: Habit II (n = 14)	PAI 26	2703	234	1591	479	17.9	Palmira
	ICA 15403	3403	137	2823	456	9.6	Popayan
Guali and Calima types (n = 14)	PVA 844	3158	145	2629	706	16.0	Popayan
	PVA 844	1213	159	903	500	33.0	Palmira
Red Kidney type	ZAA 105	1322	181	834	389	28.0	Palmira
	ZAA 105	3335	128	2386	705	17.7	Popayan
Small White: Navy	EMP 175	2559	120	1838	794	25.5	Palmira
	PAN 126	3753	102	3087	703	13.5	Popayan
Carioca type	AFR 81	3540	106	2978	589	11.7	Popayan
Mulatinho type	RIZ 62	3820	104	2705	828	18.2	Popayan

Table 11. Yield of experimental lines and checks when the lines outyielded the check. IBYAN 1976-1985.

Year	No. of trials			No. of lines		No. of cases	
	Total	Sig.	%	Total	Sig.	Sig.	%
Black Beans							
76	43	10	23.3	10	10	28	6.5
77	33	4	12.1	20	6	7	1.1
78	37	5	13.5	20	18	23	3.1
79	36	10	27.8	18	11	18	2.8
80	47	17	36.2	13	13	81	13.3
81	27	4	14.8	12	4	4	1.2
82	32	10	31.3	12	10	24	6.3
83	19	9	47.4	15	14	31	10.9
84	20	5	25.0	11	8	9	4.1
85	31	10	32.3	13	13	40	9.9
TOTAL	325	84	25.8	144	107	265	5.6
Small Red Beans							
80	28	16	57.1	8	8	46	20.5
81	10	3	30.0	7	3	3	4.3
82	16	1	6.3	7	1	1	0.9
83	14	9	64.3	15	15	41	19.5
84	11	5	45.5	11	11	29	24.0
85	19	11	57.9	14	14	65	24.4
TOTAL	98	45	45.9	62	52	185	18.6
Red Mottled Beans							
81	21	7	33.3	6	6	26	20.6
82	20	2	10.0	8	3	3	1.9
83	20	8	40.0	9	9	22	12.2
84	12	8	66.7	11	11	32	24.2
85	35	9	25.7	18	18	62	9.8
TOTAL	108	34	31.5	52	47	145	11.9
Cream Beans							
80	17	10	58.8	13	13	40	18.1
81	12	4	33.3	9	9	15	13.9
82	5	2	40.0	18	2	3	3.3
83	21	6	28.6	16	15	28	8.9
84	7	1	14.3	11	1	1	1.3
TOTAL	62	23	37.1	67	40	87	10.7

B. LATIN AMERICA

1. Central America and the Caribbean

The Central American and Caribbean bean project, financed by COSUDE, entered a new stage in 1987 as national programs assumed more responsibility for technical and administrative activities. The Executive Committee, composed of the 10 national bean program leaders from the region, met for the first time in Guatemala during the XXXV Annual PCCMCA Meeting. During this meeting regional research subprojects were approved and funds to support these projects were distributed.

Research highlights

The principal achievements this year have been the consolidation of strong research networks to address the regional disease problems of Apion, BGMV, and Mustia; and the increase in a horizontal exchange of technology and information among national programs.The project continued to receive strong logistical support from IICA through its offices in each of the countries in the region as well as from headquarters. ICTA also brought considerable support to the project from its headquarters in Guatemala.

Because of the progress that has been made in developing varieties and germplasm resistant to the bean golden mosaic virus, the Executive Committee decided that this disease should no longer be considered top priority and should be replaced by an earliness project. This new sub-project will be the responsibility of Guatemala, with support from Mexico, Cuba and Nicaragua. CBB will continue to be the responsibility of Cuba, with support from Nicaragua, the Dominican Republic, and Haiti. Apion research will be under the direction of Honduras, with support from Guatemala, El Salvador, and Mexico. Mustia activities will be led by Costa Rica, with collaboration from the Dominican Republic, Panama, El Salvador and Honduras. Project scientists continue their research on BGMV, Mustia, adoption studies, and on-farm research, particularly in El Salvador.

Training continues to place major emphasis on courses for on-farm research. Additional emphasis is placed on courses directed towards developing "artesanal" seed production to overcome the quality-seed bottleneck that often obstructs the adoption of new varieties by small farmers. These courses always include agricultural leaders from the community. Similarly, in on-farm research the farmer whose land is used always participates as one of the researchers. Thus far the results are very encouraging.

All courses have been conducted in such a way as to maintain an active interchange between CIAT, national programs, trainees

and farmers. Various workshops were conducted on breeding, BGMV, and Apion to evaluate recent progress and plan future activities, based on the needs and abilities of each program. Exchange of personnel and materials among the countries within the region has increased markedly, to reinforce the multidiciplinary nature of the various sub-projects.

National programs have released several improved varieties, the advantages of which are familiar to farmers because of their superior performance in on-farm trials. Examples include ICTA-Ostua in Guatemala, Chirripo in Costa Rica, Catrachita in Honduras, and Siboney in Cuba. Mexico, El Salvador, the Dominican Republic, and Nicaragua have lines in on-farm trials ready for release as varieties. Despite drought stress suffered by most of these lines, a stable yield increase was observed in almost all trials.

Apion continues to be the most important insect pest of beans in Mexico, Guatemala, El Salvador, Honduras, and northern Nicaragua, where almost 90% of the harvest of susceptible varieties is attacked. This year the research network to address this problem was backstopped by conducting a workshop in evaluation methods in order to standardize approaches used by the different programs. Selection criteria as well as basic studies on the insect were addressed in the workshop, as well. The results of various trials evaluating progeny of crosses among tolerant parents indicate that not only is the tolerance heritable, but levels of parents can be surpassed, perhaps through transgressive segregation.

Efforts continued to improve integrated control of web blight by addressing cultural practices. From mean yields it was determined that a planting distance of 0.60 m between hills was superior to a spacing of 0.45 and 0.30 m. Highest yields were obtained from planting densities of 200,000 plants/ha (Table 1). The superior results of this spacing and density combination is probably because better aeration and lighting in the plots is unfavorable for pathogen development.

In addition to spacing, planting on raised hills gave yields which surpassed by 36% those obtained from planting on level ground. The highest yields were from Revolution 81, Huetar, Chirripo, Huasteco, ICTA Osuta, and Talamanaca Significant variety x planting system interaction showed the highest yields for the following varieties: Chirripo (137 g/p), Huasteco (129 g/p), Revolution 81 (117 g/p), and Huetar (109 g/p).

Nurseries

Thirteen nurseries were planted throughout the region in 1987, and various lines selected. From the Elite BGMV nursery were selected: ICTA-Quetzal, Porrillo Sintetico, HT 7719-5-2-M (=Chirripo), Negro Huasteco, ICTA 883-2-M, RAB 70, ICTA 81-64,

DOR 364, DOR 366, and NDDG 12440-CM (20-c). Selections from the Elite Mustia nursery were: HT 7716, Cgirripo, Orgulloso, MUS 30, XAN 226, and RAB 48. From the Elite National Mustia nursery selections were: XAN 222, HT 7700-1-M, ICTA 883-2-M, RAB 377, and lines RZHC 13672, RZHC 13665, RAO 3, RAO 27, and A-40.

Table 1. Effect of distance and densities on yield and losses caused by T. cucumeris.

EFFECT	YIELD	% LOSS
Distance 0.60 m	68.0 a	
0.45 m	24.0 b	65
0.30 m	22.0 c	68
Density 200,000 pl	43.0 a	
250,000 pl	34.0 c	21
300,000 pl	38.0 b	12

Table 2. Differences in yield (g/p) and severity (%) of T. cucumeris in two planting systems with 10 cultivars of common beans.

	HILLS		LEVEL	
CULTIVAR	YIELD	SEVERITY	YIELD	SEVERITY
Revolucion 81	117	31	101	35
Huetar	109	28	83	40
Chirripo	138	20	49	37
Huasteco	129	24	44	42
Icta 883	64	26	41	40
Icta Ostua	62	23	37	37
Talamanca	62	27	33	45
Bat 1297	47	36	27	40
Orgulloso	28	38	22	56
	7	42	6	42
Mean	76	30	44	41

2. Andean Zone

Cultivar improvement for the Andean Zone was continued in 1987 in collaboration with the national programs of Colombia, Ecuador, and Peru. Seed shipments to these countries were comprised of F_2 segregating populations and advanced lines from the VEF, EP, IBYAN, and international disease nurseries. A total of 572 crosses were made this year among beans of bush and climbing growth habits for the three countries. The principal objectives of the Andean Zone breeding programs are to combine disease resistance with commercially acceptable grain types.

Breeding work directed toward the cool, high altitude regions (1800-2800 masl) placed emphasis on combining resistance to anthracnose, Ascochyta, and halo blight into acceptable grain types. The majority of the crosses for these regions are among climbing beans which are intercropped or relayed with maize. For the mid-altitude regions of Colombia and Peru (1000-1700 masl) bush beans are generally grown either in association (with maize or other crops) or in monoculture, and breeding efforts are aimed at incorporating resistance to web blight, angular leaf spot, common bacterial blight, rust and anthracnose. For coastal Peru, resistance to BCMV, rust, root rots, and nematodes are given highest priority.

Breeding to increase yield potential in medium to large seeded bush beans is also being conducted at CIAT principally by combining appropriate grain types into indeterminate type 2 and 3 growth habits. Breeding lines from this project are now being evaluated in VEF and EP nurseries and the best lines will enter into a series of trials over several locations to measure yield stability over time and enviromental conditions, while determining the relative yield advantage of these new materials over traditional large seeded determinate growth habit varieties.

Regional program: Colombia

Climbing bean improvement programs for Colombia are conducted in collaboration with ICA at the research stations of La Selva, Medellin (2100 masl) and Obonuco, Pasto (2600 masl), although some selections are also conducted at Popayan (1700 masl) for warmer temperature adaptation.

ICA-La Selva

At ICA-La Selva, the collaborative breeding program focuses principally on improving climbing beans grown in relay with maize. In 1987, 151 crosses were made to combine resistance to anthracnose and Ascochyta in high yielding commercially acceptable grain types.

Yield trials were conducted with 94 advanced lines and 3 local checks. Of these, 43 lines were selected for further trials based on their grain type, yield and resistance to anthracnose. None of the lines tested, however, were higher yielding than Frijolica LS-3.3 (1826 kg/ha) a variety released by ICA in 1985, though the majority of the lines were superior in yield to the other two local checks: ICA Viboral (1138 kg/ha) and ICA Llanogrande (1247 kg/ha). The best of these lines will enter the VEF 88 and be tested in on-farm trials within the region during 1988.

Studies were also conducted on-station with 32 elite lines to identify materials with good yield under high and low soil fertility. Of these, 14 lines (LAS L-67, 74, 79, 79, 94, 106, 109, 110, 111, 181, 210, 231, 219, 220, and 231) were selected as candidates for regional trials in the cool, highland regions of Colombia (Table 1). The majority of these elite lines come from crosses with G 5702 (Cargamanto), the popular local variety, and G 12488 (ICA Llanogrande), a variety resistant to anthracnose.

Breeding bush beans for adaptation to medium-high elevtions is also conducted at ICA-La Selva and the ICA experimental station of Tulio Ospina (1400 masl). At present 84 F_7 lines from Tulio Ospina, and 188 from La Selva have been selected.

Advanced elite bush bean lines were evaluated in 33 locations in regional trials in the department of Antioquia. The line PVA 476, resistant to anthracnose, had yields superior to the local farmers check in 56% of the locations and the grain type was considered to be acceptable for the local market requirements.

Seed multiplication of PVA 476 is underway for possible variety release.

ICA-Obonuco

At ICA-Obonuco, the major emphasis of the collaborative ICA-CIAT breeding program is on improving climbing beans grown in association with maize for high elevations and cold temperatures. In 1987, 102 crosses were made at Obonuco to combine resistance to anthracnose, ascochyta and halo blight into commercially acceptable cultivars.

Regional trials of elite advanced lines were conducted in four locations in southern Nariño near the city of Ipiales. Four lines had yields superior to the local check Mortiño, though the differences were not significant (Table 2). The line TrB 3042 has continued to show good adaptation and tolerance to the principal diseases on research station and on-farm trials, and is a candidate for varietal release in 1988. The highest yielding line in the regional trial, Frijolica 0.3.2 -released as a variety in 1986- continues to perform well within the region and is resistant to anthracnose, halo blight and rust, and matures 30 days earlier than Mortiño.

The principal objective of the bush bean breeding program at Obonuco is to obtain varieties adapted to the cold climate that are

resistant to halo blight and anthracnose. The potential advantage of bush beans in this region is for use in rotation with other crops such as potatotes, wheat or barley, and the early maturity (6 months) of the bush beans as compared to climbers (8-10 months) would enable farmers to obtain two crops per year. In 1987, 13 bush bean crosses were made. Frijolica 0.3.1, a bush beam variety released in 1986, resistant to anthracnose and halo blight, figured prominantly as a parent in the crosses. Another line Antioquia-8(11) was also used as a parent and it continues to show good adaptation from 1700-2700 masl. In a yield trial conducted in Funes (2200 masl) in Nariño, Antioquia-8 (11) had significantly higher yields (334 kg/ha) than the local check Argentino (143 kg/ha). This line is also being considered for variety release.

Regional program : Ecuador

The national legume program of INIAP has two main research stations located at Santa Catalina (2700 masl) and Cuenca (2200 masl). The Ecuadorian program is comprised of three persons who are faced with too few resources and personnel to easily conduct trials. Nevertheless, F_2 segregating populations and advanced lines from CIAT were sent to INIAP during 1986 and 1987 for screening and selection.

Regional trials of red and white seeded climbing beans were planted in 1987 in Santa Catalina and Ereuqui (Table 3). E 605 (Frijolica 0.3.2 in Colombia), G 8160, and ZAV 84011 red climbing bean lines were well adapted to both locations. E 605 is presently in seed multiplication for possible official variety release.

Among white seeded climbers, G 11780-F has continued to show high yields over the last two years, and E 849 (Bolon Bayo) is presently being multiplied as a possible variety release due to its high yields and highly preferred grain type in the market. Unfortunately, E 849 is very susceptible to anthracnose and is late maturing.

Regional Program: Peru

The major bean producing areas of Peru are the coastal and sierra regions, with some minor production from the selva. Bean production in the coastal region is comprised predominately of medium to large seeded canario bush beans (center and southern coastal region) and bayos (northern coastal region) while small seeded "panamito" bush beans are also cultivated on a smaller scale, primarily in the north. Canario grain types have the highest demand and market price in Peru. Beans on the coast are grown in monoculture under irrigation and usually in rotation with other crops, especially rice. Water availability during the normal bean growing season in many areas is scarce and as a result the bean crops may only receive one irrigation (at planting) during the entire growing season. Because of the unique climatic conditions of the coastal region of Peru (a cool desert), many of CIAT's elite lines are not adapted to the region. Breeding and selection activities, therefore, are carried out by the national program of INIPA. CIAT assists in providing sources of resistance to diseases and drought, and in their BCMV resistance verifications.

The predominate cropping system in the sierra region is climbing beans in association with maize, although bush beans may also be grown with maize or in monoculture in the southern sierra regions. The majority of the farmers in the sierra are subsistence agriculturalists and the bean crop may receive little or no inputs with correspondingly low yields. The principal grain types are large white beans (caballeros) in the north, and large yellow and red beans in the south.

The production constraints of the sierra region of Peru are similar in many ways to the sierra region of some areas of Colombia. CIAT collaborates with INIPA in the breeding and selection of materials for this region. In 1987, 49 segregating F_4 populations from crosses designed to incorporate anthracnose and ascochyta blight resistance into large seeded white and yellow grain types and ñuñas (pop beans), and 93 advanced climbing and bush bean lines, were sent to Cajamarca for screening and selection.

Variety yield trials were conducted in on-farm trials in the department of Cajamarca in association with maize (Table 4). Gloriabamba, the climbing bean variety released in 1985 from CIAT's germplasm bank (accession G 2829) continues to show a large yield advantage over the local checks and other promising materials being evaluated. Puebla 444 (accession G 3410), a white seeded material, is also being considered for possible variety release.

Table 1. Yield of selected elite climbing bean lines under high and low fertile soils, ICA-La Selva, Colombia.

Identification	Cross	Growth Habit	Anthracnose	Ascochyta	100 seed wt.	Seed color[1]	Fertility level[2] high	Fertility level[2] low
LAS LS-67	G 5702 x G 12488	4B	1	4	50.6	C/R	1132	1066
LAS LS-74	G 5702 x (G 5702 x G 5141)	4B	1	4	52.5	C/R	1342	1029
LAS LS-79	G 5702 x G 12488	4B	1	4	51.4	C/R	1238	733
LAS LS-94	G 5702 x (G 5702 x G 5141)	4B	1	4	56.6	C/R	1232	775
LAS LS-106	G 5702 x G 12488	4B	1	4	54.4	C/R	1779	975
LAS LS-109	G 5702 x G 12488	4B	1	4	55.5	C/R	1873	1002
LAS LS-110	G 5702 x G 12488	4B	1	5	57.0	C/R	1817	1204
LAS LS-111	Bolivia 17 x Bola Roja	4B	1	3	64.6	C/R	1575	1049
LAS LS-181	G 2371 x V 7918	4A	1	4	35.9	R	1144	1152
LAS LS-210	G 11821 x G 12488	4B	2	5	50.8	R	1720	1125
LAS LS-213	G 11821 x G 12488	4B	1	4	55.3	R	1714	965
LAS LS-219	G 11821 x G 12488	4B	1	5	63.7	R	1389	1140
LAS LS-220	G 11821 x G 12488	4B	1	4	65.5	R	1534	1179
LAS LS-231	G 11821 x G 12488	4B	1	4	56.2	R	1176	874
Frijolica LS-3.3	Mex. 235 x Bola Roja	4B	1	4	59.5	C/R	1793	876
LSD 5%							413	412

[1] Seed color: C/R (cream with red mottled)
R (red)

[2] High fertility = 2.5 tons of chicken manure/ha and 200 kg/ha of 10-30-10.
Low fertility = 2.5 tons of chicken manure/ha.

Table 2. Yield of regional trials of climbing bean lines grown in association with maize in Ipiales (average of four locations).

Material	Seed Color	100 seed wt.	Yield (kg/ha)	
			Beans	Maize
Frijolica 0.3.2[1]	Purple/cream	71.4	567	1466
TIB 3042	Red/cream	64.3	547	1594
V 8001-433	Red	64.2	521	1893
G 12592	Red/cream	61.3	467	1956
Mortiño (check)	Purple/cream	71.0	458	1437
32980-1-41	Cream/black	64.8	449	1652
G 12261	Cream/black	83.2	442	1850
Sangretoro	Red	59.7	432	1669
V 8014-424	Red	61.7	432	1794
OBO-V-26	Purple/cream	46.1	426	1637
V 8001-423	Red	52.7	416	1672
G 11806	Cream/purple	82.0	411	1719
V 8001-47	Red	65.3	397	1537
G 12716	Cream/pink	68.2	384	1632
V 8012-43 (AND 53)	Red	54.6	359	1659
Mean		63.9	442	1686
LSD 5%			133	477

[1] Variety released in 1986 previously known as E 605.

Table 3. Regional yield trials of red and white seeded climbing beans in Ecuador.

Red seeded climbers				White seeded climbers			
Material	Santa Catalina	Urcuqui	Mean	Material	Santa Catalina	Urcuqui	Mean
E 794	1877	656	1266	G 11780-F	1424	1246	1335
G 8160	1840	945	1392	E 849	1300	845	1072
V 8001-443	1826	615	1220	G 11768	1241	606	923
V 8012-43 (AND 53)	1788	464	1126	G 12667	1076	404	740
V 8001-438 (AND 39)	1573	717	1145	G 11821	1002	657	829
ZAV 84011	1528	869	1198	V 8008-427	959	385	672
TIB 2041	1504	629	1066	G 11780	835	651	743
E 605*	1500	1057	1278	V 8008-430	794	505	649
G 11820	962	643	802	Bolon Blanco*	710	568	639
TIB 1441	649	658	653	V 8008-428	297	386	341
Mean	1505	725	1115	Mean	964	625	794
LSD 5%	484	227		LSD 5%	593	203	

* Local Checks

Table 4. On-farm bush bean variety trials grown in association with maize in the department of Cajamarca, Peru.

Material	Growth habit	Cajabamba[1]		Chota		San Marcos		Cutervo	Means	
		beans	maize	beans	maize	beans	maize	beans	beans	maize
Gloriabamba	4A	918	3981	634	1866	1028	3007	349	732	2951
Puebla 444	4A	588	4268	475	2211	1112	3074	322	624	3184
Cajamarca 64-1	4B	548	3965	208	1873	672	2658	176	401	2832
Guatemala 1076	4A	515	3731	743	1916	674	2676	489	605	2774
ZAV 8398	4A	470	4282	445	2089	810	3271	151	469	3264
G 2333	4A	420	3166	346	1941	1383	3227	241	597	2778
PG 149 x PI 311915	4A	376	3085	216	2054	736	3075	169	349	2738
Local Check	4A	329	3816	371	1553	897	2992	147	436	2787
V 7423-27-473	4A	295	3890	376	2026	504	3134	156	333	3017
G 10889	4A	258	4336	174	2036	791	2749	305	382	3040
V 7423-27-173	4A	245	4508	351	1791	655	3314	179	358	3204
PG 106 x PG 154	3B	309	3977	294	2035	778	3249	361	436	3087
Linea 23	1	217	4665	360	2017	448	3211	162	297	3298
Red Kloud	1	163	4413	224	1612	550	3368	154	273	3131
Mean		397		528		779		256	449	
LSD 5%		181		-		239		45		

[1] Average of three locations in Cajabamba, two locations in Chota, and one location in San Marcos and Cutervo.

3. Brazil

The participation of CIAT lines in Preliminary Yield Trials (EPR) in Brazil has decreased over the years. This is the result of CIAT shipping fewer fixed lines to Brazil as the capability of the Brazilian breeders to produce their own advanced breeding lines increased. In the EPR 1986-88, CIAT fixed lines equalled 20% of the total with CNPAF providing 65%. Experience with shipments received from CIAT indicated that it would be more effective if CNPAF-CIAT breeders jointly planned any project involving importation of lines. Implementing this new approach, 280 segregating populations were jointly chosen and shipped to CNPAF in 1985. In the meantime, CNPAF began generating their own breeding lines. From a combination of the joint breeding project and CNPAF's own breeding project, CNPAF breeders generated more than 13,000 advanced breeding lines, the best of which will be incorporated in the coming cycle of EPR 1988-90. CIAT's participation, in the future, is expected to be limited to supplying the source or parental materials for the breeding program as well as some fixed lines. The same strategy may be applied in the future to some state institutions where the need for receiving breeding lines from outside the state decreases as breeding programs become stronger, with these institutions receiving CNPAF's and CIAT's help with segregating populations only upon request. Depending on their progress, they may also in the future receive, as does CNPAF, the sources for the breeding programs and, to a lesser extent, the fixed lines.

Germplasm flow

The 738 materials received during 1986 were planted in CAM in late March 1987 and were distributed to the corresponding institutions.

Institutions that received germplasm from CIAT:

Institution	Varietal character	Quantity
EPAMIG/Minas Gerais	White large seeded	36 lines
EMCAPA/Espirito Santo	Black seeded bush	44 lines
	Climbers	102 lines
EMPASC/Santa Catarina	1985/86 IBAT	100 lines
CNPAF/Goias	Early maturing	18 lines
	Web blight tolerant	6 lines
PESAGRO/Rio de Janeiro	Snap bean	236 lines

IAPAR/Parana	Snap bean	236 lines
IAPAR/Parana	Low soil phosphorus	11
EMGOPA/Goias	Snap bean	236 lines

EPR (Preliminary Yield Trials) 1986-87

In each seed color group the number of entries of the third generation EPR is rather small in order to best serve the needs of several institutions that can handle only small amounts of entries. In addition to the EPR, CNPAF in 1987, began the EPL (Ensaio Preliminar de Linhagen), an equivalent of the VEF at CIAT. The EPL was offered to state institutions whose better infrastructures and personnel capacities could handle it. This EPL was shipped to EMGOPA, EMPAMIG, and CPATB, with CNPAF expecting selected lines from these nurseries to compose future EPRs. Outstanding lines from the EPL can be tested in state trials since many institutions used the EPL as the introduction nursery.

Partial EPR results:

The Black EPR

Nine experiments (six from the south and three from the centralwest of Brazil) were reported. The ten best advanced breeding lines and their elite and local checks are shown in Table 1. Maximum yield in some locations reached three tons/ha but means greater than two tons/ha for advanced breeding lines were reached in only three locations. The AN 512573-0, AN 51574-0, 84 VAN-18, AN 512646-0, and W 22-24 were the lines that most frequently appeared among the 10 best.

The Cream EPR

The traditional cream seeded locations in the northeast of Brazil suffered severe drought. Only two results were reported from the northeast when beans were planted late in the season (in Poco Verde/SE and Santana de Ipanema/AL). When climatic conditions during the growing season were favorable, mean yields above 1.5 ton/ha were obtained by the 10 best advanced breeding lines (in Poco Verde and Ponta Grossa). On the other hand, when climatic conditions were unfavorable (in Santana de Ipanema/AL and Selviria/MS), maximum yields were less than 600 kg/ha and another set of advanced breeding lines appeared in the 10 best advanced breeding lines. The most frequent lines appearing in the 10 best advanced breeding lines were : AN 512579-0, AN 512648-0, AN 512650-0, BZ 2231-7, and BZ 2231-11.

The Carioca EPR

Seven experiments were reported during 1987. The advanced breeding lines within the 10 best in each location did not always yield higher than the elite checks (Carioca or A 281). The local check, such as Pintado in Patos de Minas, yielded higher than the best Carioca. ESAL lines, such as ESAL 522, ESAL 514, and ESAL 511, were outstanding on cerrado soil conditions whereas AN 512537-0, AN 512558-0, AN 512561-1, AN 512678-0, AN 511661-0, and ESAL 522 were always outstanding in all locations.

The Purple EPR

Only four experiments were reported and comprised the smallest entries in the EPR. This reflects the difficulties in generating this particular seed color (light purple/opaque). Some advanced breeding lines of this light purple color yielded higher than the elite checks, Carioca or LM 10348. In cooler regions, such as Patos de Minas/MG and Ponta Grossa/PR, CNF 10 outyielded the elite check, LM 10348. Lines AN 512737-0, AN 512852-0, TY 3361-1, TY 3364-15, and AN 511637-0 were outstanding and outyielded the elite check, LM 10348, in many locations.

Results from state trials

EPAMIG/MG

Tables 5 and 6 show the results of the state trials conducted by EMPAMIG during 1985/86 for black and cream seeded, respectively. In the black seeded group, CNF 290, GUAT L 81-37, CNF 289, DOR 241, and BAT 437 were the outstanding lines. However, there was no significant yield improvement over the already released lines such as RICO 1735 and Milionario 1732. In the cream seeded group, conducted in 10 locations during two semesters, ESAL 505 and EMGOPA 201-OURO were the best lines with yields higher than their checks (Ricomig 1896 and Fortuna 1895). In the precoce experiments, conducted in seven locations during two semesters, BAT 304 (Capixaba Precoce), G 6616, Vi 1916, Vi 1934, and CNF 246 were the outstanding lines (Table 7).

UEPAE - Dourados/MG

Table 8 shows the results of the state trials conducted by UEPAE-Dourados in 1986. Some good lines, such as A 379 and Aroana 4, unfortunately do not have commercial acceptance. A 295 (EMGOPA 201-Ouro), and A 388 look promising.

CNPCO/SE

Twenty-five lines were tested in the state trials in Sergipe in 1987 under monoculture and intercropped with maize. Two outstanding lines were L 10110 and A 295 (EMGOPA 201-Ouro). The check, Bagajo, yielded almost as well as these two and has a cranberry seed type. This seed type has commercial value in the

northeast of Brazil but has received, up to this moment, no attention in the breeding program (Table 9).

EPABA/BA

Table 10 shows the results of the state trials in 1987, testing 25 lines intercropped with maize. A 244, A 252, IPA Cult. 4211, and A 245 yielded higher than Carioca and A 295 yielded better than Mulatinho Vagem Roxa and Argenosinho, the local checks.

EMGOPA/GO

In the black bean trials, ICA Col 10103, BAT 67, BAT 1647, LM 20363, and BAT 431 were the outstanding lines and yielded about 200 kg over the recommended variety, RICO 23. No recommendations can be made since these lines are too susceptible to anthracnose disease (Table 11).

In the colored bean trials, BAT 1458, ESAL 502, BAT 614, and BAC 37 were the best lines of the state trials over five locations in 1987 (Table 12).

Regional meetings

Bean research in Brazil is divided into three regions in order to serve local needs more efficiently. Region 1 is comprised of Rio Grande do Sul, Santa Catarina, Parana, Rio de Janeiro, and the southern part of Espirito Santo. All of these areas mainly grow black cultivars. Due to seed color grouping, Espirito Santo and Rio de Janeiro are grouped in Region 1 although they are closer to the Minas Gerais Zona de Mata region where black beans dominate. Region 2 is comprised of Minas Gerais, Sao Paulo, Goias, Mato Grosso do Sul, Mato Grosso, Rondonia, and other states in the north. These states mainly grow colored beans and just small quantities of black beans. Region 3 is crompised of Bahia, Pernambuco, Alagoas, Sergipe, Paraiba, Rio Grande do Norte, and Ceara. Most of these states grow cream seeded beans.

This year, in each region, a meeting was held to discuss the results of the EPR and the state trials and to try to establish a regional network of state trials beyond the state borders. These networks will provide opportunities to use advanced breeding lines more efficiently which can then be released simultaneously by several state institutions. Joint release will make seed production easier. Results of the three regional meetings can be seen in Table 13. These lines are then officially registered and farmers can get agricultural credit when using these recommended or tolerated cultivars of the state. Table 13 shows the new advanced breeding lines that are slowly replacing the traditional varieties. However, in many state institutions, (especially in the northeast of Brazil and in Rio Grande do Sul), traditional

varieties in the recommended group still outnumber the released advanced breeding lines; greater research activity in these regions should be encouraged.

For the first time, several state institutions this year (based on data from state trials) agreed to simultaneously recommend EMGOPA 201-Ouro in the states of Mato Grosso do Sul and Minas Gerais in Region 2, and Alagoas and Sergipe in Region 3, where it is called Ouro. Capixaba Precoce is also recommended for Rio Grande do Sul.

From these meetings, it was suggested that advanced breeding lines with off colors, or that are too far from the local commercial values, should not in the future be included in the EPR stage or state and regional trials, in order to avoid testing advanced breeding lines. It was also proposed that only lines with resistance to BCMV be advanced to state trials.

Evaluation of advanced breeding lines under high input

Beans are traditionally grown under rainfed systems, but production from this type of system is unpredictable. For example, the northeast normally produces about 30% of Brazil's bean crop, but this year's lack of rainfall caused vast losses. To stabilize food production, Brazil is promoting an irrigation system in the northeast and also in the cerrado region. It is estimated that, at the moment, less than 5% of beans are grown under irrigation in Brazil, with the state of Sao Paulo leading in bean production under irrigation systems (during the wintertime with high input). Yield above 3000 kg/ha is not a rarity. Unfortunately, little information has been generated for this high input operation. Agronomic practices, e.g. fertilizer recommendations, spacing, density, suitable germplasm (erect types for mechanical harvest, high yielding and responsive to fertilization), and cold temperature tolerance are areas which demand urgent attention.

In the winter of 1987, 401 lines, divided into seven groups of promising lines, were yield tested under a central pivot irrigation system. The groups were:

1.	Black seeded 1	64 entries
2.	Black seeded 2	64 entries
3.	Cream seeded	100 entries
4.	Carioca type	64 entries
5.	Purple seeded	36 entries
6.	White seeded	25 entries
7.	Precoce	48 entries

Each group had its own checks. The results are shown in Table 14. In general, the yields were lower than expected because during flowering, the most critical period for bean production, the irrigation system broke down. For sixteen days

the beans did not receive sufficient water, and relative humidity of the air was below 30%. Beans still yielded reasonably well because low temperatures prevailed.

The precoce lines performed as well as the other color groups under sub-optimum irrigation systems because they had already reached the pod-filling stage when the water stress occurred. Some new lines, coded as POT (yield potential), showed very encouraging results. These POT lines, derived from segregating populations of the high yielding potential project, were shipped to CNPAF in 1984. These are lines for the high input production system planted during the wintertime where high yield is the main objective. Disease and insect incidence during this season are low and resistance to these biotic constraints is not as high a priority as is response to fertilizer and irrigation (Table 14). Lines TY 1558-1, TY 1558-3, and TY 3326-1 have the best architecture for mechanical harvest and will be tested when sufficient seed becomes available.

Screening for low soil phosphorus efficiency

Field screening for efficiency to low soil phosphorus continues this year by evaluating the advanced breeding lines that came to Brazil in 1986 and some lines from the yield potential project developed at CNPAF. A total of 244 lines were evaluated and divided into 4 seed color groups: black, mulatinho, carioca, and purple. Table 15 shows the efficient lines with the minimum additional phosphorus requirements to reach maximum yield. In general, yield under phosphorus stress conditions were slightly higher than the checks. In the black seeded group, POT 51, LM 30638, and LM 30630 were not only efficient, but also had very high yields (above 2 t/ha) under non-stress conditions. In the cream seeded group, BZ 1621-1, BZ 2231-11, BZ 2240-2, and TY 3446-2 were the outstanding lines in the group. In the carioca group, BZ 1977-6, BZ 3836-3, BZ 1977-5, and BZ 2511-5 performed well but yields under non-stress conditions were much lower than the other seed groups. The best of the purple seeded group were POT 96, TY 3361-1, and TY 3332-1.

Purification of A 176

Advanced breeding line A 176 has similar characteristics as EMGOPA 201-Ouro and has the advantage of larger seed size and higher yield. The main problem is its seed color which is comprised of three hues: dark, medium, and light. This line is not too dificult to market but its slightly different hues make it difficult to pass seed unit tests for releasing this line. About 500 plants were selected and stored. After six months storage the content of the envelopes was selected. Contents with different hues in a single envelope were discarded. Only 157 envelopes out of 500 were selected and then placed into three groups according to their hues. During the following semester, it was planted in a single row and one pod per plant was harvested. The seed derived from the same row was bulked. In

the following semester, before planting, seed color was checked again. Those seeds with segregating hues were discarded. Only 14 families were selected, four dark, six medium, and four light hues, and will be yield tested next semester.

Table 1. The 10 best black lines from EPR 1986/88.

	CHAPECO/SC		PONTA GROSSA/PR	
	ADVANCED BREEDING LINES			
01	84 VAN-18	1957	AN 512575-0	2601
02	AN 512573-0	1951	AN 512574-0	2525
03	84 VAN-163	1752	84 VAN-163	2343
04	BZ 1719-2	1705	84 VAN-18	2338
05	AN 512567-0	1680	AN 511619-0	2184
06	AN 512575-0	1647	AN 512646-0	2120
07	AN 512574-0	1597	BZ 1719-2	2120
08	AN 511619-0	1582	W 22-24	2107
09	AN 512572-0	1565	84 VAN-196	2103
10	HONDURAS 35	1484	AN 512567-0	2073
$\overline{X}10$		1692		2251
	ELITE CHECKS			
01	LM 30074-0(TE)	1590	CARIOCA	1574
02	LM 21135-0(TE2)	1610	RIO TIBAGI	1234
03	CARIOCA	1742	LM 30074-0 (TE)	2059
04	RIO TIBAGI	947	LM 21135-0 (TE2)	2006
$\overline{X}4$		1472		1718
	LOCAL CHECKS			
01	T.LOCAL 1	1445	T.LOCAL 1	1634
02	T.LOCAL 2	967	T.LOCAL 2	2079
03	T.LOCAL 3	1634	T.LOCAL 3	1136
04	T.LOCAL 4	1130	T.LOCAL 4	1803
$\overline{X}4$		1294		1663
EXP. MEAN $\overline{X}36$		1288		1860
LDS (5%)		221		770
CV (%)		8.3		20.1

Table 1 (cont.) The 10 best black lines from EPR 1986/88.

	IPAGRO/RS		CNPFT 1/RS		CNPFT 2/RS		CNPFT 3/RS	
	ADVANCED BREEDING LINES							
01	AN 512573-0	1500	PRETO CARIRI	1050	AN 512638-0	2640	AN 512574-0	3247
02	BZ 1719-2	1238	AN 512575-0	1050	HONDURAS 35	2283	AN 512575-0	2765
03	84 VAN -163	1150	W 22-24	1017	AN 512573-0	2240	AN 512567-0	2174
04	W 22-52	1150	BZ 1719-2	950	BZ 1719-2	2090	W 22-52	1994
05	PRETO CARIRI	1113	W 21-58	833	84 VAN - 196	2070	AN 512573-0	1943
06	W 22-27	1100	AN 512646-0	783	84 VAN - 163	2050	84 VAN - 18	1941
07	AN 512572-0	1088	W 22-52	750	W 22-24	2050	AN 512572-0	1834
08	84 VAN - 18	1088	AN 512630-0	700	AN 512646-0	2040	W 22-24	1783
09	AN 512567-0	1075	AN 512572-0	700	84 VAN - 18	1990	HONDURAS 35	1720
10	AN 512575-0	1000	84 VAN-196	700	AN 512631-0	1980	84 VAN - 163	1644
$\bar{X}10$		1150		853		2143		2105
	ELITE CHECKS							
01	LM 30074-0	775	LM 30074-0	517	LM 30074-0	2130	LM 30074-0	1694
02	LM 21135-0	375	LM 21135-0	550	LM 21135-0	1770	LM 21135-0	1570
03	CARIOCA	350	CARIOCA	1017	CARIOCA	1870	CARIOCA	1801
04	RIO TIBAGI	775	RIO TIBAGI	1050	RIO TIBAGI	0	RIO TIBAGI	1304
$\bar{X}4$		569		784		1442		1592
	LOCAL CHECKS							
01	GUATEIAN 6662	1138	GUATEIAN 6662	433	RAI 76	1750	FT 83-120	2481
02	RIO TIBAGI	638	RIO TIBAGI	433	RIO NEGRO-EMPASC	1280	RAI 76	1213
03	MAQUINE	563	MAQUINE	583	FT 83-120	1570	TURRIALBA 4	941
04	TURRIALBA 4	788	TURRIALBA 4	400	TURRIALBA 4	1360	RIO NEGRO-EMPASC	1034
$\bar{X}4$		782		462		1490		1417
EXP. MEAN $\bar{X}36$		871		589		1814		1495
LSD (5%)		408		456		676		733
CV (%)		22.5		39.4		17.9		23.8

Table 1 (cont.) The 10 best black lines from EPR 1986/88.

	GNPAF/GO		ANAPOLIS/GO		BARREIRAS/BA	
			ADVANCED BREEDING LINES			
01	HONDURAS 35	1689	AN 512646-0	1479	PRETO CARIRI	1657
02	AN 3508	1426	HONDURAS 35	1456	AN 512575-0	1447
03	SPB 5	1337	SPB 5	1449	W 22-24	1334
04	W 22-14	1273	AN 3508	1434	BZ 1779-2	1293
05	AN 512573-0	1204	AN 512574-0	1351	W 21-58	1281
06	W 21-58	1177	AN 512637-0	1306	AN 512646-0	1263
07	W 22-27	1133	AN 512575-0	1299	W 22-52	1246
08	AN 512637	1117	W 22-27	1254	AN 512630-0	1181
09	W 22-24	1104	AN 512567-0	1231	AN 512572-0	1179
10	SPB 1	1096	VAGEM ROXA.EV BR.	1224	84 VAN-196	1143
X10		1256		1348		1302
			ELITE CHECKS			
01	LM 30074-0	666	CARIOCA	938	LM 30074-0	1210
02	LM 21135-0	1073	RIO TIBAGI	841	LM 21135-0	999
03	CARIOCA	1006	LM 30074-0	1351	CARIOCA	1445
04	RIO TIBAGI	774	LM 21135-0	578	RIO TIBAGI	773
X4		886		927		1107
			LOCAL CHECKS			
01	BAT 1647	998	SPB 1	1351	CARIOCA	1761
02	BAT 451	946	PRETO CARUARU	1014	TPA 74-19	1218
03	BAT 67	1358	RIO NEGRO	983	EPABA 1	947
04	ICA COL 10103	1061	RICC 23	908	MUL.VAGEM.ROXA	679
X4		1091		1064		1151
EXP. MEAN X36		1003		1099		1068
LDS (5%)		443		584		528
CV (%)		22.5		27.1		24.0

Table 2. The 10 best Mulatinho lines from EPR 1986/88.

	CNPAF/GO		BARREIRAS/BA		POCO VERDE/SE		STIPAN/AL	
	ADVANCED BREEDING LINES							
01	SX 2232-2	1532	AN 512579-0	1805	AN 511669-0	1897	BZ 3858-1	588
02	AN 512712-0	1455	AN 512594-0	1678	SX 2232-2	1841	AN 512717-0	559
03	BZ 2231-11	1433	CB 511691-0	1502	CB 511679-0	1787	AN 512579-0	540
04	AN 512650-0	1287	BZ 2231-7	1362	AN 512711-0	1683	AN 512594-0	523
05	AN 511648-0	1212	TY 3499-3	1276	AN 512650-0	1667	AN 511624-0	503
06	TY 3499-3	1163	AN 512712-0	1261	CB 511691-0	1661	SX 2232-2	418
07	AN 512579-0	1152	AN 511669-0	1229	AN 512717-0	1656	AN 511625-0	417
08	AN 512648-0	1151	BZ 2519-7	1196	BZ 2518-1	1653	CB 511691-0	412
09	BZ 2519-7	1128	AN 512717-0	1184	BZ 2231-7	1650	BZ 2231-7	403
10	AN 511625-0	1109	BZ 2231-11	1143	AN 512620-0	1648	BZ 2231-11	398
$\bar{X}10$		1262		1364		1714		477
	ELITE CHECKS							
01	CARIOCA	1119	CARIOCA	1369	CARIOCA	1402	CARIOCA	318
02	IPA 6	1661	IPA 6	811	IPA 6	1586	IPA 6	86
03	EMGOPA 201 OURO	1132	EMGOPA 201 OURO	776	EMGOPA 201 OURO	1650	EMGOPA OURO	504
$\bar{X}3$		1304		985		1546		303
	LOCAL CHECKS							
01	LM 21303	1103	MUL.VAGEM ROXA	1346	BAGAJO	1714	VAGEM ROXA	462
02	LM 21303	1157	CARIOCA	1247	IPA 6	1455	BAGAJO	269
03	M.MULATINHO	1107	IPA 74-19	1237	IPA 1	1308	IPA 1	248
04	A 351	654	EPABA 1	1062	RIM DE PORCO	1235	RIM DO PORCO	230
$\bar{X}4$		1005		1223		1428		302
EXP. MEAN $\bar{X}49$		994		969		1458		365
LSD (5%)		314		522		249		258
CV (%)		16.1		27.5		8.7		33.3

Table 2 (cont.) The 10 best Mulatinho lines from EPR 1986/88.

	PONTA GROSSA/PR		SELVIRIA/MS	
	ADVANCED BREEDING LINES			
01	AN 512717-0	2706	BZ 2518-1	675
02	TY 3499-3	2529	AN 512648-0	627
03	AN 512648-0	2510	BZ 3858-1	575
04	AN 512594-0	2376	AN 512650-0	529
05	AN 512650-0	2356	JALINHO MG	524
06	SX 2232-2	2351	BZ 2519-7	496
07	AN 511648-0	2333	AN 512711-0	474
08	AN 511624-0	2332	BZ 2231-11	435
09	AN 512712-0	2327	AN 511624-0	409
10	AN 512615-0	2249	SSC 52	407
$\overline{X}$10		2407		515
	ELITE CHECKS			
01	CARIOCA	965	CARIOCA	547
02	IPA 6	1822	IPA 6	1037
03	EMGOPA 201 OURO	1465	EMGOPA 201 OURO	150
$\overline{X}$3		1417		578
	LOCAL CHECKS			
01	T.LOCAL 1	1452	T.LOCAL 1	198
02	T.LOCAL 2	1381	T.LOCAL 2	477
03	T.LOCAL 3	1190	T.LOCAL 3	272
04	T.LOCAL 4	1953	T.LOCAL 4	131
$\overline{X}$4		1494		270
EXP.MEAN X49		1693		317
LSD (5%)		663		253
CV (%)		20.0		40.6

Table 3. The 10 best Carioca lines from EPR 1986/88.

	PATOS/MG		CNPAF/GO		ANAPOLIS/GO		BARREIRAS/BA		STIPAN/AL	
		ADVANCED BREEDING LINES								
01	ESAL 514	2243	ESAL 522	1522	AN 512678-0	1720	AN 512678-0	1557	AN 512537-0	523
02	AN 511661-0	2150	ESAL 511	1326	AN 511661-0	1535	AN 511604-0	1548	AN 511608-0	517
03	AN 512678-0	2137	ESAL 514	1260	AN 512561-1	1500	ESAL 522	1484	AN 512561-1	513
04	AN 511608-0	2102	AN 512558-0	1217	AN 512558-0	1471	AN 512513-0	1407	AN 512804-0	494
05	AN 512545-0	1852	ESAL 513	1070	ESAL 514	1400	ESAL 511	1404	AN 512678-0	489
06	ESAL 522	1767	AN 511608-0	1027	ESAL 522	1399	ESAL 519	1293	BZ 2180-1	455
07	ESAL 513	1730	AN 511661-0	1022	AN 511608-0	1291	AN 511661-0	1283	AN 512513-0	437
08	ESAL 511	1662	AN 512545-0	992	AN 512787-0	1255	BZ 2180-1	1256	AN 512558-0	404
09	AN 512558-0	1642	AN 512561-1	979	ESAL 513	1255	AN 512810-0	1156	AN 512545-0	400
10	AN 512537-0	1572	AN 512678-0	974	AN 512537-0	1237	AN 512804-0	1118	AN 511661-0	400
$\bar{X}10$		1886		1139		1406		1351		463
		ELITE CHECKS								
01	CARIOCA	1666	CARIOCA	1023	CARIOCA	1055	CARIOCA	873	CARIOCA	295
02	A 281	1750	A 281	758	A 281	939	A 281	936	A 281	546
$\bar{X}2$		1708		890		972		905		421
		LOCAL CHECKS								
01	JALO	1344	IAPAR 14	816	EMP 117	1228	EPABA 1	834	BAGAJO	341
02	PINTADO	2265	A 252	943	A 255	1165	IPA 74-19	707	R.PORCO SI	171
03	ERIPARZA	1547	A 247	1185	A 268	936	CARIOCA	1064	IPA 1	573
04	ESAL 506	2174	IAPAR 16	581	AN. ENXOFRE	514	MUL.VAGEM ROXA	932	VAGEM ROXA	249
$\bar{X}4$		1832		881		961		884		334
EXP. MEAN $\bar{X}25$		1681		973		1159		1072		258
LSD (5%)		709		352		347		499		365
CV (%)		20.0		17.6		14.1		22.0		33.3

Table 3 (cont.) The 10 best Carioca lines from EPR 1986/88.

	PONTA GROSSA/PR		CHAPECO/SC	
	ADVANCED BREEDING LINES			
01	AN 511608-0	2367	AN 511661-0	1542
02	AN 512558-0	2317	AN 512785-0	1528
03	AN 512785-0	2283	AN 512678-0	1497
04	AN 512787-0	2250	ESAL 511	1469
05	AN 512804-0	2133	AN 512810-0	1430
06	AN 512545-0	2083	AN 511608-0	1419
07	AN 512678-0	2000	AN 512558-0	1383
08	AN 511661-0	1967	AN 512537-0	1340
09	AN 512513-0	1833	ESAL 522	1289
10	AN 512537-0	1800	ESAL 519	1204
$\overline{X}10$		2103		1410
	ELITE CHECKS			
01	CARIOCA	1433	CARIOCA	1377
02	A 281	2033	A 281	1374
$\overline{X}2$		1733		1376
	LOCAL CHECKS			
01	T.LOCAL 1	1583	T.LOCAL 1	1017
02	T.LOCAL 2	1667	T.LOCAL 2	1259
03	T.LOCAL 3	1817	T.LOCAL 3	1034
04	T.LOCAL 4	2250	T.LOCAL 4	814
$\overline{X}4$		1829		1031
EXP. MEAN $\overline{X}25$		1805		1227
LSD (5%)		616		307
CV (%)		16.5		12.1

Table 4. The 10 best purple lines from EPR 1986/88.

	PATOS/MG		CNPAF/GO		PONTA GROSSA/PR		ANAPOLIS/GO	
	ADVANCED BREEDING LINES							
01	AN 512821-1	2233	AN 511637-0	1264	AN 512843-0	2383	TY 3361-1	1715
02	AN 512852-0	1817	AN 512737-0	1259	TY 3364-15	2333	MX 1423-3	1663
03	TY 3364-15	1650	TY 3361-1	1187	AN 512852-0	2267	AN 511637-0	1619
04	MX 1423-3	1550	VERMELHINHO DESC. RS	1162	AN 511637-0	2167	AN 511638-0	1592
05	AN 512737-0	1533	CAPUCAL VERMELHO	1150	TY 3361-1	2100	AN 512852-0	1507
06	VERMELHINHO DESC. RS	1533	AN 512843-0	1101	AN 511668-0	1917	TY 3364-15	1410
07	AN 511637-0	1533	ESAL 520	1072	AN 512655-0	1817	AN 512655-0	1386
08	ESAL 520	1433	AN 512852-0	1016	AN 512560-0	1650	VERMELHINHO DESC. RS	1377
09	AN 512843-0	1400	AN 511638-0	995	AN 512813-0	1633	AN 512843-0	1234
10	TY 3361-1	1400	AN 512821-1	963	AN 512821-1	1550	AN 512907-0	1206
$\bar{X}10$		1608		1107		1982		1471
	ELITE CHECKS							
01	CARIOCA	1633	CARIOCA	926	CARIOCA	1683	CARIOCA	1040
02	PARANA 1	1233	PARANA 1	733	PARANA 1	1750	PARANA 1	1294
03	LM 10348	1300	LM 10348	1540	LM 10348	1167	LM 10348	910
04	CNF 0010	1383	CNF 0010	780	CNF 0010	1800	CNF 0010	715
$\bar{X}4$		1387		995		1600		990
	LOCAL CHECKS							
01	JALO	1433	CNF 0105	673	T.LOCAL 1	1333	AN 512737-0	1198
02	PINTADO	1833	CNF 0037	691	T.LOCAL 3	1542	CAPUCAL VERMELHO	1179
03	ERIPARSA	1333	LM 30068	1213	T.LOCAL 4	1542	AN 512560-0	1159
$\bar{X}3$		1533		859		1472		1179
EXP. MEAN $\bar{X}25$		1449		960		1676		1168
LSD (5%)		657		257		716		328
CV (%)		22.0		25.7		20.1		13.2

Table 5. Results of the state trials conducted by EPAMIG in the Zona de Mata region during 1985/86 for black seeded materials.

	----- DRY SEASON -----			- WET SEASON -		
LOCATION:	A.R. DOCE	PONTE NOVA	LEOPOL-DINA	PONTE NOVA	COIMBRA	MEAN
IDENTIFICATION:	---------- kg/ha ----------					
01 CNF 290	2255	1995	416	1326	609	1320
02 GUAT L 81-37	1915	1755	643	1075	942	1266
03 CNF 289	2050	1602	754	873	847	1225
04 DOR 241	2130	1696	649	1132	376	1197
05 RAI 78	2235	1715	528	1034	471	1197
06 BAT 431	1875	2067	508	1009	467	1185
07 CNF 291	1975	1438	546	934	872	1153
08 CNF 0158	2030	1530	308	1018	732	1124
09 GUAT L 81-37	2085	1500	517	705	705	1102
10 FT 83-120	1855	1421	393	1378	454	1100
11 A 236	2120	1597	518	722	471	1086
12 BAT 165	2135	1526	465	904	368	1080
13 CNF 351	1865	1522	703	713	537	1068
14 82 B VAN 28	1970	1627	419	765	541	1064
15 BAT 549	1885	1783	460	718	364	1042
16 82 B VAN 77	1935	1431	526	497	675	1013
17 BAT 148	1650	1511	468	775	439	969
$\overline{X}_{17}$	1998	1630	519	916	581	1129
CHECKS						
01 RICO 1735	2150	1916	430	992	989	1295
02 MILIONARIO 1732	2300	1944	438	736	816	1247
03 RIO TIBAGI	2180	1556	299	358	726	1024
$\overline{X}_3$	2210	1805	389	695	844	1189
GENERAL MEAN $\overline{X}_{20}$	2030	1657	499	883	620	1138

Table 6. Results of the state trials conducted by EPAMIG during 1985/86 for colored seeded materials.

	WET SEASON				DRY SEASON						
LOCATION:	PONTE NOVA	CALDAS	LAVRAS	COIMBRA	PONTE NOVA	CALDAS	MACHADO	COV. VALAD.	LEOPOL-DINA	VICOSA	MEAN
IDENTIFICATION:	kg/ha										
ESAL 505	987	2329	1471	–	1807	1604	281	2086	–	1558	1515
EMGOPA 201-OURO	1446	1531	1433	1649	1761	1549	270	2115	437	2628	1482
ESAL 506	827	2216	1134	606	1790	1391	449	2188	389	1743	1274
LM 30013-0	1192	1670	1365	724	1584	1651	359	1295	429	1999	1227
ESAL 508	1040	2199	1192	522	1575	1442	427	1704	435	1669	1221
ESAL 502	1091	1825	1336	488	2193	1157	169	1729	348	1704	1204
Vi 1958	585	1665	1182	1395	1688	919	255	1935	238	2114	1198
ESAL 501	–	1940	1173	–	–	1134	475	–	–	–	1180
C.V. 1055 (IPA 6)	641	1593	1231	380	1625	1371	312	1811	469	1758	1119
A 288	573	1897	961	791	1508	1452	320	1296	490	1889	1118
A 246	551	1592	1163	568	1625	1412	208	1627	400	1840	1099
CARIOCA 80	410	1746	1269	455	1514	1350	217	1814	510	1656	1094
LM 10100-0	818	1319	1048	560	1452	1387	131	1563	368	1534	1018
A 377	552	982	615	702	1516	1164	290	1678	449	1791	974
Vi 1955	339	1410	692	823	1547	994	273	1413	311	1826	963
ESAL 509	400	–	–	461	1694	–	–	1466	324	1458	960
VERMELHO UBA	423	1389	808	989	1563	1278	142	1283	457	1230	956
RC 5	–	–	–	–	1947	–	–	–	–	1423	1685
$\bar{X}$18	742	1706	1130	741	1670	1328	286	1688	404	1754	1183
CHECKS											
RICOMIG 1896	1121	1853	971	630	1768	1583	405	2074	418	1611	1243
MILIONARIO 1732	663	1862	1202	636	1430	1521	259	2438	458	1577	1205
CARIOCA	593	1774	1173	437	1675	1157	347	1948	443	1612	1116
FORTUNA 1895	659	1284	942	651	1439	1068	176	1984	410	1261	987
$\bar{X}$4	759	1693	1072	589	1578	1332	297	2111	432	1515	1138
EXP. MEAN $\bar{X}$22	746	1704	1118	709	1652	1339	288	1772	410	1709	1174

Table 7. Results of the state trials conducted by EPAMIG during 1985/86 for precoce materials.

LOCATION:	DRY SEASON VICOSA	DRY SEASON P. NOVA	DRY SEASON LEOPOLDINA	DRY SEASON G.VALADARES	WET SEASON P. NOVA	WET SEASON JANAUBA	WINTER (VARZEA) LEOPOLDINA	MEAN
IDENTIFICATION:	kg/ha							
01 BAT 304	2150	1396	[illegible]	2558	2247	2423	1287	1802
02 G 6616	2354	1863	[illegible]	2508	1998	2070	830	1761
03 Vi 1916	2440	1744	574	2583	1713	2075	931	1723
04 Vi 1934	1974	1770	549	2502	1733	2537	949	1716
05 CNF 246	2094	1686	444	2476	2086	2100	1106	1713
06 BATATINHA	2450	1707	452	2246	2225	1706	931	1674
07 EEP 543175	2261	1504	506	2464	1765	2407	802	1673
08 CNF 243	2190	1614	546	2213	1711	1961	1003	1606
09 Vi 1032	1009	1607	664	2504	2103	2207	1018	1587
10 AMENDOIM	2053	1683	426	2181	1710	2056	820	1562
11 ERIPARSA I	1847	1586	461	2188	1742	2078	821	1539
12 DOR 196	1305	1431	313	2335	1839	2357	1065	1521
13 CNF 252	1438	1413	467	2285	1575	2548	787	1502
14 CNF 261	2193	1024	501	1650	1891	2113	889	1466
15 BOLINHA	1785	1256	428	1710	1432	1679	938	1318
16 CNF 255	1724	1231	329	1623	1289	1592	894	1240
$\bar{X}$16	1954	1532	495	2252	1816	2119	942	1588
CHECKS								
01 PRETO 60 DIAS	1859	1989	640	2129	1775	2469	942	1686
02 CNF 10	1250	1594	289	2546	1745	1955	763	1449
03 GOIANA PRECOCE	1783	1269	331	1754	1501	1694	847	1311
$\bar{X}$3	1631	1617	420	2143	1674	2039	851	1482
GENERAL MEAN $\bar{X}$19	1903	1546	483	2234	1794	2107	928	1571

Table 8. Yield and comercial acceptance grade of lines and cultivars tested in state trials of UEPAE - DOURADOS/MS in 1986.

LOCATION:	DOURADOS	CAARAPO	MEAN	COMERCIAL VALUE*
IDENTIFICATION:				
A 338	1491	2394	1942	1
A 377	1578	2103	1840	2
AROANA 4	1546	2082	1814	3
A 241	1803	1817	1810	1
BAT 336	1803	--	1803	1
A 255	1653	1937	1795	1
A 295	1385	2192	1788	1
H 7 B	1767	--	1767	1
H 9 B	1407	2115	1761	1
EMP 117	1485	1993	1739	2
A 353	1766	1695	1730	1
IPA 1	1446	1987	1716	1
A 282	1212	2217	1714	2
A 251	1710	--	1710	1
A 372	1618	1754	1686	1
A 294	1416	1951	1683	1
A 352	1234	2112	1673	1
CULTIVAR 7310	1454	1847	1650	1
A 268	1419	1720	1569	2
A 242	1104	2025	1564	1
CULTIVAR 6191	1373	1684	1528	1
A 249	1394	1601	1497	2
A 250	1472	1344	1408	1
MD 93	1427	1328	1377	1
CULTIVAR 7012	1252	1487	1369	1
CARIOCA 80	1288	1390	1339	2
A 75	1377	1299	1338	1
RICO PARDO 896	996	1648	1320	3
CARIOCA	1256	1279	1267	1
BAT 332	1370	1151	1260	1
A 62	1266	1223	1244	2
RAPE	1221	1255	1238	2
JALO EEP 558	1095	--	1095	1
VERMELHO	711	909	810	3

* 1 = widely accepted, 4 = no commercial value.

Table 9. State trials conducted by CNPCO-SERGIPE in monoculture and intercropped with maize, 1987.

	IDENTIFICATION	YIELD (kg/ha) MONOCULTURE	INTERCROPPED WITH MAIZE	MEAN
01	L 10110	1561	1005	1283
02	A 295	1523	995	1259
03	L 10111	1535	947	1241
04	L 10081	1529	933	1231
05	ESAL 505	1437	1012	1225
06	82 PVBZ 1718	1479	952	1216
07	L 12155	1474	900	1187
08	L 12118	1419	945	1182
09	L 10101	1412	943	1178
10	A 344	1399	908	1154
11	L 10146	1335	913	1124
12	A 254	1370	847	1109
13	L 10238	1305	890	1098
14	A 251	1275	860	1068
15	82 PVMX 1638	1323	811	1067
16	82 PVMX 1637	1258	788	1023
17	82 PVMX 1648	1161	752	957
18	LM 21303	1136	734	935
$\overline{X}18$		1385	896	1141
	CHECKS			
01	IPA 6	1497	1081	1289
02	BAGAJO	1500	986	1243
03	CARIOCA	1385	861	1123
04	CACINHO	1302	767	1035
05	IPA 74-19	1383	672	1028
06	IPA 1	1210	813	1012
07	RIM DO PORCO	1199	689	947
$\overline{X}7$		1354	838	1096
EXP. MEAN		1376	880	
LSD (5%)		194	137	
CV (%)		7.0	7.7	

Table 10. Results of the state trial conducted by EPABA in IRECE intercropped with maize during 1987.

	IDENTIFICATION	YIELD (kg/ha)
01	244	1726
02	252	1697
03	IPA CULT 4211	1668
04	A 245	1615
05	MD 94	1532
06	EMP 117	1530
07	IPA 1	1528
08	MD 94	1527
09	BAT 332	1447
10	A 295	1432
11	BAT 731	1405
12	BAT 336	1391
13	A 268	1363
14	A 73	1357
15	A 248	1335
16	A 281	1255
17	A 351	1209
18	A 240	1082
19	BAT 160	1058
20	A 301	858
$\overline{X}$20		1401
LOCAL CHECKS		
01	CARIOCA	1592
02	MUL. VAGEM ROXA	1294
03	ARGENOSINHO	1248
04	IPA 74-19	1127
05	EPABA 1	1063
$\overline{X}$5		1265
$\overline{X}$25		1373
LSD (5%)		228
CV (%)		12.0

Table 11. Yield of 20 lines or cultivars of black bean obtained in the dry season. EMGOPA, 1987 (GOIAS).

LINE/CULTIVAR	GOIANIA (GO)	ANAPOLIS (GO)	ANTH*	ALS*	BAC*	PIRENOPOLIS (GO)	ITAPURANGA (GO)	SAO LUIS DE MONTES BELOS (GO)	MEAN
ICA COL 10103	1278 a	1308 a	7	–	–	1396 a	2332 abc	1163 ab	1495 a
BAT 67	800 ab	1250 a	–	2	4	790 ab	2471 abc	1301 a	1323 ab
BAT 1647	687 b	1558 a	2	5	–	1125 ab	2415 abc	710 fg	1299 ab
LM 20363	850 ab	1271 a	5	–	5	1092 ab	2283 abc	998 abcdef	1299 ab
BAT 431	740 ab	1154 a	6	–	4	894 ab	2512 a	1081 abc	1276 abc
LM 21124	723 ab	1212 a	6	–	–	1128 ab	2487 ab	662 g	1243 abc
BAT 451	632 b	1362 a	2	4	–	[illegible]1 ab	2262 abc	794 cdefg	1220 abcd
LM 30074	788 ab	1188 a	7	–	–	963 ab	2211 abc	950 bcdefg	1220 abcd
82 B VAN 38	540 b	1221 a	6	5	–	1060 ab	2108 abc	1023 abcde	1190 bcd
LM 30016	656 b	1367 a	6	–	–	767 ab	2261 abc	876 bcdefg	1185 bcd
RICO 23	709 b	1362 a	6	5	–	825 ab	2221 abc	731 efg	1170 bcd
LM 10401	826 ab	1133 a	5	5	–	934 ab	2086 abc	842 cdefg	1164 bcd
RIO NEGRO	660 b	1142 a	–	2	7	320 ab	2144 abc	1051 abcd	1163 bcd
RICO 1735	717 ab	1329 a	5	–	7	536 b	2422 abc	763 defg	1154 bcd
LM 20720	553 b	1262 a	8	–	–	933 ab	2032 abc	717 efg	1099 bcd
LM 30036	650 b	1225 a	7	–	–	937 ab	1947 abc	664 g	1085 bcd
PORRILO SINTETICO	735 ab	875 a	6	4	–	669 ab	2207 abc	661 bcdefg	1069 bcd
LM 21132	621 b	1875 a	8	–	–	837 ab	2185 abc	657 g	1035 bcd
82 B VAN 84	520 b	1108 a	–	5	–	871 ab	1617 c	813 cdefg	988 cd
SPB-1	504 b	971 a	–	5	–	843 ab	1637 bc	712 efg	933 d
MEAN	710	1209				924	2192	868	1181
L.S.D. (5%)	562	784				837	866	313	298
C.V.	25	21				29	13	12	19

Means followed by the same letters do not differ significantly between themselves at the level of 5% probability by Tukey's test.

* Disease scoring: ANTH = Anthracnose, ALS = Angular leaf spot, BAC = Bacterial Blight, scoring 1-9 where 1 = symptomless and 9 = plant death.

Table 12. Yield and disease score of 20 lines or cultivars of colored bean obtained in the dry season. EMGOPA 1987 (GOIAS).

LINE/CULTIVAR	GOIANIA (GO)	ANAPOLIS (GO)	ALS*	BAC*	ORDUM*	PIRENOPOLIS (GO)	ITAPURANGA (GO)	SÃO LUIS DE MONTES BELOS (GO)	MEAN
BAT 1458	1119 a	1488 ab	2	3	S	1091 a	2946 abc	1338 a	1596 a
ESAL 502	717 ab	1254 ab	5	4	S	547 a	3187 a	1219 ab	1385 ab
BAT 614	792 ab	1383 ab	–	4	S	705 a	2908 abc	1032 abc	1364 ab
BAC 37	613 ab	1379 ab	1	2	S	1028 a	2789 abcd	871 abc	1336 abc
EMGOPA 201/OURO	1047 ab	1258 ab	–	5	–	684 a	2581 abcde	1050 abc	1324 bc
ESAL 503	649 ab	1108 ab	7	4	S	766 a	2994 ab	1080 abc	1320 bc
LM 10092	753 ab	1462 ab	5	2	–	666 a	2594 abcde	971 abc	1290 bc
BAT 363	835 ab	1200 ab	3	4	S	765 a	2462 abcde	930 abc	1238 bcd
BAC 57	858 ab	1162 ab	–	–	S	510 a	2679 abcd	894 abc	1221 bcd
LM 10348	681 ab	1542 a	3	3	S	543 a	2328 bcdef	840 abc	1187 bcd
LM 10061-0	571 b	946 b	6	–	–	540 a	2710 abcd	1061 abc	1161 bcde
CARIOCA	592 ab	1050 ab	7	–	S	534 a	2527 abcde	1079 abc	1156 bcde
82 PVBZ 1838	654 ab	1421 ab	6	4	–	790 a	2104 defg	740 bc	1142 bcde
LM 10069-0	575 b	1108 ab	7	–	–	761 a	2274 bcdef	768 bc	1097 cde
ROXAO RG	732 ab	1375 ab	6	5	–	568 a	1627 efgh	1094 abc	1079 cde
LM 10089	572 b	1371 ab	7	3	S	610 a	1667 fgh	829 abc	1010 de
ROSINHA G2	562 b	975 ab	8	–	–	622 a	2190 cdefg	672 c	1004 de
JALO EEP 558	547 b	1225 ab	–	–	S	525 a	1481 gh	1172 abc	990 de
LM 30068	594 ab	1125 ab	6	5	–	637 a	1905 efgh	676 c	988 de
LM 30013-0	702 ab	1300 ab	–	6	–	473 a	1271 h	783 bc	906 e
MEAN	707	1257				668	2361	955	1190
L.S.D. (5%)	541	581				694	758	532	265
C.V.	25	15				34	10	18	17

Means followed by the same letters do not differ significantly between themselves at the level of 5% probability by Tukey's test.

* Disease scoring: ALS = Angular leaf spot, BAC = Bacterial Blight, scoring 1-9 where 1 = symptomless and 9 = plant death.

Table 13. Recommended cultivars in Brazil for 1987/88.

STATE	RECOMMENDED	TOLERATED
GOIAS	EMGOPA 201 (OURO)* CARIOCA	JALO EEP 558 RICO 23 CNF 010 CARIOCA 80
SAO PAULO	CARIOCA 80 AROANA 80 MORUNA 80 AYSO AETE 3 CATU	NONE
M. GROSSO DO SUL	CARIOCA CARIOCA 80 RIO TIBAGI JALO EEP 558 OURO (EMGOPA 201)	ROSINHA G-2 CARNAVAL RICO 23 CNF 010
RONDONIA	IPA 7419 CARIOCA	RIO TIBAGI ROSADO
MINAS GERAIS	RIO TIBAGI NEGRITO 897 MILIONARIO 1732 RICO 1735 CARIOCA 80 OURO (EMGOPA 201)	CARIOCA PALMITAL PRECOCE ERIPARSA 1 MANTEIGAO FOSCO II FORTUNA 1895 RICOMIG 1896 JALO EEP 558
DISTRITO FEDERAL	OURO (EMGOPA 201) CARIOCA	JALO EEP 558 RICO 23 CNF 010 CARIOCA 80
MATO GROSSO	CARIOCA ROSINHA G-2 CNF 010 JALO EEP 558 RIO TIBAGI	NONE
RIO DE JANEIRO	BR 1 - XODO BR 2 - GRANDE RIO BR 3 - IPANEMA PORRILLO SINTETICO CAPIXABA PRECOCE	MORUNA RIO TIBAGI CARIOCA

* RECOMMENDED IN MORE THAN 1 STATE.

Table 13 (cont.) Recommended cultivars in Brazil for 1987/88.

STATE	RECOMMENDED	TOLERATED
ESPIRITO SANTO	CAPIXABA PRECOCE*	IGUACU
	RIO TIBAGI	VITORIA
	CARIOCA	IPA 1
	ESAL - 1	RICO PARDO 896
RIO GRANDE DO SUL	TURRIALBA 4	
	RIO TIBAGI	
	GUATEIAN 6662	
	MAQUINE	
	CARIOCA	
	TAHYU	
	IRAI	
	EMPASC 201-CHAPECO	
	RIO NEGRO	
	CAPIXABA PRECOCE	
SANTA CATARINA	EMPASC 201-CHAPECO	IGUACU
	FT 83-120	
	RIO TIBAGI	
	TURRIALBA 4	
	CARIOCA	
	CARIOCA 80	
PARANA	CARIOCA	
	IAPAR 3 - RIO IVAI	
	IAPAR 5 - RIO PIQUIRI	
	RIO TIBAGI	
	IAPAR 8 - RIO NEGRO	
	IAPAR 14	
	IAPAR 16	
	IAPAR 20	
	FT TARUMA	
	FT 83-120	
BAHIA		
- BARREIRAS	IPA 74-19	MULATINHO V.ROXA
	CARIOCA	
	EPABA 1	
- NORTHEAST	BAGAJO	IPA 1
	FAVINHA	MULATINHO V.ROXA
	CACHINHO	
	CARIOCA	
	PITOCO	

* RECOMMENDED IN MORE THAN 1 STATE.

Table 13 (cont.) Recommended cultivars in Brazil for 1987/88.

STATE	RECOMMENDED	TOLERATED
BAHIA (CONT.)		
- PARAGUACU VALLEY	IPA 74-19 EPABA 1 IPA 1 CARIOCA	MULATINHO V.ROXA BAGAJO FAVINHA SANTA ROSA
- IRECE	IPA 74-19 CARIOCA EPABA 1	MULATINHO V.ROXA IPA 6
SERGIPE	IPA 6 IPA 1 BAGAJO CARIOCA RIM DO PORCO OURO (EMGOPA 201)*	IPA 74-19 FAVINHA MULATINHO V.ROXA CACHINHO MILAGRE DE STO.ANDRE BICO DE OURO
ALAGOAS	OURO (EMGOPA 201)* JALO EEP 558 BAGAJO CARIOCA IPA 1 MULATINHO V.ROXA	IPA 74-19 RIM DO PORCO SANTANA DO IPANEMA COSTA RICA RIQUEZA
FERNAMBUCO	IPA 6 IPA 1 IPA 3 IPA 5	GORDO FAVITA BAGAJO HF 465-63-1 VAGEM ROXA BICO DF OURO COSTA RICA CARIOCA
PARAIBA		
- AGRESTE	IPA 1 CARIOCA	IPA 74-19 RIM DO PORCO
- SERTAO CURIMATAU	IPA 6 IPA 1 IPA 3 IPA 5	FEIJAO DE CACHO

* RECOMMENDED IN MORE THAN 1 STATE.

Table 13 (cont.) Recommended cultivars in Brazil for 1987/88.

STATE	RECOMMENDED	TOLERATED
CEARA		
- SERRA IBIAPABA	IPA 1 IPA 6	IPA 74-19 CARIOCA GURGUTUBA MULATAO GORDO
PARA	ROSINHA JALINHO CARIOCA JALO	---
RIO GRANDE DO NORTE	NO RECOMMENDATIONS MADE	
MARANHAO	NO RECOMMENDATIONS MADE	
AMAZONAS	NO RECOMMENDATIONS MADE	
ACRE	NO RECOMMENDATIONS MADE	
AMAPA	NO RECOMMENDATIONS MADE	
RORAIMA	NO RECOMMENDATIONS MADE	

Table 14. The 10 best lines from the high input experiment planted during the winter season of 1987 under central pivot irrigation.

CARIOCA		CREAM		BLACK 1		BLACK 2	
IDENT.	MEAN YIELD (kg/ha)	IDENT.	MEAN YIELD (kg/ha)	IDENT.	MEAN YIELD (kg/ha)	IDENT.	MEAN YIELD (kg/ha)
01 BZ 1977-5	2114	AN 512712-0	2176	POT 59	2517	DOR 145	2235
02 BZ 1977-6	1985	LM 21306	2161	POT 51	2314	BZ 2401-1	2201
03 BZ 3871-5	1939	BZ 2643-1	2089	POT 69	2297	84 VAN 118	2044
04 POT 88	1892	AN 512594-0	2089	LM 30628	2262	EMP 130	2025
05 POT 84	1872	TY 3435-3	2038	LM 30630	2231	DOR 165	2020
06 POT 94	1858	POT 5	2024	POT 72	2206	BZ 3855-2	2005
07 BZ 1179-15	1832	BZ 1698-7	2014	LM 30637	2190	EMP 82	1974
08 POT 93	1831	POT 4	2002	POT 66	2144	DOR 54	1881
09 BZ 1977-3	1828	POT 28	1942	POT 48	2100	LM 21124	1877
10 BZ 1977-1	1769	82 PVBZ 1770	1939	LM 30638	2095	84 VAN 145	1859
$\overline{X}$10	1892		2047		2236		2012
CHECKS							
01 RIO DOCE	1398	IPA 6	2239	PRETO 132	1774	PRETO 132	1986
02 A 281	1330	EMGOPA 201 OURO	2109	RIO TIBAGI	1864	RIO TIBAGI	1962
03 CARIOCA	1524	IPA 74-19	1861	ICTA QUETZAL	1732	ICTA QUETZAL	1883
04 A 252	1740	JALO EEP 558	1210	XODO	1636	XODO	1725
$\overline{X}$4	1498		1855		1752		1889
EXP. AVER. (64)	1503	EXP.AVER.(100)	1676	EXP.AVER. (64)	1721	EXP.AVER. (64)	1622
LSD (5%)	313		419		460		360
CV (%)	14.9		18.0		19.2		15.9

Table 14 (cont.) The 10 best lines from the high input experiment planted during the winter season of 1987 under central pivot irrigation.

PRECOCE		WHITE		PURPLE	
IDENT.	MEAN YIELD (kg/ha)	IDENT.	MEAN YIELD (kg/ha)	IDENT.	MEAN YIELD (kg/ha)
01 EEP 876/75	1930	73 VUL 3246	1848	MX 1418-1	2078
02 A 410	1928	COL 3246	1825	TY 3356-9	1912
03 82 BGMV 14	1897	GUATEMALA 547	1742	TY 3361-6	1770
04 DOR 202	1891	CALIF.S.W.643	1700	TY 3364-15	1761
05 A 440	1887	PERRY MARROW	1642	TY 3350-3	1751
06 AN 520176	1806	PANAMITO MEJOCA	1608	MX 2709-24	1742
07 EEP 404/75	1787	OAX - 68	1573	TY 3332-1	1725
08 CF 840081	1773	ANDINO 3	1556	AN 512907-0	1699
09 CF 3415	1771	EEP 25623	1535	RAO 33	1674
10 BAT 1258	1694	CALIF.S.W.643A	1419	MUS 6	1642
$\overline{X}$10	1837		1645		1775
CHECKS					
01 JALO EEP 558	1881	JALO EEP	1482	BAT 41	1290
02 BAT 41	1722	CARIOCA	1468	LM 10348	1026
03 G. PRECOCE	1378	--		CNF 10	1268
04 HUETAR	1174	--		--	1330
$\overline{X}$4	1539	$\overline{X}$2	1475	$\overline{X}$4	1229
EXP. AVER. (48)	1532	EXP. AVER. (25)	1366	EXP. AVER. (36)	1491
LSD (5%)	385		241		327
CV (%)	18.0		12.5		15.7

Table 15. Average yield of the best lines under non-stress and P-stress conditions with their response factor and additional P-requirement to reach maximum yield.

IDENTIFICATION	YIELD (KG/HA) NON-STRESS	YIELD (KG/HA) P-STRESS	RESPONSE FACTOR ALPHA	ADDITIONAL P-REQUIREMENT TO REACH MAXIMUM YIELD
BLACK SEEDED				
01 POT 51	2328	1075	10.4	135
02 LM 30638	2000	765	10.3	166
03 LM 30630	2049	995	8.8	169
04 LM 30628	1958	789	9.7	174
05 BAT 48	1825	909	7.6	206
06 DOR 352	1790	908	7.3	215
07 POT 65	1746	841	7.5	218
08 SAN FERNANDO	1645	679	8.1	222
09 DOR 147	1617	625	8.3	223
10 ESPARSA 21	1652	731	7.7	227
CHECKS				
01 ICTA QUETZAL	1149	711	3.6	490
02 ICTA JUTIAPA	1282	637	5.4	341
03 PUEBLA 152	1176	244	7.8	286
04 RIO TIBAGI	1483	516	8.1	242
05 LM 30074	861	148	5.9	394
EXPERIMENT MEAN	1387	579	6.7	-
CREAM SEEDED				
01 BZ 1621-1	2170	1101	8.9	158
02 BZ 2231-11	2044	1066	8.2	176
03 BZ 2240-2	1763	747	8.5	207
04 TY 3446-2	1843	968	7.3	211
05 POT 23	1887	1132	6.3	219
06 BZ 2643-1	1900	1153	6.2	219
07 POT 2	1717	757	8.0	219
08 BZ 2518-1	1730	777	7.9	219
09 BZ 3918-5	1804	948	7.1	220
10 POT 6	1695	750	7.9	223
CHECKS				
01 A 351	1805	879	7.7	211
02 G 4000	1614	657	8.0	232
03 EMGOPA 201 OURO	1600	910	5.8	275
04 G 5059	1651	786	7.2	239
05 IPA 74-19	1113	369	6.2	345
EXPERIMENT MEAN	1367	667	5.8	-

Table 15 (cont.) Average yield of the best lines under non-stress and P-stress conditions with their response factor and additional P-requirement to reach maximum yield.

IDENTIFICATION	YIELD (KG/HA) NON-STRESS	YIELD (KG/HA) P-STRESS	RESPONSE FACTOR ALPHA	ADDITIONAL P-REQUIREMENT TO REACH MAXIMUM YIELD
CARIOCA TYPE				
01 BZ 1977-6	1588	923	5.5	254
02 BZ 3836-3	1616	974	5.3	25[illegible]
03 BZ 1977-5	1571	948	5.2	264
04 BZ 2511-5	1532	972	4.7	287
05 POT 84	1507	925	4.8	290
06 BZ 3836-2	1353	861	4.1	356
07 TY 3463-1	1296	915	3.2	439
08 POT 83	1523	1219	2.5	440
09 POT 90	1249	864	3.2	455
10 POT 93	1596	1359	2.0	481
CHECKS				
01 A 247	1242	572	5.6	312
02 A 283	1284	967	2.6	520
03 CARIOCA	1144	834	2.6	571
04 A 281	1467	1041	3.5	366
EXPERIMENT MEAN	1239	829	3.41	-
PURPLE SEEDED				
01 POT 96	1864	826	8.7	166
02 TY 3361-6	1793	585	10.1	167
03 TY 3332-1	1795	740	8.8	174
04 TY 3361-1	1808	842	8.1	177
05 RAB 96	1845	965	7.3	179
06 TY 3361-2	1696	558	9.5	181
07 MX 1418-2	1681	764	7.6	199
08 TY 3350-4	1641	695	7.7	205
09 MUS 6	1583	620	8.0	207
10 TY 3350-2	1431	888	4.5	308
CHECKS				
01 BAT 41	906	288	5.2	381
02 LM 10348	1005	387	5.2	362
03 CNF 10	787	369	3.5	544
EXPERIMENT MEAN	1349	554	6.6	-

C. AFRICA

1. Interregional Cooperation in Africa

The three separately funded regional bean projects in Africa are implemented by CIAT in a manner that is intended to take advantage of a decentralized pattern of staffing while maintaining interdisciplinary team-work among a critical mass of scientists. Very close cooperation with national scientists is encouraged by basing regional staff with four national programs located in distinct agroecological zones, while regional research strategies are prepared by interdisciplinary groups of regional and national scientists.

The Great Lakes Project is supported by the SDC, the Southern Africa Project by CIDA, and the Eastern Africa Project jointly by USAID and CIDA. The three regional groupings cooperate closely in the areas of research strategy design, regional research, training and information exchange.

While general research strategy for a region is designed in consultation with its own steering committee, (composed of the national bean program coordinators of participating national programs) specialized Africa-wide workshops are held periodically to review in detail the research needs for a selected topic. Following last year's meeting on beanfly, a group of experienced bean pathologists and breeders from national programs, CIAT regional and headquarters scientists and specialists from elsewhere, met at Kigali, Rwanda to review approaches to fungal and bacterial diseases of beans. Progress in overcoming specific diseases was analyzed, research needs were identified and methodology was compared so as to ensure compatibility of results to be expected from the many collaborating scientists. The proceedings will be published. A similar meeting is planned for 1988 on maintenance and improvement of soil fertility in bean-based cropping systems.

Each regional project provides technical support for collaborative research subprojects focussed on priority topics. The majority of these subprojects focus on bean diseases, and encourage regional cooperation through national specialization. For example, Burundi has good environmental conditions and the necessary personnel to screen large amounts of germplasm for resistance to common bacterial blight (CBB), and has taken a leadership role in this topic. As Eastern Africa has also now identified CBB as a priority, Ugandan scientists met with their Burundi counterparts in 1987 to develop a subproject for that region that would complement work in the Great Lakes region. An increasing number of examples are appearing of this form of inter-regional cooperation.

Exchange of germplasm across Africa, facilitated by regional projects, often brings together countries that are geographically far apart. For example, in 1987 Ethiopia requested Rwanda and Zambia, located in the Great Lakes and in Southern Africa regions, to assist in providing climbing bean germplasm that is adapted to relatively warm environments. The AFBYAN series represents a systematic approach to the exchange of germplasm across Africa, and its results, reported in another section, suggest the utility of this type of trial for identifying environments across the continent that are sufficiently similar to warrant further direct exchanges of material.

Although each regional project is provided with a plant breeder and an agronomist, other disciplines are present in only one or two of the programs so that the overall staff complement in Africa is a balanced one. Certain regional scientists therefore cover a larger area than their base region, by acting in a support capacity to another region's scientists. For example, in 1987 the Great Lakes regional anthropologist assisted in a diagnostic survey conducted in Uganda, and in the previous year the Southern Africa regional pathologist assisted in a training course for Ethiopia in research methods.

Regional coordinators serve as the primary link with other regions, and one has additional duties related to Africa-wide coordination. These scientists keep abreast of activities and results in other regions, for example by attending other steering committee meetings in an observer capacity. Direct contact among national scientists across regional borders also occurs frequently, both at specialist Africa-wide meetings and to a lesser extent at region-specific workshops. Researchers from the adjoining countries of Rwanda, Tanzania and Uganda are particularly encouraged by the three regional projects to visit one another and to present results at meetings held in a neighboring country.

2. Headquarters Support for African Regional Projects

For over a decade prior to the placement of CIAT staff in the three regional projects of Eastern, Southern and the Great Lakes Regions in Africa, CIAT headquarters was collaborating with various African national programs through the shipment of international bean nurseries such as the IBYAN, EP and VEF. From these nurseries several varieties had been released in different African countries (Table 1).

Beginning in 1983, with the arrival of the CIAT staff in the Great Lakes Region, larger numbers of breeding materials (advanced lines and segregating populations) began to be despatched to the national programs (Table 2). The purpose of these materials was to provide the African bean programs with diverse germplasm containing sources of resistance or tolerance to major diseases and other production constraint factors. Many of these materials are presently in advanced yield trials as potential variety candidates, and advanced lines from selections made locally within segregating population have been sent to CIAT via third country quarantine in NVRS, England to enter the VEF 88 and future crossing blocks as parents in a second cycle of breeding (Table 3). The Africa bred materials, as part of CIAT's VEF, will also be sent to other bean producing regions in Latin America and Africa allowing other national programs to use these materials in their own varietal improvement programs.

The shipment of segregating populations to Africa reflected a fundamental change in CIAT headquarters' bean improvement strategy. Prior to 1983, CIAT's approach generally was to send to national programs elite advanced lines that had successfully passed through various stages of evaluations.

Modifications of this approach evolved over time when national programs became more self sufficient in their breeding programs and began requesting specific crosses specially tailored to meet their local production constraints. For Africa, depending on the strength of each national program, the shipment of segregating populations for local selection was viewed as critical. Ample evidence existed that novel species of insects and pathogens were present in Africa that were not found in Latin America such as the bean fly (three species of *Ophiomyia*), the leaf eating blue beetles (*Ootheca bennigsenni*) and scab (*Elsinoe phaseoli*). Different races and strains of the major bean pathogens such as BCMV, anthracnose, halo blight, angular leaf spot, and others were also identified in Africa that were not present in Colombia. These disease and pest differences with Latin America, and especially with Colombia, coupled with different African cropping systems and consumer acceptability preferences, required that selection in segregating generations

be conducted under local conditions in Africa within crosses specifically planned to combine appropriate resistance factors with local adaptation. In order to plan and execute these crosses, superior African bean varieties were brought to CIAT's germplasm bank through quarantine in England. Sources of resistance were chosen using data provided by the national programs from evaluations of the international disease nurseries and crossing blocks (CIAT's advanced lines), and crosses planned for each country. In 1987, 668 crosses were made for Africa and 534 segregating populations were despatched.

Besides the general crossing support that CIAT headquarters provides to African national programs and regional staff, CIAT also collaborates with African varietal improvement programs through the incorporation of specific reistance genes into local bean varieties and elite lines using a backcross breeding program. Three breeding programs (BCMV, anthracnose and halo blight) are presently in operation. The largest of these is the BCMV project which was described in the CIAT Annual Report, 1986. Basically, the presence of necrosis (black root) inducing strains of BCMV found in most bean producing regions of Africa severely limit the usefulness of many elite breeding lines from CIAT which contain only the I gene giving resistance to mosaic inducing strains of the virus. The necrosis inducing strains in Africa attack bean genotypes which only contain the I gene causing systemic necrosis and plant death. Plants without the I gene (local African varieties) are also attacked by these BCMV strains and mosaic symptoms are expressed.

The BCMV backcross breeding programs is designed to incorporate known sources of resistance to both mosaic and necrosis inducing strains into African varieties and elite CIAT lines. Crosses are planned to combine I gene with the recessive genes bc1.2 or bc2.2, or bc3 alone, which give resistance to black root strains of the virus. Two cycles of backcrossing are conducted for each cross and resistant F_4 selections sent to Africa for field evaluation.

Similar backcrossing programs are also being conducted to incorporate resistance to certain races of anthracnose and halo blight into African materials. These breeding programs have also been described in previous CIAT Annual Reports (1985, 1986).

At the same time as segregating generations and backcrosses are despatched to Africa, these materials are also planted in Colombia in CIAT's experimental stations. Evaluations and selections under Colombian local conditions are made and advanced lines originating from these crosses enter the VEF as "AFR" coded lines. In 1987, 86 advanced AFR lines were evaluated in the VEF. These materials also went to Africa for local screening and evaluations.

Table 1. Bean varieties released in Africa from CIAT germplasm and breeding lines.

Country	Varietal Name	CIAT Identification
Burundi	Calima	G 4435 (Diacol Calima)
Rwanda	Rubona 5	G 4523 (ICA Palmar)
	Ikinyange	A 197
Rep. South Africa	Cordoba	BAT 317
Tanzania	Uyole 84	G 1821 (Garbancillo)
Zambia	Carioca	G 4017 (Carioca)

Table 2. Breeding materials dispatched to the Great Lakes Region from CIAT, 1983-1987A.

	Segregating Populations			Advanced Lines		
Country	83/84	85	86/87A	83/84	85	86/87A
Rwanda	223	678	30	397	1229	102
Burundi	-	106	42	420	667	-
Zaire	-	64	40	-	329	-

Table 3. Advanced lines from Rwanda selected from segregating populations sent from CIAT headquarters.

Rwanda Advanced Lines Code	CIAT cross sent as F_4 bulk
RWR 45[1]	ICA 10847 x BAT 1580
RWR 47	G 8043 x BAT 1222
RWR 58	G 6636 x A 117
RWR 63	G 6415 x XAN 43
RWR 96	G 8106 x Kabanima
RWR 104	Royal Red x Canadian Wonder
RWR 201	G 14308 x BAT 1386
RWR 209	G 14307 x BAT 1345
RWR 221	Rubona 5 x G 7480

[1] Rwandan advanced lines will enter CIAT's VEF 88 for evaluation.

3. Great Lakes Regional Project

The Great Lakes Regional Bean Project, serves the Central African area comprised of Burundi, Rwanda and Zaire. The project works with the region's national agricultural research institutions: Institut des Sciences Agronomiques du Rwanda (ISAR); Institut des Sciences Agronomiques du Burundi (ISABU); and with both Zaire's Programme National Legumineuses (PNL) and its Institut National des Etudes et Recherches Agricoles (INERA).

Varietal development and evaluation

Varietal development at ISABU, ISAR and PNL-Mulungu continues to progress. Each of the programs has a complete varietal development program including management of segregating populations from crosses either made at CIAT or by the programs themselves. The programs are now screening large number of breeding lines for yield with the purpose of identifying a few select varieties for multilocational testing and on-farm trials. With the close of the 1987 B season, each of the programs will initiate a new cycle of varietal selection, advancing new promising varieties. Promising varieties from ISAR multilocation bush bean trials of 1987 are RWR 221, RWR 222, Kinyugwe, Amashongoshwa, Kibuya and PVA 1438, all of which outyield the ISAR standard variety, Rubona 5 (ICA Palmar). These varieties will most likely be moved into on-farm testing in September. Climbing beans are still being emphasized by ISAR, and Rwanda continues to have the most advanced climbing bean program withing the region. The program has several very promising varieties including G 685, G 13932, G 811, Puebla 444, Criolla, Urunyumba 3, G 2333, G 858, and more recently identified varieties such as Giseny 2 Bis, Kiruli, 82/265-MG-MG-2 and G 2338.

During the first quarter, a large series of climbing bean confirmation/diffusion trials were installed in south central Rwanda in collaboration with ISAR and the Agroforestry project, PAP. Although climbing beans are rarely seen in that region, on-station research has shown their high yield potential. Because of the simple design and farmer participation in their establishment and management, it was possible to set up a large number of trials.

ISABU is also making climbing beans a high priority for densely populated areas. A smaller number of more preliminary climbing bean trials were also installed in Burundi. Sources of staking materials appears to be the major problem in climbing bean adoption, but some farmers are finding local solutions including cassava stems and banana fibers.

Collaboration in varietal development in lower Zaire (Bas Zaire, Shaba, Kasai Oriental) was initiated this season with the planting of regional bush and climbing bean trials and several other nurseries of CIAT germplasm. Bas Zaire is an important bean production region with up to 50,000 hectares planted mostly in March and April.

The bean research initiated in 1985 by PNL-Zaire in other important bean production zones outside of the Kivu region is now being rapidly expanded. Several bean nurseries sent from CIAT, including the 1985 EP and nurseries, specially prepared to test a wide range of germplasm, were planted in October at the Gandajika and Kaniama stations in Kasai Oriental. About 400 lines were tested at the two stations this season. Surprisingly, yields at Gandajika were good with replicated yields of the best varieties at 1000 to 1500 kg/ha without fertilizer or other inputs. Promising lines from these evaluations include RAB 164, RIZ 53, EMP 154, A 429, A 411, A 445, EMP 112, Carioca and, possibly, the two most promising, A 321 and BAT 1449. Several of these lines, especially A 321, have been previously identified as high yielding in a wide range of locations including Kivu, Zaire and Moso, Burundi. Bean varietal testing was extended to Bas Zaire and Lubumbashi, Shaba during the 1987 B season (February to March plantings).

Plant protection trials

The development of plant protection technology, which began with a diagnosis of major pathogens and insect pests to be controlled to increase yields, is now producing the fruits of several years' work. High levels of resistance to angular leaf spot and anthracnose have been identified, and an international Ascochyta nursery comprising best materials from Africa and America has been assembled and distributed. In addition, funding is being sought for a collaborative project with two Dutch institutes to clarify the taxonomy of the Ascochyta blight complex and the pathogenic variation of components.

Mixture trials, which focus on the effect of resistant varieties as added to mixtures, were initiated in collaboration with PNL-Zaire during the last quarter of 1986. A small set of on-farm artesanal seed production research trials were established near Rubona, Rwanda.

The efficiency of varietal selection programs in the region, particularly those focusing on disease resistance, need to be improved. Selection nurseries often do not have sufficient uniform disease pressure to select disease-resistant lines effectively. In Rwanda two of the most promising varieties released recently (A 197 and Rubona 5) are both very susceptible to anthracnose, an important disease in Rwanda.

The strength of the bean pathology and entomology work in the region was evident at a regional pathology seminar organized by IRAZ and ISABU under the leadership of Dr. A. Autrique and financed by the Centre Technique de Cooperation Rural (CTA). Pathologists working with food crops from Zaire, Rwanda, and Burundi and representatives of Kenya, Cameroun and Belgium were represented. It was gratifying that the most substantial and best presented presentations came from scientists working on beans. This was clearly reflected in remarks from many delegates including Dr. Meyer, the chief delegate of the Belgian aid program.

Nurseries

The PRELAAC (Regional Evaluation Nursery of Advanced Lines in Central Africa) was initiated during the 1987 A season with 176 promising advanced lines from the three national programs. During 1987 A and B, the nursery was evaluated for eight different characters including beanfly, Xanthomonas, halo blight, Ramularia resistance (at ISABU), Ascochyta, anthracnose and BCMV (at ISAR), and rust and angular leaf spot (ALS) resistance (at PNL). Data from this trial should considerably increase the efficiency of the national varietal selection programs. The PRELAAC is also currently being evaluated for cooking time and water absorption.

On-farm research

A large number of on-farm trials were established in the Plateau Central region of Rwanda in order to test the potential of climbing beans. If they do, in fact, show promise, on-farm comparative varietal trials will be initiated by ISAR on the Plateau Central in September. More emphasis should also be placed on on-farm trials in northern Rwanda, a traditional climbing bean region, to evaluate the large amount of climbing bean varieties developed or identified at ISAR's northern highland station, Rwerere.

Several bush bean varieties currently in on-farm testing in Rwanda and Burundi will soon be released. Additionally, the climbing bean varieties G 2333, Urunyumba 3 and Giseny 2 Bis are also concurrently being multiplied for possible release. An important recent achievement is the transfer of responsibility for Rwandan on-farm varietal trial planning and management from the CIAT agronomist to ISAR researchers and technicians. This transfer of responsibility follows CIAT's strategy of reinforcing national research through participation, followed by gradual withdrawal to a coordination and advisory role.

A new simplified system of farmer evaluation of on-farm bush bean variety trials carried out directly by collaborating projects in Rwanda is working well. All projects receiving evaluations forms completed them. The varieties PVA 1272, G 23333 (climbing bean), Kilyumukwe and Kidundo were most often cited by farmers as superior to their own mixtures; whereas G 13671 and Urubononono were almost universally disliked for their sprawling plant type, poor grain quality, susceptibility to disease and late maturity.

The follow-up survey of climbing bean potential trials, conducted in collaboration with PAP and the communes of Syand and Ngoma of Rwanda, showed considerable promise for producing climbing beans in nonclimbing bean areas. Over 90% of the participating farmers interviewed indicated their plans to re-sow the climbers in the 1988 A season and to increase the area planted with climbing beans. The variety Giseny 2 Bis was especially well liked for its combination of high yield, vigor and very fast cooking time.

Staking material continues to be the major constraint to increasing production, and research on this problem is ongoing.

Analysis of a survey focusing on climbing bean farming methods, conducted with 49 farmers in southern Kivu, Zaire, was also completed during the second quarter of 1987. The data will be used in the transfer of climbing bean technology to neighboring areas. In addition, on-farm trials in nonclimbing bean production zones will be designed on the basis of the cultural methods identified in this survey. It is interesting that plant densities in southern Kivu climbing bean production zones are very high (over 300,000 p/ha) as they are in many production zones in northern Rwanda.

Production surveys

Data collection was initiated the first quarter to document current production of Kilyumukwe in the eastern lowland areas of the country for future adoption studies. This variety shows great promise in the east, and a good extension effort should expand its use, with subsequent production increases. ISAR, SSS (the national seed production service) and at least one project, Kibungo II, are multiplying large quantitites of Kilyumukwe.

Case studies

Case studies were initiated in Southern Kivu, Zaire and in the eastern Plateau of Rwanda, in collaboration with PNL-Zaire and Enquete Agricole, Rwanda (USAID).

A case study of 15 bean farmers in the Kigali Prefecture was carried out in collaboration with SESA (Agricultural Statistical Services) of Rwanda. The case study focused on the relationship between bean marketing and bean production techniques. It was found that net bean purchasers tend to cultivate a smaller, but more productive and labor-intensive surface area of beans than net bean sellers. Analysis of a second case study in Kabare, Southern Kivu, was also completed during the second quarter of 1987. Many of the results in the Kabare case study conducted in 1987 A supported the results obtained in the 1986 A - 1986 B Zaire diagnostic survey. The case studies indicate the possibility of increasing farmers' bean production by modifying their current soil fertility management practices.

Seed treatment

Advanced seed treatment trials utilizing selected chemicals to control root rots and beanfly are being conducted by ISABU in Burundi and on farms in collaboration with ISAR agricultural projects in Rwanda. Seed treatments are showing good potential for control of beanfly and seed-borne pathogens. The extension of seed treatment technology using small amounts of effective, but safe chemicals would have a strong impact on bean yields in the region. The possible health hazard in using these chemicals remains the difficult question. In or-station trials in Burundi, endosulfan 35% WP was found to perform better than lindane, and good pest control was obtained at

concentrations as low as 1g/kg seed. These results need to be further verified, but yield data suggest that only 25 kg/ha yield increase is needed to repay investment. For soil and seed-borne pathogens, a seed treatment with benomyl and thiram resulted in a 275 kg/ha increase in yield in the first season of on-farm experiments.

Nutritional and bean-quality studies

The project received additional bean cookers from CIAT, which were sent to Gandajika (Kasai Oriental), the national legume program headquarters, for bean-quality evaluations. New Mattson Bar Drop cookers to be used in laboratory screening for cooking time of advanced lines by national programs, manufactured and delivered by CIAT, were calibrated in the ISAR Rubona laboratory. These new cookers were given to Burundi and Zairian national programs. There is a very good correspondence between on-farm cooking time and the laboratory cooking time index using these bar drop cookers. An analysis of bean samples from the Kampala market was also performed, the results of which were sent to the Ugandan national program.

Concerning quality research, a study was initiated at the farm level to document how differences in cooking time (caused either by the cooking method or the variety of seed cooked) affect firewood needs. The correspondence between actual cooking time under farmer methods and the laboratory cooking time index used for varietal screening in the breeding program was evaluated.

The study was initiated with five farmers during the 1987 A season and will be repeated during 1987 B with 18 farmers. This season's results showed farmers used about eight kg of wood to cook 1.5 kg of beans; average cooking time was about three hours. Varietal differences in cooking time and corresponding fuel needs were observed. Soaking before cooking reduced cooking time and firewood use about 50%.

Regional subprojects

The successful division of research responsibilities among national programs is ongoing. The subprojects that are most developed are the ALS subproject carried out by PNL-Zaire (yield reduction studies and resistance selection nurseries), beanfly by ISABU (resistance evaluations and chemical and cultural control), and *Pseudomonas* and *Xanthomonas* (the two important bean bacterial pathogens) subprojects also carried out by ISABU (varietal screening, yield reduction studies, race identification). Complementing these projects, CIAT staff are placing emphasis on BCMV screening and resistant variety selection. In addition, the ISABU virologist is planning a regional survey of BCMV strains. Results will be very important as black root appears to be much more frequent in Rwanda than in Burundi and Zaire.

Regional subprojects concerning common and halo blight, *Ascochyta* and anthracnose were initiated in 1987. Research carried out as part of these subprojects has already provided very useful information to

the national programs including the refinement of inoculation techniques for some of these diseases. This will allow more accurate evaluation of disease resistance for these diseases.

In steering committee discussions, the following regional subprojects were approved:

- ALS, screening and research project, PNL-Zaire
- Beanfly, cultural and chemical control and varietal screening, ISABU.
- Bacterial diseases, screening and research project, ISABU

Regional collaboration and training

Communications between national programs within the Great Lakes area was facilitated by steering committee meetings held throughout the past year in which research topics were discussed among representatives of the national programs and CIAT scientists. A descriptive pamphlet (in French) of the Great Lakes Regional Project was completed and is being printed at CIAT headquarters in Colombia for dispersal to aid further communication and understanding between the project and national programs. Training continued to receive high priority within the project as seen in a series of proposed and/or completed workshops.

The Sovu Workshop, the Second Technical Training Course, which was held from 8 to 12 December, 1986 at Sovu and Rubona (Rwanda) with 25 participating technicians, was organized in collaboration with ISAR. The objective was to train technicians in field-oriented topics such as planning, installation, management and harvest of both on-farm and station trials, identification and scoring of diseases and insect damage, simple farmer survey techniques, seed storage, data preparation and practical math exercises. Participants came from ISAR, ISABU, PNL-Zaire and agricultural projects from the three countries. Topics were presented by national program scientists from the three countries and by CIAT staff.

From 12 to 15 May a Farming Systems Orientation Workshop was held at Bujumbura, Burundi with the purpose of promoting on-farm research at ISABU and Burundian agricultural projects. The workshop, co-organized by ISABU, CIAT and CIMMYT, had 30 participants.

The Third Regional On-Farm Research Seminar, organized by EMSP of ISAR and CIAT, took place from 15 to 22 May at Remera, Ruhengeri. The purpose of this seminar was to learn about the on-farm research approach of the projects collaborating with ISAR, to visit their trials, and to make recommendations on on-farm research methodology and management at ISAR. The seminar attracted 45 participants who discussed each others' programs. The ISAR director who expressed his interest in this activity, gave the opening address on the state of

on-farm research at ISAR and participated actively throughout the seminar.

The Third Regional Technical Training Workshop was held from 25 May to June 3 with the participation of 30 trainees. It focused on management of grain legume research with an emphasis on beans and soybeans. This was the first technical training workshop held in collaboration with IITA. The workshop was co-organized by CIAT, ISAR and IITA. The workshop was also notable in that the majority of presentations were given by national program scientists in the region.

A Pathology Workshop to exchange information on major diseases and their control and to devise means of sharing responsibilities for research between regions was held in Kigali in November 1987.

The Third Regional Seminar with the participation of selected outside participants from the previous workshop, as well as regional staff was held in Kigali in November 1987.

4. East Africa Regional Project

The Eastern Africa region comprises Ethiopia, Somalia Uganda and Kenya. Coordination is provided by an agronomist based with the Institute of Agricultural Research (IAR) in Ethiopia and the second regional agronomist position is based at the Kawanda Research Station of the Ministry of Agriculture and Forestry, Uganda.

Germplasm set

A germplasm set of over 1200 accessions representing the total range of variability in the CIAT collection was grown at ecologically diverse locations in Ethiopia - Pawe (low altitude, dry) and Kachwekano (high altitude, dry). The principal stresses were: web blight (Pawe), common bacterial blight (Melkassa, Awassa, Kawanda), rust (Awassa); root rots and drought (Melkassa); and angular and floury leaf spots (Kawanda). Data have not yet been fully compiled but several accessions combined resistance to stresses with better yields than the checks at each location and have been promoted to the first stage of national variety tests in both countries.

VEFs

Entries from the 1986 VEF with satisfactory seed type were grown in Ethiopia and Uganda. The best have been included in the national testing systems. Entries from the 1987 VEF were multiplied at Melkassa, Ethiopia under quarantine for further tests in 1988.

In Uganda a yield trial was grown in 1986 to compare the most promising seven introductions made through CIAT VEF nurseries in earlier years with two landraces and two released varieties. All introductions significantly outyielded the local materials, and in several cases by substantial margins, due in part to better resistance to CBB and rust. (Table 1). A multilocational national yield trial was composed from the best entries and from more recent introductions, including those from the AFBYAN. On-farm testing commenced in the second season of 1987.

Ethiopia's system, faced with extreme ecological variation, used 19 locations this year for its final stage of on-station evaluation, with materials being grouped as before into three trial series by grain size and color---white peabean, medium colored and large colored types. Some locations were changed this year in order to adjust trial coverage so as to better represent principal production zones and to match farmers preferences for grain type. With the increasing flow of promising lines of those grain types preferred locally for food, especially reds, it proved possible this year to replace

non-preferred types such as blacks in all advanced trials in the colored (food bean) series.

In the smaller grain legume program of Somalia, a much smaller set of materials, about 100 in all, has been introduced this year, using the primary criteria of appropriate grain color and adaptation to other hot, dry regions of the world. Both CIAT's WANABAN nursery and selections from the germplasm bank are included. The best yields in the first season's unreplicated observations were obtained from materials from Turkey, France, Colombia, USA and Hungary. Both beanfly and leafhoppers were particularly damaging at the Afgoi location.

The potential contribution to be made by introductions to Ethiopia is shown in Table 1, which presents preliminary results form the national variety trial series in the large kidney bean category (data for all locations will be presented in the next annual report). The local check variety (Brown Speckled) was significantly outyielded by two introductions at Awarra and by all entries at Melkarra. It is noteworthy that the Carioca crosses A 410 and A 262 were introduced only in 1985, through the IBYAN.

On-farm testing of bean varieties started in Uganda in 1987, and continued in Ethiopia. In each case, simple trials were used to compare three or four selections from previous multilocation trials with farmers' varieties, under management provided by the farmer. Up to 15 farms were used in each area, and plot sizes from 50 to 100 m^2 with one or two replications per farm were employed. A separate series of varieties is tested for each area.

Results from on-farm testing in the food bean series are not yet available. The entry W-117-0150-1 was the best yielder of the four newer materials included in the white peabean on-farm trial for the Rift Valley zone of Ethiopia. Its mean performance across locations however, was not significantly different from that of the local check, Mexican-142. As rust was not a serious problem this year in the areas where these trials were located, the improved level of resistance shown by the entry GR-385-08 gave no advantage. As part of this commercial crop is produced for canning, entries in this trial were evaluated this year also for canning quality, in collaboration with Michigan State University, USA. As all experimental varieties proved to be inferior to Mexican-142 in this aspect, adequate canning quality is being introduced as a necessary criterion for advancement of this class of germplasm through the earlier stages of the national program.

On-farm research

The two principal objectives of on-farm research have been to understand the principal bean production systems, thereby identifying worthwhile opportunities for research to raise bean

productivity, and to evaluate innovations under realistic conditions.

The past two years have been marked by a considerable improvement in understanding of farmers' constraints in bean production. As a consequence, several adjustments have been made in national research priorities and in evaluation criteria. However, the methods and institutional arrangements used to achieve this have been different in each country.

Initial diagnoses of bean research needs in Ethiopia relied upon the results of general surveys of farming systems in selected areas, particularly near Nazret Research Center for the drier Rift Valley zone of bean cash cropping, and near Awassa Research Center in representing southern areas where beans are a principal food crop. These surveys, conducted before the start of CIAT's regional program, were followed in 1986 by the first on-farm variety trials. The management of these trials, determined largely by cooperating farmers, has provided more detailed information on farmers' production practices and constraints. The same two series of on-farm trials continued in 1987, with some changes in varietal entries in the food bean series to reflect farmers' preferences for grain types for consumption.

Results from 12 Rift Valley locations of the peabean series, reported above under variety development, showed a wide range of mean yields on farms from 154 to 1522 kg/ha, with an overall mean of 719 kg/ha. The principal causes of variability in farm yields in this area appear to be rainfall and soil fertility, both being highly variable over short distances in the Nazret area. Large differences in weed competition were noted between locations having a similar rainfall pattern.

A focussed survey of 50 bean producers in the Rift Valley, using a formal questionnaire with open-ended questions to accompany observations of each farmer's bean crop, was designed cooperatively and administered in 1987 by IAR's Farming Systems and Agricultural Economics Program from Nazret. Preliminary results have confirmed 1986 observations that farmers broadcast seed at higher rates than those developed and recommended for row planting, and that they do this consciously to suppress weeds and reduce competition of labor with manual weeding of other crops, particularly teff. Farmer's plant populations reached 750, 000 bean plants per ha in wetter and more fertile areas, or more than twice the recommended rate; rates used by farmers in the variety trials varied from about 240,000 to 550,000 per ha. While these rates indicate a direct cost associated with this form of weed management, the survey also showed that, contrary to earlier impressions, some farmers are prepared to handweed once if potential bean yield appears to warrant doing so. In the drier areas of the Rift Valley, lack of crop rotation appears to lead to buildup of weeds, to reduced fertility and to the eventual abandonment of the field.

A characteristic aspect of the role of bean production within farming systems in Ethiopia is the ability of this crop to fit into relatively short periods of rainfall. Beans have become an important crop in the Rift Valley despite the generally low yields obtained in an unfavorable climate: annual rainfall is only 600-800mm, less than in most bean growing areas of Africa. With a delayed start to this year's main rainy season and below normal rainfall thereafter, farmers adjusted their cropping patterns to crops with shorter maturity periods, and there were large increases in areas planted to beans and to early maturing varieties of teff, at the expense of maize and sorghum. Beans were common this year also at higher elevations of 1900 to 2100 meters, displacing production of lower yielding but preferred traditional pulses, particularly faba beans and lentils. While it is certain that the area sown to beans in Ethiopia is much greater than official statistics suggest, reliable estimates are not available.

In the food bean production zone of southern Ethiopia, a bean production survey planned for 1987 was postponed due to staff changes related to graduate training. Instead, a collaborative effort was mounted between IAR Awassa Station agricultural economists and the Home Economics Department of the Ministry of Agriculture to determine more about farmers' varietal preferences from the on-farm variety trial .

In Uganda, on the other hand, there is no farming systems research program. Diagnostic work was started in 1987 by assisting the national bean program, which includes several disciplines, in a survey of the important bean-producing area of Kabale in south-west Uganda. As in similar areas of Ethiopia (1750-2100 meters altitude with good rainfall), intercropping food beans with sorghum is common. Diseases were found to be a major constraint, either directly or through causing susceptible varieties to be planted later than optimally for yield, in order to avoid the wet season. This is the only area of the Eastern Africa region where varietal mixtures are commonly grown, and farmers were found to identify advantages and disadvantages for each component. Generally advantageous characteristics of a variety included yield stability (i.e. disease resistance), large seeds which are easier and quicker to shell from green pods, "sweet" taste, early maturity, color other than black, fast cooking time, and erect plant habit.

Agronomy research for this area needs to be focussed on maintaining and improving soil fertility. Uganda's present emphasis on breeding for disease resistance has been confirmed as correct, while a new area requiring research, is the control of bruchids in storage.

It may be noted here that in neither country has use been made so far of multi-factorial diagnostic trials. The surveys and farmer-managed variety trials have already provided what is felt to be an adequate working assessment of farmers'

constraints, which have permitted the focussing of available research resources. The Ethiopian on-farm trial of weeding x genotype x seeding rate is partially exploratory in nature, in that its results could feed back new criteria for the selection of varieties in the future.

Agronomy

Research on cropping and management practices for bean production continues to be given greater attention in Ethiopia. In Somalia and Uganda, there has been inadequate information available on the potential for agronomic research to raise productivity, and national programs have tended to concentrate their manpower resources upon the development of new varieties.

The effectiveness of Ethiopia's research review and planning process, already well developed both at station and national levels, was enhanced this year by the requirement that each research proposal be addressed explicitly to priority constraints identified during local surveys of farming systems. This steady evolution within IAR has been encouraged by workshops, training courses and exposure of commodity scientists to on-farm research. CIAT has contributed to national workshops, as well as by working closely with scientists at Nazret, while other IARCs are more closely associated with other commodity-based research stations.

A new trial on seeding rates and varieties was initiated both at Nazret and on farms, under the aegis of IAR's Agronomy Department, to develop recommendations appropriate to the low-input Rift Valley production system. Three bush pea bean varieties of differing growth habits and competitiveness, grown at three broadcast seeding rates with zero and one hand weeding, are being compared in a factorial arrangement on the premise that optimal levels of these factors will not be the same as for well weeded, row-planted crops. Meanwhile, the development of on-drawn interrow cultivation equipment is being encouraged at Nazret for weed control using the existing recommendations for variety and spacing.

The second principal theme of agronomy research in progress in Ethiopia is the intensification of cropping patterns. Sorghum and beans, principal crops in the Rift Valley, are grown in this area in pure stands. An experiment at Melkassa has been conducted by IAR agronomists to evaluate sorghum/bean intercropping, treatments being replacement series at a range of plant populations. The experiment was concluded this year after obtaining a consistent response from replacing one third of the sorghum population with bush beans. Land equivalent ratios and cash returns per unit area were increased by between 50 and 100 per cent. IAR entomologists working at the same station had also shown that pod boring by African bollworm, *Heliothis armigera*, could be reduced by strip cropping beans with maize as a trap crop.

It remains to be seen whether and how farmers will accept intercropping in the labor-scarce areas where it is not a tradition. The on-farm trials started this year from Bako research station indicated the type of followup that is required. For this wetter and predominately maize-producing zone in western Ethiopia, a promising maize/bean intercropping treatment identified on the station in row-cropped replacement experiments has been translated into on-farm tests of beans broadcast into maize during weeding.

Intercropping of bush beans and maize is common in more densely populated high-rainfall areas of southern Ethiopia, served by Awassa research station. Further intensification of these systems through the development of novel double cropping and relay cropping patterns, based on cereal/legume associations, is the objective of new experiments started by IAR agronomists this year. Initial results suggest that vigor of bean plants can be higher in the first rainy season with less incidence of rust. As all variety development work presently is conducted in the second or main rainy season, it is planned to repeat evaluations in the first rains in this area.

AFBYAN

An Africa-wide variety trial, called the African Bean Yield and Adaptation Nursery (AFBYAN), has been established with the following objectives:

1. To distribute and evaluate the performance of existing local cultivars more widely.

2. To provide a vehicle for the regional evaluation of new materials.

3. To initiate an African network of bean breeders.

4. And to examine varietal performance in relation to environment.

Management of the AFBYAN is currently undertaken by the national program in Ethiopia.

The AFBYAN, comprising 25 entries contributed by African national programs, was grown at Melkassa in Ethiopia, at Kawanda (first and second seasons) and Kisindi and Kachwekano (second seasons) in Uganda within Eastern Africa; at Mulungu in (Zaire) and Rubona (first season) in Rwanda within the Great Lakes Region; and at Msekera (Zambia) in Southern Africa.

Preliminary data obtained during 1987 are presented in Tables 3-6, after combined analyses across environments. Table 3 shows that varietal differences are essentially cancelled by environmental interactions, indicating that there is need for harnessing specific adaptation. Although these data are very

preliminary, being based only on six environments, they do indicate a need to relate differences to varietal performance and to determine the factors that underlie Genotype x Environment interactions. The data demonstrated dramatic interactions between entries and locations for seed yields (Table 6) and other characters. For example, K20 was the poorest in performance in two seasons in the area where it was bred and recommended, and yet it was ranked top and second in terms of seed yield at Rubona and Msekera, respectively. G 2816 performed outstandingly well at Mulungu under heavy pressure from bean fly infestation. Urubonobono, which ranked second at Kawanda was among the poorest yielders at Msekera.

Analysis of stability by regression of variety mean yield on environment mean yield (Table 3) shows that in some cases only a small proportion of the total variation can be accounted for, so indicating that other factors are involved in these interactions: disease severity is likely to be one such factor. Table 4 shows that Variety x Environment interactions are larger than varietal effects in the cases of angular leaf spot, rust and BCMV, but not so with common bacterial blight. This accords well with expectation, based on current knowledge of the degree of pathogenic variation each exhibits.

Regional collaboration and training

The third regional steering committee meeting was held at Debre Zeit, Ethiopia, with participation of national coordinators from all four countries, of representatives from both donor organizations and of the regional coordinator. This meeting, besides approving the program's annual workplan and allocating budget items for training and network activities, approved three proposals for collaborative regional research subprojects.

In the first of these subprojects, which accord with regional priorities identified by the steering committee, the bean pathologist of IAR, Ethiopia, is quantifying crop losses caused by bean rust, screening germplasm for resistance, developing local capability in inoculation and screening techniques and investigating aspects of the epidemiology of the disease. A regional leadership role in research on this topic is expected to develop, leading to organization of a regional resistance nursery from Ethiopia. To encourage the development of complementary research, a monitoring tour of bean rust research locations in Ethiopia was organized for visiting Tanzanian and regional scientists.

Two other regional subprojects, on common bacterial blight and on Ascochyta blight, were started by Ugandan teams each comprising a pathologist and a breeder.

A First Eastern Africa Regional Workshop on Bean Research was held at Mukono, Uganda. The 33 participants, representing a

wide range of disciplines, came from the four countries of the region, from two adjoining countries and from CIAT programs.

Cooperation among national research programs is being encouraged also through the exchange of progress reports. Assistance has taken various forms, including translation, editing, and support for producing larger numbers of copies.

Training efforts this year included the following:

A two-week course in field research methods was held in Uganda for 18 technicians from that country and two from Somalia. Resource persons were drawn from senior staff of the Ministry of Agriculture and from two CIAT regional programs. This course, which alternated classroom sessions with field practice, was modelled on the 1986 course held in Ethiopia.

A two-week in-country course for 50 graduate agronomists from all stations of IAR, Ethiopia was organized and sponsored jointly by IAR, CIMMYT and CIAT. This course concentrated upon problems in design, analysis and interpretation of agronomy experiments. Formal training is being reinforced by continuing participation of the regional agronomist in IAR program review and planning meetings, which are designed to ensure that each station's annual research plans reflect the priorities identified by farming system surveys of each area.

The regional program also assisted an IAR/IITA Regional Research and Production Course on Cowpea and Soybean, held in Ethiopia. Participants from Somalia, where beans and other grain legumes are handled in the same research program, were sponsored by CIAT and the regional agronomist organized the agronomy session of the workshop. Opportunities for further collaboration in training among IARC regional programs were highlighted in CIAT's presentation to a Regional Workshop on Training Needs for Agricultural Research in Eastern and Southern Africa, organized by IITA and Tanzania. Regional staff also contributed to a weed management course for zonal level extension workers in Ethiopia.

Sponsorship of postgraduate training at Master's level started this year with a Ugandan entomologist at Sokoine University of Agriculture, Tanzania and with a Ugandan agronomist at the University of Florida, USA. Another Ethiopian bean entomologist returned to the national program to start field research in connection with his PhD program at a Canadian university, under IDRC sponsorship. His work on the management of beanfly through screening for genetic resistance, evaluations of seed dressings and study of pest ecology is contributing to the overall efforts in Africa towards controlling this insect.

Boxed sets of English-language CIAT audiotutorial teaching materials on topics related to bean research and production, some of them specially produced at CIAT for Africa, were provided to the principal agricultural university in each of the four

countries. Further sets were provided to national research programs for in-service training purposes, and the accompanying study guides have been widely utilized during the year in training courses and for extension workers.

Table 1. Yield, disease reactions, and adaptation of bean varieties introduced from CIAT grown at Bukalasa, 2nd Season 1986.

Variety	Vigor	Habit	CBB	Rust	Anthracnose	Mean Yield/Kg/ha
* Kanyebwa	3	1	4	4	1	694
* Kampulike	3	2	3	2	1	101
* K 130	3	1	4	3	1	1062
* K20	3	1	4	4	1	1215
BAC 36	3	2	1	1	1	1750
A-83	3	2	2	1	1	1930
A-140	3	2	2	1	1	2194
CATU	3	2	3	2	1	2438
CARIOCA	2	2	2	1	1	2454
A-162	3	2	3	1	1	2639
BAT 1220	2	2	2	2	1	3243

* Local varieties/land races LSD 0.05 = 17

Vigor and disease reactions were rated on a scale of 1 to 5

Source : Ugandan Bean Program, Annual Report, 1986.

Table 2. Yield and earliness in Ethiopian national variety trial for large kidney bean type, at Awarra and Melkassa, 1987.

	Awarra		Melkassa
Entry	Yield (kg/ha)	Days to maturity	Yield (kg/ha)
Aguascalientes	2368	87	1350
A 410	3250	91	1140
A 262	2957	92	1075
Epicure	1992	90	1002
Diacol Calima	3470	92	982
Acc No. 3142-1	2481	91	916
Brown Speckled	2579	90	488
LSD	507		264

Source : Institute for Agricultural Research, Ethiopia

Table 5. Stability parameters for some entries in AFBYAN at six locations (1987).

Entries	Mean	b	S.E.	R^2
Black Dessie	1058	0.70	0.296	58
G 13671	1039	1.20	0.427	73
G 2816	1387	0.20	0.771	2
K-20	970	1.39	0.559	22
Carioca	1271	0.58	0.559	22
Urubonobono	1116	1.35	0.356	78
N. de Kiyondo	1034	0.38	0.480	14
KAN 76	1344	0.90	0.409	55

Table 6. Yields (kg/ha) of entries in AFBYAN at six locations (1987).

Location	Kawanda 7A	Kawanda 7B	Msekera 87	Rubona 7A	Mulungu 7A	Kisindi 7A	Mean
Black Dessie	1633	1363	957	1251	403	738	1058
G 13671	2275	845	553	1483	313	767	1039
G 2816	1650	908	928	1826	2543	467	1387
K-20	817	271	1580	2400	0	688	956
Carioca	1692	2175	1175	1361	703	521	1271
Urubonobono	2191	888	584	1851	280	900	1116
N. de Kiyondo	1667	577	799	1281	1564	417	1034
XAN 76	1908	1093	2049	1572	453	900	1344
Mean	1489	823	999	474	631		
C.V.	28.7	31.4	32.2	17.3	70.2	36.8	
S.E.							

Table 3. AFBYAN. Plant characters and yield components. % total sums of squares.

	Plant Height	Ground Cover	Pods DFF	Pods DM	Seeds /M^2	Seed /POD	Seed WT	YIELD
No. trials	4	4	4	3	4	4	4	6
Environments	19.3	27.0	53.2		25.3	2.6	8.0	49.9
(E)	*	***	***		***	**	***	**
Varieties	10.9	19.3	27.4		24.9	57.3	66.3	5.8
(V)	ns	***	ns		***	***	***	ns
V x E	38.1	21.7	16.7		23.4	13.7	9.5	27.6
	***	***	***		***	ns	ns	***

Table 4. AFBYAN. Disease scores. % total sums of squares.

	ALS	RUST	CBB	BCMV
No. trials	3	3	3	3
Environments	71.8	32.4	49.3	46.3
(E)	**	**	***	***
Varieties	8.9	11.3	17.8	20.3
(V)	ns	ns	***	*
V x E	10.9	26.5	11.6	19.3
	**	***	**	***

5. Southern Africa Regional Project

The Southern Africa Regional Bean Project supports national program bean research in Angola, Botswana, Lesotho, Malawi, Mozambique, Swaziland, Tanzania, Zambia, and Zimbabwe.

Varietal evaluation

Following is a summary of research progress made during the 1986/87 season, the credit for which rests firmly with the individual National Program involved. No report is presented on Botswana, owing to the lower priority accorded to beans in that country; nor are results from Angola and Malawi included because CIAT materials are not yet under evaluation in either country.

Other progress has been achieved through Special Projects, with which CIAT is involved elsewhere, including CIAT/NVRS/ODA on halo blight, and now the CIAT/Braunschweig/BMZ project on virus identification. Close contacts were maintained with the TARO/Wye College/ODA project on BNF/micronutrients.

TANZANIA

Yield data from the 1987 Tanzania Phaseolus Bean Preliminary Yield Trial show that the top 15 of the 64 entries outyielded the best of the three check varieties, Lyamungu 85, over the two sites (Selian and Lambo). The top 5 genotypes (A line 15, LB 588, Cargabello x BAT 1386, LB 533 and A line 13) produced mean seed yields above 2600 kg/ha (trial mean yield = 2062 kg/ha, cv = 17%). This indicates that there are some excellent materials in the 'pipeline' for northern Tanzania.

From combined analysis of seed yield across the five sites (Lyamungu, Lambo, Selian, Maruku and Mubondo) at which Advanced Trial I (bush types) was run, only one entry (PVAD 1406) outperformed Lyamungu 85, giving a mean yield of 1853 kg/ha as against 1731 kg/ha. In Advanced Trial II (climbers), Lyamungu 85 was outperformed, but not significantly, only by Carioca selection 2 across these sites. Many of the entries in the latter trial were severely damaged by white mold at Lambo and Selian, exacerbated perhaps by lack of staking.

In the Tanzania Phaseolus Bean Uniform Cultivar Trial at 7 locations, a CIAT germplasm accession (G 5621, Diacol Calima) produced the heaviest yield of 1548 kg seed/ha: XAN 66 (1472 kg) ranked second and Lyamungu 85 (1434 kg/ha) was third.

In the Uniform Cultivar Trial for the Southern Highlands, CG 104 was top yielder (1557) kg/ha acroos 3 sites - Uyole, Mbimba, Ismani - in 1986/87 season), followed by the recently released 'standard' cultivar Uyole 84 (1478 kg/ha). Lyamungu 85 appears to perform less well, in these southerly sites, and was ranked 10th in performance amorg the 15 entries (mean yield 1083 kg/ha).

Results from the Tanzania Phaseolus Bean Uniform Cultivar Trial across 3 sites (Lyamungu, Lambo, Selian) show that only G 5621 (Diacol Calima) outyielded the check, Lyamungu 85 (1777 kg/ha) compared to 1614 kg/ha).

Results from the National Bean Yield Trial, (medium altitude), combined across the two northern sites (Lambo & Selian) for which data are currently available, show that only UAC 56 outyielded Lyamungu 85 (2257 and 2229 kg/ha, respectively). Other heavy yielding entries were TMO 216 (= UAC 258), P 285 and Kabanima (2191), 1955 and 1884 kg/ha, respectively). Uyole 84 performed poorly and was ranked 14 th among the 16 entries. Data from the National Bean Yield Trial (high altitude) across two sites in the Southern Highlands (Uyole and Mbimba) show that the three top yielders were EMP 86, XAN (= BAC) 66 and Masai Red (1921, 1704 and 1621 kg/ha, respectively), with the check varieties Uyole 84 and Lyamungu 85 producing 1399 and 1239 kg/ha.

Crop loss studies conducted across sites in the Southern Highlands have established disease priorities and have confirmed that yield loss is positively related to disease score, especially in the more susceptible varieties.

Studies on pathogenic variation in the halo blight bacterium collected in 1986/87 from three bean growing regions have confirmed the presence of three races in Tanzania. Two isolates of Race 2 produce a brown pigment the significance of which remains unknown. The principal species of broad-leaved weed of bean fields in northern Tanzania have been identified, and herbicide efficacy in managing them has been elucidated.

Variety evaluation on-farm in northern Tanzania has shown a mean yield across sites (ranging from 700-1400 m altitude) of 1078 kg/ha, but Lyamungu 85 was not significantly superior overall. Canadian Wonder performed relatively better on farms at lower altitude, where disease pressure was less heavy. In work at Sokoine University, Canadian Wonder is considered a good N-fixer, and substantial response to rhizobium inoculation (with added P) have been obtained on-farm using locally produced inoculart (strain ELP 3 from Mgeta, especially).

The National Program is expanding its network of on-farm trials into new areas in 1987, including Arusha, Lushoto and Kagera.

ZAMBIA

Results from the Zambia National Dwarf Bean Variety Trial over six locations during the 1986/87 season demonstrate the superiority of PAT-10, PAI-78, PAT-12 and A-429 over the standard variety, Carioca. PAT-10 produced yields in excess of 1000 kg/ha at all sites. All four lines are candidates for pre-release testing next season. Meanwhile, seed of Carioca was distributed

in bulk to interested small farmers. In the African Bean Yield and Adaptation Nursery (AFBYAN), XAN-76 and K-20 (contributed by Rwanda and Uganda, respectively) outyielded all the three Zambian check varieties. A preliminary evaluation of 192 promising lines from CIAT at Msekera and Mbala led to the identification of 30 excellent yielders (more than 2000 Kg/ha). Trials of climbing cultivars in maize confirmed the superiority of ACV-8312, ACV-8313, and VRA 81054.

BCMV strain identification studies confirmed that N 3 is predominant in Zambia. Among lines with BCMV resistance, ZPV 292, G 5066, G 10357 and G 13595 were found especially promising. Twenty-one lines (including G 6040) selected from CIAT disease nurseries were found to possess combined resistance to angular leaf spot, ascochyta blight and anthracnose, and had heavy yield potential. Sources of scab resistance were identified, and partial resistance to bean fly in A 62 and A 74 was confirmed.

ZIMBABWE

Yield data obtained from testing 190 genotypes in Preliminary Variety Trials at two sites in the Highveldt (Harare and Gwebi) in the 1986/87 season reveal that a high proportion outyielded the widely grown check variety, Natal Sugar. Three genotypes (RAB 263, RAB 296 and RAB 290) were significantly superior at both sites, auguring well for the release of new heavier yielding cultivars in Zimbabwe. Disease ratings at Harare for BCMV black root, mosaic and common bacterial blight indicated an association between heavier yield and lower incidence of BCMV.

Seed yield results obtained from the Intermediate and Advanced Variety Trials, conducted at two and three locations (including Henderson) respectively, also show that many entries outyielded Natal Sugar at some sites. Although the top five genotypes in each trial did not significantly outperform Natal Sugar at all sites, the yield advantange across sites over this cultivar was large. The release of one or more of these promising genotypes (including Carioca, PVMX 1671, A 107 and A 79) as a new cultivar should benefit Zimbabwe through increased seed production of food beans.

LESOTHO

Results from bean variety trials conducted at two sites (Maseru and Teyateyaneng) in the lowlands have demonstrated the superiority of Pinto NW 590 over the local control variety, Bonus. Subsequent evaluation at Maseru has shown that other materials are now available that outperform NV 590. In the Bean Variety Trial--1986/87, six entries outyielded the check variety, (Bonus), two significantly so; these were Red Mexican NW 59 and A 268 (1300 and 738 kg/ha, respectively). In the Pinto Bean Variety Trial, outstanding entries included Olathe, Harold, UI 126 and NW 410 (top yielder 1501 kg/ha). In the SARCCUS Bean

Nursery, Umvoti and NW 590 were the top yielders (1074 and 1039 kg/ha, respectively), each substantially better than Bonus (497 kg/ha). On-farm trials with Pinto NW 590 are being designed to evaluate its acceptability and performance under low management before release. The national germplasm base is being broadened through introduction, and these new materials will be evaluated alongside local lines also at sites in the foothills and highlands.

SWAZILAND

Results from International Bean Yield and Adaptation Nurseries (IBYAN) from CIAT at two sites (Malkerns and Nhlangano) have identified various genotypes as substantially superior to the local check, Bonus. In particular, A 445 (a Carioca progeny) is particularly promising: its mean yield over three seasons at both sites was 2174 kg/ha, as against 747 kg/ha from Bonus (mean of 14 trials). Various other lines show almost equal yield advantage. In 1987, the International Halo Blight Nursery, the BCMV Nursery and Sugarbean Nursery were received from CIAT and evaluated at Luyengo where several Pinto types were also grown out. Among the latter, Olathe was particularly promising, yielding about double the check variety, Bonus. A Swaziland Bean Nursery is being established to evaluate the most promising lines from all sources over a wider range of environments.

On-farm surveys are needed to establish the acceptability of the promising genotypes, and the best lines are to be tested on-farm.

MOZAMBIQUE

Evaluation of local germplasm and introduced materials at two contrasting sites (under irrigation at Chokwe in the South, and under rainfed conditions at Lichinga in the North) which are representative of the most important systems of production, has led to the identification of a Manteiga type (INIA 10) and a Brazilian material (HF 465-63-1) which are being considered for release. On-farm trials near Chokwe have shown that HF 465-63-1 is suited to maize intercropping. Future breeding effort will focus on incorporating resistance to BCMV, rust, angular leaf spot and bean fly into an early maturing Manteiga type, with large light brown seed and erect habit. The potential of climbing types in maize association will be investigated.

Bean fly is recognized as a major constraint in northern rainfed areas where recommendations are being made to treat seed with basudin.

Agroecological zones suited to bean production in Mozambique have been defined and extension leaflets for bean farmers are being prepared.

Information for the preceeding reports was provided by CIAT scientists at SADCC Headquarters in Arusha as well as E. Koinange and the Proceedings of the 6th Bean Research Workshop, Sokoine Agricultural University (Tanzania); the Grain Legume Annual Report 1986/87 (Zambia); H. E. Gridley (Zimbabwe); D. J. Allen (Lesotho); R. Kuhn, J. Pali Shikhulu, D. J. Allen (Swaziland); and M. Moraes (Mozambique).

Regional collaboration and training

Despite the handicap of physical separation between the regional and national teams, excellent relations have been achieved.

Regional scientists travelled extensively within the SADCC region during the year: tours were made of all the principal bean growing regions of Tanzania, and visits were made during the main season to Malawi and Zambia. The Regional Coordinator also visited Mozambique, Lesotho and Swaziland to present progress to the SACCAR Board and to strengthen cooperation with the respective national programs. The Breeder also undertook consultancy travel to Ethiopia and Uganda, on behalf of the Eastern Africa program. CIAT's Board of Trustees, Headquarters Administration and Bean Program scientists visited Arusha, as did CIDA personnel.

Links were further strengthened with the national program staff at TARO-Lyamungu with whom exchange visits were made frequently. Regional scientists took part in the National Commodity Crop Coordinating Meeting on Beans as well as contributing to the Sixth Bean Research Workshop in Tanzania.

The second and third meetings of the steering committee of the regional program were convened during the year, in Malawi in March and in Zambia in November, respectively. Representatives from eight of the nine SADCC countries have participated in these meetings, in conjunction with representatives of SACCAR, CIDA and CIAT, and good progress has been made in setting priorities for the procurement of research equipment in support of national programs and in identifying training needs. Three proposals for regional collaborative research sub-projects were submitted and a fourth is under review. Conditional approval has been given to a sub-project on angular leaf spot resistance by the national program of Malawi.

Training efforts this year included the following:

--- Twenty-one participants from six SADCC countries attended a SADCC/CIAT/IITA course on grain legume research for technical assistants, held in Lilongwe from 14-28 March.

--- Mr. O.S. Mbuya has been accepted for an MS in Agronomy at the University of Florida, Gainsville for where he expects to leave at the end of the year.

--- The Regional Project supported five national program pathologists at the First African Bean Pathology Workshop in Kigali in November, one of whom stayed on to attend the Great Lakes Regional Seminar. A breeder from Malawi attended the International Trials Workshop at CIAT headquarters, and a pathologist from Tanzania participated in a Regional Workshop on Phaseolus Bean Research in Eastern Africa in Uganda.

IV. TRAINING

The training section of CIAT's Bean Program emphasizes training in appropriate technology for various agronomic situations in a range of course topics offered both at CIAT headquarters and in the trainees' countries. The opportune existence of good quality seed combined with ready availability to the farmers, facilitates the training program's promotion and distribution of recently identified promising germplasm to farmers through the vehicle of trainees.

On-going project follow up courses offered in topics such as On-Farm Trials, and Artesanal Seed Production continue to be an essential aspect of the training methodology.

Courses given in-country are planned to contain 2-4 phases. Each phase encompasses meetings of the participants to review and revise information, or to train the participants in hands-on practical experience that will form the following phase. The interphase duration, or length of time between phases, is equal to all or part of the growth cycle of the crop under dicussion. During these interphases, participants make on-farm visits to backstop their practical work, and in the succeeding phase, they evaluate results and plan new activities.

Objectives

Courses are oriented toward the following :

1. Promotion of promising germplasm, through training in technology appropriate to different systems of farming.

2. Identification of factors limiting production and subsequent search for alternatives or solutions congruent with the problems, resources and objectives of the farmers.

3. Support of good quality seed production on-farm by farmers.

Courses

Fifteen courses were given in 1987 throughout Latin America. Three of these were given at CIAT-Palmira; and the remaining 12 were divided between Costa Rica, Nicaragua, El Salvador, Honduras, Paraguay, Cuba and the Dominican Republic.

Results

a) The number of scientists trained in 1987 surpassed the figure for 1986 by 88%; the number of courses offered went from 10 in 1986 to 15 in 1987.

b) Course follow-up and continuity as practiced with the phase and interphase methodology, proved to be effective and

unseful this year, as shown by the knowledge learned and re ained by course participants.

c) Genetic materials useful to farmers were released and/or identified during activities which concurrently served to train participants in diffusion of new materials and complementary crop technology.

d) Courses on seed production for farmers proved their value by reducing seed shortage.

Training in specific disciplines

Sixty-six scientists received training in 16 different disciplines during 1987. All training in disciplines was accomplished at CIAT headquarters in Colombia. The largest number of trainees (55) come under the category Visiting Scientist, while the most popular courses were Farming Systems (23), followed by Pathology (8) and Interdisciplinary Studies (7). The largest proportion of participants came from Brazil, Colombia, Costa Rica, Mexico and Paraguay.

Workshops

The following workshops ere held at CIAT-Palmira, Colombia.

1. Latin American Bean Workshop for On-Farm Research (ICDA). 16-25 February, 1987.

2. Workshop on Snap Bean Improvement. 11-15 May, 1987

3. Evaluation, Selection and Management of Legume-Rhizobium Symbiosis (Follow Up Workshop for Special Project Participants). 30 August-5 September, 1987

4. International Bean Trials Workshop. 12-16 October, 1987

5. International Workshop on Drought Tolerance in Beans. 19-21 October, 1987

6. Field Workshop for Bean Breeders in Central America. 19-21 October, 1987

Table 1. Courses given in 1987 in Latin America and the Caribbean.

Country	Course Emphasis	Collaboration Institution	Number of participants
Costa Rica	Research and Tech. Transfer (II phase)	MAG, Univ of Costa Rica	25
Nicaragua	On-Farm Research (III phase)	MIDINRA	11
El Salvador	On-Farm Research (III phase)	CENTA	9
Honduras	On-Farm Research (II phase)	RRNN	21
Costa Rica	Research and Techn. Transfer	MAG, Univ. of Costa Rica	20
Colombia	XIV Research and Prod. (Intensive Phase)	International	22
Colombia	IV On-Farm Research	International	22
Cuba	VII Production	MINAGRICULTURA	35
Honduras	On-Farm Research (III Phase)	RRNN	23
Colombia	Production	EMPRATER	18
Paraguay	Production	SEAG	24
El Salvador	Production and Promotion (I Phase)	CENTA	31
El Salvador	Production of Artesanal Seed (I Phase)	CENTA	25
Dominican Republic	Production and Promotion (I Phase)	SEA	28
El Salvador	Diagnostic Workshop	CENTA	24

Table 2. Training provided at CIAT in specific disciplines in 1987.

Program: Beans	Training category													
	PHD Thesis		No Thesis		M.S. Thesis		Specialization		Specialization plus intensive multidisciplinary course		Multi-disciplinary course		Sub-totals	
	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months
DISCIPLINE:														
BIOTECHNOLOGY							1	(2.7)					1	(2.7)
ECONOMICS							2	(1.3)					2	(1.3)
ENTOMOLOGY							3	(6.9)	1	(1.2)			4	(8.1)
FARMING SYSTEMS	1	(9.7)					14	(24.0)	8	(25.3)			23	(59.0)
PHYSIOLOGY									1	(5.2)			1	(5.2)
INTERDISCIPLINARY											7	(7.9)	7	(7.9)
BREEDING			1	(12.0)			9	(21.7)	3	(15.5)			13	(49.2)
MICROBIOLOGY							3	(6.1)					3	(6.1)
PATHOLOGY	2	(11.4)			1	(10.4)	5	(13.0)					8	(34.8)
PRODUCTION									2	(6.9)			2	(6.9)
VIROLOGY							2	(3.4)					2	(3.4)
PROGRAM TOTAL	3	(21.1)	1	(12.0)	1	(10.4)	39	(79.1)	15	(54.1)	7	(7.9)	66	(184.6)

Table 3. Number of man-months of training provided by CIAT, by country, in 1987.

Program: Beans	Training category													
	PHD Thesis		No Thesis		M.S. Thesis		Specialization		Specialization plus intensive multidisciplinary course		Multi-disciplinary course		Sub-totals	
	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months
LATIN AMERICA AND THE CARIBBEAN														
ARGENTINA							1	(0.4)	2	(9.0)			3	(9.4)
BOLIVIA									1	(2.9)			1	(2.9)
BRAZIL					1	(10.4)	7	(19.4)	3	(13.1)	1	(1.2)	12	(44.1)
COLOMBIA							3	(5.1)	1	(2.9)	4	(4.4)	8	(12.4)
COSTA RICA							7	(13.3)					7	(13.3)
CUBA							1	(1.6)					1	(1.6)
ECUADOR							1	(2.9)					1	(2.9)
EL SALVADOR							4	(6.9)					4	(6.9)
GUATEMALA							2	(4.2)	1	(5.0)			3	(9.2)
HONDURAS							1	(1.2)					1	(1.2)
MEXICO	1	(4.9)					2	(3.4)	1	(2.9)	2	(2.3)	6	(13.5)
PARAGUAY							1	(1.7)	4	(9.9)			5	(11.6)
PERU							2	(3.6)	1	(4.4)			3	(8.0)
DOMINICAN REPUBLIC							2	(4.1)					2	(4.1)
AFRICA														
RWANDA							1	(1.5)					1	(1.5)
UGANDA							1	(0.8)					1	(0.8)
ZAIRE							3	(9.0)					3	(9.0)
DEVELOPED COUNTRIES														
BELGIUM			1	(12.0)									1	(12.0)
SPAIN									1	(4.0)			1	(4.0)
USA	1	(6.5)											1	(6.5)
ENGLAND	1	(9.7)											1	(9.7)
PROGRAM TOTAL	3	(21.1)	1	(12.0)	1	(10.4)	39	(79.1)	15	(54.1)	7	(7.9)	66	(184.6)

The following courses or workshops were co-sponsored or co-organized by CIAT's African projects in 1987.

1. Third Regional Technical Training Course (Rubona, Rwanda).
2. Farming Systems Orientation Workshop (Bujumbura, Burundi).
3. First African Bean Pathology Workshop (Kigali, Rwanda).
4. Third Regional On-Farm Research Seminar (Rhengeri, Rwanda).
5. East African Regional Workshop on Bean Research (Mukono, Rwanda).
6. Field Research Methods Course (Mukono, Rwanda).
7. In-Country Course on Agronomic Experimentation (Ethiopia).
8. Regional Research Course on Cowpea and Soybean (Ethiopia).
9. Weed Management Course (Ethiopia).
10. SADCC/CIAT/IITA Course on Grain Legume Research (Lilongwe, Malawi).
11. Sixth Bean Research Workshop (Arusha, Tanzania).

APPENDIX A. LIST OF COLLABORATING INSTITUTIONS

CARDI	Caribbean Agricultural Research Development Institute, West Indies.
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica.
CDA	Collaboration for Development in Africa.
CENARGEN	Centro Nacional de Recursos Genéticos, Brazil.
CENICAFE	Centro Internacional de Café, Colombia.
CENTA	Centro Nacional de Tecnología Agropecuaria, San Salvador, El Salvador.
CGIAR	Consultative Group for International Agricultural Research, New York, New York.
CGPRT	Course Grains, Pulses, Roots and Tuber Crops Center,
CIAB	Centro de Investigación Agrícola del Bajío, México.
CIAGOC	Centro de Investigación Agrícola del Golfo Centro, México.
CIANOC	Centro de Investigación Agrícola Norte Central, México.
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo, Londres, México.
CIP	Centro Internacional de la Papa, Lima, Perú.
CNP	Consejo Nacional de Producción, Costa Rica.
CNPAF	Centro Nacional de Pequisa em Arroz e Fejiao, Brazil.
CIPA	Centro de Investigación y Promoción Agropecuario (I and II), Perú.
CPATU	Centro de Pesquisa Agropecuaria de Trópico Úmido, Brazil.
CRSP	Collaborative Research Support Program, Tanzanía

CVC	Corporación Autónoma Regional del Valle y Cauca, Colombia.
DIGESA	Dirección General de Servicios Agropecuarios, Guatemala.
DRI	Desarrollo Rural Integrado, Colombia.
EEAOC	Est. Exptl. Agrícola Obispo Colombres, Brazil.
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria, Brasilia, Brazil.
EMCAPA	Empresa Capichaba de Pesquisa Agropecuaria, Brazil.
EMGOPA	Empresa Goianía de Pesquisa Agropecuaria, Brazil.
EMPASC	Empresa de Pesquisa Agropecuaria de Santa Catarína, Brazil.
EPABA	Empresa de Pesquisa Agropecuaria de Bahía, Brazil.
ESAL	Escola Superior de Agricultura de Lauras, Brazil.
FAO	Food Agricultural Organization of the United Nations, Rome, Italy.
FFDECAFE	Federación Nacional de Cafeteros, Colombia.
IAPAR	Fundacao Instituto Agropecuario de Paraná Brazil.
IAR	International Agricultural Research.
IARC	International Agricultural Research Centers Network.
IBPGR	International Board for Plant Genetic Resources, Rome, Italy.
ICA	Instituto Colombiano Agropecuario, Colombia.
ICARDA	International Center for Agricultural Research in the Dry Areas, Beirut, Lebanon.
ICTA	Instituto de Ciencia y Tecnología Agrícola, Guatemala. Cita, Guatemala.
IDIAP	Instituto de Investigaciones Agricola Pana-

	meñas, Panama.
IICA	Instituto Interamericano para la Cooperación Agrícola, Costa Rica.
IITA	International Institute of Tropical Agriculture, Nigeria
INCAP	Instituto de Nutrición de Centroamérica y Panamá, Costa Rica.
INERAL	Institut Nacional des Etudes es Rechervhes Agrícolas, Zaire.
INIA	Instituto Nacional de Investigación Agrícola, Perú.
INIAP	Instituto Nacional de Investigaciones Agropecuarias, Ecuador.
INIPA	Instituto Nacional de Investigaciones y Promoción Agraria, Lima, Perú.
INRA	Institut Nacional de Recherches Agronomiques, Guadalupe.
INTA	Instituto Nacional de Tecnología Agropecuaria, México.
INTA	Instituto Nacional de Tecnología Agropecuaria, Argentina.
INTA	Instituto Nicaraguense de Tecnología Agropecuaria, Nicaragua.
IPA	Instituto de Fesquisa Agropecuaria, Pernambuco, Brazil.
IPAGRO	Instituto de Pesquisas Agronómicas, Brazil.
ISABU	Institut de Sciences Agronomiques du Burundi, Burundi.
ISAR	Institut Scientifique et Agronomique du Rwanda, Rwanda.
ISNAR	International Service for National Agricultural Reserach, The Hague, Netherlands.
IVT	Institut Veredeling, Tuinbouwge, wassen, Holland.
NVRS	National Vegetable Research Station, Wellesbourne,

	England.
ONS	Oficina Nacional de Semillas, Costa Rica.
PCCMCA	Programa Cooperative Centroamericano de Mejoramiento de Cultivos Alimenticios.
PESAGRO	Pesquisa Agropecuario - Rio, Brazil.
SDC	Swiss Development Cooperation, Switzerland.
SEARCA	Southeast Asian Regional Center for Graduate Study and Research in Agriculture.
UEPAE	Unidad de Execucao de pesquisa de Ambito Estadual, Brazil.
VISCA	Visayas State College of Agriculture, the Philippines.
VICOSA	Universidade Federal de Vicosa, Brazil.

APPENDIX B. BEAN PROGRAM PERSONNEL (December 1987)

Pachico Douglas, Ph. D., Agricultural Economics, Bean Program Leader

Allen, David, Ph.D., Plant Pathology, Pathologist, Regional Coordinator, Southern African Bean Project (stationed in Arusha, Tanzania)
Beebe, Stephen, Ph.D., Plant Breeding
Cardona, Cesar, Ph.D., Entomology
Davis, Jeremy H.C., Ph.D., Plant Breeding. Regional Coordinator, Central Africa Bean Project (stationed in Rubona, Rwanda)
Dessert, Michael, Ph.D., Plant Breeding, Regional Coordinator, Central America Bean Project (stationed in San Jose, Costa Rica)
Edje, Todo Ohgenetsevbuko, Ph.D., Agronomy (stationed in Arusha, Tanzania)
Frias, Gustavo, Ph.D., Pathology (stationed in San Jose, Costa Rica)
Galvez, Guillermo E., Ph.D., Plant Pathology, Regional Coordinator, Andean Bean Project (stationed in Lima, Peru)
Graf, Willi, Dip. Ing. Ag. (stationed in Rubona, Rwanda)
Janssen, Wilhelmus, Ph.D., Agricultural Economics
Kipe-Nolt, Judith, Ph.D., Microbiology
Kirkby, Roger A., Ph. D., Agronomist, Regional Coordinator East Africa Bean Project, (stationed in Ethiopia)
Kornegay, Julia L., Ph.D., Plant Breeding
Lynch, Jonathan, Ph.D., Physiology (Postdoctoral Fellow)
Morales, Francisco J., Ph.D., Virology
Orozco, Silvio H., MS., Agronomy, Central America Bean Project (stationed in Guatemala City, Guatemala)
Pastor-Corrales, Marcial, Ph.D., Plant Pathology
Singh, Shree P., Ph.D., Plant Breeding
Smithson, Barry, Ph.D., Plant Breeding, (stationed in Arusha)
Thung, Michael D., Ph.D., Agronomy (stationed at CNPAF, Goiania, Brazil)
Tohme, Joseph, Ph.D., Plant Breeding (Postdoctoral Fellow)
Trutmann, Peter, Ph.D., Plant Pathology, Great Lakes Bean Project (stationed in Rubona, Rwanda)
Voss, Joachim, Ph.D., Cropping Systems Specialist, Great Lakes Bean Project (stationed in Rubona, Rwanda)
Voysest, Oswaldo, Ph.D., Agronomy
White, Jeffrey, Ph.D., Plant Physiology
Woolley, Jonathan, Ph.D., Agronomy, Cropping Systems
Wortmann, Charles, Ph.D., Agronomy, Cropping systems Specialist, East Africa Bean Project (stationed in Kawanda, Uganda)

Research associates and other staff

Castaño, Mauricio, Ing. Agr., Virology
Gutierrez, Jose Ariel, M.Sc., Plant Breeding
Guzman, Pablo, M. Sc., Pathology
van Herpen, Dorein, M.S., Economics
Londoño, Nohra Ruiz de, Ing. Agr., Economics
Luna, Carlos Adolfo, M.Sc., Economics
Maquet, Alain, Agronomy, M. Sc., CIAT Gembloux Project
Niessen, Andrea, M.Sc., Virology
Schmit, Veronique, M.Sc., Associate Expert, FAO

Research assistants

Beltrán, Jorge A., Ing. Agr., Cropping Systems
Cajiao, César, Ing. Agr., Plant Breeding
Castillo, Jesús A., Ing. Agr., Physiology
Chavarro, Carlos Francisco, Ing. Agr., Office of the Coordinator
Cortés, María Luisa, Ing. Agr., Entomology
Erazo, Oscar, Ing. Agr., Agronomy
Gonzáles, Alonso, Biol., Physiology
Guerrero, María del Pilar, Ing. Agr., Economy
Jara, Carlos, Ing. Agr., Plant Pathology
Lareo, Leonardo, Nutritionist, Nutrition
Lopez, Yolanda, Biol., Breeding
Martínez, Nelson, Ing. Agr., Agronomy
Montes de Oca, Gustavo, Ing. Agr., Agronomy
Ocampo, Gloria Isabel, Bact., Microbiology
Ochoa, Ivan, M.Sc., Breeding
Pino, Carlos, Ing. Agr., Physiology
Posso, Carmen Elisa, Biol., Entomology
Quiroz, Jairo, Ing. Agr., Breeding
Santacruz, Diego, Ing. Agr., Agronomy
Tejada, Gerardo, Ing. Agr., Agronomy
Trujillo, Fernando, Ing. Agr., Cropping Systems
Urrea, Carlos, Ing. Agr., Breeding
Valderrama, Hernando, Ing. Agr., Economics
Vargas, Herney, Ing. Agr., Microbiology

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