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BEANS

CIAT
CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL

CIAT is a nonprofit organization devoted to the agricultural and economic development of the lowland tropics. The Government of Colombia provides support as host country for CIAT and furnishes a 522-hectare farm near Cali for CIAT's headquarters. In addition, the Fundación para la Educación Superior (FES) makes available to CIAT the 184-hectare substation of Quilichao, situated near Santander de Quilichao, Departamento del Cauca. Collaborative work with the Instituto Colombiano Agropecuario (ICA) is carried out on several of its experimental stations and similar work is done with national agricultural agencies in other Latin American countries. CIAT is financed by a number of donors represented in the Consultative Group for International Agricultural Research (CGIAR). During 1979 these donors were: the United States Agency for International Development (USAID), the Rockefeller Foundation, the Ford Foundation, the W.K. Kellogg Foundation, the Canadian International Development Agency (CIDA), the International Bank for Reconstruction and Development (IBRD) through the International Development Association (IDA) the Inter-American Development Bank (IDB), the European Economic Community (EEC) and the governments of Australia, Belgium, the Federal Republic of Germany, Japan, the Netherlands, Norway, Switzerland and the United Kingdom. In addition, special project funds are supplied by various of the aforementioned entities plus the International Development Research Centre (IDRC) of Canada and the United Nations Development Programme (UNDP). Information and conclusions reported herein do not necessarily reflect the position of any of the aforementioned agencies, foundations or governments.

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BEAN PROGRAM

In 1979, the Bean Program, with only minor modifications, continued to pursue its strategies as described in CIAT Annual Report, 1977. In 1979 major efforts were made on germplasm improvement for resistance to diseases and insects, especially to bean common mosaic virus (BCMV), rust, common bacterial blight, angular leaf spot, anthracnose and leafhoppers, while simultaneously improving plant architecture. Increased attention was also given to tolerance to other production constraints, such as drought, low P availability in the soil, and biological N_2 fixation. Emphasis was again on selecting germplasm for seed color and size to meet consumer preferences in Latin America and for meeting agronomic requirements of existing cropping systems in the region. Also, generated technology should be scale neutral, profitable and of low risk to the producer.

New technology is validated under farm conditions to measure profitability and risk, and to determine its acceptability by farmers. This information is used to make recommendations for producers and as a feedback for researchers.

Because the Program's research is designed to provide useful technology for evaluation and adoption by national programs, the latter's active collaboration in all phases of technology development is essential. Such collaboration depends upon outreach personnel, travel by CIAT-based staff, and intensive training efforts by the bean program.

HIGHLIGHTS

Germplasm improvement continued being the Program's major effort, through evaluating new germplasm bank accessions and using improved lines as parents in crossing programs. All improved lines are now resistant to BCMV, while lines resistant to multiple diseases and pests entered the international yield trials. Materials in the 1979 IBYAN were still deficient in meeting consumer acceptability, but had a high agronomic value. New breeding lines combining characteristics for consumer acceptability and high agronomic quality are expected to enter international tests in 1980-81.

Screening methods for tolerance to low P and high Al saturation in soils were improved and breeding efforts were started; in these trials, Brazilian entries were superior.

Methodologies for the Bean Team Nursery (VEF) and the Preliminary Yield Trial (EP) were improved this year (Figure 1) and entries are now planted simultaneously in multiple nurseries to evaluate them for resistance to diseases and pests and adaptation factors, including yield. Some lines, especially non-black seeded ones, outyielded the best controls by approximately 1 t/ha.

Successful results were achieved in improving biological N_2 fixation under higher temperature

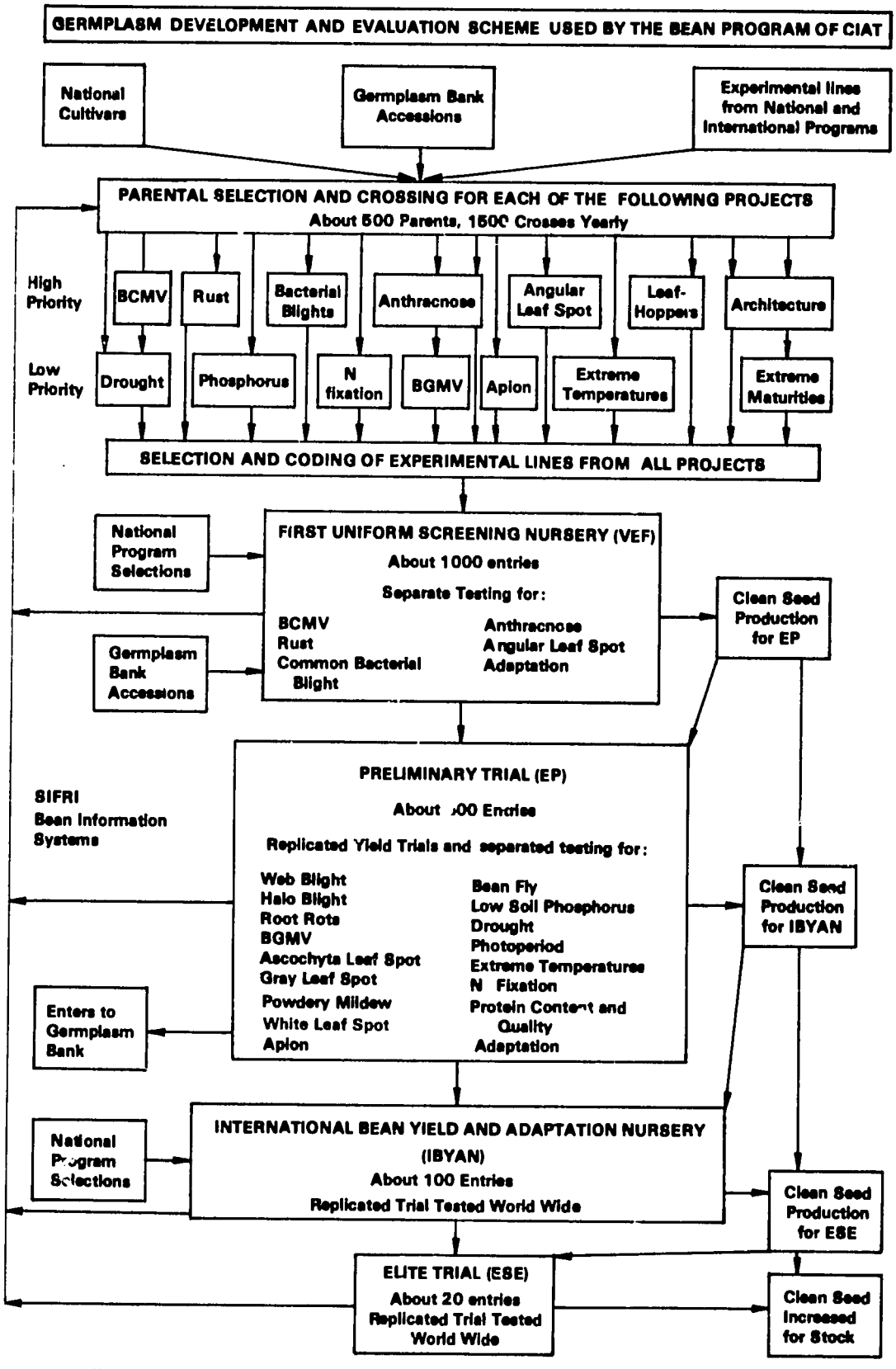


Figure 1. Germplasm development and evaluation scheme of CIAT's Bean Program.

conditions. At CIAT-Quilichao (avg. temp. 24°C) high fixation rates were obtained, and a breeding effort was begun for increased N_2 fixation.

Maize-bean interactions in multiple cropping systems were intensively studied in climbing beans. Varietal characteristics of both maize and beans were identified for different cropping systems. Segregating populations need to be selected and evaluated under these cropping systems. Significant differences in disease and insect pest incidence were confirmed in maize-bean associations as compared to monocultures.

Farm trials of new technology for bush beans confirmed that higher plant densities with better disease control methods (appropriate fungicide treatments) increase yield significantly (over 30%). Disease-free seed did not give yield increases. In trials with climbing beans, yields more than doubled with a different fungicide treatment and better agronomic practices plus a modification in the support system enabling an increased plant density.

A methodology was developed to test for bean quality; variability was found for cooking time and seed protein content.

Strong emphasis was placed again on training professionals of national bean programs in Latin America. As in previous years, two courses were offered with substantial involvement of the entire team. Some trainees stayed for additional discipline-oriented research.

The first contact with African bean producing entities was made to initiate an international cooperation program in Eastern Africa. A conference is planned on bean production potential for Eastern Africa in March 1980. Bean program coordinators of African countries have come to CIAT to interact with the Bean Program.

A noticeable impact of CIAT's Bean Program ac-activities on bean production in Latin America is expected within the next five years. Twenty one IBYAN entries are either in farm trials or are being multiplied, or have already passed this stage and are being considered as varieties in different countries. In Cuba, ICA-Pijao is under multiplication (about 2000 ha). INIAP-Bayito (Brazil 2) is a newly named variety in Ecuador. Acacia 4 and Acacia 6 are lines that are being advanced in Honduras. Three BGMV-tolerant varieties were released this year in Guatemala: ICTA-Quetzal, ICTA-Jutiapan, and ICTA-Tamazulapa.

AGRO—CLIMATOLOGY STUDY

The purpose of this study is to provide the Bean Team with an integrated management and analysis system for the climatic, edaphic, and cropping systems data on the target area. The project can be divided into the following phases: development of data management software; data collection, verification and storage; data analysis; and data maintenance and updating.

Development of Data Management Software

This phase is practically completed. The climatic data base system (SAMMDATA, South American Monthly Meteorological Data, CIAT Annual Report, 1978) is now in full operation.

Data Collection, Verification and Storage

Data from approximately 2700 meteorological stations have been processed and are stored in the direct access files of SAMMDATA. Work is underway on the processing of further data from all parts of the target area. A regression model to predict daily temperature range has been developed and is being used to estimate maximum and minimum temperatures for those stations where these values are presently available. Other unavailable data will be estimated in a similar way with the best model available.

Micro-region definition and data storage is now underway. To date 27 micro-regions in Mexico are being processed. A survey to define regions and collate agronomic and regional data has been undertaken in Guatemala. Seven micro-regions have been defined using local production figures. Agronomic data are being summarized for storage in the micro-region data file.

Data Analysis

Although full micro-region descriptions are not yet

available for the complete target area, results were obtained from a preliminary file of production allocations. Approximate extents of all production regions were estimated and sets of representative meteorological stations chosen for each area. The production figures allocated to each area were then divided between the representative station sites and seasons. For these stations, maximum and minimum temperatures were estimated where necessary and potential evapotranspiration estimates were obtained by the modified Pennan equation. Using estimates of sowing date, season length and a simple proportional relation to determine flowering date, mean values for various climatic variables were calculated for the vegetative, flowering, and reproducted stages.

Growing season temperature distribution

The mean growing season temperature distribution was recalculated (CIAT Annual Report, 1978). While the first estimates were based on average regional temperatures, often taken from climatological atlases, the more precise method of actual station site data shows a more accurate distribution (Figure 2). This year's results show a slightly wider range due to elevational differences between stations within regions. Thus the regional mean temperature method probably underestimates the spread, while the station site method probably overestimates it.

Accuracy of results

In studies such as this, it is not easy to place statistical limits as to the precision or accuracy of the results. Particularly problematic in this study is the often arbitrary nature of production figure assignments to growing seasons in stations within each micro-region. To investigate the sensitivity of the results to random reallocation of the production quantities a series of trials was made, alternately halving and doubling the production assignments for adjacent stations. Results showed that stations were sufficiently similar to each region that quite larger errors of assignment did not greatly affect the results.

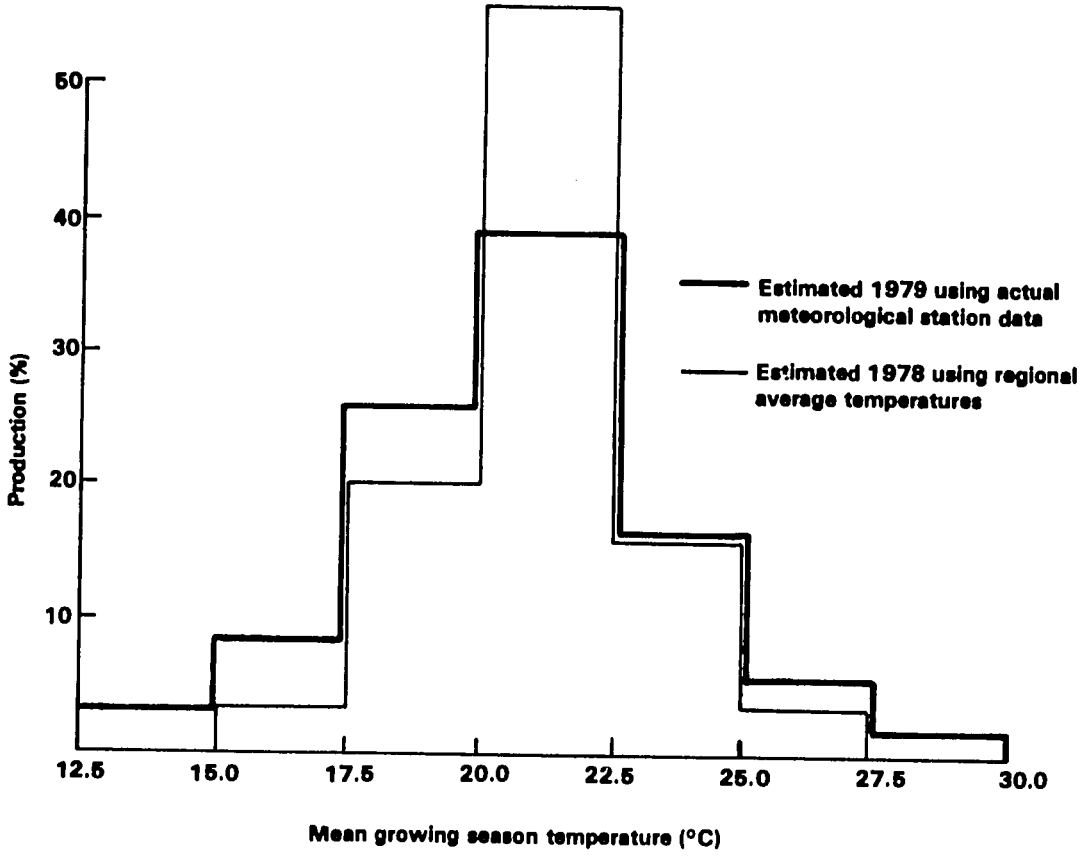


Figure 2. Proportion of total bean production in the target area by mean growing season temperature.

Temperature stress during flowering period

Figure 2 shows that the majority of the bean production occurs in a relatively restricted temperature regime. This does not exclude the possibility of either periods of temperature stress or abnormally high day temperatures or low night temperatures. Because a sensitive growth phase in beans is the flowering period, the temperature range experienced by beans during flowering was investigated (Figure 3). The distribution of mean temperature during flowering was very similar to that for mean season temperature shown in Figure 2. Mean minimum temperature showed a much narrower distribution, indicating that night temperature during flowering could be a more stringent restriction than day temperature.

Despite the fact that the distribution of maximum temperature exhibited a much broader range, the proportion of bean production under stress day temperatures was still estimated to be small. It appears that CIAT's experimental sites, Palmira and Popayán, are representative of most temperature conditions under which beans are presently grown. Screening for tolerance to higher and lower temperatures appears justified to extend bean production to situations outside the restricted range of conditions under which it is cultivated.

Photoperiod regimes by temperatures in the target area

The phenology of *Phaseolus vulgaris* is controlled by temperature and often photoperiod. The two main selection sites of CIAT, with daylengths somewhat over 12 hours, are well outside the daylength range of most of the production of the target area. For this reason screening is carried out for photoperiod insensitive materials. The range of season temperatures appears to increase with increasing daylength (Figure 4) suggesting photoperiod response should be calculated in more than one temperature to ensure that no interaction will be found in CIAT-improved germplasm, complicating its transfer to longer daylength regimes.

Preliminary classification of bean growing season climates

To provide some insight into the range of climatic

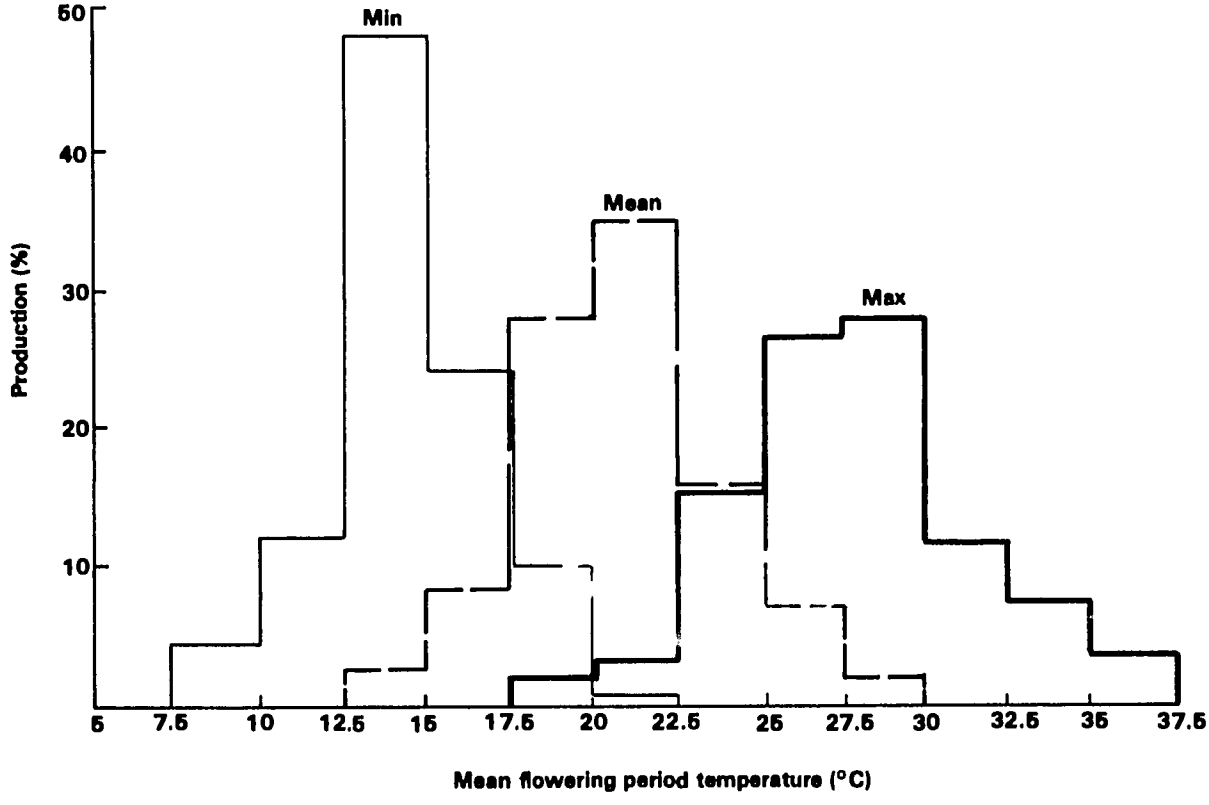


Figure 3. Proportion of total bean production in the target area by mean temperature during flowering stage.

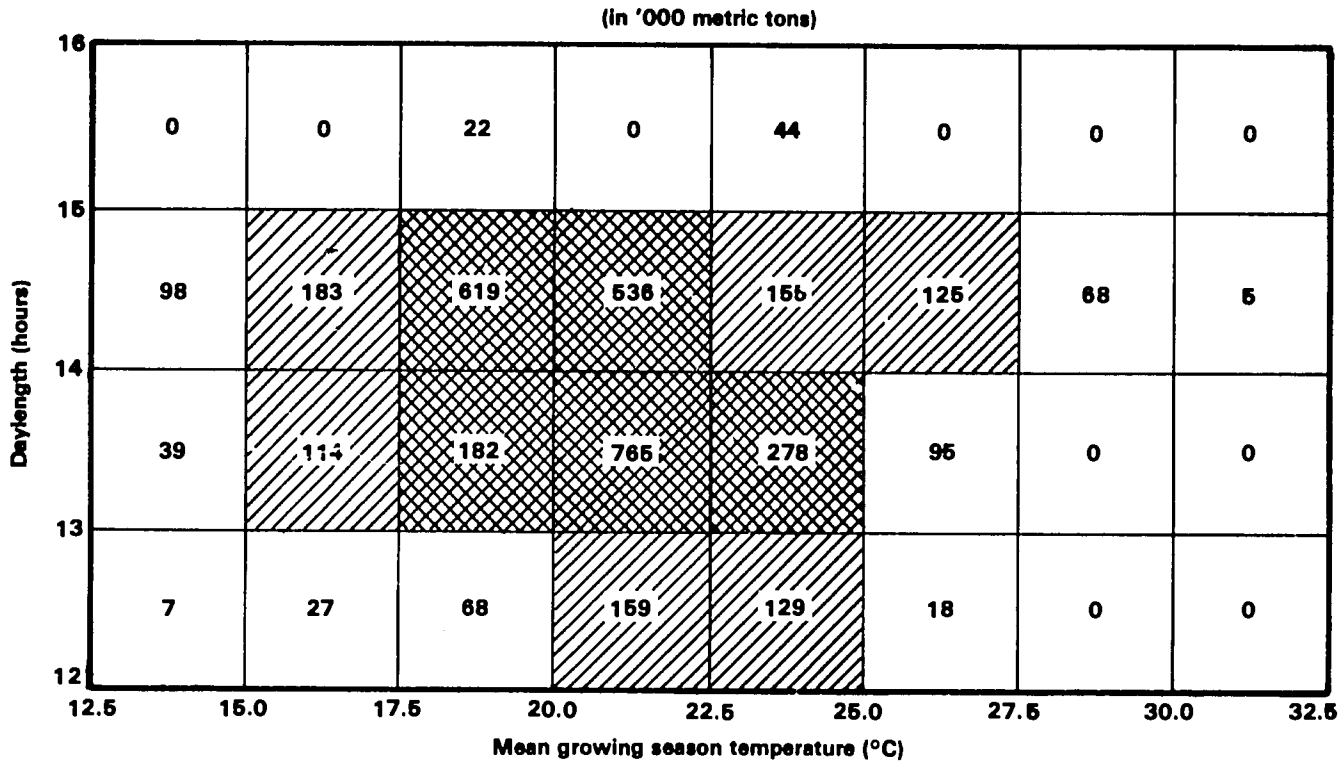


Figure 4. Bean production in the target area by daylength and temperature.

types currently experienced by bean crops, a cluster analysis was performed. Variables were chosen to represent key climatic factors. These include maximum, minimum and mean temperatures during the flowering period and the mean daily balance of precipitation and evapotranspiration for the vegetative, flowering, and reproductive periods. Site-seasons were clustered using a single linkage algorithm. Inspection of the clusters at the 10 cluster level showed that there are seven main groups and three outliers from atypical regions in Panama and Venezuela which only represent 7% of the total bean production (Table 1).

It is important to note that this is not a classification of the year-round regional climate of the sites, but a classification of only that part during the bean growing season. This explains why Veracruz, Mexico, is found in groups A and D, and why Salta in Argentina and Huila in Colombia with different overall climates, can occur together in group A.

It is noteworthy that Antioquia and Huila, sites of the Bean Team on-farm testing program, fall into groups A and E. These groups account for almost 60% of the total target area production figures. Although the production systems used in other regions within these climate groups may be very different to those used in Antioquia and Huila, it can be suggested that there will not be climatic constraints to the transfer of technology developed in these test areas to similar areas within these groups.

The evaluation of water balance used in this classification is only a first approximation. Soil moisture and short-term rainfall fluctuations are not taken into account. However, on this preliminary basis it appears that a considerable proportion of the target area production is subject to some drought stress from flowering onwards. This emphasizes the need for continued drought tolerance screening and further studies in season lengths and crop phenology to fit the cultivars to the available rainfed growing season.

Table 1. Preliminary classification of bean micro-regions within the target area according to climate types as determined by cluster analysis.

Climate type	Overall description	No. micro-region seasons	Production ('000 tons)	Production (%)	Flowering temp. (°C) max.	Flowering temp. (°C) mean	Flowering temp. (°C) min.	Water balance (mm/day) V[1]	Water balance (mm/day) F[1]	Water balance (mm/day) P[1]	Example of sites
A	Average temperature, adequate water	19	661	17	28.9	22.3	16.3	0.36	-0.89	-1.50	Salta, Argentina; Huila, Colombia; Celaya and Veracruz, Mexico; Juticalpa, Honduras.
B	Average temperature, slight excess water	12	118	3	30.7	23.2	15.9	0.45	4.00	1.90	Turrialba, Costa Rica; Tabasco, Mexico
C	Average temperature, very dry (irrigation areas)	15	538	14	31.0	23.1	15.2	-5.20	-5.60	-5.10	Goias, Brazil; Culiacan, Mexico
D	High temperature, late season water stress	11	262	6	34.6	26.2	17.7	-0.29	-2.70	-4.15	Central Bahia, Brazil; Nicoya, Costa Rica; Jamapa, Honduras; Veracruz, Mexico; Ciudad Granada, Nicaragua; Villarica, Paraguay
E	Average temperature, possible late season water stress	29	1672	42	26.1	19.6	13.2	-1.57	-2.49	-2.75	Antioquia, Colombia; Chimaltenango, Guatemala; Durango, Mexico; Cajamarca, Perú; Merica, Venezuela
	Moderately low temperatures, moderate deficits (includes irrigation areas)	19	451	11	22.0	16.1	10.0	-1.60	-1.90	-2.30	Rio Grande do Sul, Brazil; Chihuahua, Mexico; Bailadores, Venezuela
G	Low temperature, adequate water	5	45	1	17.6	12.6	7.8	-0.58	-0.52	-0.86	High altitudes in Bolivia, Ecuador and Peru.
Atypical				6							

1 Growth stages: V = vegetative; F = flowering; P = pod filling

GERMPLASM SCREENING FOR DESIRABLE VARIABILITY

Search for desirable genetic variability and screening of germplasm continued to be one of the major activities during the year.

Resistance to Viral Diseases

Bean Common Mosaic Virus (BCMV)

The Bean Program has set as its objective to develop germplasm resistant to all of the known pathogenic strains of the bean common mosaic virus. Initially the dominant I gene for resistance will be incorporated in all breeding lines, followed by incorporation of recessive genes in selected lines to protect the dominant I gene from necrosis-inducing strains of BCMV.

Distribution of BCMV strains in Latin America

Among the mosaic-inducing strains of BCMV detected in Latin America, the type strain and the Florida strain appear to predominate. The New York 15 strain of BCMV is also commonly observed in temperate countries, causing mosaic in bean cultivars of the Michelite and Pinto 114 groups.

Among the necrosis-inducing strains, BCMV NL 6 is frequently isolated from bean plants affected by systemic necrosis, especially under high temperature conditions. A temperature-independent necrosis inducing strains, BCMV NL 3, has also been isolated in Chile and Colombia.

The incidence of systemic necrosis on plants having dominant resistance continues to be moderate in CIAT's fields. The incorporation of recessive genes that protect against necrosis-inducing strains of BCMV, however, will be progressively taken into accounts as the number of new cultivars possessinng the I gene increases.

As a consequence of the above distribution of BCMV, three strains (Florida, New York 15 and NL 4) with a combined pathogenicity sufficient to detect mosaic-susceptible bean genotypes are now routinely used in the screening sequence (Table 2).

Screening of germplasm accessions and introductions

The first step in developing BCMV resistance is the screening of germplasm accessions stored in the Genetic Resources Unit, for their resistance to BCMV.

Table 2. Pathogenicity of selected BCMV strains on mosaic-susceptible bean cultivars.[1]

Cultivar group	BCMV strain		
	Florida	New York-15	NL4
Double White	+[2]	+	+
Imuna	+	+	+
Great Northern 123	+		+
Michelite		+	
Pinto 114		+	
Great Northern 31		+	+

1 According to E. Drijfhout.
2 + = systemic infection. Blank spaces mean resistance to the respective BCMV strains.

This year a total of 10,000 germplasm accessions were inoculated and evaluated under screenhouse and field conditions at CIAT and in Popayán. Results showed that 67% of the accessions evaluated were susceptible, 13.8% was segregating for their resistance to BCMV, and only 8.7% could be considered as homozygous resistant to the virus (the remaining 10.5% could not be evaluated). Promising accessions segregating for resistance are further tested to identify homozygous BCMV resistant lines.

Screening of segregating populations

A modification in the screening methodology this year was the inoculation and evaluation (progeny test) of individual F or advanced selections under screenhouse conditions rather than the field inoculation of F_2 families. This modification considerably increased the screening efficiency (approximately a 93% efficiency for the first screening as determined for the 1979 VEF entries) despite the high number of plants that were progeny tested this year (135.000 plants).

Another mayor development in the screening methodology was the implementation of the necrosis test to detect the presence of the dominant necrosis I gene which confers resistance to BCMV. This test consists of the manual inoculation of leaves detached from the test material with a necrosis-inducing strain (BCMV NL 3 or NL 5) under high light, temperature, and humidity conditions. A few days after the inoculation, those leaves having the dominant I gene show vein necrosis.

The results obtained for the first necrosis test performed this year with the 1979B IBYAN lines (Table 3), showed that the BCMV-screening methodology had been highly efficient for the selection of mosaic-resistant breeding lines.

Screening for BCMV resistance was also done in backcross progenies of important local cultivars with strong local consumer preference and market demand due to their grain color and size, but susceptible to this virus.

Serological detection of seed-borne viruses

Serology is the fastest and most reliable technique used today for the detection of plant viruses. This technique, however, was very difficult to adapt to bean seed, due to the presence of serum-agglutinating compounds in seed extracts which made the interpretation of results impossible.

Recently, a new serological technique known as ELISA (Enzyme-Linked Immunosorbent Assay) was tested for the detection of two seed-borne viruses in bean (BCMV and the bean southern mosaic virus, BSMV) at CIAT. Results obtained show that this technique can be successfully applied to detect seed-borne virus infection levels in seeds below 1% without the occurrence of non-specific reactions. This technique is to be used to reduce the quarantine period required for new bean germplasm introductions.

Bean Yellow Mosaic Virus (BYMV)

The incidence of both mosaic- and necrosis-inducing strains of this virus continues to be considerable in Chile. The virus is also present in Argentina and possibly in Bolivia.

The diversity of BYMV strains and their heterogeneous host range makes it the main bean disease problem where the virus exists. Future EP nurseries will be planted in Chile to observe their reaction to this virus.

Resistance/Tolerance to Fungal and Bacterial Diseases

Most efforts during last year were concentrated on the development and improvement of pathogen inoculation and disease evaluation procedures required by the Bean Program to test large numbers of germplasm accessions and breeding progenies for their resistance to diseases.

Diseases given high priority by the Bean Program include rust, anthracnose, angular leaf spot and common bacterial blight. Natural infection by other pathogens allowed to conveniently evaluate materials in the VEF and EP nurseries for resistance to other diseases such as gray leaf spot (*Cercospora vanderysti*), white leaf spot (*Pseudocercosporella albida*), Ascochyta leaf spot (*Ascochyta* sp.), powdery mildew (*Erysiphe polygoni*), and web blight (*Thanatephorus cucumeris*).

Simultaneously, improved screening methodology was developed to evalute restricted numbers of advanced materials for resistance to other lower priority diseases such as halo blight (*Pseudomonas phaseolicola*), Fusarium and Rhizoctonia root rots,

Table 3. Results of the necrosis test with the CIAT 1979B IBYAN lines.

Experimental line	Grain color	Necrosis test (BCMV NL3)[1]
A21	Red	+
A22	Beige	+
A25	Mottled brown	±
BAT 41	Red	+
BAT 44	Brown	+
BAT 85	Cream	+
BAT 93	Yellow	+
BAT 160	Cream	+
BAT 202	Red	+
BAT 317	Beige	+
BAT 332	Cream	+
BAT 336	Cream	+
BAT 338	White	+
BAT 340	White	+
BAT 363	Brown	+
BAT 419	Mottled brown	+
BAT 482	White	+
BAT 561	Cream	+
BAT 614	Mottled	+
EMP 28	Cream	+
BAT 58	Black	+
BAT 64	Black	+
BAT 76	Black	+
BAT 140	Black	+
BAT 140	Black	+
BAT 179	Black	+
BAT 240	Black	+
BAT 261	Black	+
BAT 271	Black	+
BAT 304	Black	+
BAT 445	Black	+
BAT 448	Black	+
BAT 450	Black	+
BAT 518	Black	+
DOR 15	Black	+

1 + = dominant I gene present; ± = dominant I gene present in some but not in all plants tested.

Southern blight (*Sclerotium rolfsii*), and ashy stem blight (*Macrophomina phaseolina*).

Rust

Bean rust (*Uromyces phaseoli*) continues to be one of the most widespread pathogens of beans in Latin America and other regions of the world. The fungus is reported to consist of many different pathogenic races which comprise rust populations present at a given location during a growing season. The Bean Program is not involved in collecting, purifying, and identifying Colombian rust isolates as races, but its major concern is to efficiently identify germplasm and progeny that are resistant or intermediate to all populations of rust endemic in CIAT's testing sites. The pathogenic variability of different rust populations can still be studied, however, by monitoring the disease rections of a standard group of entries planted in different nurseries.

Figure 5 illustrates a series of frequency distribution

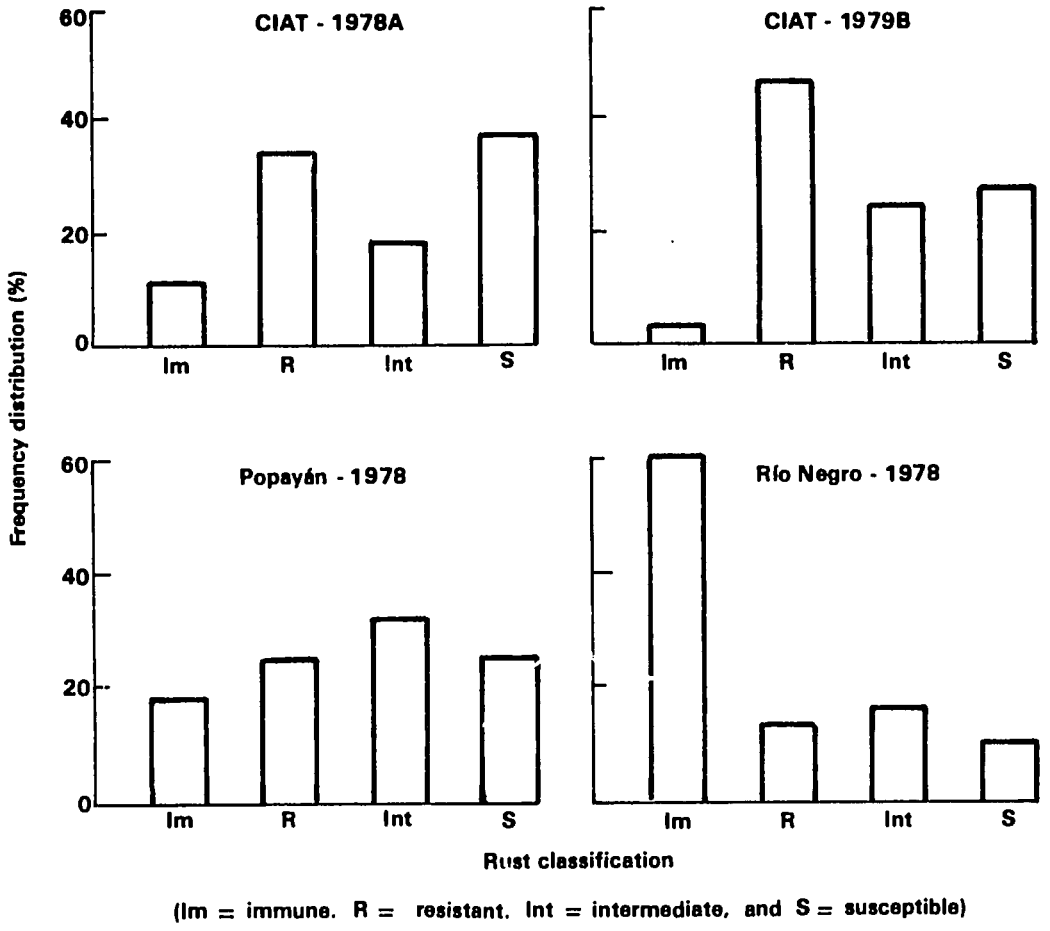


Figure 5. Pathogenic variability displayed by bean rust populations which infected the IBRN monitoring entries in four nurseries grown in Colombia during 1978 and 1979.

graphs constructed from the 41 standard IBRN (International Bean Rust Nursery) monitoring entries which were immune, resistant, intermediate or susceptible when evaluated in different nurseries during 1978 and 1979. Location specific variability is illustrated by comparison of the Popayán, Río Negro, and CIAT-Palmira frequency distributions. Specific variability over time is illustrated by the two CIAT graphs. These contrasting locations and seasons form a complementary germplasm-testing network which permits the identification of entries that are widely resistant or intermediate to the pathogenic variability inherent in rust populations present in these regions of Colombia.

The Bean Program routinely screens germplasm and breeding progeny for their rust reactions at CIAT and other locations in Colombia. Populations and selected progeny are commonly evaluated during three to five season at CIAT in inoculated and naturally infected nurseries. Promising selections from these nurseries are then uniformly evaluated for their rust resistance in the VEF nursery planted at CIAT (inoculated) and Popayán (natural infection). Selections which then enter the EP nursery are further evaluated for their resistance again at CIAT (inoculated) and at other Colombian sites (natural infection) such as Popayán, Cajibío and Pitalito.

Figure 6 illustrates the rust classification frequencies of the 180 EP entries evaluated during 1979. The value of multiple evaluations and regional trials is apparent since 73% of these entries were reported to be resistant or intermediate in the 1978 VEF, but only 44% remained resistant or intermediate to rust populations encountered during the 1979 EP trials. Various materials that remained resistant or intermediate entered the 1979 IBYAN. Results from these trials will allow the Bean Program to identify those entries which possess the most effective and stable rust resistance or intermediate reactions at other locations.

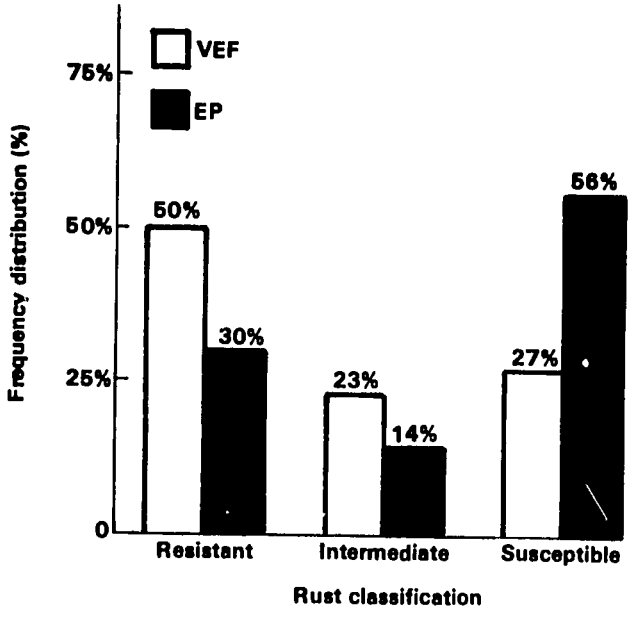


Figure 6. Frequency of 180 entries rated as resistant, intermediate or susceptible to rust at CIAT in the 1978 VEF and at CIAT, Popayán, Cajibío, and Pitalito in the 1979 EP.

The IBRN results for the 1975-1976 and the 1977-1978 nurseries have now been submitted by collaborators, analyzed and published. Table 4 summarizes the reactions of some widely resistant or intermediate entries reported for the four years. It is important to note that all entries were susceptible at one or more locations during one or more years. However, various entries were widely resistant or intermediate to many of the complexes of rust races present throughout Latin America and other regions of the world, and could still provide useful sources of rust resistance for bean improvement programs. These materials and others are continuing to be evaluated throughout Latin America, the United States and Africa in the 1979-1980 IBRN which is currently being distributed to collaborators.

Studies are underway to determine the usefulness and degree of yield protection conferred by various intermediate rust resistance reactions such as small pustules (less than 300 μ in diameter), moderate size pustules (300-400 μ in diameter), and necrosis limiting pustules. Work is also underway to detect the presence of and to determine the potential value of slow rusting resistance.

Table 4. Reactions of widely resistant entries reported in the 1975-76 and 1977-78 IBRN's.

Entry identification	Number of nurseries where the entry was classified as:[1]														
	1977					1976					1977-1978				
	I	R	Ir	S	ND	I	R	Ir	S	ND	I	R	Ir	S	ND
Cocacho	5	4	0	1	5	0	5	2	2	8	2	7	8	0	0
Compuesto Chimalteco 3 (G5712)	4	3	2	1	5	5	9	2	1	0	2	9	4	1	1
Mexico 309 (G5652)	6	5	1	0	3	8	4	3	2	0	8	7	1	1	0
Ecuador 299 (G5653)	5	7	1	0	2	3	6	6	2	0	4	6	4	2	1
Mexico 235	2	1	2	0	10	6	4	4	2	1	5	6	2	2	2
Cuilapa 72 (G4489)	4	7	1	0	3	8	3	3	3	0	7	7	3	0	0
Redlands Pioneer	0	0	0	0	15	2	7	5	2	1	3	11	2	0	1
Redlands Greenleaf B	7	3	2	0	3	2	8	5	2	0	3	11	2	0	1
Redlands Greenleaf C	1	2	2	0	10	1	7	6	2	1	4	8	4	0	1

1 I = immune; R = resistant; Ir = intermediate; S = susceptible; ND = no data.

Anthracnose

The anthracnose fungus (*Colletotrichum lindemuthianum*) is also well-known for its pathogenic variability throughout the world. Glasshouse screenings are utilized to verify field reactions of promising selections and to expose them to mixtures of anthracnose isolates collected from many regions of Colombia. Nearly 2000 germplasm entries and breeding progenies involving the Are (Cornell 49-242) gene and other more promising sources of resistance were evaluated in the glasshouse (Figure 7).

The first 10,000 accessions in the germplasm bank were inoculated with 15 local isolates of *C. lindemuthianum* under field conditions in Popayán (Figure 8). Various accessions appear highly promising for their resistance and agronomic characteristics. These may provide new and useful sources of resistance effective against the broad spectrum of anthracnose races endemic in Colombia and other bean production regions.

Angular Leaf Spot

Angular leaf spot (*Isariopsis griseola*) inoculations were very successful this year in Popayán, and revealed that few materials were immune to infection. However, some promising germplasm accessions of the 10,000 tested and additional breeding materials were identified with a high level of resistance or intermediate degrees of infection in the foliage. Additional work has determined that germplasm and breeding materials also possess varying responses to pod infection.

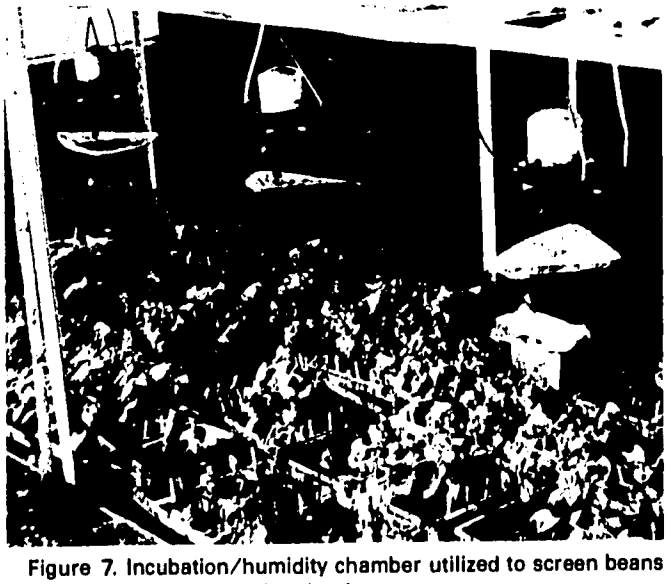


Figure 7. Incubation/humidity chamber utilized to screen beans for disease resistance in the glasshouse.

Figure 8. Inoculation of germplasm accessions and breeding progeny with a mixture of anthracnose isolates. This method is also utilized to inoculate materials with rust, angular leaf spot or common bacterial blight.

Table 5 demonstrates the pathogenic variability expressed by angular leaf spot when materials were inoculated with different isolates or infected naturally by isolates endemic to different locations. There was a dramatic difference in disease reactions between the 1978 VEF and 1979B trials due to inoculation with two local isolates under extremely favorable environmental conditions for disease development in 1979B. The 1979 VEF data also show that a low proportion of entries were resistant (0.3%) or intermediate (20.0%) to these two isolates. Additional work is underway to collect and utilize more local isolates in field tests, as well as to further characterize the pathogenic variability displayed by this pathogen.

Common Bacterial Blight

Development of resistance to common bacterial blight (*Xanthomonas phaseoli*) has received increased

Table 5. Disease reactions of selected 1979 EP entries to different isolates of the angular leaf spot fungus.

Entry identification	Disease reaction[1]		
	1978 VEF[2]	1979 EP[3]	1979 B[4]
BAT 165	1	1	2
BAT 332	1	1	3
BAT 76	1	1	4
BAT 160	1	1	5
BAT 448	1	1	5
G1753	1	1	5
BAT 346	1	2	4
BAT 89	1	2	5
A 21	1	3	5
BAT 148	2	1	5
BAT 317	2	2	5
BAT 44	3	1	5
G4017	3	3	5
BAT 394	3	4	5
BAT 256	4	4	5

1 Disease reaction: 1 = immune; 2 = resistant; 3 = intermediate; 4 = susceptible; 5 = very susceptible.
2 Inoculated with one local isolate at Popayán.
3 Natural infection at Cajibío and Pitalito.
4 Inoculated with the same isolate used in 1978 VEF and one additional local isolate at Popayán.

attention this year. Inoculation, evaluation, and breeding methodologies were improved to more efficiently manage large populations of segregating materials and advanced lines or germplasm accessions. Studies were undertaken to determine the effect of plant age, inoculum concentration, and evaluation scales upon plant resistance in the field.

In order to develop increased reliability in rating common blight reactions in the field, two evaluation scales were utilized to compare lesion size to foliage incidence within the following five classes: 1 = highly resistant; 2 = resistant; 3 = intermediate; 4 = susceptible; and 5 = highly susceptible. The foliage incidence scale was defined as: 1 = 0% foliage infected; 2 = 1-5% foliage infected; 3 = 6-10% foliage infected; 4 = 11-25% foliage infected; and 5 = 26-100% foliage infected. The lesion size (diameter) scale was defined as: 1 = lesions up to 5 mm; 2 = lesions 6-10 mm; 3 = lesions 11-20 mm; 4 = lesions 21-40 mm; and 5 = lesions coalescing and covering more than 50% of leaflet area.

Plant age, physiological adaptation, and inoculum concentration affected disease incidence when differently aged plants of 10 materials were inoculated by aspersion at flowering and three weeks after flowering. Lesion incidence was increased by inoculating older plants with increasing inoculum concentrations. Lesion size was fairly consistent for a genotype in all inoculated treatments and may be a more reliable parameter than lesion incidence for evaluation of disease resistance, especially if environmental conditions are variable. However, evaluation of lesion size was less effective in the presence of natural infection which may induce lesions of different age and hence more variable lesion size. Uniform inoculation of materials at or shortly before flowering enables the Bean Program to compare differences in lesion size and rate of lesion development. Entries are differentially planted according to maturity group so as to facilitate inoculation at a similar plant physiological stage. Additional studies are underway to detect other potentially useful mechanisms of resistance such as the presence of large lesions at a consistently low incidence.

A modification of the scissor inoculation method (CIAT Annual Report, 1977) was devised to permit a

more rapid and uniform infection of large segregating populations. Two razor blades are mounted 2 cm apart and parallel to each other on a wooden handle (Figure 9), which are then used to make two 2 cm long cuts in a leaflet placed on a sponge soaked in a bacterial cell suspension (5 x 10^7 cells/ml). This technique is rapid, uniform, and easily applied by field workers and permits evaluations for other characters. In the field a single trifoliate leaf per plant is inoculated, and susceptible plants can be rogued after evaluation. Of the resistant plants, the trifoliate may be removed after evaluation to permit harvest of relatively uncontaminated seed. Resistant selections are subsequently inoculated in the screenhouse to verify their reaction for lesion size, and again in the field to measure foliage incidence, as well as to determine their pod reaction to common bacterial blight.

Halo Blight

The 1979 EP entries were inoculated in the glasshouse with local isolates of halo blight (*Pseudomonas phaseolicola*) obtained from infected plants in Popayán and Tenerife. Various entries were resistant to these isolates and additional work is underway to compare the virulence of these and other Colombian isolates to that reported for the bacterium in other regions of the world, as in Africa where the disease is more prevalent and economically important.

Figure 9. Razor blade technique utilized to inoculate plants with common bacterial blight.

Nearly 1500 germplasm accessions, many of which are resistant to BCMV, have also been screened in the glasshouse to identify promising sources of resistance to halo blight.

Disease loss studies

Studies were conducted to measure the importance of certain diseases or disease complexes in terms of yield loss differences between selected materials that have been inoculated or infected naturally with various cool climate bean pathogens at Popayán. These studies also indicate the level of protection that may be conferred by different resistance mechanisms. Table 6 presents 1979A data for entries which were either inoculated with a mixture of local isolates of Ascochyta leaf spot (Exp. 1) or anthracnose (Exp. 2), and which were naturally infected by white leaf spot. Table 7 presents 1979B data for entries which were either inoculated with a local isolate of halo blight (Exp. 3) or a mixture of local isolates of angular leaf spot (Exp. 4), and which were naturally infected by Ascochyta leaf spot.

A standard experimental design was used in all trials whereby all treatments were replicated three times (plot size = 15 m^2 per entry per treatment) and included appropriate chemical controls. Moderate levels of inputs and plant density were used to approximate local grower conditions. Therefore, protected yield values are generally lower than those reported by other disciplines. For example, the fertilizer applications consisted only of 150 kg 10-30-10, 150 kg triple superphosphate, and 5 kg foliar fertilizer and urea/ha.

Ascochyta leaf spot alone caused 41% (G 2618) and 52% (BAT 131) yield loss in Experiments 1 and 3, respectively. White leaf spot alone caused more than 40% yield loss to BAT 93 and BAT 508 in Experiment 2. Halo blight was responsible for a 55% yield loss to BAT 445 in Experiment 3, while angular leaf spot reduced the yield of BAT 394 by nearly 80% in Experiment 4. Tables 6 and 7 also illustrate the level of yield losses attributable to the combined infection by two pathogens, as well as the value of disease resistance.

Not all disease reactions were related to the yield losses reported for each entry. This indicates the need of developing a more reliable methodology to measure disease incidence in foliage and pods as compared to the disease reaction scales used to

Table 6. Yield losses of entries inoculated with Ascochyta leaf spot (Exp. 1) or anthracnose (Exp. 2), and naturally infected with white leaf spot (Exp. 1 and 2) at Popayán in 1979A.

Entry identification	Yield (kg/ha) Inoculated	Yield (kg/ha) Protected	% yield loss	Disease reaction[1] Inoculated	Disease reaction[1] Protected	Disease reaction[1] Inoculated	Disease reaction[1] Protected
Experiment 1							
				Ascochyta leaf spot		White leaf spot	
G2618	1139a[2]	1927a	41	4.7	1.0	1.0	1.0
G5764	1121a	1968a	43	3.0	1.0	1.0	1.0
BAT 522	1217a	2125a	43	3.7	1.0	3.3	2.0
BAT 496	831b	1543bc	46	3.3	1.0	4.0	1.3
BAT 76	506cd	1130d	55	2.3	1.0	4.3	2.0
BAT 246	729bc	1842ab	60	3.7	1.0	4.3	1.7
EMP 9	531cd	1438cd	63	3.3	1.0	4.7	1.3
DOR 12	465cd	1388cd	67	2.7	1.0	5.0	2.3
BAT 341	370d	1470cd	75	3.3	1.3	5.0	2.3
CV (%)	18.6	13.4					
Experiment 2							
				Anthracnose		White leaf spot	
BAT 146	969b[2]	1015cd	5	3.0	1.0	3.3	1.7
BAT 44	1505a	2055a	27	1.0	1.0	3.0	2.0
BAT 93	850bc	1495bc	43	1.3	1.0	5.0	2.3
BAT 508	838bc	1577a	47	1.0	1.0	4.7	3.0
BAT 48	563bc	1113bcd	49	3.7	2.7	4.7	2.7
BAT 328	452c	942d	52	3.3	2.0	5.0	3.7
BAT 429	550bc	1172bcd	53	3.0	1.0	5.0	3.7
CV (%)	31.3	21.2					

1 Disease reaction: 1 = highly resistant; 2 = resistant; 3 = moderately susceptible; 4 = susceptible; and 5 = highly susceptible.
2 Values within a column followed by the same letter are not significantly different at P = 0.05.

routinely screen germplasm and breeding progeny. For example, BAT 160 and BAT 394 both exhibited a susceptible disease reaction in Experiment 4, but suffered yield losses of 3% and 80%, respectively. Further studies are planned to verify these results, and to determine if BAT 160 possesses true tolerance to angular leaf spot under heavy disease pressure.

Resistance/Tolerance to Insect Pests

Germplasm evaluations for resistance to *Empoasca kraemeri* and recurring selection programs to increase resistance levels to this insect pest were continued this year. Field evaluation techniques for resistance to the red spider mite, *Tetranychus desertorum,* were improved, as well as the laboratory methodologies to evaluate for resistance to *Acanthoscelides obtectus* and *Zabrotes subfasciatus.*

Empoasca kraemeri

More than 4000 materials from the various nurseries from the Bean Program were evaluated during 1979 for their resistance to the leafhopper, *Empoasca kraemeri.* Approximately 5% of the materials evaluated showed high levels of tolerance to

Table 7. Yield losses of entries inoculated with halo blight (Exp. 3) or angular leaf spot (Exp. 4), and naturally infected with Ascochyta leaf spot (Exp. 3 and 4) at Popayán in 1979B.

Entry identification	Yield (kg/ha) Inoculated	Yield (kg/ha) Protected	% yield loss	Disease reaction[1] Inoculated	Disease reaction[1] Protected	Disease reaction[1] Inoculated	Disease reaction[1] Protected
Experiment 3							
				Halo blight		Ascochyta leaf spot	
Carioca	984a[2]	1012ab	2.8	3.0	1.0	3.7	2.8
BAT 473	973a	1019ab	4.5	1.0	1.0	3.7	2.0
BAT 104	478b	738ab	35.2	5.0	1.0	3.0	3.0
BAT 369	925a	1441a	35.8	1.0	1.0	4.0	2.7
BAT 339	195b	306b	36.3	5.0	1.0	3.3	2.0
BAT 131	382b	800ab	52.3	1.0	1.0	4.0	2.3
BAT 445	506b	1135ab	55.4	5.0	1.0	2.7	2.3
CV (%)	30.7	49.9					
Experiment 4							
				Angular leaf spot		Ascochyta leaf spot	
BAT 160	879ab	910ab	3.4	5.0	1.0	2.0	2.0
BAT 48	1149a	1427ab	19.5	5.0	1.0	2.3	2.0
BAT 256	662bc	840b	21.2	5.0	1.0	2.3	2.0
BAT 346	871ab	1106ab	21.2	3.7	1.0	2.3	2.0
BAT 332	871ab	1195ab	27.1	3.0	1.0	2.3	2.7
A 21	1011ab	1544a	34.5	5.0	1.0	2.7	2.3
BAT 76	887ab	1418ab	37.4	3.7	1.0	2.7	2.0
Carioca	852ab	1527a	44.2	5.0	1.0	3.0	2.3
BAT 148	634bc	1247ab	49.2	5.0	1.0	3.3	2.3
BAT 394	274c	1342ab	79.6	5.0	1.0	2.0	2.0
CV (%)	28.8	26.1					

1 Disease reaction: 1 = highly resistant; 2 = resistant; 3 = moderately susceptible; 4 = susceptible; and 5 = highly susceptible.
2 Values within a column followed by the same letter are not significantly different at P = 0.05.

this insect (a visual damage rating of $\leq$ 2.0), in a scale where tolerance ranges from 0 to 2, intermediate from 2 to 3, and susceptible, more than 3. Although no equally high levels of resistance were identified in red-seeded materials, special emphasis was made in selecting the most resistant entries from resistance evaluations and the recurring selection program.

As reported previously (CIAT Annual Report, 1978), the highest proportion of susceptible materials was observed in climbing beans this year; under high infestation levels of the leafhopper, these materials changed their growth habit from type IV to type II.

Special emphasis was given to the formation of the International *Empoasca* Resistance Nursery. The 54 most resistant selections entered this nursery, which is being evaluated in Mexico, Guatemala, the Dominican Republic, El Salvador, Honduras, Nicaragua and Cuba. Breeding for resistance to *E. kraemeri* continued through the second cycle of recurrent selection.

In a yield trial designed to compare the levels of resistance of black and non-black materials, progress was achieved in the selection of red and white seeded beans for resistance to the insect. The red resistant

varieties showed the lowest yield losses under high *Empoasca* infestations and all were significantly superior to the susceptible red-seeded control, Diacol-Calima (Table 8). The white seeded resistant materials were also superior to their susceptible control, ICA-Bunsi. Spearman's correlation coefficient between the visual damage rating and yield loss was significant ($r = 0.757$; $P<0.05$).

In studies with *Phaseolus* species other than *P. vulgaris,* four sources highly resistant to *Empoasca* were confirmed in the *P. acutifolius* collection. In 185 introduction of *P. lunatus* studied, 5 highly resistant sources were identified.

In experiments to study the influence of leaf pubescense on *Empoasca* populations, a significant negative correlation was found between the number of trichomes per cm^2 and the visual damage score ($r = -0.87$; $P<0.05$) (Figure 10), a correlation which has not been found for *P. vulgaris.*

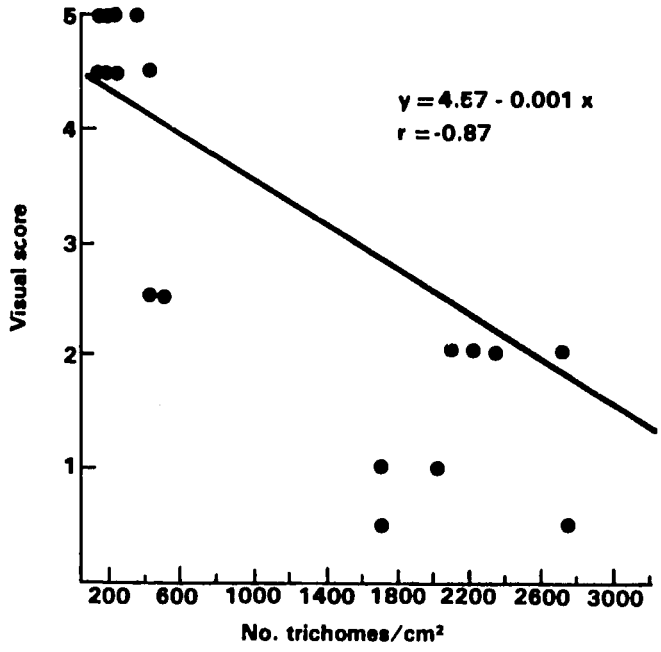


Figure 10. Correlation between leaf pubescence and visual damage score in *Phaseolus lunatus.* .

Table 8. Yield reduction percentage and damage as determined by a visual rating scale due to a high natural infestation of Empoasca kraemeri in 10 bean varieties (mean values of four replications; CV= 12.41%).

Variety	Color	Disease reaction[1]	Yield reduction %	Visual damage ratings
BAT 2	Red-cream	R	24.2a[2]	3.2
BAT 15	Red-cream	R	29.2a	2.6
G05468	Black	R	32.9ab	2.8
BAT 14	Red-cream	R	33.1ab	3.0
G00124	White	R	34.5ab	2.7
G04211	Black	R	40.9ab	3.1
Ex-Rico 23	White	R	41.1b	3.4
ICA-Tuí	Black	R/I	40.3c	3.2
Diacol-Calima	Red	S	57.5c	4.4
ICA-Bunsi	White	S	57.7c	3.8

1 Disease reaction as determined in previous experiments: R = resistant; S = susceptible; and I = intermediate.

2 Means within columns followed by the same letter are not significantly different at P = 0.05.

Spider Mites

Efforts were concentrated in developing a reliable methodology to evaluate for resistance to the spider mite *Tetranychus desertorum*. No correlation was found between the visual damage rating done in the field and meshhouse.

Correlation coefficients ranging between $r = 0.63$ and 0.78 ($P < 0.05$) were found between evaluations carried out in the field in different semesters, suggesting that selection could be more reliable under natural conditions. Furthermore, correlations between replicates within each semester were high ($r = 0.81$-0.82; $P < 0.05$). On the basis of these results more than 300 materials were evaluated in the field, 6 of which showed a high level of resistance. A preliminary study suggests that the final yield could be another selection criteria. Significant negative correlations ($r = -0.897$) were found between the visual damage ratings and the percentage of materials that produced seed after an early mite infestation.

Tolerance to Moderately Acid Soils

Methodology improvement

The screening method for efficiency in low soil P utilization was described in CIAT's 1978 Annual Report. This year, the method to screen for tolerance to moderately acid conditions at CIAT-Quilichao was further refined.

Two cultivars that were inefficient and 10 that were efficient in utilizing low available P in the soil were planted at three levels of P, and two levels of N fertilization. When both nutrients were limiting, yields were low and no differences could be observed between efficient and inefficient cultivars. The differences were only expressed when N was not limiting (Figure 11), indicating that screening for tolerance to low P must be done under adequate N fertilization.

To select cultivars that are efficient in using low soil P, and also responsive to applied P, more than 150 kg P_2O_5/ha were required. There were minor differences in yield at different N application rates for the inefficient cultivars at 150 kg P_2O_5/ha, but yield differences were observed in efficient cultivars. This suggests that cultivars efficient in using P are also efficient in using N. There were no differences in yield

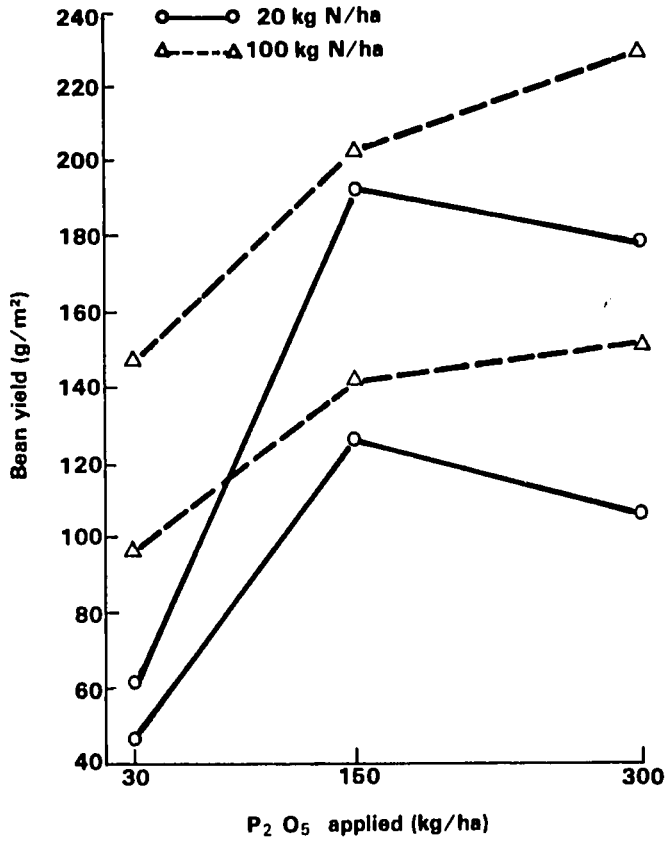


Figure 11. Range of response of beans to different P levels as affected by the N fertilization status.

increases between inefficient and efficient cultivars at increasing P levels. However, the total biomass production increased differently (Figures 12 and 13). In the field, this may lead to select the most vigorous plants, but these may not produce grain. When adequate levels of N were applied, total biomass production correlated strongly with grain yield and the responsive, efficient cultivars showed their superiority. Leaf area index and pod number were only slightly correlated with yield; however, the weight of 100 seeds and the number of grains/pod correlated significantly with yield in stress conditions. This suggests that yield is the best parameter for screening for moderately acid soil conditions.

The Al stress level used in experimental plots last year was too high (80%) and only few materials produced seed although available soil P was adequate. This year the stress level of Al saturation used was 65% (800 kg $CaCO_3$/ha broadcasted). The 65% Al saturation rate is high for beans, but due to high organic matter content in the CIAT-Quilichao soil, it is however possible to grow beans there. The high

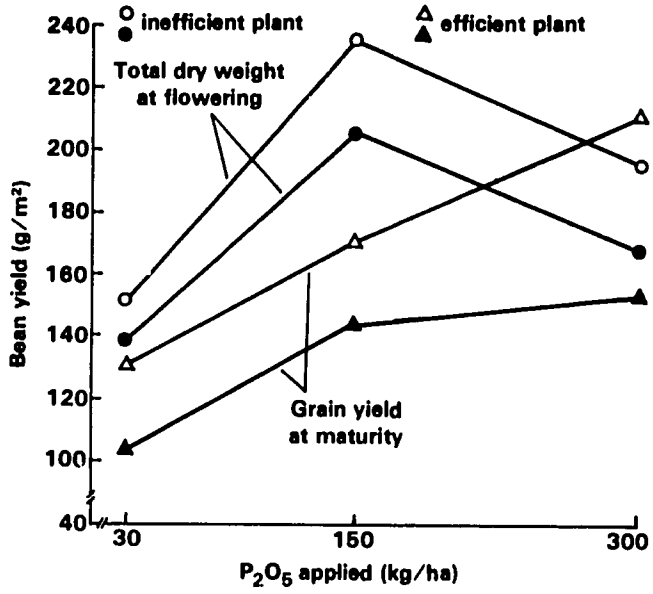


Figure 12. Response curves of efficient and inefficient beans to different levels of applied P, with adequate N supply.

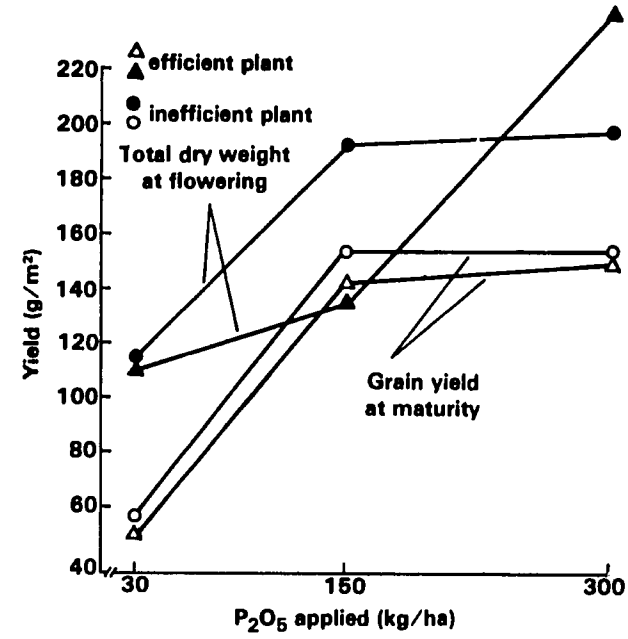


Figure 13. Response curves of efficient and inefficient beans to different levels of applied P, with limited N supply.

organic matter content of this soil and the application of 800 kg $CaCO_3$/ha reduced the Mn content below toxic levels, whereas the soil pH did not change significantly.

The decrease in Al saturation from 65% to 5% as liming rates are increased is almost linear (Figure 14). Yields also increased linearly with increasing liming rates. Above the 65% Al saturation level yields were highly variable due to difficulties in applying lime evenly over the field. In general, yields were high this year due to favorable climatic conditions and residual P accumulated in the soil after three consecutive growing seasons.

Screening results

Field screening for tolerance to high Al and Mn and

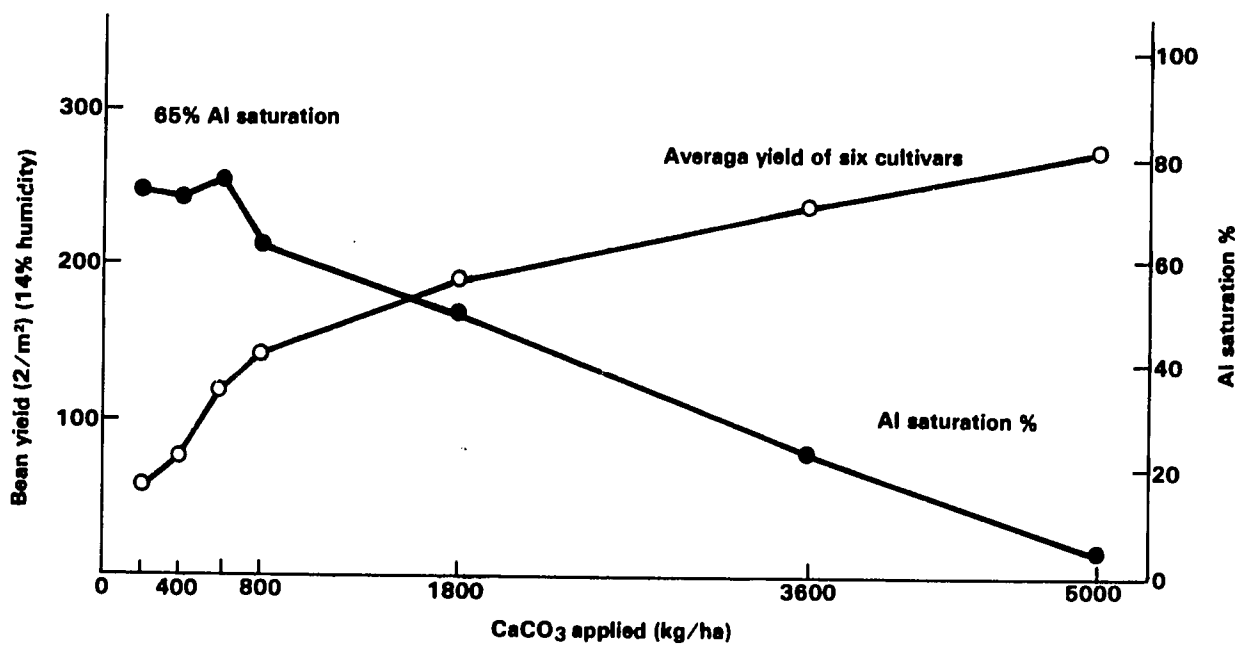


Figure 14. Effect of Al saturation during the flowering period on bean yield (mean for 12 varieties) in CIAT-Quilichao, 1979A. (CV = 22%; LSD = 39.5, P = 0.05)

low soil P showed that out of 188 materials only 49 were tolerant to low soil P, and 35 to moderately acid soils. The 10 best materials are listed in Tables 9 and 10. Twenty-four of the materials combine tolerance to low soil P and to high Al and Mn levels (Table 11). This indicates that plants efficient and responsive to low P are not necessarily tolerant to moderate Al and Mn toxicities.

Red-seeded materials required higher soil fertility levels than materials of other colors.

Figure 15 shows yield correlations of the best tolerant materials to low P *versus* high Al and Mn in the soil. The majority of the materials show no correlation but some well-known entries, especially those from Brazil, showed positive correlations. These materials are well-adapted to the moderately acid soil conditions commonly encountered in Brazil. Some CIAT breeding lines have higher yields under moderate input levels, but did not perform as well as Brazilian entries under these adverse conditions.

The 24 outstanding materials showed a positive correlation between yield under stress conditions *versus* their potential yield under high fertility (Figures 16 and 17). This indicates the advantage of selecting only materials from the upper righthand quadrant (efficient and responsive or tolerant and responsive) in Figure 18.

The index for the efficiency of added P fertilizer ($\mathcal{L}$) varied between semesters due to agroclimatic conditions and averaged 1.11 and 2.41 for 1979B and 1979A, respectively. However, the classification of efficient or inefficient cultivars remained constant, although the average yields on stress plots were lower in the second semester. Only few materials showed inconsistent responses (Figure 18).

Tolerance to Water Stress

Research continued in the development of a screening procedure for identifying germplasm tolerant to water stress. Ninety-eight lines that had

Table 9. Ten most efficient materials on low soil P with a 10% aluminum saturation in CIAT-Quilichao, 1979A.

Entry	Seed color	Growth habit	Yield (kg/ha) 50 kg P_2O_5/ha	Yield (kg/ha) 300 kg P_2O_5/ha	Efficiency coefficient $\mathcal{L}$
G4682	Red	II	2151	2942	3.2
Iguazu = G04120	Black	II	2118	2811	2.8
G5059	Cream	II	1963	2711	3.0
G5201	Black	I	1937	2935	4.0
G3800	Black	II	1928	2549	2.5
BAT 51	Black	II	1899	2530	2.5
BAT 27	Red	III	1836	2783	3.8
BAT 57	Black	II	1826	2566	3.0
BAT 31	Red-brown	II	1822	2807	3.9
BAT 26	Pink	III	1780	2751	3.9

1 Efficiency coefficient $\mathcal{L} = \frac{\text{yield high } P_2O_5 - \text{yield low } P_2O_5}{\text{high } P_2O_5 \text{ rate} - \text{low } P_2O_5 \text{ rate}}$

Table 10. Ten most tolerant materials to moderate Al and Mn levels in the soil with a 65% Al saturation in CIAT-Quilichao, 1979A.

Entry	Seed color	Growth habit	Yield (kg/ha) 65% Al saturation	Yield (kg/ha) 10% Al saturation	Efficiency coefficient β'
G5059	Cream	II	1203	2712	25.1
Iguazu	Black	I	1119	2811	28.2
BAT 21	White	II	1112	2482	22.8
BAT 94	Brown-pink	II	1028	2403	22.9
BAT 1186	Brown	II	996	2320	22.1
Rio Tibaji Lote 10	Black	II	994	2611	26.9
G4464	Black	II	963	2294	22.1
G3627	Black	II	950	2503	25.9
BAT 74	Black	II	946	2630	28.1
G3781	Black	II	943	2377	23.9

1 Efficiency coefficient $\beta = \frac{\text{yield low Al sat.} - \text{yield high Al sat.}}{\text{high Al sat. \%} - \text{low Al sat. \%}}$

Table 11. Materials most tolerant to low soil P as well as to moderate Al and Mn toxicity levels in CIAT-Quilichao during 1979A.

Entry	Common name	Seed color	Yield (kg/ha) Control plot	Yield (kg/ha) Low P plot	Yield (kg/ha) High Al sat. plot
Iguazu	-	-	2811	2119	1119
G5059	Brazil 349 Mulatinho	-	2712	1963	1203
G5201	Brazil 1074 México 528	Black	2935	1937	936
Carioca	-	Cream mottled-brown	2124	1883	1274
BAT 26	-	-	2751	1780	783
BAT 28	-	Black	2399	1727	906
G4464	Turrialba 2 N	Black	2295	1658	963
G4000	Nep 2 Bayo 22	-	2537	1650	928
G3800	Venezuela 72	Red	2279	1635	894
BAT 68	-	Black	2699	1627	747

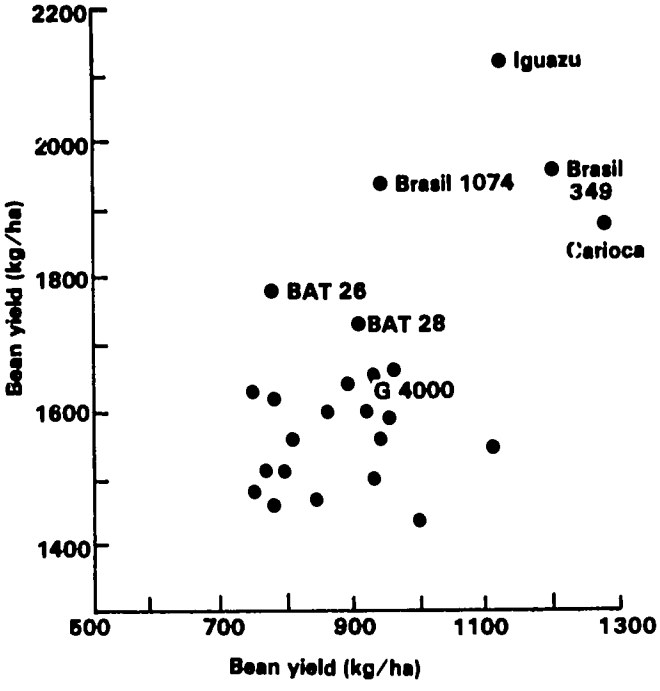


Figure 15. Correlations between yields obtained in low P plots (50 kg P_2O_5/ha) and high Al saturation plots (800 kg $CaCO_3$ equivalent/ha).

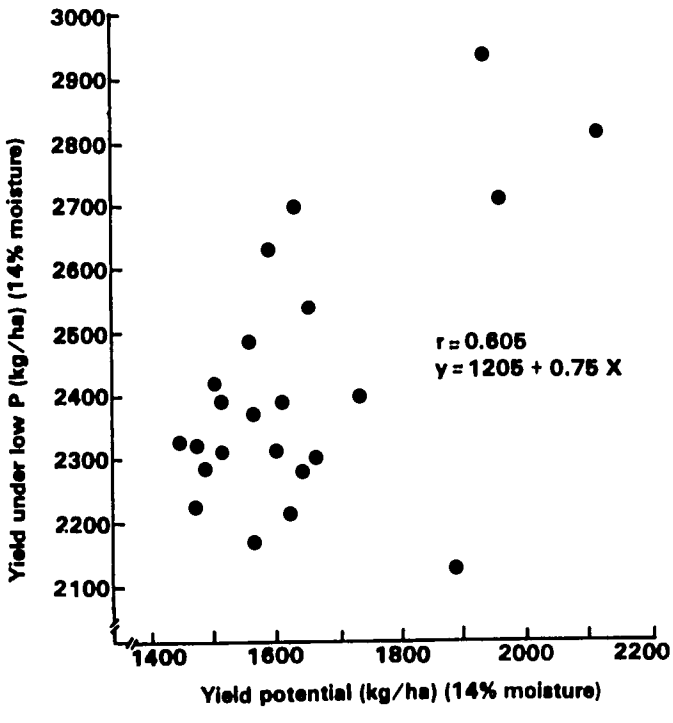


Figure 16. Correlation between bean yield potential and yield under low soil P in CIAT-Quilichao, 1979A

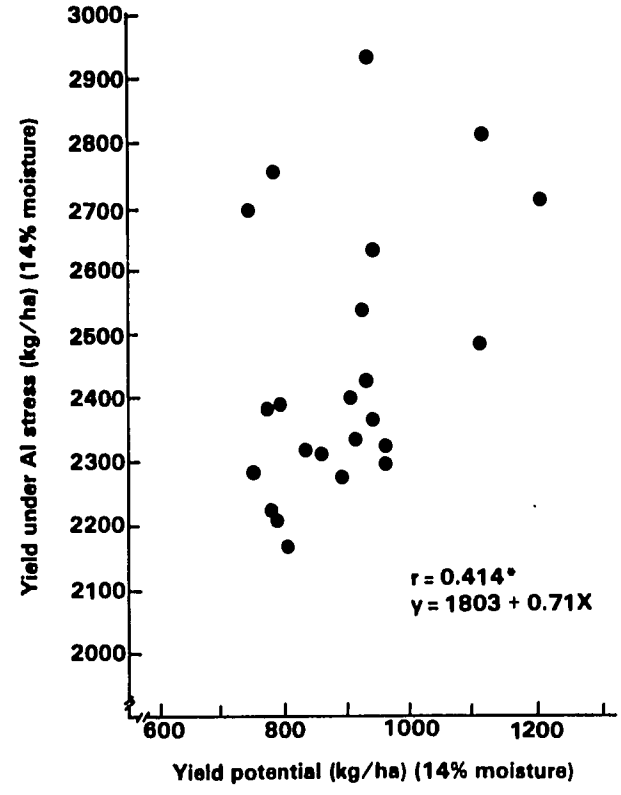


Figure 17. Correlation between bean yield potential and yield under Al stress conditions in CIAT-Quilichao, 1979A

exhibited both tolerance and susceptibility to water stress in experiment 7816 last year, plus 186 lines from the germplasm and EP trials were screened at CIAT-Palmira this year. Sequential planting was arranged such that all the lines initiated flowering in a four day period. Irrigation was suspended four days before flowering and stress continued for 2-3 weeks in the stress treatment.

During the stress period, canopy temperatures for the stress and control plots were determined using infrared thermometry. It has been shown that a strong relationship exists between the difference in canopy temperatures in stressed and control plots with stomatal resistance and plant water potential (CIAT Annual Report, 1978).

Figure 19 shows yield reduction *versus* the summation of differences in temperature ($\Sigma \Delta T$) for experiment 7910. The number of entries in each quadrant in relation to the total number of materials planted were similar in both experiments. The use of $\Sigma \Delta T$ as a primary screening technique for stress tolerance appears to be consistent from season to season. The material with low yield reduction and tolerance to

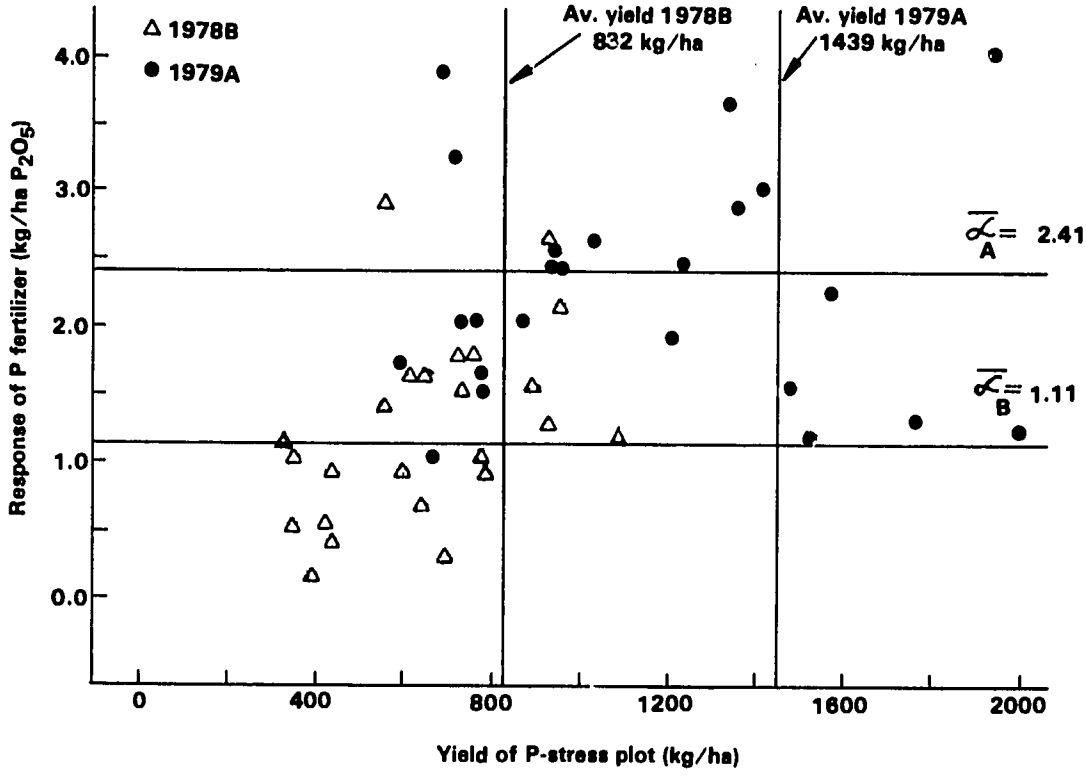


Figure 18. Effect of different planting seasons on bean yields under P stress conditions.

stress are located in the lower left quadrant. Materials that were susceptible to water stress but still exhibited a low yield reduction are located in the lower right quadrant. The material in this lower quadrant could be used for breeding purposes due to their ability to produce even under high stress conditions.

Data obtained for yield reduction of the 98 materials common to both experiments (7816 and 7910) are presented in Figure 20. Materials in the lower left quadrant are those which exhibited yield reduction below the means for both experiments. Out of the 23 lines that fell into this quadrant 15 also exhibited a low stress index in both experiments (Table 12). The other eight lines that did not show this low stress index were very close to the center mean point (Figure 21). Further studies are necessary to determine if the promising $\xi\Delta T$ methodology can be used as an initial screening procedure.

Variability from Interspecific Hybridization

The CIAT/University of Gembloux Project

The objective of this project is to secure useful contributions from other species of *Phaseolus* by means of interspecific hybridizations to develop a wider range of genetic diversity within *P. vulgaris*, especially in plant architecture and disease and insect resistance. Desired characteristics sought include (a) plant architecture features such as reduced flower and pod abortion, outcrossing mechanisms, resistance to lodging, long hypocotyl and epicotyl, and outrigger racemes with more than four pod-bearing insertions and two or more pods per insertion; (b) tolerance to drought and low P levels; and (c) resistance to common bacterial blight (*Xanthomonas phaseoli*), leafhoppers (*Empoasca kraemeri*), Ascochyta leaf spot and bean golden mosaic virus (BGMV).

Previous taxonomical and interspecific crossing compatibility studies indicate that *P. coccineus* and *P. acutifolius* are species closely related to *P. vulgaris*. *P. acutifolius* could be of interest for its resistance to common bacterial blight and leafhoppers, and tolerance to drought. Many problems, especially related to fertility, still hamper crossing this species with *P. vulgaris*. At the University of Gembloux, research is conducted to study the restoration of fertility in progenies of these crosses. Several combinations of parental genotypes have given F_1 plants

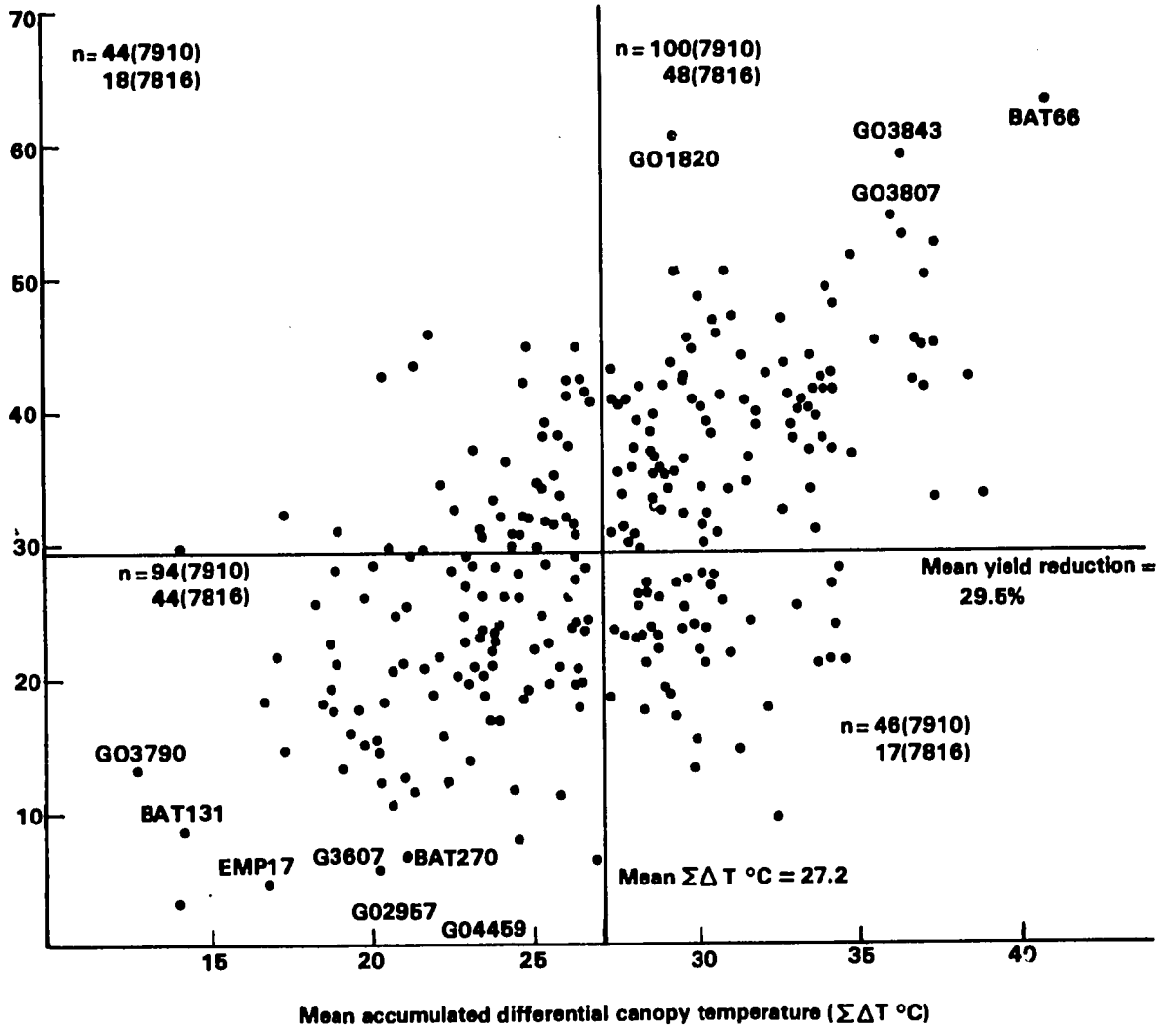


Figure 19. Yield reduction due to water stress in 282 entries versus mean accumulated differential canopy temperature. (Experiment 7910).

without embryo culturing. However, in spite of numerous backcrosses, these plants have remained sterile up to now. Future plans include using other *P. acutifolius* accessions, embryo culturing, and colchicine doubling of chromosomes.

P. coccineus, the species closest to *P. vulgaris,* is of interest for its plant architectural characteristics such as its long epicotyl, inflorescence with long peduncle and high number of flower insertions, cross-pollination mechanism, and others, as well as for its resistance to bean common mosaic virus (BCMV), bean yellow mosaic virus (BYMV), anthracnose *(Colletotrichum lindemuthianum),* Ascochyta leaf spot, halo blight *(Pseudomonas phaseolicola)* brown spot *(Pseudomonas syringae),* and beanflies *(Ophiomyia* sp.). Four *P. coccineus* subspecies have been defined: *coccineus, obvallatus, formosus* and *polyanthus,* the latter being taxonomically intermediate between *P. vulgaris* and *P. coccineus* subsp. *coccineus.*

P. coccineus can be rather readily crossed with *P. vulgaris* and the constraints usually found in interspecific crosses can be overcome. Two will be discussed here, i.e. viability and fertility of the F_1 generation.

Several crosses between *P. vulgaris* and *P. coccineus* subsp. *coccineus* gave various types of lethal, semi-lethal, and cripple dwarf plants (Table 13). No cross between *P. vulgaris* and *P. coccineus* subsp. *polyanthus* displayed these abnormal plant types.

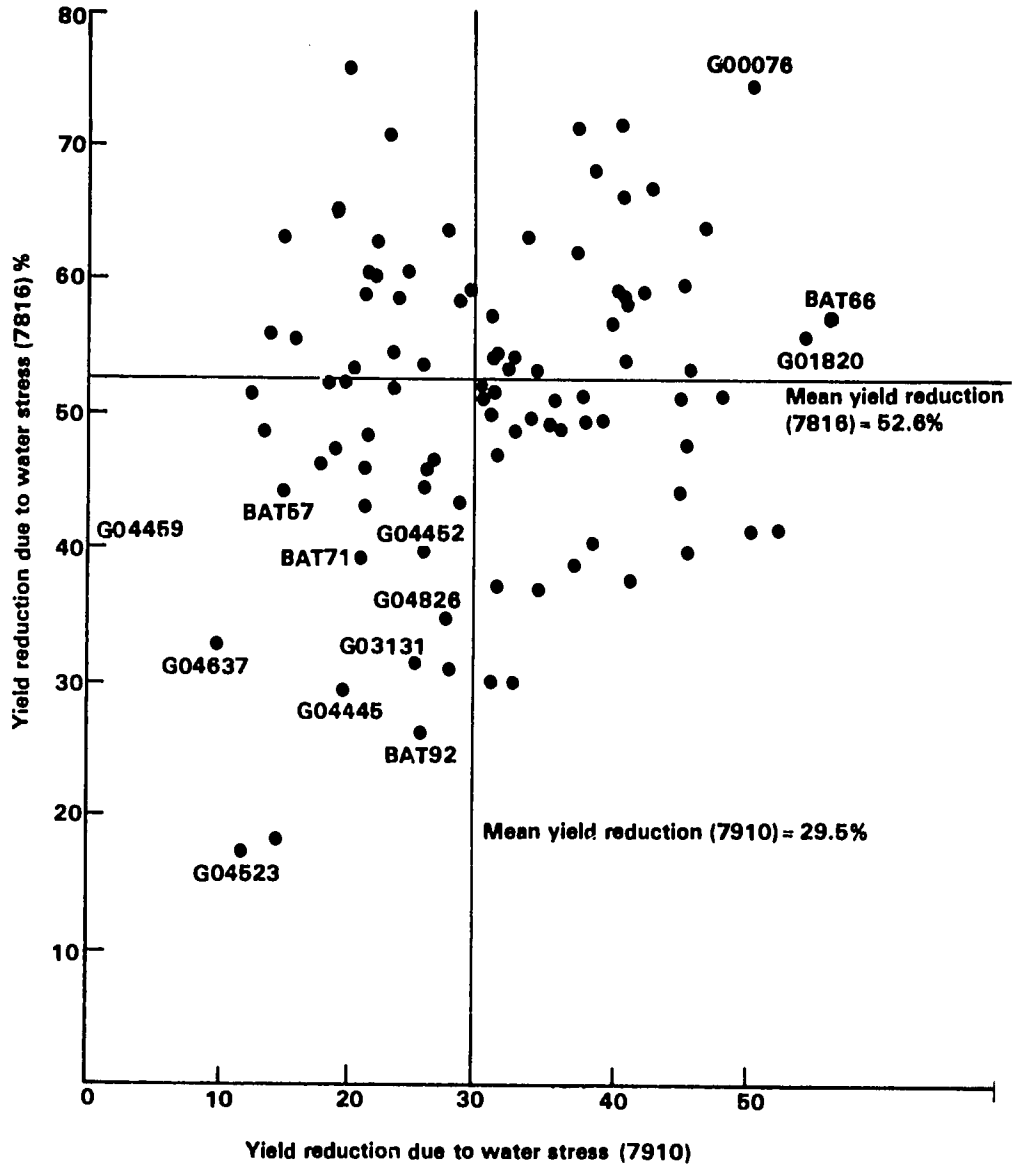


Figure 20. Yield reduction in materials common to experiments 7816 and 7910.

The F_1 of these interspecific hybrids is also characterized by low fertility. Under meshhouse conditions, the number of seeds per plant produced during a four-month period ranged from 3 to 136 depending on the combination of parental genotypes. Manual self-pollinations (i.e., tripping the flowers to place pollen on the stigma surface) significantly increased the number of seeds produced, although efficiency was low due to reduced fertility of these hybrids. Fertility of *P. vulgaris* x *P. coccineus* subsp. *polyanthus* crosses was markedly higher as compared to *P. vulgaris* x *P. coccineus* subsp. *coccineus* crosses (Table 14).

Backcrosses may restore fertility in sterile combinations, as fertility increased in backcross progenies compared to progenies resulting from self-pollinations (Table 15). Backcrosses, however, increase the shift towards the *P. vulgaris* parent and, therefore, increase the risk of losing useful *P. coccineus* characteristics.

The F_2 shows an important segregation, especially for viability and fertility. In this generation, plants showing vigor and reasonable fertility rates could be selected, mainly in the *P. vulgaris* x *P. coccineus* subsp. *polyanthus* crosses. Progenies of these plants have

Table 12. Yield reduction and accumulated differential temperature ($\Sigma\Delta T$ °C) for materials most tolerant to water stress (yield reduction below the mean values) for experiments 7816 and 7910.

Entry	Yield reduction (%)			Control yield (%)		$\Sigma\Delta$ °C[1]	
	Mean	7816	7910	7816	7910	7816	7910
GO4523*[2]	14	17	12	3.46	2.86	46	24
GO4459*	20	41	0	3.44	2.38	59	22
GO4637	21	33	10	4.00	2.47	79	33
GO4445*	25	30	20	2.77	2.67	75	26
BAT 92	26	26	26	3.60	2.31	54	28
GO3131*	26	31	21	3.72	2.80	45	25
BAT 57	30	44	15	4.13	2.56	75	31
BAT 71*	30	39	21	3.78	2.79	62	26
GO3790	31	49	14	3.37	2.37	87	13
BAT 81*	32	51	13	4.30	2.02	63	21
BAT 70*	32	43	21	4.67	3.15	45	19
GO4452*	33	40	26	2.66	1.97	75	27
BAT 100*	33	48	19	3.87	2.81	60	24
GO4525	33	46	21	3.86	2.91	71	29
BAT 114*	35	48	21	3.76	2.80	71	21
GO1401*	35	45	26	3.30	1.71	57	15
BAT 16*	35	52	19	3.93	2.65	75	21
GO4446	36	43	28	4.23	3.30	77	34
BAT 115*	36	46	26	4.34	3.08	43	27
GO2006	36	46	26	3.34	3.09	83	24
BAT 85*	36	52	20	4.09	3.20	73	26
GO5201*	38	52	23	4.08	2.89	75	23

1 Twenty-three readings for 7816 and seven for 7910 during periods of stress.

2 * = lines that showed yield reduction and $\Sigma\Delta T$ values below mean figures for experiments 7816 and 7910.

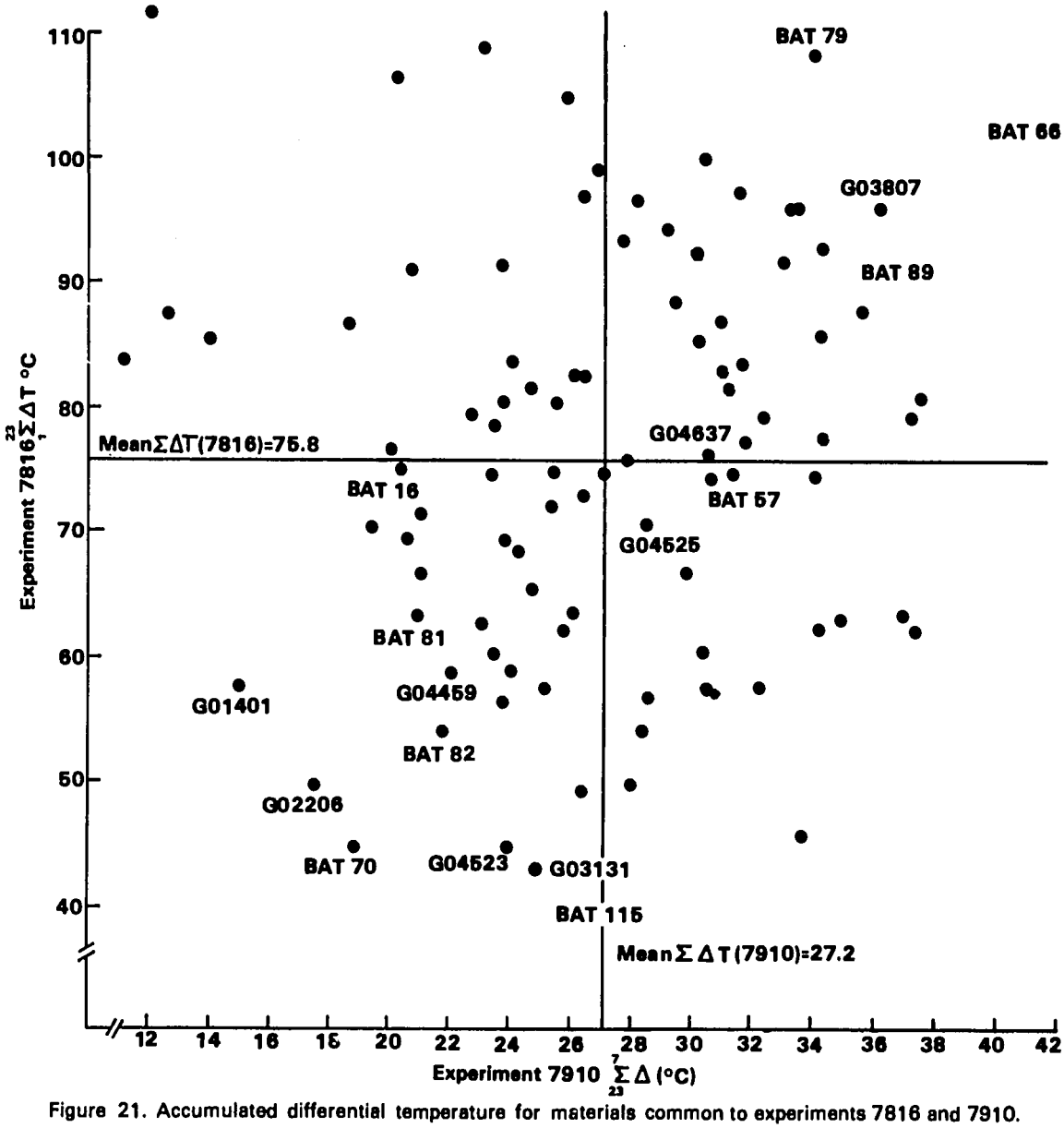


Figure 21. Accumulated differential temperature for materials common to experiments 7816 and 7910.

Table 13. Viability in the F_1 of P. vulgaris x P. coccineus subsp. coccineus and P. vulgaris x P. coccineus subsp. polyanthus.

Interspecific crossing	Parental combinations tested	Plant types obtained			
		Lethal	Semi-lethal	Cripple	Normal
P. vulgaris x P. coccineus subsp. coccineus	52	5	4	8	35
P. vulgaris x P. coccineus subsp. polyanthus	16	0	0	0	16

Table 14. Fertility observed in the F_1 of *P. vulgaris* x *P. coccineus* subsp. *coccineus* and *P. vulgaris* x *P. coccineus* subsp. *polyanthus*. (Data shown correspond to a four-month harvest period).[1]

Interspecific crossing	Seeds per plant		Success rate of manual self-pollinations	Seeds per pod
	Natural crossing	Manual crossing		
P. vulgaris x *P. coccineus* subsp. *coccineus*				
NI 161 x NI 191	0	3	5	1.0
Line 17 x NI 2	2	12	8	1.2
NI 161 x NI 229	3	27	12	1.1
G2047 x G35160	12	4	22	1.3
Nep 2 x NI 132	5	28	28	1.4
Average	4	18	13	1.2
P. vulgaris x *P. coccineus* subsp. *polyanthus*				
NI 161 x NI 520	23	8	19	1.2
G159 x NI 490	29	21	15	1.2
ICA-Pijao x NI 490	53	32	14	1.2
G2047 x NI 520	120	16	40	2.0
Average	68	32	19	1.3

1 Meshhouse trial.

Table 15. Effect of backcrossing on fertility in interspecific crosses between *P. vulgaris* and *P. coccineus*. (Data shown correspond to a two-month harvest period.)[1]

Crossings and backcrossings	Seeds per plant	Seeds per pod
P. vulgaris x *P. coccineus* subsp. *coccineus*		
NI 161 x NI 2: F_1	25	1.3
NI 161 x NI 2: F_2	3	1.2
(NI 161 x NI 2) x NI 161: BC_1F_1	65	2.1
P. vulgaris x *P. coccineus* subsp. *polynathus*		
NI 568 x NI 490: F_2	72	2.3
(NI 568 x NI 490) x NI 568: BC_1F_1	274	3.3

1 Field trial.

been included in various nurseries of the Bean Program for their evaluation.

Promising variability found so far include:

- Lignified stem: a three-way hybrid *(P. vulgaris* x *P. coccineus* subsp. *coccineus)* x *(P. coccineus* subsp. *polyanthus)* showed a lignified main stem, which could provide additional resistance to lodging.

- High number of pods per raceme: a plant was selected which showed racemes with up to 12 pods. This plant resulted from a cross between a wild *P. vulgaris* and *P. coccineus* subsp. *polyanthus,* backcrossed to the wild *P. vulgaris.* It combined the reduced flowers and pod abortion of the wild *P. vulgaris* parent and the higher number of insertions of *P. coccineus* subsp. *polyanthus.*

Both materials are now being evaluated for their use in the Bean Program's varietal improvement program.

Further evaluations of wild *P. vulgaris* and *P. coccineus* subsp. *polyanthus* accessions will continue, as these are the materials more readily crossed with the cultivated *P. vulgaris.* Seed increase of *P. coccineus* subsp. *polyanthus* will require a preliminary study as this form has a high degree of cross-pollination. Viability and fertility restoration, and subsequent evaluations of selections from crosses with *P. coccineus* accessions will be carried out.

Photoperiod Screening

The screening method presently used for photoperiod response was discussed in CIAT's 1977 Annual Report (page B-36). Table 16 presents a summary of the response of 174 advanced breeding lines during the EP stage of the breeding process. While photoperiod is not being used as a strict selection criterion during the 1979 EP stage, it is interesting to note that the total proportion in each photoperiod response class this year is similar to the distribution observed for the bean germplasm collection. An increase in the proportion of sensitive lines occurred in the 1979 EP as compared to the 1977-78 EPs.

Table 16. Photoperiod screening results for advanced breeding lines (EP stage) at CIAT-Palmira compared to the distribution of photoperiod sensitivity in germplasm previously screened.

	Classification of photoperiod response[1]					
Growth habit	<4	4-10	11-20	21-30	>30	Total
I	42[2] (57)	2 (29)	1 (14)	-	-	45 (100)
II	62 (51)	8 (7)	26 (21)	13 (11)	13 (11)	122 (100)
III	10 (22)	2 (4)	14 (31)	16 (36)	3 (7)	45 (100)
Total	76 (44)	12 (7)	41 (24)	29 (17)	16 (9)	174 (100)
Distribution in 78 EP + 77 EP	248 (70)	34 (10)	59 (17)	7 (2)	5 (1)	353 (100)
Distribution in germplasm collection	(41)	(12)	(23)	(12)	(12)	(100)

1 Flowering delay in 18 hour days as compared to 12 hour 20 min. natural daylength.
2 Data in the body of the table gives the number of entries in each class by growth habit and the corresponding percentage in parenthesis.

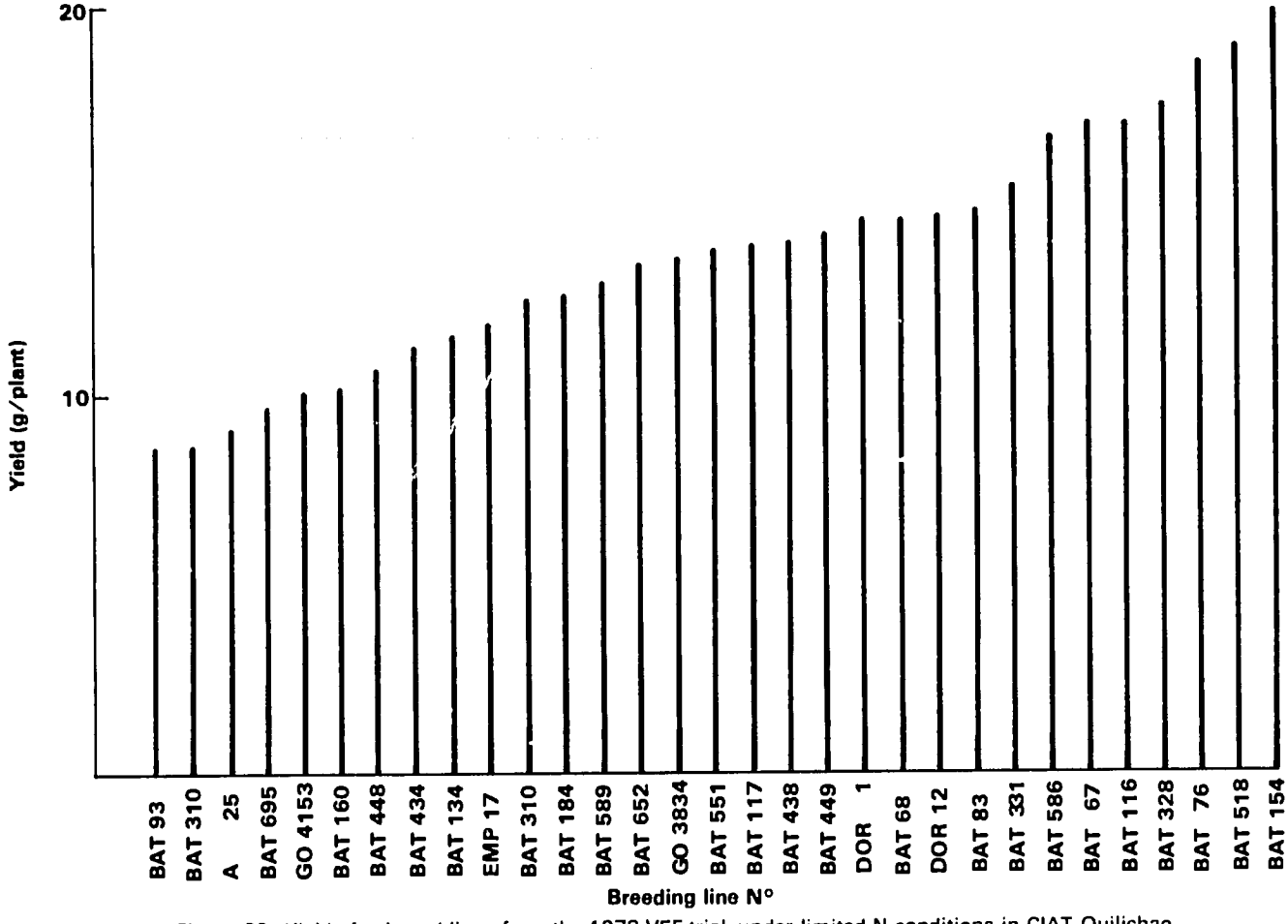


Figure 22. Yield of selected lines from the 1978 VEF trial, under limited N conditions in CIAT-Quilichao.

Ability to Fix Nitrogen

Evaluation of Breeding Lines

CIAT advanced breeding lines were evaluated for their ability to fix N and identify genes deleterious to N fixation. One hundred lines from the 1978 VEF trial were grown in CIAT-Quilichao in a soil made N-deficient by the addition of milled corn cobs. Nodule development was measured early in the growth cycle with yield taken as an expression of seasonal rates of N_2 fixation. Cultivars varied widely in both nodulation and yield (Figure 22) with some cultivars yielding more than 3.0 t/ha. Several of these materials, including the highly promising BAT 76, have been included in the 1980 IBYAN. A modified form of this method will be used to screen all lines in future EP trials.

Nutritional and Quality Factors

Quality factors in beans include both nutritional value and aspects of consumer acceptance. Screening for bean quality is integrated into the Bean Program's overall screening and evaluating schemes, and currently include seven factors assayed in CIAT's Food Quality and Nutrition Laboratory: protein content, water absorption, cooking time, broth thickness, flavor, storability, and overall consumer acceptance.

Protein Content

Protein contents in 132 advanced lines tested this year ranged from 23% to 31%. Higher protein was not strictly correlated with low yield, or vice versa; approximately one-third of the lines with high protein (28-31%) had higher yields than the average yields of the low protein (23-25%) lines in the 1979A season. Thus selection can be made for higher protein yields within this advanced material. Observations indicate 35% of these advanced lines have a high protein content (over 28%). Digestibility (protein availability) and protein quality (balance of sulfur amino acids) will be studied in the future.

Water Absorption

This factor measures the swelling of the beans and hence their appearance and softness when cooked. Standardized absorption tests are done over a period of four hours in water containing 1% (weight/volume) of sodium chloride and of sodium bicarbonate. This period of soaking results in subsequent cooking times that are the same as from longer soaking periods. The salts do not change the extent of water absorption, but do reduce cooking times by nearly 50%, a practical aspect in households where fuel is scarce or expensive. For a group of ten advanced lines, the correlation coefficient between water absorption and cooking time was -0.64 with freshly harvested beans and -0.66 after beans had been stored al 40°C for 25 days. This implies a relatively close relationship between these two factors; beans that absorb water readily tend to cook more quickly.

Cooking Time

A standardized test has been developed and 50 samples per week can be analyzed. The test consists of cooking 10-20 g lots of beans in boiling water (after their soaking in salt solution and rinsing with water). Every 5 minutes 10 seeds are taken from the cooking vessel and tested in the mouth for texture (hardness) and flavor. The first point at which all the beans sampled are judged as thoroughly cooked is taken as the cooking time. This rapid test was developed from more complete tests of bean texture measured with a cone pcnetrometer during soaking and cooking (Figure 23). To determine the more subtle aspects of textural change when the bean passes from the partially cooked to the fully cooked state, testing by the mouth was judged more accurate than by machine.

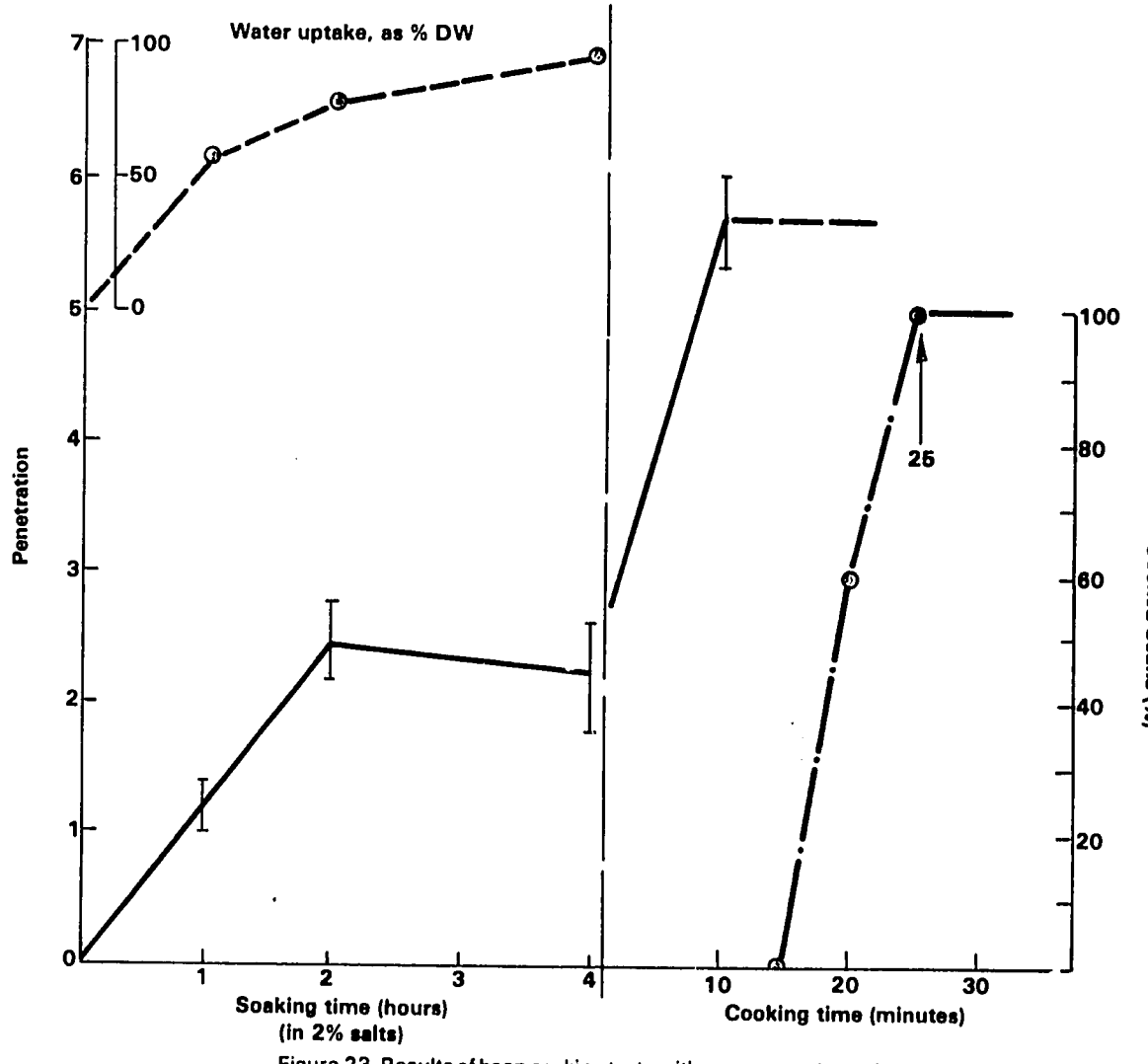


Figure 23. Results of bean cooking tests with a cone penetrometer.

Over 500 cooking tests have been carried out on CIAT bean lines. In 154 lines from the 1979 EP, cooking times ranged from 25-80 minutes. Both genetic factors and storage conditions strongly influence cooking time.

Broth Thickness

A characteristic of beans that strongly influences consumer preference and hence market value is the consistency of their broth after cooking. A thick broth is favored and such beans may receive a higher price. Brazil beans producing a good broth receive 35% higher prices as compared with only a 11% mean price premium for non-black beans * The measure of broth thickness used is based on weight of suspended soils in the cooking medium. A known proportion of the cooking broth is taken and evaporated to dryness at low heat. Results are expressed as percent of fresh bean sample weight (before soaking and cooking). For the 1979 EP lines tested (154 materials), broth values ranged from 3.5% (very thin, unacceptable) to 25% (thick, very acceptable); about half of the lines were judged acceptable for this character. Cooking time was not highly correlated with broth thickness; the reasons for this will be investigated.

Flavor

This character is somewhat subjective and will probably differ from region to region. However, taste panel tests done with CIAT personnel have consistently differentiated beans as good or poor in flavor. It is felt that major flavor classifications determined at CIAT will serve as guidelines for most bean consumers. It should be noted that an association between certain colors of beans and flavor is made by many consumers.

Storability and Hard Seed Coat

It has long been recongnized that poor storage conditions produce hard seed coats in beans. A long term storage test continued for nearly 1.5 years under controlled conditions of seed moisture and temperature has demonstrated that dried beans stored at relatively high temperature (26°C) develop a hard seed coat and hence require longer cooking times than do beans with higher moisture contents stored at relatively low temperature (12°C) (Figure 24). Results with one red and one black variety show similar trends.

J.H. Sanders and G.N. Nicdeti, "A Situacao do Feijao (*Phaseolus vulgaris* e *Vigna*) no Brasil (com algumas sugestoes para a política) CIAT, Cali, Colombia, Abril 1979.

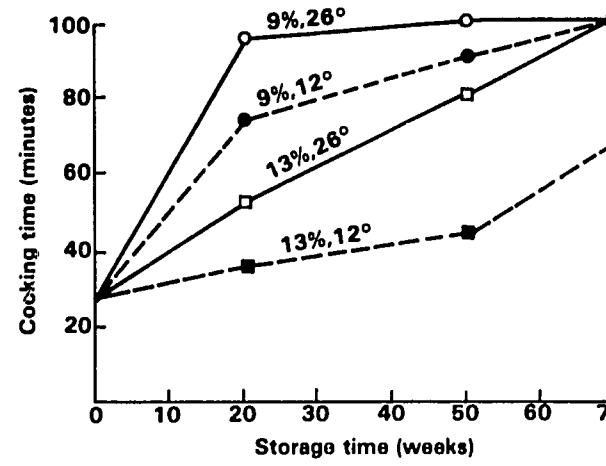


Figure 24. Effect of storage on cooking time for beans var. Diacol Calima.

After such extended storage, beans tend to come to a similar (possibly maximal) cooking time, which seems to be a varietal-dependent character.

The time required for such storage tests can be reduced considerably using accelerated storage tests done at 40°C in sealed pouches to maintain constant seed moisture. Of 10 EP lines tested, two develop their maximum cooking time within 25 days, whereas three lines required over 50 days. Five lines were intermediate in their behavior. Such a simple test seems sufficient to identify bean lines with good storage properties, but needs to be tested further.

The oil treatment of beans to control weevil infestation influences the subsequent cooking properties of the bean. Treatment with either maize or soybean oil (about 5 ml/kg of beans) was found to increase water absorption of beans during soaking. Cooking time in 6 of the 9 lines tested increased, but only by about 10 minutes. In 5 of the 9 lines, broth thickness increased. It appears that at least for some bean varieties, oil treatment has beneficial effects besides controlling insects.

Overall Consumer Acceptability

This factor is being measured by feeding new CIAT lines to consumers under controlled, reproducible conditions. Taste panels consisting of 16-18 persons are given two bean samples prepared as typical Colombian dishes using various recipes. The members are asked to compare one sample with the other, rating them both for flavor, appearance, texture, and general acceptability. By means of these taste panels, full

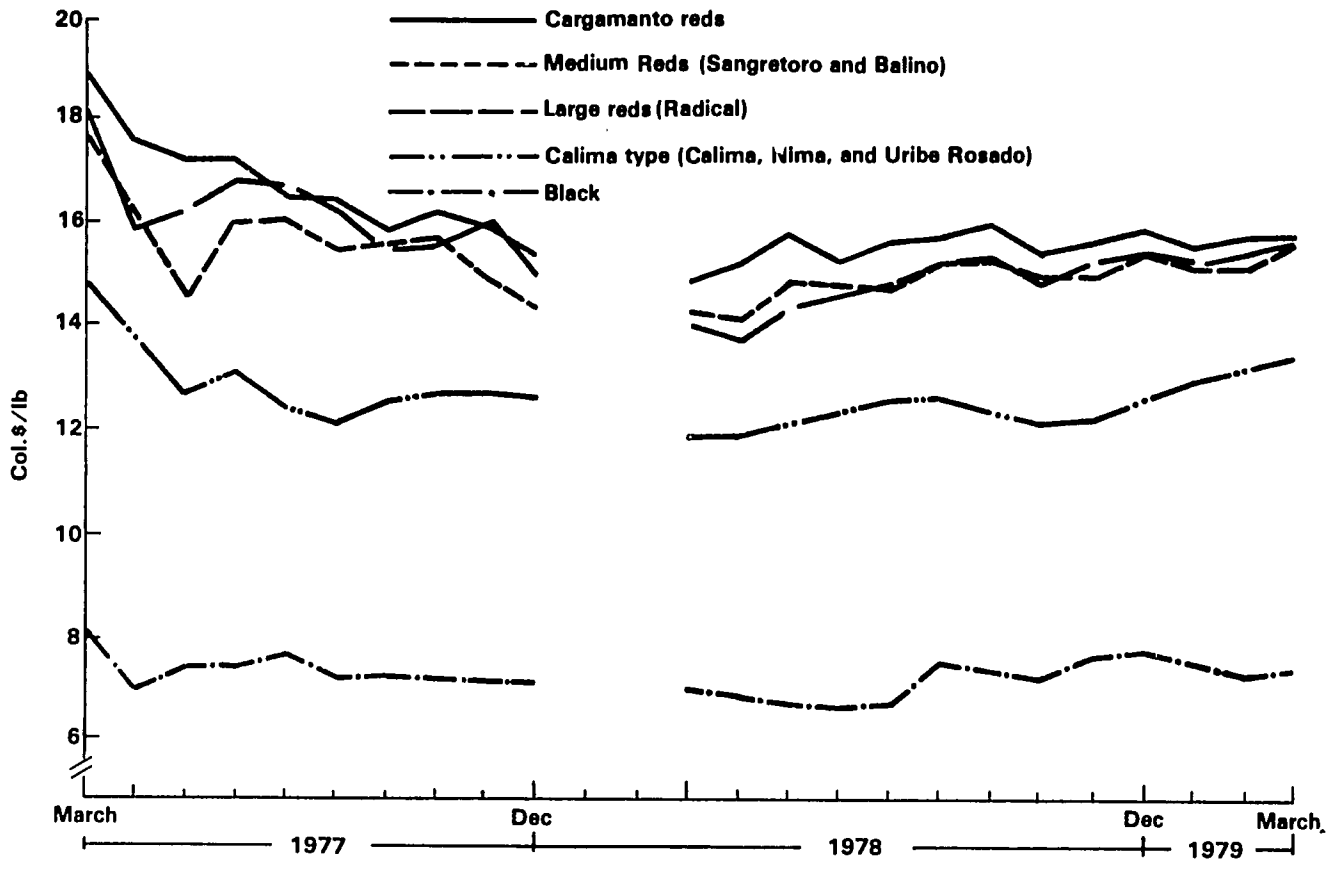


Figure 25. Retail bean prices (deflated with a Cali food price index), Palmira, March 1977-March 1979 monthly averages.

consumer evaluation is being given to the 30 lines selected from the 1979 EP lines.

Three characteristics that determine bean prices have been observed: seed color, size, and broth thickness. In most countries, except for Venezuela, Cuba, Guatemala, and parts of México, there is a substantial price discount for black seed color. Seed size is often a specified requirement for consumer acceptability, with large seed sizes receiving a price premium. Finally, certain beans are known to produce a better or thicker broth and these sell at a higher price.

Colombia is an interesting special case to evaluate for changes in consumer preferences over time. With the abrupt closing of the Venezuelan export market, a large stock of black beans was acquired in the Valle del Cauca region. Black beans have not been traditionally eaten in Colombia, however. From February 1977 to the present, weekly data on bean prices by variety have been obtained for Colombia. The black bean price increased from slightly less than Col.$18/kg in late 1977, to Col.$28/kg in August, 1979. However, the traditional red seeded bean prices increased at an even faster rate from about Col.$40/kg to over Col.$60/kg during the same time period.

There is no evidence that the lower price of black beans has induced low income consumers to change their preference towards black seeded varieties. A closing of the price differential or increased black beans sales would indicate shifts in consumer tastes. Neither has been observed.

Besides the difference in color, the preferred bean types in Colombia are also much large than the black beans. From March 1977 to March 1979, utilizing five month averages at the beginning and end of the period, black beans were 54% and 43% of the Calima type real price, and 43% and 39% of the real Cargamanto price (Figure 25). In breeding terms, if farmers can get 1.5 t/ha with Calima type beans with better agronomy, a new black variety would need to yield about 3.5 t/ha to give a financial return equivalent to that obtained with Calima.

HYBRIDIZATION AND PROGENY EVALUATION

Routine incorporation of resistances to diseases, pests, and other production constraints is a main objective. The total number of crosses made in each individual project during 1979 ia given in Table 17. Table 18 shows a list of those national cultivars utilized in crossings in the last two years. In Figure 1 the sequential development and evaluation of hybrid lines is given.

Bush Bean Improvement

Separate projects have been developed for several traits to enhance levels of resistance or other desired variabilities insufficiently expressed in the germplasm. A brief description of each project follows.

Bean Common Mosaic Virus (BCMV)

In collaboration with the Institute for Horticultural Plant Breeding (IVT), Holland, crosses were made to combine multiple resistance genes with the dominant I gene for protection against necrosis-inducing strains of BCMV. F_2 seed from crosses of multiple resistant F_3 families identified in Holland, with tropically adapted lines and a series of grain types has been sent to the IVT for testing. Due to the relatively poor adaptation of European sources, several backcrosses are anticipated.

Leafhoppers

The crossing program was continued this year to incorporate resistance to *Empoasca* in various materials. Seventy three parents were selected from improved materials and other nurseries to carry out the respective crosses under field and greenhouse conditions. The F_2 of the third cycle of intermating was evaluated and 176 single plant selections harvested. Emphasis was made in the selection of non-black materials, especially red seeded, resistant to rust and BCMV.

A replicated yield trial was conducted to assess advance in *Empoasca* resistance following two cycles of recurrent selection and intermating. Yield, a visual damage score, and insect counts were used to

Table 17. Number of crosses made and parental lines utilized in 1979 by breeding project.

Breeding project	No. crosses	No parents
BGMV	418	179
Empoasca	117	100
Common bacterial blight	76	52
Rust	19	18
Rhizobium	239	53
Apion	21	11
BCMV (backcrosses, multiple genes)	244	138
Anthracnose	170	76
Angular leaf spot	43	10
Low soil phosphorus	61	4
Drought	-	-
Architecture and yield	198	75
Range in maturity	11	5
Extreme temperatures	6	4
National cultivars	111	29
Miscellaneous	-	75
Climbing beans: (combining BCMV, rust, Empoasca, common bacterial blight)	193	81
Total	2065	872

Table 18. Cultivars from Latin American countries used in crosses.

Cultivar	Origin	Cultivar	Origin
Alubia	Argentina	Nahizalco Rojo	El Salvador
Chita fina	Brazil	S-184	El Salvador
Favinha	Brazil	Rojo de Seda	El Salvador
MVLR	Brazil	Tineco	El Salvador
IPA 7419	Brazil	Rabia de Gato	Guatemala
Carioca	Brazil	Sensuntepeque	Guatemala
Rosinha	Brazil	Rojo Zamorano	Honduras
Rio Tibagi	Brazil	Zamorano 2	Honduras
Andino	Colombia	Danli 46	Honduras
Calima	Colombia	Canario	Mexico
Catio	Colombia	Canario 107	Mexico
Nima	Colombia	Flor de Mayo	Mexico
Palmar	Colombia	Jamapa	Mexico
Tundama	Colombia	Mayocoba	Mexico
Mexico 80	Costa Rica	Peruano	Peru/Mexico
Constanza	Dominican Republic	Bayo Chimu	Peru
Pompadour	Dominican Republic	Blanco Local	Peru
Pompadour Checa	Dominican Republic	Peru 69	Peru
Pompadour Mocana	Dominican Republic	Canario Dive	Peru
Uribe Oscuro	Ecuador	Sataya 425	México
		Cocacho	Perú

Table 19. Spearman correlation coefficients for selected parameters used to assess damage and yield loss caused by Empoasca kraemeri, in five groups of material representing different stages of selection.

Parameters	r_s
Visual score vs. nymphs	.30*
Visual score vs. adults	.51*
Visual score vs. % yield loss	.59*
Visual score vs. protected yield	.15
% yield loss vs. nymphs	.33*
% yield loss vs. adults	.49*
% yield loss vs. protected yield	.38*
% yield loss vs. unprotected yield	-.90**

measure progress. Results (Table 19 and 20) were disappointing under a typical *Empoasca* infestation that reduced yields by an average of 53% in the unprotected plots. Correlations between visual damage score and other parameters were not as close as expected and little correlation was found between actual yield loss and nymphal or adult counts (Table 19).

Table 20. Mean yields of protected and unprotected plots, and yield loss caused by Empoasca kraemeri, in five groups of materials representing different stages of selection.[1]

Group	No. entries	Yield (kg/ha)		Yield loss (%)		Damage score	
		Protected	Unprotected	Mean	Range	Mean	Range
Controls	5	1833	852	51a	(40-64)	3.6b[2]	2.8-4.6
Parents	10	1593	681	56a	(49-74)	3.1b	2.5-4.3
Initial crosses	10	1828	882	50a	(30-63)	2.5a	2.1-3.0
Cycle I	10	1842	825	54a	(36-37)	2.6a	1.8-2.8
Cycle II	10	1840	786	55a	(44-67)	2.9b	2.4-3.5
CV = 16.2							

1 Mean of four replications.
2 Mean values within columns followed by the same letter are not significantly different at a $P < 0.05$.

While several sources of potential bias are being assessed, the trial is being repeated in a modified form to examine the potential interaction between planting date (testing environment) and resistance as expressed by yield loss. The selections from earlier cycles have been evaluated and selected more rigorously, and some parents of the most recent cycle were identified on the basis of characters other than *Empoasca* resistance.

Bean Golden Mosaic Virus

The selection and testing of advanced lines resulting from earlier cycles of intermatings are reported in the section on Regional Activities (see page). Intermating and selection continued in 1979, using the most outstanding lines from Guatemala and other locations as parents. Additional emphasis has been placed upon non-black grain types (especially for Brazilian preferences), and upon recombining BGMV resistance with other factors, especially resistance to *Empoasca, Xanthomonas,* and *Uromyces.*

The first uniform international test of 145 advanced BGMV hybrid selections was distributed.

Bean Pod Weevil

Ninety families from crosses of parents with resistance to *Apion godmani* were distributed to three Central American countries for evaluation in 1979B. New crosses have been made with very promising selections from El Salvador and México.

Common Bacterial Blight

Results of the 1978 VEF underscored the need for giving higher priority to incorporate resistance to *Xanthomonas phaseoli* into CIAT's bean germplasm. Of 1464 materials screened in 1978, only five were rated highly resistant, and only two of these were confirmed as such in subsequent trials.

The 1979 VEF materials were planted in 3-row plots and inoculated by aspersion at flowering with *X. phaseoli.* Ten families, or approximately 2% of the 594 entries, were rated resistant or highly resistant. Although still a low frequency, this represents nearly a fourfold increase over the 1978 VEF frequencies. This may be due to several factors: 1) in 1978, only percentage foliage infection was measured; 2) the planting design employed in 1979 permitted better distinction between common bacterial blight symptoms and confounding effects; and 3) the 1979 nursery included a higher proportion of breeding lines than the 1978 nursery.

Many lines which were observed to have small to intermediate size lesions also had thick, heavy-textured leaves. Particularly noteworthy were BAT 1113 and BAT 1114, sister lines with small leaves and

growth habits type I and II, respectively. These were the only lines in the nursery rated as lesion size 1, yet they are progeny of a cross of ICA Palmar x Porrillo 1, both susceptible parents. This underscores the potential of recovering transgressive segregants for *Xanthomonas* resistance, and suggests that leaf anatomy may have an important effect on blight reaction.

Large F_2 populations have been screened in the field using the double razor blade technique. At present, most resistant lines are derived from Great Northern sources of resistance (Jules, Tara, and GN #1 sel 27) but some promising breeding lines carry resistance of PI 207262, which has given favorable recombinants with opaque black seed coat color. Other lines such as BAT 93 may have resistance from both of these sources. Crosses have been made between susceptible lines and other sources of resistance, including GN Emerson, WCBT 713938, ICA L-23, and BAT 1113, in an attempt to broaden the genetic base of resistance.

Enhanced N Fixation

Two cycles of selection and intermating for increased N_2 fixation were completed in 1979. For the initial crosses 14 parents, selected for their potential to fix N, late flowering, resistance to anthracnose, and yield, were used. All crosses included at least one parent resistant to BCMV. Three hundred F_2 plants were inoculated with a mixed inoculant of five *Rhizobium* strains, and grown in a quartz sand devoid of combined N. Plants were inoculated with mixed strains of BCMV, and those found susceptible were rogued 15-20 days after planting. Immediately before flowering, plants resistant to BCMV were evaluated for growth, vigor and color (as proxies for N_2 fixation) and the best plants were intermated. The 163 new crosses included progeny from 11 of the original parents. The variation in growth under the test conditions is shown in Figure 26. For the second cycle of crosses, superior entries from the VEF and EP trials were introduced as parents. At present, 140 F_3 lines derived from promising single plant selections in cycle 1 are being evaluated for N_2 fixation, adaptation, and yield in CIAT-Quilichao.

Anthracnose

Over a dozen new sources of resistance to this disease were identified from accessions of the germplasm bank. These are tropically adapted materials from different parts of Latin America and

Figure 26. Plant growth variation in F_2 bean materials inoculated with a mix of five *Rhizobium* strains under limited N conditions.

represent desirable variation in growth habit, plant, and grain types, etc.

While the nature and type of these resistances is being studied, 170 crosses were made to transfer the resistance gene(s) into selected cultivars from Brazil, Mexico, Dominican Republic and other materials. Over 1000 F_3 selection were progeny tested and purified during the 1979B season. The surviving lines will be further evaluated and selections will enter the 1980 VEF.

A rapid cycle of intermating and selection using F_3 and F_4 families was initiated to combine various sources of resistance into more desirable agronomic backgrounds.

Angular Leaf Spot

Breeding for resistance to angular leaf spot began late this year when some resistant sources were identified in field nurseries at Popayán during the 1979B growing season. Although their resistance will be confirmed under controlled environments at CIAT, 43 crosses were made for: 1) transferring resistance

gènes into widely grown cultivars from Andean countries; 2) combining resistance to angular leaf spot with resistance to anthracnose; and 3) combining different sources of resistance to angular leaf spot.

Tolerance to Low Soil Phosphorus

This trait is being incorporated into germplasm mostly suitable for Brazil. Several Brazilian cultivars were recently identified as highly tolerant to low soil P. Fortunately F_2 populations, involving most of these cultivars with sources of resistance to anthracnose and/or with desirable architectural traits were available when their tolerance was discovered. As a result, 29 such F_2 populations were planted for screening at CIAT-Quilichao during 1979B. Also, 42 new crosses were made to incorporate the trait into a broader range of materials.

Drought Tolerance

No crosses were made for drought tolerance in 1979. This was due to a lack of dependable parental sources. However, over a dozen lines with moderate levels of tolerance to drought were identified in the 1979 EP nursery. These will be further evaluated and used in subsequent crossings.

Architecture and Yield

Architectural characteristics primarily sought are short internodes, erect stem, and small foliage and pod size. Other characteristics being investigated for improving plant architecture and yield include fewer seeds per pod and outrigger inflorescence. Most of these architectural characteristics were found in relatively poor agronomic background, and had very undesirable grain type and low yield.

Therefore, efforts were made to transfer these characters into more acceptable types. However, from the first set of crosses in which materials such as ICA-Pijao, Porrillo Sintético, NEP 2, and G 4421, were used as parents, 18 experimental lines were developed, 17 of which entered the 1979 VEF. Although lines A 43 and A 48 have small white seeds and A 40 small red grain color, and all have reasonable yield potential, none seem to have exceptional improvement in plant architecture. This reflects an absence of well-defined architectural traits in the first group of parents.

In the second phase of intermating and selection progress has been made in transferring and combining short internodes, erect stem, and small foliage. Over 1000 families are in their initial stage of evaluation and purification which is expected to be completed before mid 1980. These will enter the 1980 VEF and will be used as parents for the third cycle of crossings.

Early Maturity

This character is being sought in materials for drought areas and high altitudes (above 2000 masl) of Andean countries. Carmine, G 122, G 2402, and G 2858 are source parents used in this project. The latter two are adapted to cooler climates and also have resistance to anthracnose and small foliage. Most of the crosses and families are in the early stages of selection.

Delayed Maturity

Sources of delayed maturity are scarce within *P. vulgaris*. No materials have been identified maturing late both at CIAT and Popayán or during two or more seasons at anyone of these two sites. Late maturity is frequently associated with poor adaptation and low yield. Line 77 ICA 10310 showed a 7-10 day delay in maturity as compared to materials planted at Popayan and CIAT-Palmira; however, it yielded poorly.

Adaptation to Extreme Temperatures

Very few bush bean materials are adapted either at a mean growing temperature of 14°C at Obonuco or 28°C at Santa Fé de Antioquia and none adapted at both sites. Among other effects of extreme mean growth temperatures are excessive flower, pod and seed abortion. Thus, a project was undertaken to develop materials with better adaptation to extreme mean growth temperatures.

Six crosses were made between Andino, G 22, and G 23 (relatively well adapted to low temperatures) and G 3627, G 3807, G 4421 and Swedish brown (relatively better adapted at high temperatures). Seed of F_2 populations was divided into three parts, each one planted at CIAT-Palmira, Popayán and Obonuco. Approximately 30 F_3 selections were made at each site. Seed of each selection was split again in three parts and planted at all three sites for progeny testing and selection. Recently, G5066, G6474, G6499, BAT 425 and BAT 76 were identified as additional sources of parents for high temperature tolerance. Many of these also carry resistance to anthracnose. As a result, several F_2 and F_3 populations were available involving

most of these parents which will be screened at Santa Fé de Antioquia in March 1980.

Improvement of National Cultivars

Fifteen cultivars from Latin American countries were added in 1979 to the list of national cultivars for intensive improvement. This brought the total to 41 cultivars from 11 different countries (Table 18). Each cultivar was crossed to essential sources of disease reistance. All were also crossed to better architectural types and some cultivars from Brazil were additionally crossed with parents tolerant to low soil P. A scheme of modified backcrossing is being used for their improvement. Most of the crosses are now in early generations but advanced lines from a few should be available for uniform testing and utilization by mid-1980.

In all projects, selected families (approximately 6000/year) from the F_4 generation onwards are screened for resistance to BCMV.

Climbing Bean Improvement

Breeding Methodology

Relay cropping and varietal adaptability

Interactions between bean and maize genotypes in association compared with monoculture were analyzed in previous CIAT Annual Reports. An important cropping system to be considered is the relay system where maize is followed by beans planted between flowering time and physiological maturity of maize. An important difference between association and relay cropping is that there is no yield reduction in the maize as a result of competition from the beans. In order to determine whether this important cropping system in Central America and regions of South America requires specific breeding methodologies, a series of uniform yield trials with climbing bean varieties was planted at three locations.

The yield potential of beans in relay is also much higher than in association (Table 21), but the growing cycle of the cropping system as a whole is 3-4 months longer, so that the choice of the most appropriate cropping system largely depends on rainfall distribution and cropping sequence.

The question of whether beans should be specifically selected for relay cropping with maize was investigated by correlation analyses (Table 22). The bean varieties in the trials at CIAT were all planted on the same date, in the same field. Nevertheless, the correlations between variety yields in the different cropping systems were low, especially between relay cropping and monoculture. It appears that the behavior of varieties in relay systems is quite different from that in monoculture and this could be partly attributed to a large difference observed in the incidence of insect pests, mainly *Empoasca* and mites, with a much lower level of attack in relay than in monoculture or association systems. The combined analysis of variance for these three trials showed a variety/

Table 21. Uniform yield trials of 25 climbing bean varieties with and without maize in direct association or relay cropping systems.

Trial No.	Location	Altitude (masl)	Cropping system	Yield (kg/ha) Maize	Yield (kg/ha) Beans
7809	ICA-La Selva	2200	Relay	-[1]	2281 (12.9)
7810	CIAT-Palmira	1000	Relay	4768 (15.3)[2]	1651 (13.8)
7811	CIAT-Palmira	1000	Association	3389 (19.3)	880 (18.9)
7808	ICA-Obonuco	2710	Association	-	108 (54.3)
7812	CIAT-Palmira	1000	Monoculture	-	1806 (15.9)

1 Not measured.
2 Figures in parenthesis correspond to the C.V.

Table 22. Correlation coefficients between yields of 21 climbing bean varieties in five uniform yield trials.

Trial No.[1]	7809	7810	7811	7812
7808	-0.1560	0.0534	0.1445	0.7116***
7809	-	-0.0470	0.4189	0.0247
7810	-	-	0.3529	-0.0145
7811	-	-	-	0.3666

1 See Table 21.

cropping system interaction term which was almost as large as the main effect of varieties. The combined analysis of all trials indicated that the differences in adaptation to cropping systems were almost as important as the differences in adaptation to locations. These results demonstrate the need to select materials for specific cropping systems in the varietal improvement program for climbing beans.

With respect to adaptability to other locations, many of the varieties yielded well both at CIAT-Palmira (1000 masl) and ICA-La Selva (2200 masl), nine of them yielding significantly more than the best local control variety (Table 23). Of these nine varieties some (G4346, G2839, G3872, G3366, and G5653) have shown to be resistant to anthracnose, the most limiting disease problem in that region. There was a sharp break in adaptation between ICA-La Selva and ICA-Obonuco; none of the varieties showed potential at the highland location and for that reason the breeding of beans for cold climates is now handled as a separate project.

Planting systems for associated cropping

Research at CIAT on associated cropping has concentrated on planting beans and maize in various arrangements of rows (intercropping). Most farmers in Latin America, however, use hill plots with the two crops planted together on the same hill (mixed cropping). The advantages of the latter system for germplasm evaluations and early generation screening of breeding materials were mentioned in CIAT's 1978 Annual Report. Two trials were carried out to compare these systems. Results of the two trials showed planting in rows was advantageous for both maize and bean yields (Figure 27). The differences, however, were slight at the higher bean density (8 plants/m^2) and would not justify the additional labor for small farmers of planting by hand in rows. On the other hand, there was a large effect of the planting system on maize lodging, with less lodging in hill plots than in rows, and even less lodging at the higher bean density (Table 24). The reduced lodging in hill plots at the higher bean density was due to physical anchorage of the roots and accounts for the increase in maize yield at the higher bean density.

The importance of both root lodging and stem lodging on maize yield, as affected by the associated bean variety, was significant in both trials (Figure 28). The competitive effect of the bean variety on maize appears to be determined mainly by its effect on lodging. The most important characteristic of maize influencing its suitability for associated cropping with climbing beans is lodging resistance, and this should not be achieved through selecting for shorter plants (CIAT Annual Report 1978) but rather by concentrating on root and stem strength. The effect of the bean variety on maize lodging is largely explained by their growth habits, the most vigorous beans (habit type IVb) tending to pull down the maize (Table 25).

Varietal Improvement

Germplasm evaluation

The complete CIAT collection of climbing beans (1950 accessions) was evaluated during 1978-79 in hill-plots at Popayán, ICA-La Selva, and ICA-Obonuco in monoculture, relay cropping and direct association with maize, respectively (CIAT Annual Report, 1978).

Table 23. Yields of climbing bean varieties in two regional adaptation trials.

CIAT No.	Identification	Color	Yield (kg/ha) ICA-La Selva (Relay system)	Yield (kg/ha) ICA-Obonuco (Associated cropping)
G3144	Jamaica GUA 340	Black	2753+[1]	111
G2227	-	Gray/black	2861+	68
G2161	-	Black	1942	145
G4346	Michoacán 50	Pink	3077+	0
G2540	-	White	1255	0
G2839	Amapolo de camino	Pink	3043+	0
G2303	-	Yellow	2317	67
G3159	San Isidro media guía	Black	2397	252
G4567	Antioquia 130	Coffee	2594+	11
G3451	Guanajuato 116	Pink	2055	66
G3762	-	Black	1339	63
G574	Tombul	White	1598	0
G2764	-	Black	2854+	62
G3445	Guanajuato 22	Pink	2314	0
G3467	Michoacán 31	Cream/purple	2207	199
G2326	-	Black	1669	97
G3872	Trujillo 3	Black	2596+	37
G1821	Garbancillo	Cream/yellow	2075	93
G2512	-	Cream/brown	2204	157
G983	-	Black	2384	41
G3366	Puebla 240 A	Brown	3479+	0
G2545	-	Yellow	1801	-
G5653	Ecuador 299	Red	2800+	212
-	Sangretoro	Red	2133(T)[2]	375
-	Mortiño	Purple/cream	-	547(T)
-	Cargamanto	Cream/red	1292	-
	Mean		2281	108
	LSD 5%		408	78
	C.V. %		12.9	54.3

1 + = significantly higher yield than control.
2 T = control variety used at specific location.

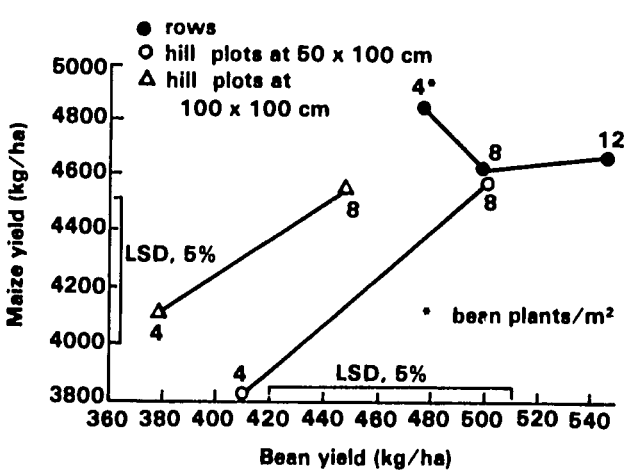


Figure 27. Effect of planting system and bean density on yields of climbing beans (means of five varieties) and maize var. Suwan-1 in association.

Selections were taken from each location on the basis of adaptation (yield potential) and field resistance to local diseases and pests. The selections are currently being tested in multilocation yield trials and have been tested at CIAT under greenhouse conditions for resistance to anthracnose and BCMV.

Of a total of 180 selections, 14 were selected both in Popayán and La Selva, compared with 8 selected both in Popayán and Obonuco and 9 selected both in La Selva and Obonuco. Adaptation to each location was specific with a marked break in adaptation between the 2200 m (La Selva) and the 2710 m (Obonuco) locations. Differences in adaptation were reflected in various characteristics of the plants, especially seed weight which was almost twice as large for the selections made in Obonuco compared with selections made at

Table 24. Effects of planting system and associated climbing bean density on lodging of maize var. Suwan-1.

Planting system	Bean density (plant/m^2)	Stem lodging (%)	Root lodging (%)	Total lodging (%)
Rows	4	6.7	10.3	17.1
	8	6.9	13.9	20.9
	12	7.9	10.9	18.8
Hill plots, 50 x 100 cm	4	3.8	12.1	15.9
	8	5.2	4.0	9.2
Hill plots, 100 x 100 cm	4	4.2	5.4	9.7
	8	1.9	3.5	5.4

the other locations. There was also a difference in growth habit: most of the type IVb selections were made in Obonuco, whereas the type IVa tended to be better adapted to the lower altitudes at Popayán and La Selva (Table 26). There was also a difference in seed color; very few black seeded varieties were selected at the extreme highland location, Obonuco. These differences largely reflect the origin of the materials; those selected in Obonuco originating mainly in the highlands of Ecuador, Perú and Colombia, while there were many accessions from México and Central America selected at Popayán and La Selva.

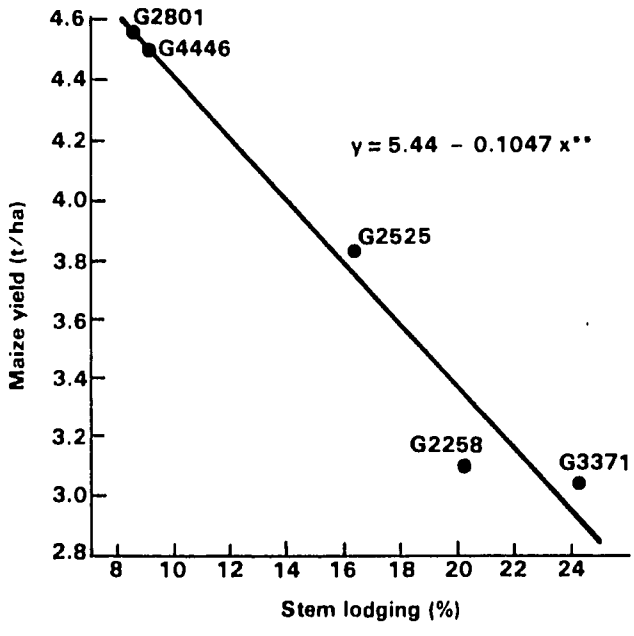


Figure 28. Effect of five climbing bean varieties on stem lodging and yield of maize var. Suwan-1.

ICA-La Selva was an excellent location for selecting resistance to anthracnose under natural field conditions (Table 27). A number of promising new sources of resistance, not only to races beta and gamma but also to other races virulent to Cornell 49-242, were selected at that location. These results were obtained by screening under controlled conditions with inoculation at CIAT-Palmira. The success of field selection for resistance to BCMV was somewhat lower and Popayán and La Selva were better locations for this purpose than Obonuco. The differences reflect the levels of natural infection in the field (Table 27).

Highly promising materials from germplasm evaluations enter the VEF nurseries and follow the same course as advanced breeding materials, ultimately to enter international testing and farm level trials. Two accessions (G5653 and G2333), selected for yield potential in relay cropping and resistance to anthracnose, are currently being tested in on-farm trials in Antioquia, Colombia.

Hybridization and selection

The climbing bean breeding program is aimed at combining high yield potential with major disease and pest resistances (especially anthracnose, BCMV, and *Empoasca*), for small-farm cropping systems, prin-

Table 25. Effect of climbing bean variety used on lodging of maize var. Suwan-1 in associated cropping systems.

CIAT No.	Growth habit	Stem lodging (%)	Root lodging (%)	Total lodging (%)
G4446	IIIb	9.0	2.1	11.2
G2801	IVa	8.5	2.5	11.0
G2525	IVa	16.3	3.9	20.2
G2258	IVb	20.2	6.3	26.5
G3371	IVb	24.2	5.1	29.3

Table 26. Climbing bean germplasm evaluations at three locations in Colombia.

Location	Altitude	Frequency of growth habits (%)			100-seed mean weight (g)	No. of selections
		IIIb	IVa	IVb		
Popayán	1850	2	88	10	38.8	56
ICA-La Selva	2200	5	78	17	36.3	95
ICA-Obonuco	2710	3	56	42	60.5	115

Table 27. Frequencies of resistance to anthracnose and BCMV detected in selections made at three locations in Colombia by inoculation under controlled conditions in climbing beans germplasm evaluations.

Location	Frequency (%)					
	Anthracnose[1]				BCMV[2]	
	R	I	I*	S	R	S
Popayán	-	-	-	-	11	89
ICA-La Selva	21	31	21	27	10	90
ICA-Obonuco	1	23	21	55	1	99

1 Anthracnose races beta and gamma, R = resistant; I = moderately resistant in hypocotyl leaves; I* = moderately susceptible in hypocotyl leaves; and S = susceptible.
2 BCMV races Florida and NY-15. R = resistant and S = susceptible.

cipally relay and associated cropping with maize. Relatively little emphasis is placed on selecting for monoculture. Hybridization programs are divided into projects according to temperature adaptation: 1) materials for warm to medium temperatures (17°-25°C), with small to medium size seeds of various colors including black; 2) materials for cold temperatures (12°-17°C), with medium to large size seeds of various colors except black.

The distribution of hybrid populations for individual plant selections to different locations and cropping systems depends on the project. The nurseries are planted in hill-plots of approximately 1 m^2 with one bean plant per hill and with or without maize according to the cropping system. This methodology has proved to be successful both in relay and direct association.

F_3 and F_5 progeny trials

Progenies from single plant selections continue to replicated yield trials at two locations and are simultaneously tested for resistance to anthracnose, BCMV, and *Empoasca*.

Selection for yield is carried out on a family basis, where a family is a group of lines originating from the same hybrid. Approximately 50% of the families are eliminated completely at this stage of testing. The trials are carried out in monoculture, relay cropping or direct association with maize (Table 28). In the latter case, maize yield is considered as well as bean yield in the selection process (Figure 29). In every trial carried out to date in direct association with maize a negative correlation between bean and maize yields has been found. Desirable bean families (each represented by a number in Figure 29) are found above the regression line in the upper right quadrant. These are families which produce a relatively high yield of beans and permit an acceptable yield of maize. Selection of lines within this group of families is then based on their resistance to BCMV, anthracnose and *Empoasca* and on their grain type. The reason for selecting on a family basis is that a much higher level of confidence can be attached to family yield data than to the data for individual lines at this preliminary level of testing.

Selections found to be susceptible to BCMV are eliminated at this stage and those that are segregating for resistance are returned to single plant selection nurseries.

The position of bean families on the graph in Figure 29 has been found to correspond with the growth habits of the individual lines within those families; i.e., growth habit IVb generally results in lower maize yields due to severe competition and induced lodging; high maize and bean yield is generally associated with habit IVa; and high maize yield and low bean yield frequently associates with habit IIIb.

Table 28. Results obtained with the climbing bean F_3 progeny yield trials for 1978-79, and F values calculated for differences between family yields and lines within families.

Location	Cropping system	No. of families	No. of entries	Bean yield (kg/ha)	C.V.	F values: Families	F values: Lines within families
CIAT-Palmira	Association[1]	35	300	1420	24.2	9.39***	1.31*
Popayán	Relay[2]	35	300	1104	34.1	9.67***	1.47**
CIAT-Palmira	Monoculture	48	127	1357	21.3	14.15***	2.48***
Popayán	Monoculture	48	127	1997	20.9	-	-
CIAT-Palmira	Association[3]	49	221	792	35.7	4.79***	1.48**
Popayán	Monoculture	49	221	1835	19.7	17.37***	2.99**

1 All entries associated with maize var. ICA H-210.
2 All entries in relay cropping with maize var. Yucatán.
3 All entries associated with maize var. Suwan-1.

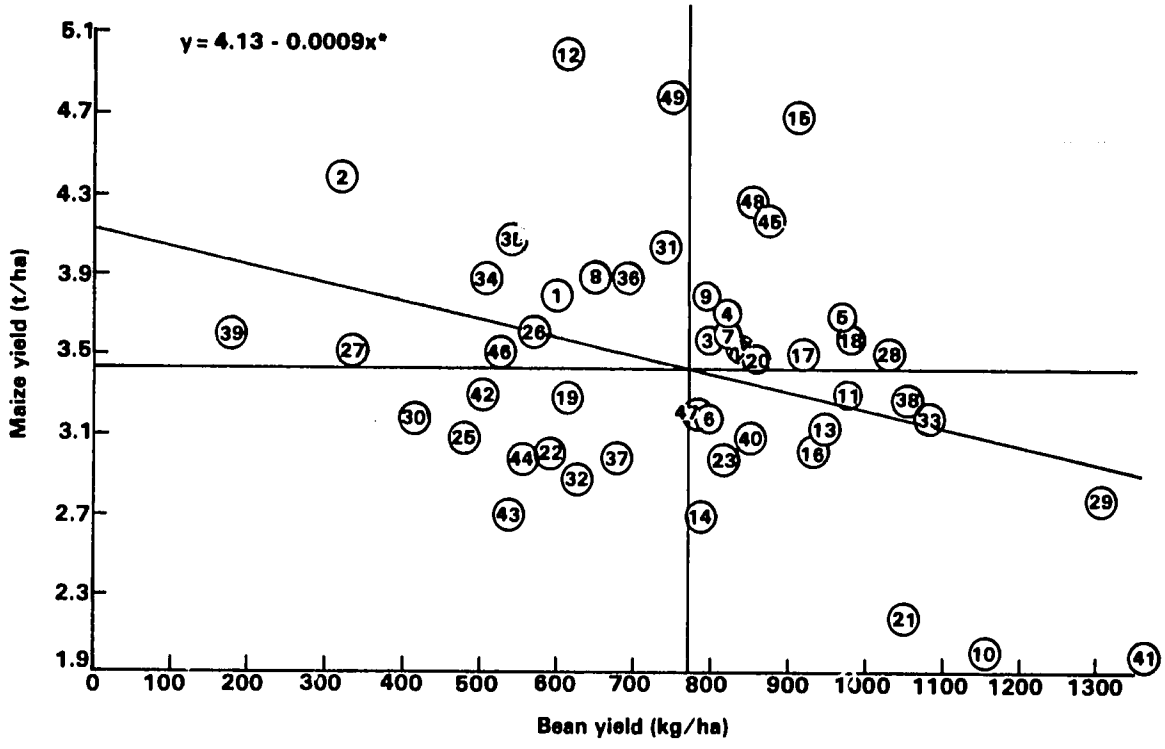


Figure 29. Yields of 49 climbing bean families of F_3 lines grown in association with maize var. Suwan -1.

Lines selected in the progeny tests are given a unique code and entered into the VEF and are simultaneously tested in a uniform yield trial at three locations (Table 29). Breeding selections with adaptation to cold climates have not yet reached this stage of development.

At the level of international testing of climbing bean varieties, a number of advanced materials have been distributed internationally in 1979 (Table 30).

Modified backcrossing programs

In addition to the hybridization and testing program

Table 29. Mean yields of climbing beans entries in the 1978-79 VEF.

Cropping system	Location	Mean yield of beans (kg/ha)	C.V.
Associated[1]	CIAT-Palmira	626	18.5
Monoculture	Popayán	1985	20.4
Relay[2]	ICA-La Selva	972	23.7
Associated[1]	CIAT-Palmira	999	23.0
Associated[1]	Popayán	1255	17.9

1 All lines associated with maize var. Suwan -1.
2 All lines in relay cropping with maize var. ICA V453.

Table 30. Climbing bean varieties being used for breeding purposes at CIAT released for international testing in 1979.

Breeding line	Color	Growth habit	Reaction to: Anthracnose[1]	BCMV[1]	Empoasca[2]
V7816	Black	IIIb	S	R	2.5
V7817	Black	IIIb	S	R	2.0
V7825	Black	VIa	S	R	2.8
V7833	Black	IIIb	R	R	3.0
V7836	Black	IIIb	S	R	2.8
V7842	Black	IIIb	S	R	2.7
V7847	Black	IVa	S	R	3.3
V 781	Red	IIIb	R	R	2.5
V7844	Red	IIIb	S	R	2.7
V7917	Coffee	IVa	R	R	2.0
V7951	Cream/red	IVa	S	R	3.7

1 R = resistant and S = susceptible.
2 Mean of three readings on a 1-5 scale; values up to three indicate acceptable tolerance levels.

outlined above, widely grown and commercially acceptable cultivars are being included in modified backcrossing programs to simultaneously incorporate resistance to anthracnose and BCMV. The first such program with the Colombian variety Cargamanto was initiated using Cornell 49-242 as the donor parent. As new sources of resistance are being detected from germplasm screening and breeding, these will be incorporated into backcrossing programs. The results of the first backcross show almost perfect agreement with the expected segregation of two dominant genes in the absence of linkage. Selections of uniform double resistant lines of Cargamanto for on-farm testing are expected to be available by the end of 1980.

Uniform Evaluation of Bush and Climbing Bean Selections

The germplasm development and distribution flow of the Bean Program is shown in Figure 1 (see page 6). The genetic improvement activities are divided into projects from which superior lines of both bush and climbing beans enter the uniform bean team nursery VEF, in which the whole bean team participates and national program entries can compete with CIAT developed lines or germplasm bank selections. Superior selections enter yield trials (EP) and further disease and adaptation evaluations in the EP, from which the IBYAN lines are selected.

VEF - Bean Team Nursery

In the second year of operation of the VEF, small modifications were made for further improvement. The major modification was a reduction in the number of entries, from 1464 in 1978 to 594 in 1979. This reduction was achieved by increasing the requirements for a material to become a VEF entry; i.e., better adaptation to the CIAT-Palmira and Popayán conditions and resistance to BCMV. All entries prior to

entering VEF receive a unique code (e.g., BAT, EMP, A. etc.) according to the breeding project they are derived from, followed by a number.

The proportion of black entries from the 1978 VEF to the 1979 VEF was further reduced, with only 22% of the entries being black. The 1978 VEF contained few entries of large and medium size seed while their proportion in the 1979 VEF increased to 45% (Table 31).

BCMV resistance was achieved in 92% of the CIAT improved lines; 6% of the lines were found segregating for mosaic resistance in confirmation tests (Table 32).

The 1979 VEF contained 20 germplasm bank accessions of high value as potential parents, mostly BCMV susceptible, for the purpose of obtaining general adaptation data.

The VEF is primarily evaluated for resistance to the principal diseases — BCMV, rust, angular leaf spot, common bacterial blight, anthracnose, and *Empoasca* (Table 33)—besides adaptation at CIAT and Popayán. While 17% of the 1978 VEF entries were resistant or intermediate to anthracnose, this frequency increased to 38% in the 1979 VEF. Other disease and insect resistance frequencies can also be compared, however, relative differences may occur due to differences in disease pressure. Thus, resistance to *Empoasca* increased from 12% to 33%, clearly indicating the fluctuating pest pressure from year to year and the difficulty to measure program progress in this way in pest resistance breeding. For angular leaf spot the reverse trend was shown; only two entries were rated as resistant under the very heavy disease pressure in 1979 VEF.

About 65% of the VEF entries were well adapted to the CIAT-Palmira conditions, a lower proportion to Popayán conditions. This is based on adaptation data being collected in small plots not protected from diseases (Table 34).

EP - Preliminary Yield Trial

In preliminary yield trials (EP) advanced breeding lines, selected from the VEF trial, were yield tested at CIAT-Palmira and Popayán. The same set of standard checks as last year was included (CIAT Annual Report,

Table 31. Number and proportion of entries from the CIAT breeding programs and other sources in the 1979 VEF by seed color and size.

Seed type	No. CIAT entries	No. entries other sources
Size:		
Large	33 (6.8)[1]	10 (9.2)
Medium	204 (42.6)	20 (18.3)
Small	248 (50.6)	79 (72.5)
Total	485 (100.0)	109 (100.0)
Color:		
Black	96 (19.8)	35 (32.1)
Red	68 (14.2)	13 (11.9)
Other colors	321 (66.0)	61 (56.0)
Total	485 (100.0)	109 (100.0)

1 Figures in parenthesis are percentages.

Table 32. Number and proportion of entries from the CIAT breeding programs and other sources in the 1979 VEF by their reaction to BCMV.

BCMV rating	No. CIAT entries	No. entries other sources
Resistant	446 (92.0)[1]	84 (77.1)
Variable	30 (6.2)	4 (3.7)
Susceptible	9 (1.8)	20 (18.3)
No data available	-	1 (0.9)
Total	485 (100.0)	109 (100.0)

1 Figures in parenthesis are percentages.

1978). Entries were divided into groups according to their growth habit and seed color to be compared with their respective standard checks. At Popayán Al and Mn toxicities combined with P deficiency are the principal limiting soil factors. A correction for these adverse conditions was made to obtain soil uniformity and to test for yield potential rather than for yielding ability under suboptimal conditions.

At CIAT-Palmira the trial was irrigated when needed, however, at Popayán a two-week dry period caused drought stress, forcing early maturity. Drought affected yield negatively as it occurred at the pod-filling stage of most materials. However, yields of both breeding lines and standard checks were not lower than those at CIAT-Palmira.

Yields across all materials, colors, and growth habits averaged 15% above those of last year's trials. The reason for higher yields was due to better quality of the breeding lines following rigid selection in the previous VEF nurseries. Additionally, seed quality of the

Table 33. Number and proportion of entries in the 1979 VEF according to their reaction to disease and insect pests.

Rating	Rust	Angular leaf spot	Common bacterial blight	Anthracnose	White spot	Empoasca
Resistant	42 (7.1)[1]	2 (0.3)	10 (1.7)	87 (14.6)	33 (5.6)	
Tolerant	-	-	-	-	-	50 (8.4)
Intermediate	118 (20.0)	118 (20.0)	80 (13.5)	138 (23.2)	395 (66.5)	144 (24.2)
Susceptible	427 (71.9)	449 (75.6)	498 (83.8)	359 (60.4)	149 (25.1)	401 (67.5)
Variable	6 (1.0)	24 (4.0)	-	9 (1.5)	-	15 (2.5)
No data available	1 -	1 -	6 (1.0)	1 -	1 -	-

1 Figures in parenthesis are percentages.

Table 34. Number and proportion of entries from the 1979 VEF by adaptation ratings to the CIAT-Palmira and Popayán conditions.

Rating[1]	Adaptation to: CIAT-Palmira	Popayán
1	0	0
2	30 (5.0)[2]	3 (0.5)
3	356 (59.9)	46 (7.7)
4	147 (24.8)	184 (31.0)
5	60 (10.1)	360 (60.6)
No data available	1 (0.2)	1 (0.2)
Total	594 (100.0)	594 (100.0)

1 Visual adaptation score: 1 = excellent; 2 = very good; 3 = good; 4 = poor; 5 = very poor.
2 Figures in parenthesis are percentages.

controls has improved, providing better yield performance than last year (Table 35).

Although yields of the red seeded breeeding lines of growth habits II and III were not much higher than last year they out-yielded their checks. Breeding lines with growth habit I, tested for the first time, did not yield better than their checks, but had BCMV resistance. The best breeding lines of growth habit III outyielded the checks by more than 0.5 t/ha (Tables 36 and 37). Large differences in yield performance were found in breeding lines within growth habits III and I, but not within habit II.

The black-seeded type II materials yielded better than last year. This was not observed in the growth habit III. It is believed that the severe dry spell did not permit this bean type to recover as it normally can. At Popayán, breeding materials generally yielded significantly better than controls (Tables 38 and 39).

Table 35. Yield improvement of the advanced breeding lines and local checks by seed colors from the 1978 EP to the 1979 EP at CIAT-Palmira.

Materials	Red 1978	Red 1979	Red % increase	Black 1978	Black 1979	Black % increase	Non-black 1978	Non-black 1979	Non-black % increase	Average increase
Advanced breeding lines	2050	2433	19	2330	3011	29	2200	2692	22	23
Local checks	1470	2223	50	2020	2628	20	1790	2408	35	38
International checks[1]	1370	2293	67	2018	2916	45	1530	2490	63	58

1 Varieties Jamapa, Porrillo Sintético, ICA Pijao, Diacol Calima, Brazil 2, G4445.

Table 36. The best red breeding materials compared to controls in the 1979 EP at CIAT-Palmira.

Growth habit I		Growth habit II		Growth habit III	
Identification	Yield (kg/ha)	Identification	Yield (kg/ha)	Identification	Yield (kg/ha)
Breeding materials					
Calima flower		BAT 202	2832	BAT 44	2579
purple	2592	A21	2764	BAT 189	2348
ICA 10213	2507	G5066	2626		
BAT 674	2312	G6533	2583		
BAT 706	1605	G5169	2536		
		BAT 363	2531		
		BAT 258	2196		
Mean	2254	Mean	2581	Mean	2464
Controls					
ICA Guali	2893	BAT 41	2765	Rojo 011	2481
Pompadur 2	2734	Forty days	2194	Nahizalco	1989
Diacol Calima	2346	Huila 14 I-652	2191	BAT 47	1860
Sangre de Toro	2025			Flor de Mayo	1731
G0677	1908			Zamorano 2	1473
Mean	2381	Mean	2382	Mean	1907
Mean of 9 materials	2325	Mean of 10 materials	2522	Mean of 7 materials	2066
CV %	14	CV %	11	CV %	18
LSD .05	323	LSD .05	278	LSD .05	374

At CIAT, the non-black seeded group showed the same tendency as the black-seeded materials. Lines in growth habits II and III were significantly superior to the controls but no improvement was obtained in lines with growth habit I. The results showed a better yield performance for new breeding lines than last year's materials (Tables 40 and 41).

In general the results of the trials showed lower coefficients of variation (CV) than last year, at both locations. CV's varied from 10 to 18% at CIAT-Palmira and from 11 to 12% at Popayán.

Summarizing the results, it is concluded that improvements in yield in growth habits II and III in all color groups were significant. Among 81 black-seeded materials of growth habit II, 16 yielded more than 3.0 t/ha at the two locations and lowest yields were still above 2.0 t/ha.

Besides yield, the EP nursery is evaluated for resistance to diseases and insect pests, tolerance to climatic and edaphic constraints, and seed quality factors. Drought tolerance was found in black and cream seeded materials (Table 42). Table 43 shows frequencies of resistance to high priority diseases and insect pests. Common bacterial blight resistance is scarce; angular leaf spot resistance was encountered in high frequency due to low disease pressure. The EP observation nurseries provided an opportunity to evaluate for resistance to diseases given lower priority and occuring in natural outbreaks (Table 44). Web blight and Ascochyta leaf spot resistance is found in low frequencies, but resistance sources were detected which are useful for regional needs. White leaf spot resistance, a severe problem in Guatemalan highlands, was also identified.

Incorporation of multiple disease resistances, especially for combinations of priority diseases, is the

Table 37. The best red breeding materials compared to controls in the 1979 EP at Popayán.

Growth habit I		Growth habit II		Growth habit III	
Identification	Yield (kg/ha)	Identification	Yield (kg/ha)	Identification	Yield (kg/ha)
Breeding materials					
BAT 706	2197	BAT 258	3632	BAT 44	3354
Calima flower purple	2007	BAT 202	3161	BAT 41	2518
		A21	3031		
		BAT 363	2547		
		G6533	2286		
		G5066	1833		
		G5169	1486		
Mean	1925	Mean	2568	Mean	2936
Controls					
Sangre de Toro	2372	BAT 41	3074	Flor de Mayo	3577
Diacol Calima	2239	Huila 14 I-652	1777	Zamorano 2	2310
ICA Guali	1775	Forty days	1321	Rojo 011	2176
Pompadur 2	1725			BAT 47	1725
				Nahuizalco	1637
Mean	1918	Mean	2057	Mean	2285
Mean of 8 materials	1938	Mean of 10 materials	2446	Mean of 7 materials	2611
CV %	20	CV %	14	CV %	15
LSD .05	395	LSD .05	353	LSD .05	364

Table 38. The best black breeding materials compared to controls in the 1979 EP at CIAT-Palmira.

Growth habit II		Growth habit III	
Identification	Yield (kg/ha)	Identification	Yield (kg/ha)
Breeding materials			
BAT 450	3381	BAT 277	3191
BAT 445	3263	BAT 240	3190
BAT 58	3227	BAT 179	2922
BAT 502	3142	BAT 154	2890
BAT 148	3121	BAT 310	2778
BAT 518	3111	BAT 186	2765
EMP 9	3101	BAT 309	2736
BAT 448	3097	BAT 248	2732
P691-1-CM	3088	BAT 451	2699
BAT 117	3075	BAT 263	2698
Mean	3161	Mean	2860
Controls			
ICA-Pijao	3132	G2959	2837
Porrillo Sintético	2965	G2005	2422
Jamapa	2796	G3607	2382
ICA Tui	2753	Puebla 152	2290
Rio Tibaji	2581		
Sataya 425	2408		
Mean	2773	Mean	2483
Mean of 81 materials	2812	Mean of 31 materials	2606
CV %	11	CV %	12
LSD .05	320	LSD .05	306

Table 39. The best black breeding materials compared to controls in the 1979 EP at Popayán.

Growth habit II		Growth habit III	
Identification	Yield (kg/ha)	Identification	Yield (kg/ha)
Breeding materials			
BAT 148	3655	BAT 309	3514
BAT 522	3557	BAT 304	3412
BAT 137	3463	BAT 179	3244
BAT 589	3449	BAT 187	3238
BAT 518	3432	BAT 240	3188
BAT 519	3412	BAT 186	3116
BAT 67	3290	BAT 652	3108
BAT 48	3270	BAT 154	3098
P691-1-CM	3249	BAT 268	2995
BAT 445	3238	BAT 279	2810
Mean	3401	Mean	3171
Controls			
Janapa	3085	G2959	2703
Porrillo Sintético	2857	Puebla 152	2503
Río Tibaji	2765	G2005	2442
Sataya 425	2739	G3607	2231
ICA Pijao	2663		
ICA Tui	2648		
Mean	2793	Mean	2470
Mean of 81 materials	2824	Mean of 31 materials	2653
CV %	12	CV %	13
LSD .05	330	LSD .05	355

Table 40. The best non-black breeding materials compared to controls in the 1979 EP at CIAT-Palmira.

Growth habit I		Growth habit II		Growth habit III	
Identification	Yield (kg/ha)	Identification	Yield (kg/ha)	Identification	Yield (kg/ha)
Breeding materials					
G5158	2799	BAT 561	3014	Carioca	2928
G3843	2551	BAT 470	2999	G4017	2871
BAT 360	2084	BAT 70	2989	A23	2828
		BAT 332	2963	A22	2793
		BAT 42	2950	A5	2759
		BAT 108	2926	BAT 215	2700
		BAT 419	2918	BAT 339	2606
		BAT 85	2895	BAT 477	2604
		BAT 616	2876	BAT 346	2599
		BAT 740	2859	BAT 83	2405
Mean	2478	Mean	2939	Mean	2655
Controls					
Brazil 2 Blco de Ouro	2842	Carioca	3198	Brazil 343	2268
Swedish brown	2217	G4421	2557		
		Ex Rico 23	2301		
		G4000	2176		
		NEP 2	1894		
Mean	2530	Mean	2425	Mean	2268
Mean of 5 materials	2499	Mean of 54 materials	2552	Mean of 23 materials	2435
CV %	10	CV %	13	CV %	13
LSD .05	249	LSD .05	324	LSD .05	315

Table 43. Frequency of materials resistant (R) and intermediate (I) to first priority diseases and insect pests in the 1979 EP.

Seed type		Rust		Angular leaf spot		Anthracnose		Common bacterial blight		Leaf-hopper		Total
Size	Color	R	I	R	I	R	I	R	I	R	I	evaluated
Small	Black	33	19	58	42	3	21	0	15	8	52	105
Small	Brown	4	1	7	6	1	3	0	1	1	2	17
Small	Cream	4	1	7	6	0	1	0	2	2	5	14
Small	Cream mottled	1	0	1	1	0	1	0	0	0	0	2
Small	Red	1	0	0	5	0	0	0	1	0	1	5
Small	Yellow	1	0	0	1	1	0	0	1	0	0	1
Small	White	6	1	1	5	0	0	0	2	0	3	7
Small	Other colors	4	2	13	11	2	3	0	5	1	12	25
Medium & large	Red, red mottled, cream mottled	0	0	0	0	0	0	0	0	0	1	1
Medium & large	Yellow, cream, tan	0	1	0	1	1	0	0	0	0	0	1
Medium & large	White	-	-	-	-	-	-	-	-	-	-	-
Medium & large	Other colors	0	0	1	0	0	0	0	0	0	0	2
	Total	54	26	88	78	8	29	0	17	12	76	180

Table 44. Frequency of materials resistant (R) and intermediate (I) to second priority disease and insect pests in the 1979 EP.

Seed type		Southern blight		Web blight		Halo blight		Ascochyta leaf spot		Gray leaf spot		White leaf spot		Tropical mite	
Size	Color	R	I	R	I	R	I	R	I	R	I	R	I	R	I
Small	Black	92	12	2	12	5	87	0	11	10	59	1	6	1	46
Small	Brown	12	1	0	0	2	12	0	7	5	6	0	3	0	6
Small	Cream	6	6	0	0	2	11	0	3	3	8	1	0	0	11
Small	Cream mottled	1	1	0	0	1	1	0	0	0	1	0	1	0	1
Small	Red	4	0	0	0	1	3	0	3	3	2	1	0	0	3
Small	Yellow	0	1	0	0	0	1	0	0	0	1	0	0	0	0
Small	White	0	3	0	3	2	5	0	2	0	4	0	0	0	7
Small	Other colors	13	6	0	3	4	10	0	7	8	13	1	6	0	7
Medium & large	Red, red mottled, cream, mottled	1	0	0	0	0	1	0	0	0	0 0	1	0	0	1
Medium & large	Yellow, cream, tan	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Medium & large	White	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Medium & large	Other colors	0	0	0	0	0	1	0	0	1	0	1	0	0	1
	Total	129	30	2	18	17	132	0	34	31	94	6	16	1	83

Table 41. The best non-black breeding materials compared to controls in the 1979 EP at Popayán.

Growth habit I		Growth habit II		Growth habit III	
Identification	Yield (kg/ha)	Identification	Yield (kg/ha)	Identification	Yield (kg/ha)
Breeding materials					
G5158	3170	BAT 336	3698	G2618	3895
G3843	1884	BAT 550	3638	G4017	3374
BAT 360	1523	BAT 551	3509	BAT 337	3333
		BAT 85	3475	BAT 525	3301
		BAT 528	3453	BAT 153	3299
		BAT 616	3424	BAT 207	3235
		BAT 484	3297	BAT 477	3210
		BAT 332	3282	Carioca	3143
		BAT 93	3250	BAT 338	3053
		BAT 731	3187	BAT 369	3046
Mean	2192	Mean	3421	Mean	3288
Controls					
Brazil 2					
Bico de Ouro	2644	Carioca	3577	Brazil 343	2349
Swedish brown	1952	NEP 2	3446		
		G4000	2638		
		G4421	2541		
		Ex Rico 23	2173		
Mean	2298	Mean	2875	Mean	2349
Mean of 5 materials	2235	Mean of 54 materials	2871	Mean of 23 materials	2719
CV %	16	CV %	13	CV %	17
LSD .05	366	LSD .05	370	LSD .05	291

Table 42. Growth habits and frequency of drought tolerant materials for different bean types evaluated in the 1979 EP.

Seed type		Growth habit				Drought[1]		
Size	Color	I	II	III	Variable	T	I	Total evaluated
Small	Black	0	76	26	3	9	6	105
Small	Brown	0	13	3	1	0	1	17
Small	Cream	0	12	2	0	1	2	14
Small	Cream mottled	0	0	2	0	1	0	2
Small	Red	0	3	1	1	0	0	5
Small	Yellow	0	1	0	0	0	0	1
Small	White	0	3	4	0	1	0	7
Small	Other colors	1	16	8	0	0	0	25
Medium & large	Red, red mottled, cream mottled	1	0	0	0	0	0	1
Medium & large	Yellow	0	0	1	0	0	0	1
Medium & large	White	-	-	-	-	-	-	-
Medium & large	Other colors	2	0	0	0	0	0	2
	Total	4	124	47	5	12	9	180

1 T = highly tolerant and I = moderately tolerant to water stress.

most important objective of the program. Combined resistance to BCMV, rust, and anthracnose (a cooler production region disease complex) was found in 17 materials, which include high yielding lines (Table 45). Multiple resistance to the disease complex for higher temperature regions was found in two lines; this low figure is due to the low frequency of bacterial blight resistance.

IBYAN - International Bean Yield and Adaptation Nursery

The proposed objectives for the international yield trials, IBYAN, which were initiated in 1976, have basically remained unchanged. For the 1979 IBYAN, however, materials included were selected more intensively for disease resistance. The source of materials included has also varied considerably from one year to another (Figure 30). A higher proportion of advanced breeding lines from CIAT is included as compared to previous years (1976-77) when germplasm bank selections were predominant. Table 46 shows the number of sets distributed up to late 1979 to different parts of the world.

1977 IBYAN results

Data for 33 out of 58 sets of black seeded IBYAN's were received. In the case of IBYAN's of other colors, data is available for 21 out of 50 experimental sites. Among the 20 entries tested in 1976 the 9 most outstanding entries were included again in 1977 (Table 47). Due to their consistent behavior, the varieties Jamapa, Porrillo Sintético and ICA-Pijao were selected as permanent controls for future black seeded trials. For the colored trials, the varieties Ex Rico 23, Brazil 2 and Diacol Calima were selected as permanent checks too, and will be included in future IBYAN's.

The experimental sites were grouped according to productivity levels. Table 48 compares yields of the five best experimental materials with five local control varieties within each productivity level for the black seeded IBYAN. Small differences in yields when comparing the best black promising material and their controls indicated that there is at least one good black seeded variety available for the different zones. However, only in six sites was the best control variety a black seeded one.

Table 45. Lines with multiple resistance to first priority diseases in the 1979 EP.

Seed type	Yield (kg/ha) CIAT Mean[1]	CIAT Highest[2]	Popayán Mean[1]	Popayán Highest[2]	Multiple disease resistance
Small black	2827 (17)	3097 (BAT 448)	2908 (17)	3449 (BAT 589)	BCMV, rust, anthracnose
Small brown	2350 (5)	2685 (BAT 220)	2718 (4)	3184 (BAT 100)	BCMV, rust
Small cream, cream mottled	2583 (7)	2963 (BAT 332)	3044 (7)	3698 (BAT 336)	BCMV, rust
Small red	2950 (1)	(BAT 41)	2729 (1)	-	BCMV, rust
Small white	2370 (2)	2405 (BAT 482)	3075 (2)	3098 (BAT 482)	BCMV, rust CBB
International checks (black)	2964 (3)	3132 (ICA-Pijao)	2868 (3)	3085 (Jamapa)	BCMV
Non-black	2496 (3)	2842 (Brazil 2)	2352 (3)	2644 (Brazil 2)	BCMV

1 Values in parenthesis indicate the number of materials.
2 The identification of the line is given in parenthesis.

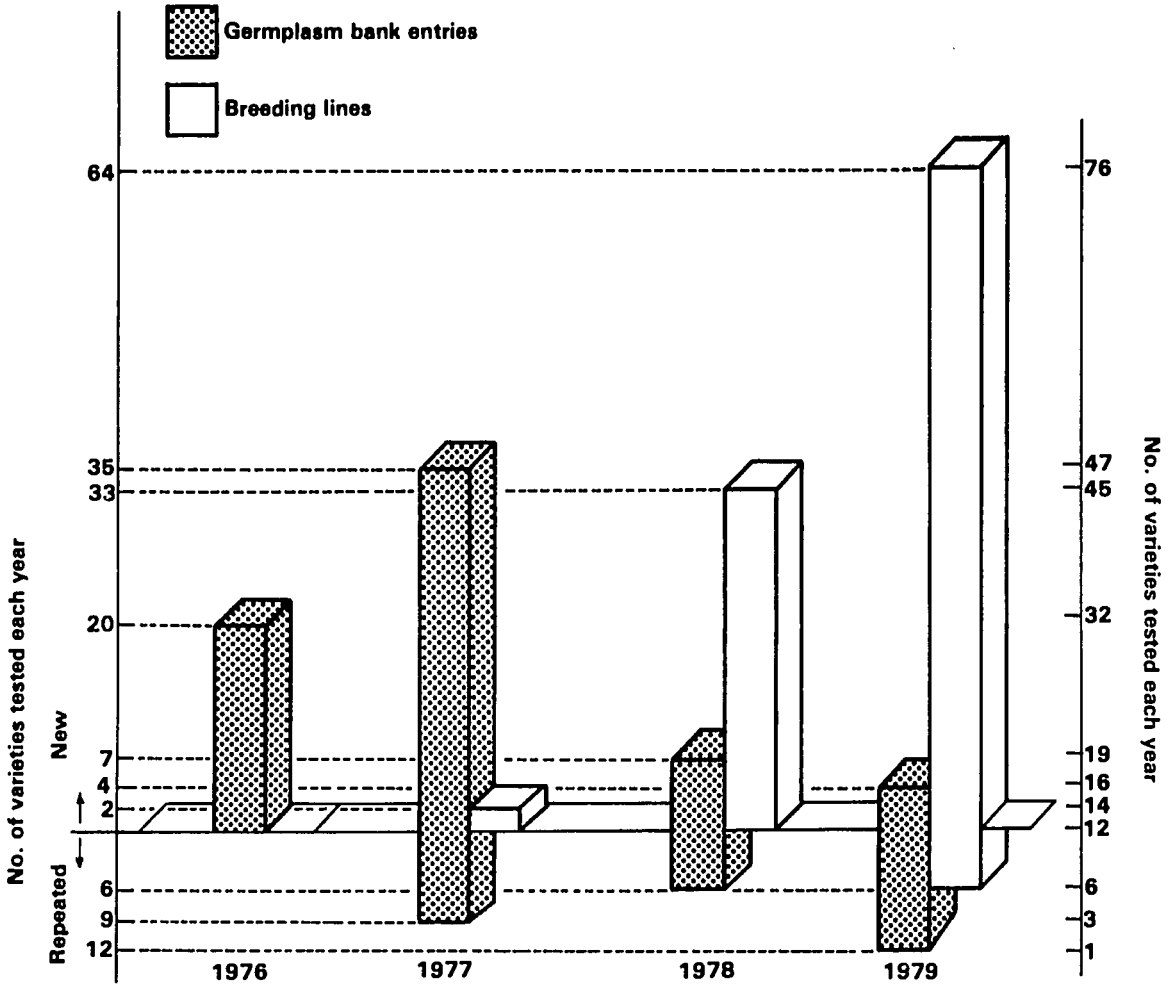


Figure 30. Kind and quantity of genetic material used for IBYAN trials in 1976-79.

Table 46. Distribution of the 1976-1979 IBYAN trials to different regions of the world.

Region	Year			
	1976	1977	1978	1979[1]
Latin America	69	80	136	101
North America, Europe and Australia	8	9	5	0
Asia	9	14	0	0
Africa	4	15	9	9
Total	90	118	150	110

1 As of November 30, 1979.

Table 47. Mean yield of the best five black and other color promising varieties tested in the 1979 IBYAN as compared to data obtained in the 1976 IBYAN trial.

Variety	Yield (kg/ha)	Seed color
IBYAN 1976		
PI 309 804	1756	Black
Jamapa*	1572	Black
ICA-Pijao	1566	Black
51051	1546	Black
Porrillo Sintético	1539	Black
Venezuela 2	1479	Black
Porrillo 1	1459	Black
Brasil 2	1458	Brown
Puebla 152 (P658)	1452	Brown
ICA-Tui	1434	Black
Puebla 152 (P498)	1433	Black
S 166 A N	1395	Black
C 63 S 630 B*	1394	Cream
Pompadour 2	1354	Mottled red
Ex Rico 23*	1354	White
Red Kloud*	1322	Red
NEP 2*	1288	White
Diacol-Calima*	1288	Mottled red
Line 17	1272	Mottled red
Sanilac	1120	White
Overall mean	1416	
LSD .05	96	
LSD .01	120	
IBYAN 1977 Black Seeds		
Line 29	1644	Black
BAT 2	1643	Black
Pecho Amarillo	1604	Black
Jamapa*	1576	Black
Porrillo Sintético*	1563	Black
Overall mean	1466	
LSD .05	167	
LSD .01	220	
IBYAN 1977 Color Seeds		
Ex Rico 23*	1954	White
Brasil 2*	1828	Brown
C 63 S 630 B*	1790	Cream
Pirate 1	1744	Tan
P17	1653	Brown
Overall mean	1572	
LSD .05	302	
LSD .01	397	

*Tested in both IBYAN 1976 and 1977

Table 48. Mean yield of the best five experimental lines and the best five local varieties within each productivity level group for the IBYAN 1977. Set of black seeded beans and beans of other colors.

Productivity level	Material	Black seed: Mean of five best materials[1]	Black seed: Mean of best material[2]	Color seed: Mean of five best materials[1]	Color seed: Mean of best material[2]
I	Experimental line	1232 (N = 135)[3]	1279 (N = 27)	958 (N = 15)	1120 (N = 3)
	Control	1051	1328	588	639
	Difference	181	-49	370	481
II	Experimental line	1683 (N = 105)	1930 (N = 21)	1406	1579
	Control	1364	1887	1011	1501
	Difference	319	43	395	78
III	Experimental line	2066 (N = 90)	2243 (N = 18)	1886 (N = 105)	2085 (N = 21)
	Control	1710	2063	1363	1678
	Difference	356	180	523	407
IV	Experimental line	2650 (N = 90)	2878 (N = 18)	2646 (N = 60)	3319 (N = 12)
	Control	2293	2768	1849	2495
	Difference	357	110	797	824
V	Experimental line	2999 (N = 15)	3063 (N = 3)	3071 (N = 15)	3404 (N = 3)
	Control	2763	3099	2528	2824
	Difference	236	-36	543	580
VI	Experimental line	4716 (N = 15)	5214 (N = 3)	3093 (N = 15)	3248 (N = 3)
	Control	4675	5513	3193	3498
	Difference	41	-299	-100	-250

1 Mean of five highest yielding promising varieties and of the five control varieties in each site.
2 Mean of the highest yielding experimental line and control in each site.
3 Number of observations.

In the IBYAN set of colored seeds the superiority of experimental lines was more evident. The control variety only outyielded an experimental line in four sites. In spite of the superiority of the experimental lines in the sets of color seeded nurseries, it is important to take into account the fact that for these beans a variety has to combine good yield with seed characteristics that meet consumer preferences.

1978 IBYAN results

As in 1977, two sets of nurseries were distributed in the 1978 IBYAN: one for black beans and another for colored beans. Table 49 shows the most outstanding materials for both sets of nurseries based on data available up to now.

In general, the best experimental lines showed similar behavior as did the best international controls, although they showed higher yields than the local controls. Again, differences observed in the black bean trials are sufficient to indicate a net superiority of the promising material, but in the case of colored beans, the differences observed, although similar to those for black beans, are not sufficient to rate a material as superior, as grain characteristics such as color and size should meet consumer preference patterns.

Table 50 shows that the best experimental lines included in the IBYAN of 1976-78 have outyielded the best local varieties. The advantage of the experimental lines over the local controls was greater for the colored materials than for the black seeded beans. Data also show that at most experimental sites there is at least one good local variety (Figures 31 and 32). Experimental lines outyielded both local and international controls in most sites.

Table 49. Mean yields of the five best black seeded and other colored materials for the 1978 IBYAN.

Black seed			Color seed			
Identification	Origin	Yield (kg/ha)	Identification	Origin	Seed color	Yield (kg/ha)
78A ICA Col 10103	Colombia	1732	BAT 23	CIAT	Cream	1622
BAT 7	CIAT	1726	BAT 32	CIAT	Cream	1534
ICA-Pijao	Colombia	1619	Brasil 2	Brazil	Brown	1530
BAT 15	CIAT	1618	BAT 24	CIAT	Red	1477
Jamapa	Mexico	1528	Ex Rico 23	-	White	1450
Overall mean		1522[1]	Overall mean			1351[2]

1 Mean for 20 varieties and 30 sites.
2 Mean for 20 varieties and 37 sites.

Table 50. Mean yield of the best promising lines and local control for the 1976-1978 IBYAN.

Year	Trial	Five best experimental lines		Five best[1] local varieties		Best[2] experimental lines		Best local varieties	
1976	Temperate zone	2450 (128%)		1913 (100%)		2730 (113%)		2416 (100%)	
	Tropical zone	1613 (135%)		1193 (100%)		1828 (121%)		1506 (100%)	
1977	Black seed	1180 (115%)	(N=490)	1629 (100%)	(N=490)	2031 (108%)	(N=74)	1883 (100%)	(N=74)
	Color seed	1888 (133%)	(N=315)	1416 (100%)	(N=306)	2279 (123%)	(N=45)	1849 (100%)	(N=45)
1978	Black seed	1764 (117%)	(N=450)	1508 (100%)	(N=444)	2230 (116%)	(N=69)	1920 (100%)	(N=78)
	Color seed	1764 (125%)	(N=551)	1413 (100%)	(N=551)	1980 (110%)	(N=99)	1798 (100%)	(N=99)

1 Mean of the five highest yielding promising lines in each site and of the five best control varieties.
2 Mean of the highest yielding promising lines and control in each site.

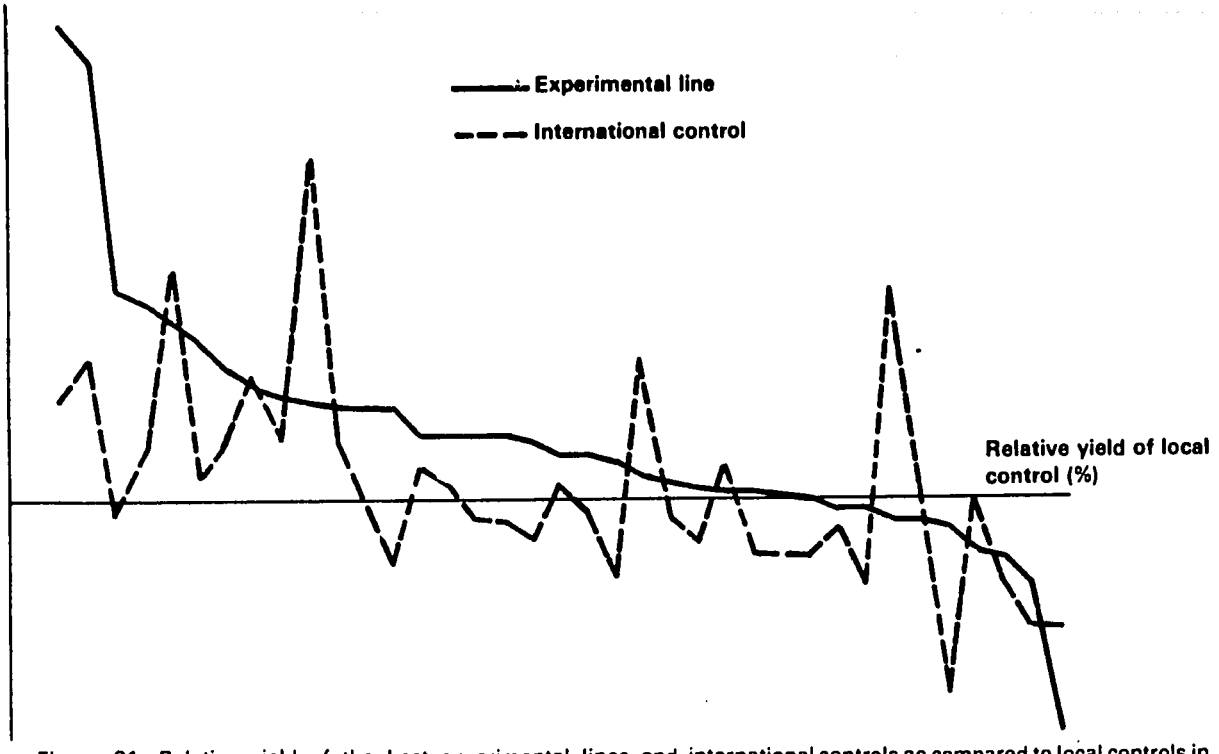


Figure 31. Relative yield of the best experimental lines and international controls as compared to local controls in 36 sites of the color seeded 1978 IBYAN.

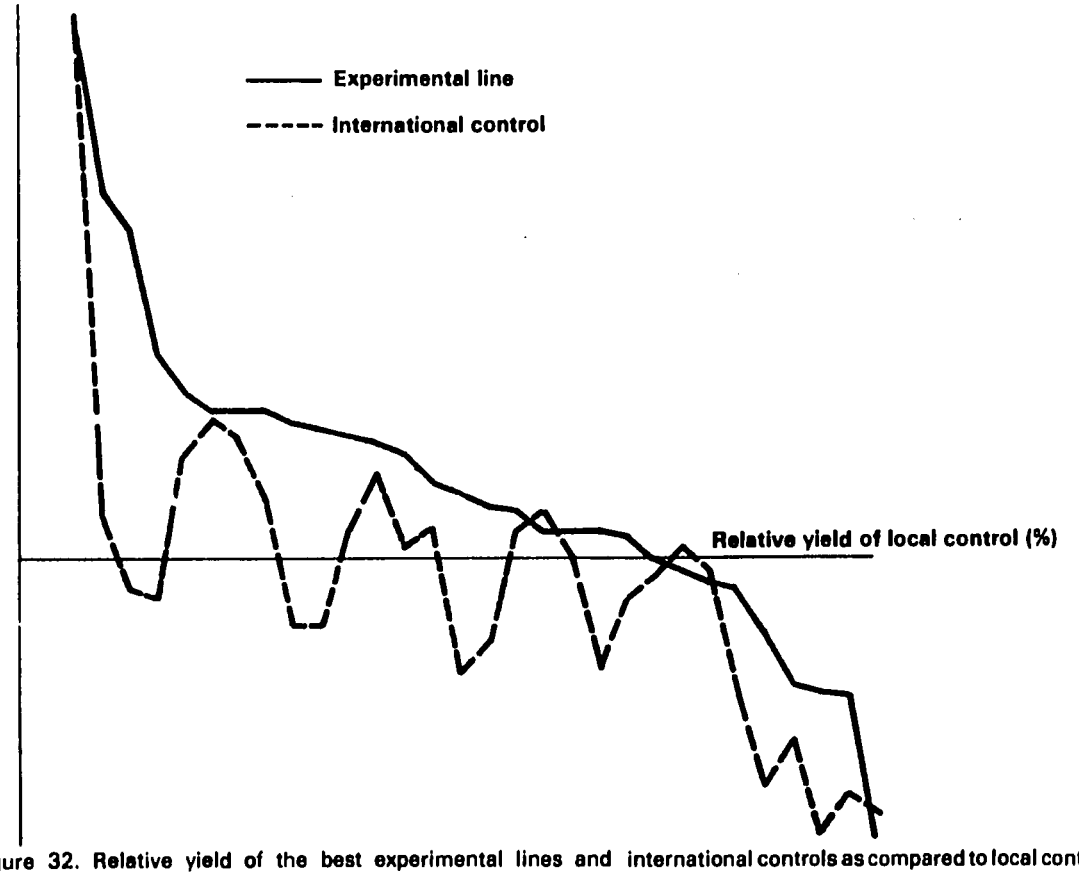


Figure 32. Relative yield of the best experimental lines and international controls as compared to local controls of 30 sites for the black seeded 1978 IBYAN.

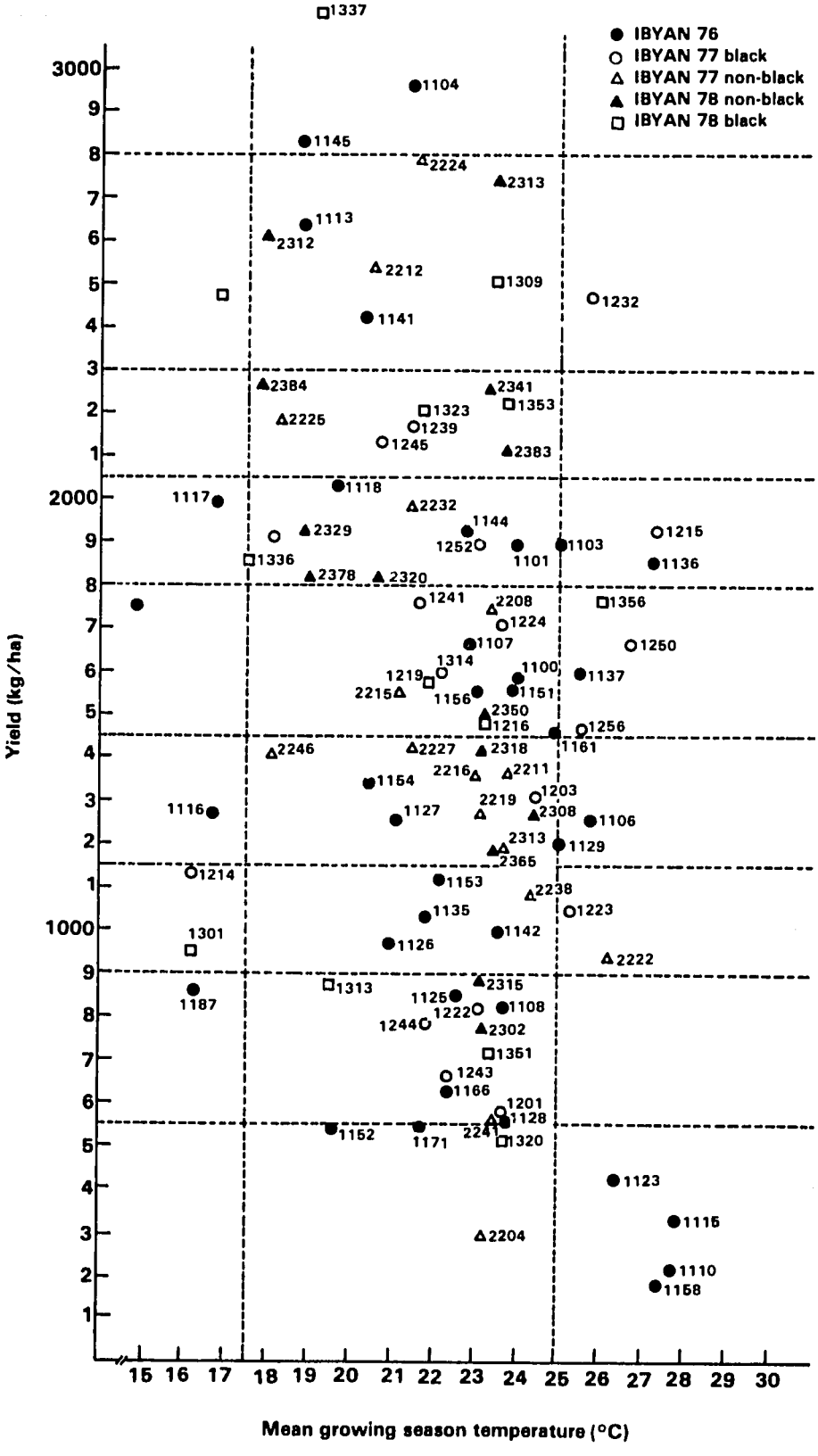


Figure 33. Mean yield of IBYAN entries *versus* growing mean temperature for 1976, 1977 and 1978.

IBYAN 1976 (Series 1100)

1100	Palmira	COL
1101	Palmira	COL
1103	Boliche	ECU
1104	Beit Dagan	ISRL
1106	San Andrés	SALV
1107	Palestina	COL
1108	Ilonga	TANZ
1110	Sta.Cruz Porrillo	SALV
1113	Ithaca	USA
1115	Camarines Sur	FIL
1116	Cambridge	ENGLD
1117	Sapporo	JAP
1118	Saginaw	USA
1123	Sta. Fé de Antioquia	COL
1125	Chiclayo	PERU
1126	Lima	PERU
1127	Londrina	BRA
1128	San Andrés	SALV
1129	San Andrés	SALV
1135	Zamorano	HOND
1136	Iguala	MEX
1137	Sebaco	NIC
1141	Culiacán	MEX
1142	Palmira	COL
1144	Stgo. Ixcuintla	MEX
1145	Santiago	CHILE
1151	Santiago	DOM REP
1152	Lavras	BRA
1153	Pato de Minas	BRA

IBYAN 1976 (Series 1100)

1154	Viçosa	BRA
1156	Janauba	BRA
1157	Graneros	CHILE
1158	Sta. Cruz Porrillo	SALV
1161	Boca de Mao	DOM REP
1166	Lima	PERU
1171	Londrina	BRA
1187	Lima	PERU

IBYAN 1977 Black (Series 1200)

1201	Jutiapa	GUAT
1203	Ahuachapán	SALV
1214	Lima	PERU
1215	Atescatempa	GUAT
1216	Goiania	BRA
1219	Viçosa	BRA
1222	Londrina	BRA
1223	Sta. Tecla	SALV
1224	Palmira	COL
1232	Stgo. Ixcuintla	MEX
1233	Chillán	CHILE
1239	Potchefstroom	S. AFR
1241	Montevideo	URUG
1243	San Jerónimo	GUAT
1244	Monjas	GUAT
1245	La Habana	CUBA
1250	Maharashtra	INDIA

IBYAN 1977 Black (Series 1200)

1252	Tiete	BRA
1256	Maracay	VEN

IBYAN 1977 Non Black (Series 2200)

2204	Cayo District	BEL
2208	Palestina	COL
2211	Palmira	COL
2212	Beit Dagán	ISRL
2215	Danli	HOND
2216	Zamorano	HOND
2219	Palestina	COL
2222	Sta. Fe de Antioquia	COL
2224	Culiacán	MEX
2225	Santiago	CHILE
2227	Viçosa	BRA
2232		
2238	Santiago	DOM REP
2241	Santiago	DOM REP
2246	Luyengo	SWAZ

IBYAN 1978 Black (Series 1300)

1301	Chimaltenango	GUAT
1309	Palmira	COL
1313	Viçosa	BRA
1314	Viçosa	BRA

IBYAN 1978 Black (Series 1300)

1320	La Huerta	MEX
1323	Alquizar	CUBA
1336	Chillán	CHILE
1337	Graneros	CHILE
1351	Rio de Janeiro	BRA
1353	Palmira	COL
1356	Sta. Cruz	BOL
1360	Popayán	COL

IBYAN 1978 Non Black (Series 2300)

2302	Zamorano	HOND
2308	Ahuachapán	SALV
2312	Popayán	COL
2313	Palmira	COL
2315	Ponte Nova	BRA
2318	Campinas	BRA
2320	Celaya	MEX
2329	Chiclayo	PERU
2341	Irece	BRA
2350	Zamorano	HOND
2365	Santiago	DOM REP
2378	Santiago	CHILE
2383	Palmira	COL
2384	Popayán	COL

Genotype/environment interaction

Correlation matrices between mean yields of any promising line in a specific environment to its mean yield in any other experimental site for the 1976 and 1977 IBYAN's showed that the relationship was relatively low. This indicates that it is difficult to predict the yield performance of a variety or line in any site. However, it is important to note that Palmira and Popayán show a high correlation in yield with those in a considerable number of experimental sites which indicates that materials adapted there should show a good overall adaptation.

Potential productivity levels of experimental sites

In the first attempt to analyze factors responsible for the different potential productivity levels of a given material in different environments, a cluster analysis, based on yields of 20 experimental lines, was carried out for each site of the 1976-1978 IBYAN. Results show that high productivity regions are found preferably in the temperate zone where the incidence of insects and diseases is less as compared to that in the tropics. In many instances beans in these areas are cultivated under irrigation and climatic conditions are favorable for a high production; i.e. high solar radiation, high day temperature and relatively low night temperatures. Low productivity regions are generally located in the tropics where climate, diseases and insects do not enhance high yields. In intermediate zones management practices can determine important variations in yield. As has been shown (CIAT Annual Report, 1978) beans are produced within a temperature range of 15°C to 28°C. Yield variations within specific temperature ranges show that besides temperature other factors limit productivity (Figure 33).

EVALUATION AND IMPROVEMENT OF AGRONOMIC PRACTICES

Nitrogen Fixation

Strain Testing

Strain testing of isolates of *Rhizobium phaseoli* continued in 1979, with more than 200 strains of *R. phaseoli* tested in Leonard Jars for N_2 fixation with the cultivar Porrillo Sintético under glasshouse conditions. Many previously untested strains proved highly efficient (Figure 34), but CIAT strain 57, widely used in previous studies at Popayán, was ineffective at the higher temperatures prevailing in the glasshouse.

Thirty-six strains of *R. phaseoli* field-tested in replicated trials at CIAT-Quilichao showed wide variation in symbiotic N_2 fixation. Three strains (CIAT 112, 127, and 612) outyielded plots receiving 100 kg N/ha (Figure 35).

International Bean Inoculation Trial

To evaluate the performance of *Rhizobium* strains at different locations in Latin America, an International Bean Inoculation Trial (IBIT) was distributed in 1979. The trial, comprising 10 *Rhizobium* strains and controls to demonstrate the response to nitrogen fertilization was distributed to workers in eight countries (Tables 51 and 52). Nodulation data is available for five locations to date (Table 53). The efficiency of CIAT 57 in highland locations, but its unsuitability for higher temperature locations was again evident. At CIAT-Quilichao uninoculated controls were heavily nodulated, obscuring response to inoculation (Table 54). A strong response to both nitrogen fertilization and inoculation was obtained at La Selva, where yields for several of the strain treatments were similar to those achieved with nitrogen fertilization.

A culture catalogue for strains of *R. phaseoli* has been prepared and will be published shortly. Biochemical characterization of strains is also provided.

Studies on Tolerance to Low pH and High Al and Mn

Twenty-two *Rhizobium* strains, efficient in N fixation with *P. vulgaris*, were evaluated for tolerance

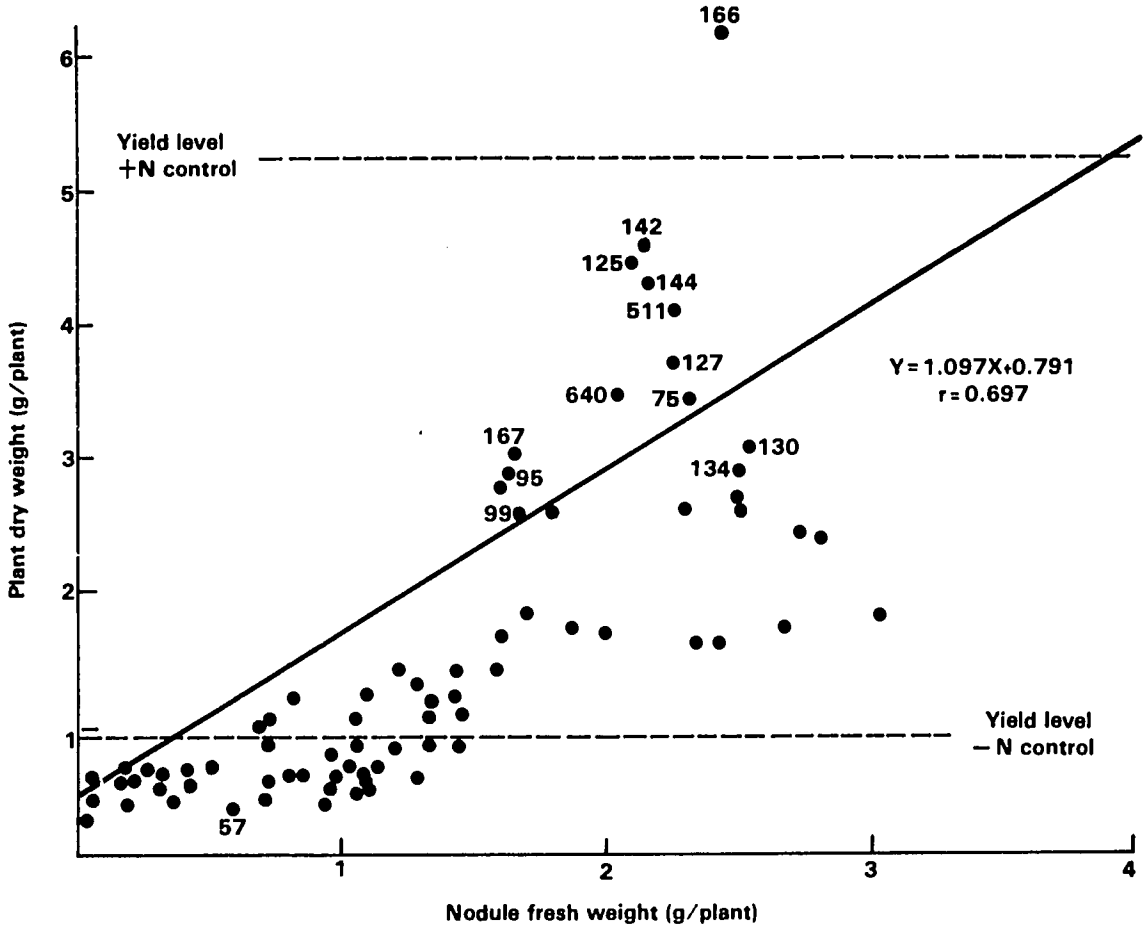


Figure 34. Correlation of plant dry weight with nodule fresh weight in the cultivar P566 inoculated with different strains of *Rhizobium phaseoli* in Leonard jars under glasshouse conditions.

to acidity (growth at pH 4.6 in agar medium with glycerol as carbon source), Al (growth at pH 4.6 in the presence of 2-4 ppm Al^{3+}) and Mn (growth at pH 4.6 and 5.0 with 200 or 400 ppm Mn^{2+}). Several highly efficient strains grew well despite the stress levels imposed in these experiments. Studies to relate strain tolerance in nutrient medium to field performance are currently underway.

Pre-selection Method for Screening *Rhizobium* Isolates

Pigment production by strains of *Rhizobium* grown on a medium containing tetrazolium hydrochloride can indicate strains efficient in hydrogen metabolism, and thus likely to be active in N_2 fixation. When 100 strains of *R. phaseoli* were grown in medium containing tetrazolium hydrochloride, only 9 (CIAT 45, 96, 125, 166, 167, 640, 895, 899, and 905) induced dye reduction in isolated colonies (Figure 36). As these are all highly efficient in symbiosis with *P. vulgaris,* additional studies on hydrogen uptake by these strains will be undertaken. One strain of *A. radiobacter* also reduced tetrazolium.

Influence of Nitrogen Fertilization on N_2 Fixation

The influence of combined nitrogen (0, 15, 45, and 90 kg N/ha) on N_2 (C_2H_2) fixation was evaluated for the varieties Cargamanto and Puebla 152. Fertilization with only 15 kg/ha of combined nitrogen reduced seasonal rates of N_2 (C_2H_2) fixation 39.6% and 17.8% for Cargamanto and Puebla 152, respectively (Figures 37 and 38). These results demonstrate the balance between the beneficial effect on yield and the deleterious effects on N fixation of starter nitrogen treatments.

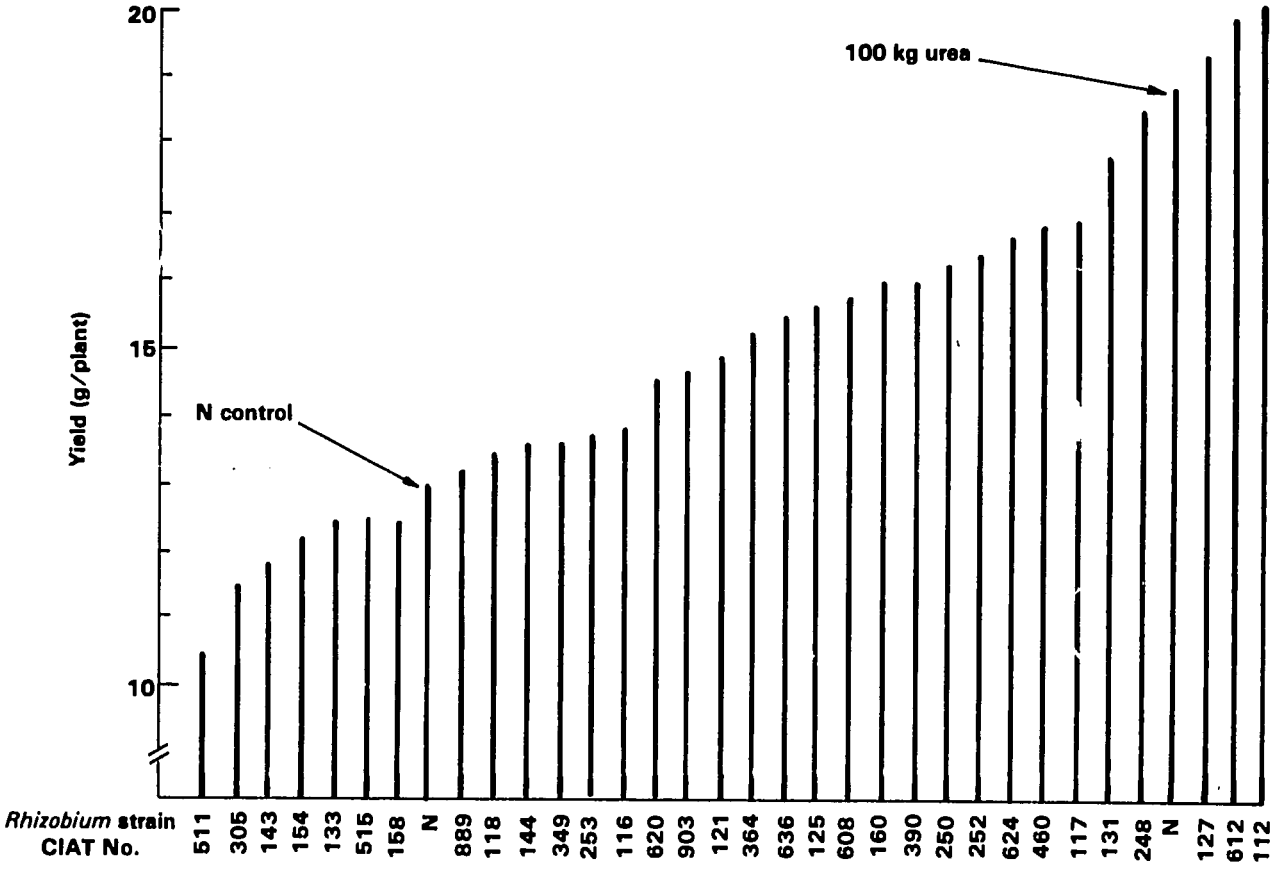


Figure 35. Yield response of Porrillo Sintético to *Rhizobium* inoculation at CIAT-Quilichao.

Table 51. Strains used in the International Bean Inoculation Trial (IBIT) in 1979[1].

CIAT No.	Origin No.	Source of origin
45	F310	IPEACS, Brazil
57	CC511	CSIRO, Australia
255	Z272	PROMYF, Honduras
632	21	ICTA, Guatemala
640	Z632	CIAT, Colombia
676	3620	Rothamsted, England
893	M20	CIAT, Colombia
903	Tal 182	NifTAL, USA
904	487	RGS, Brazil
905	127 K 17	Nitragin, USA

1 Strains 140, 147 and 625 were included in early versions of the IBIT.

Table 52. Distribution of the 1979 International Bean Inoculation Trial (IBIT).

Country	No. of sets	Locations
Brazil	1	Piracicaba
Colombia	3	La Selva and Santander
Dominican Republic	1	
Ecuador	1	Santa Catalina
El Salvador	3	Centa, Ahuachapan
Mexico	3	Guanajuato, San Juan, Tlaxcala and Celaya
Peru	1	Chiclayo
USA	1	Maui
Total	16	

Table 53. Data received on nodule development for the 1979 International Bean Inoculation Trial (IBIT).

	Location, altitude (masl), and cultivar used				
	CIAT-Quilichao 1000	Popayán 1700	La Selva 2200	Obonuco 2700	Chiclayo 100
Rhizobium strain CIAT No.	P566	P498	P590	P590	Muy finca
	Nodule fresh weight (mg/plant)[1]				
45	267	-	340	-	85
57	149	656	550	286	104
140	319	310	545	314	-
147	377	-	295	-	-
255	202	-	622	-	84
625	326	376	295	173	-
632	344	392	332	536	145
640	263	306	370	192	161
676	216	264	297	248	69
893	368	-	302	-	51
-N control	383	30	252	152	58
+N[2] control	26	100	202	58	27

1 Measured 33-45 days after planting.
2 Nitrogen fertilization: 100 kg urea/ha.

Table 54. Influence of inoculation on yield of the bean cultivars P566 at CIAT-Quilichao and P590 at La Selva in the 1979 International Bean Inoculation Trial (IBIT).

Rhizobium strain CIAT No.	Yield (kg/ha) Location: CIAT-Quilichao P566	Yield (kg/ha) Location: La Selva P590
45	932	2636
57	958	3073
140	901	2130
147	1075	3610
255	1096	2750
625	1060	3346
640	990	3590
676	1015	3060
893	922	3356
-N control	918	2300
+N control[1]	1066	3886

1 Nitrogen fertilization: 100 kg urea/ha.

Figure 36. Reduction of tetrazolium hydrochloride by strains of *Rhizobium* efficient in N_2 fixation with *Phasolus vulgaris*.

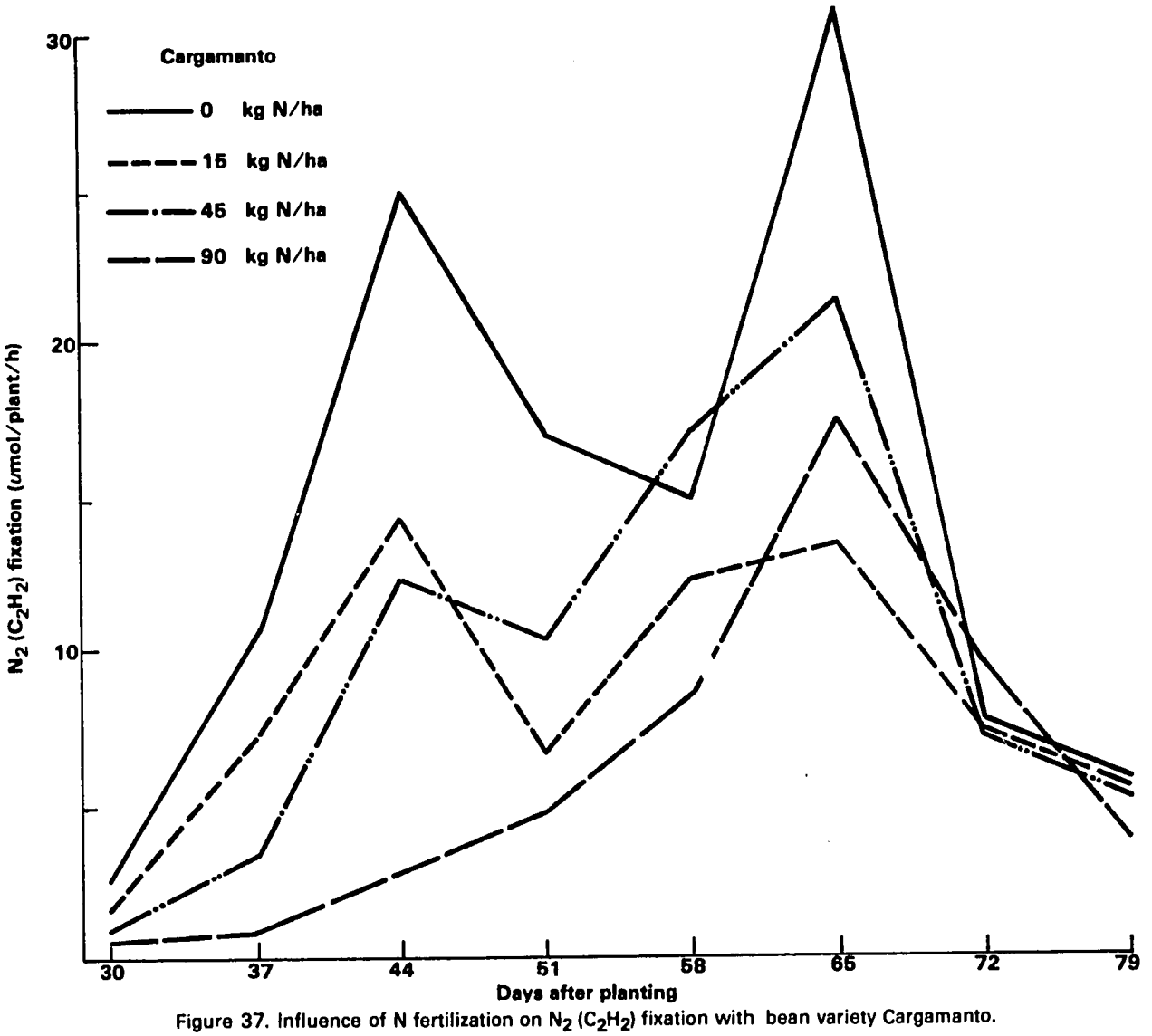


Figure 37. Influence of N fertilization on N_2 (C_2H_2) fixation with bean variety Cargamanto.

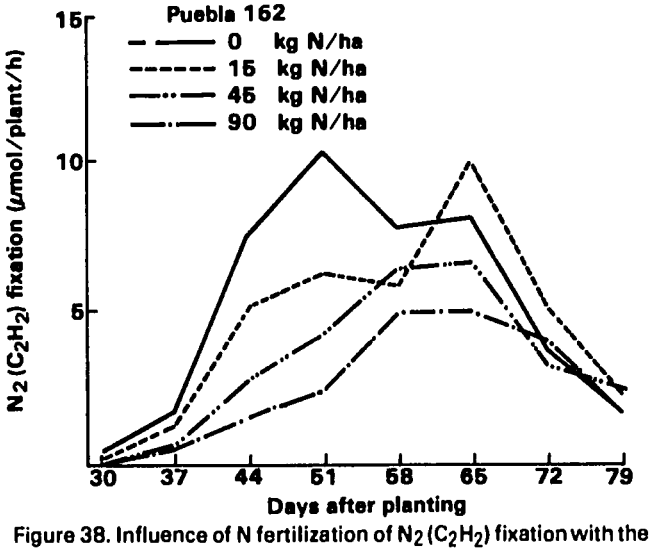


Figure 38. Influence of N fertilization of N_2 (C_2H_2) fixation with the bean variety Puebla 152.

Influence of Maize-Bush Associations on N_2 (C_2H_2) Fixation

Previous studies (CIAT Annual Report, 1977) considered the effects of association with maize on N_2 (C_2H_2) fixation in climbing beans. This year's nitrogen fixation parameters were obtained for the bush cultivar Puebla 152 planted simultaneously with maize, or two and four weeks after.

Monoculture beans were also planted at each date to show date of planting effects on fixation.

Association with maize benefited bean development in the early samplings (Figure 39). However by day 58, beans planted 28 days after maize weighed only 80% that of monoculture beans planted at the same time. By

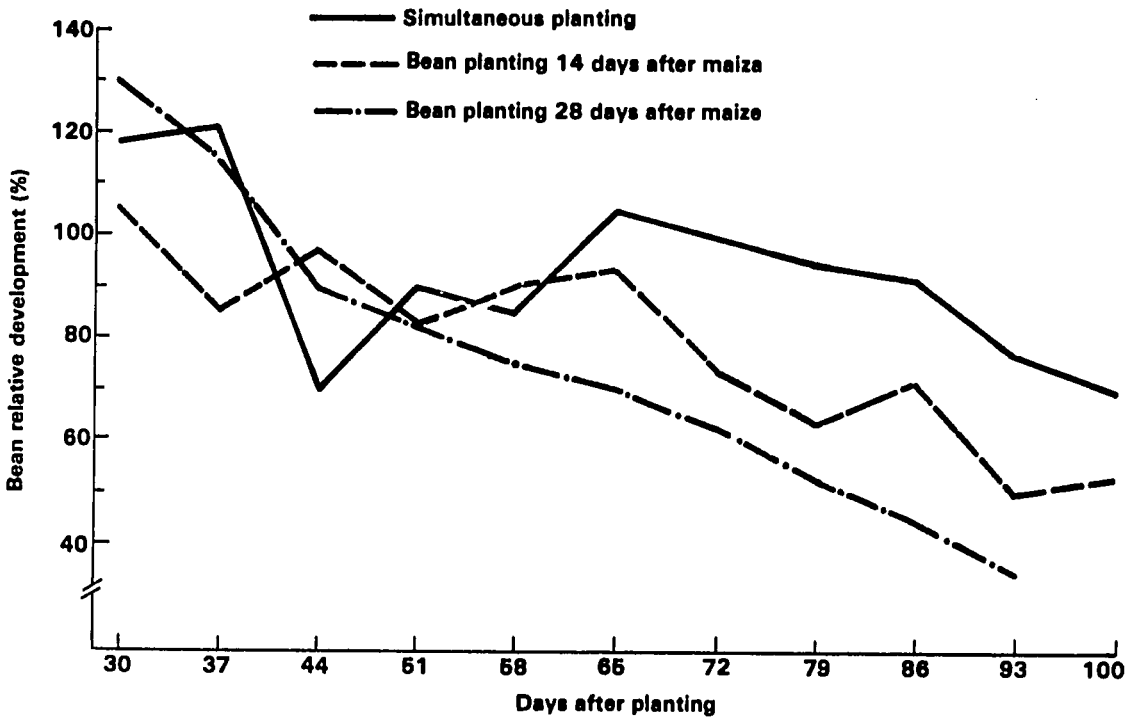


Figure 39. Effect of relative planting dates in maize-bush bean association on bean (var. Puebla 152) relative development (plant dry weight in association ÷ plant dry weight in monoculture x 100) in Popayán.

maturity the competitive effect of association with maize was evident in all three associated plantings, with yields reduced 25, 55 and 73% for the simultaneous, and the 14- and 28-day difference plantings respectively. Nodule development in associated plantings of beans with maize was also initially greater than in monoculture controls (Figure 40), and even 65 days after planting was not significantly less than in the monoculture treatments. However, nodule fresh weight decline post-flowering was much greater in associated plantings than in monoculture. Levels of N_2 (C_2H_2) fixation in associated plantings and in monoculture are shown in Table 55. Inhibition of N_2 (C_2H_2) fixation in associated plantings at the 86 and 100 day sampling is evident.

Fungicide Dressing of Seed and Inoculation Methodology

Fungicide treatment of seed is a common practice and can contribute to inoculation failure. Inoculation procedures compatible with seed treatment were sought. When *R. phaseoli* was applied in sterile peat to seeds treated with PCNB, captan or thiram, they died rapidly (Figure 41), captan being more toxic than the other fungicides. Supposing 10^3 rhizobia/seed needed for nodulation in normal soils, seeds treated with PCNB or thiram would retain sufficient viable rhizobia to meet this standard for only 24 hours after initial fungicide — inoculant contact.

When PCNB, thiram or carbofuran treated seeds were inoculated, lime pelleted, and inmmediately

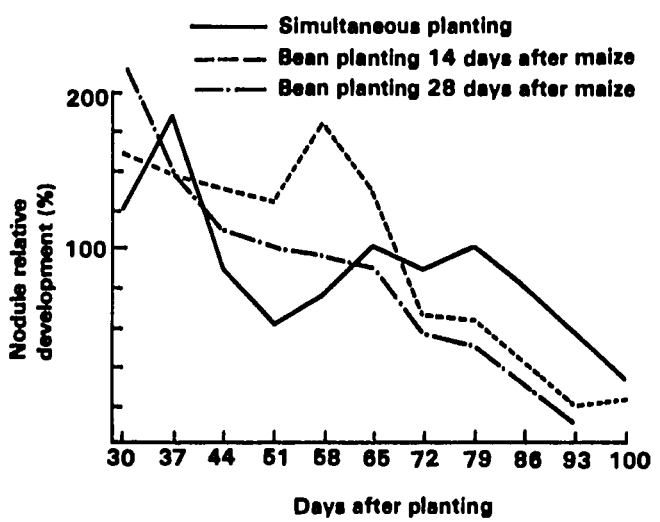


Figure 40. Effect of relative planting dates in maize-bush bean associations on nodule relative development (nodule fresh weight in association ÷ nodule fresh weight in monoculture x 100) in the bean variety Puebla 152.

Table 55. Influence of association with maize, and time of planting on N_2 fixation by the bush bean Puebla 152 at Popayán (1978B).

Planting system	µmol C_2H_4 produced/plant/h			
	Days after planting			
	58	72	86	100
Simultaneous planting				
Monoculture	17.71	12.88	12.34	4.94
Associated	10.78	15.90	12.46	2.58
Beans planted 14 days after maize				
Monoculture	19.55	12.83	12.40	7.70
Associated	29.52	14.81	7.52	0.60
Beans planted 28 days after maize				
Monoculture	31.26	9.75	15.90	2.96
Associated	13.08	8.60	3.23	0.48
SE = 0.40 - 3.07				

planted nodulation was not different from that of inoculated untreated seed and nodule fresh weight in PCNB or carbofuran treated seeds was actually improved (Table 56). Both inoculation and PCNB treatment of seed significantly increased yield in this trial. When planting was delayed seven days after inoculation, toxicity of PCNB to rhizobia was again evident. Captan inhibited nodulation in both trials.

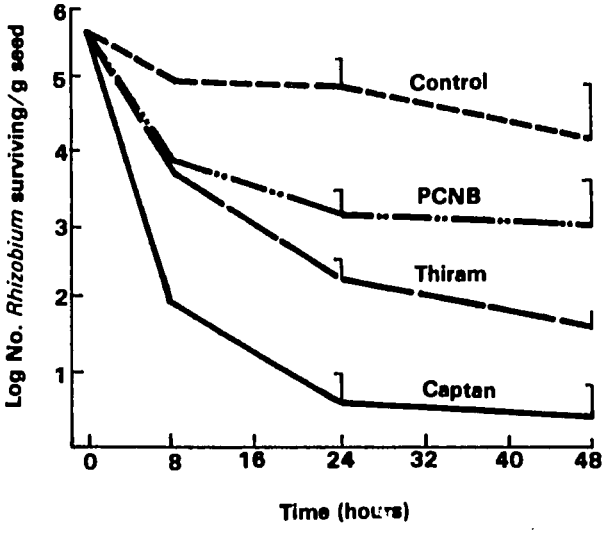


Figure 41. Survival of *Rhizobium* on seed treated with different fungicide.

Because treatment of seeds with thiram and PCNB proved toxic to rhizobia when seeds were not promptly planted, experiments were undertaken to test granular inoculants. This inoculation technique has been useful with soybean, but has not been tested previously in acid soils. Table 57 shows nodule number and dry weight for Puebla 152 and Cargamanto when different inoculation methodologies were compared at Popayán. In each case the use of granular inoculants enhanced nodulation. Later, different inoculation methods and seed treatments were compared in acid soils at La Selva experimental station (Table 58). Granular inoculants again proved superior, particularly in the presence of PCNB applied to seed or soil. In this experiment all fungicide treatments significantly reduced the incidence of root rot. Further studies are underway to confirm the value of granular inoculants in acid soils.

Table 56. Effect of seed treatment with selected pesticides and planting immediately or seven days after treatment, on nodule development.

Parameter	Control	Pesticide treatment[1]			
		thiram	captan	carbofuran	PCNB
No. of nodules[2]					
Planting immediately	15.1	12.5	4.1	10.2	19.0
Planting 7 days after treatment	13.1	1.8	0	10.8	5.9
Nodule fresh weight (mg/plant)[3]					
Planting immediately	0.22	0.23	0.10	0.50	0.51
Planting 7 days after treatment	0.27	0.08	0	0.20	0.06

1 All pesticides were applied at a 0.2% concentration.
2 30 days after planting.
3 45 days after planting.

Table 57. Influence of the inoculation method on nodule weight and number in the bean cultivars Cargamanto and Puebla 152. (Measures were taken 35 days after planting.)

Inoculation method	Cargamanto		Puebla 152	
	Nodule fresh weight (mg/plant)	No. of nodules	Nodule fresh weight (mg/plant)	No. of nodules
Uninoculated	17a[1]	0.57a	73a	5.1a
Inoculated, no pellet	66a	5.30a	55a	5.6a
Inoculated, lime pelleted	94ab	6.18a	80a	8.1a
Granular inoculant, 0.5 g/m	194bc	40.48b	93ab	17.5a
Granular inoculant, 1.0 g/m	205bc	32.50b	102ab	21.8a
Granular inoculant, 2.0 g/m	458b	116.50d	151b	51.2b
Granular inoculant, 4.0 g/m	240c	88.20c	143b	48.5b

1 Numbers not followed by the same letters are significantly different at the 5% level.

Table 58. Influence of seed or soil treatment with selected pesticides, and inoculation method on number of nodules per plant and percentage of plants showing root rot symptoms at La Selva during 1979A.

	No Inoculant	Inoculated lime pelleted	Granular Inoculant
No. of nodules/plant			
With pesticide	3.72	28.25	55.00
PCNB (0.2% to seed)	16.25	16.25	30.12
PCNB (soil applied)	5.50	7.42	41.25
Thiram (0.2% to seed)	5.67	17.20	19.62
Mean	7.78	17.28	36.49
LSD 0.05 = 7.94			
% plants showing root rot			
Without pesticide	76	72	70
PCNB (0.2% to seed)	21	35	35
PCNB (soil applied)	31	37	40
Thiram (0.2% to seed)	34	29	38
LSD 0.05 = 13.3			

On-farm Testing of Inoculant Methodologies

As part of the on-farm testing and validation of program methodologies, nodulation and N_2 (C_2H_2) fixation data and mycorrhizal infection and spore counts were obtained for the 15 farms of the Carmen de Viboral survey (see page 91). Nodulation and N_2 (C_2H_2) fixation in plots representing farmer's practices was much higher than in the 1978 study; in some samples fixation reached 70 μmol C_2H_4 produced plant/hour. Seed treatment with a mixture of PCNB and halofen reduced fixation rates in uninoculated farmer's seed from an average of 23.26 μmol C_2H_4/plant/hour to only 9.84 μmol C_2H_4 produced/plant/hour. Inoculation with a peat-base granular inoculant raised fixation levels but they were still inferior to those for farmer's practices with no seed treatment. Seed treatment also influenced endomycorrhizal development; percentage root infection declined from 36.8% in uninoculated untreated plots to 25.8% in the plots receiving brassicol and halofen. Endomycorrhizal spore counts declined from an average of 12.6 spores/500 g soil in farmer's plots to only 6.1 spores/500 g soil in the presence of the fungicides. Seed dressings compatible with *Rhizobium* inoculation are possible but further studies are needed to determine the role of indigenous mycorrhiza in phosphate fertilization of beans and how this is affected by seed protectants.

Biology and Control of Insect Pests

Cultural Control of *Empoasca*

Effects of different relative planting dates of beans in association with sugar cane on *Empoasca* population (Figure 42), crisomelids (Figure 43), white flies and other pests were studied. In all cases populations were lower in association than in monocropped beans. The association did not affect insect populations of the sugar cane nor the normal biological control program. Competition by beans was evident in the number of sugar cane stems but not in their height (Table 59). The highest bean yields were obtained when beans were planted 15 days after the sugar cane (Table 60). When beans were planted 45 days after the sugar cane production was poor due to higher infestation levels of *Empoasca* and to sugar cane competition.

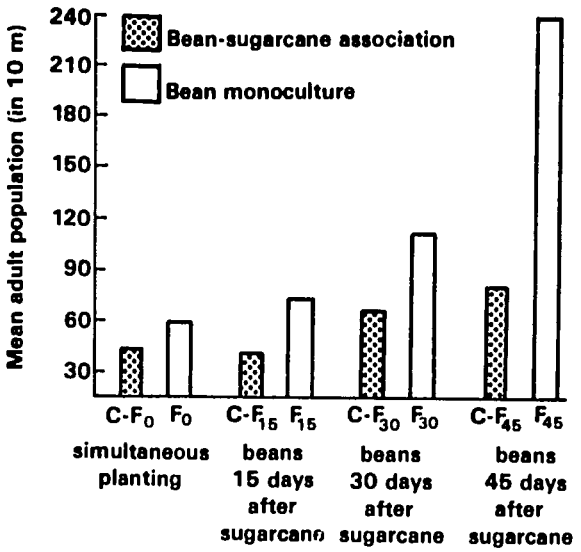


Figure 42. Effect of different relative planting dates of beans in association with sugarcane on adult populations of *Empoasca kraemeri*.

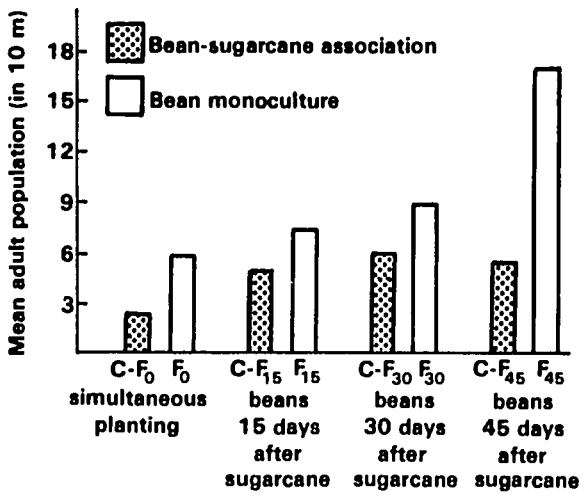


Figure 43. Effect of different planting dates of beans in associatior with sugar cane on crisomelid populations.

Biological control of *Empoasca*

In experiments to study the efficiency of *Anagrus* sp. (Hymenoptera: Mymaridae) a 79% parasitism level of *Empoasca* eggs was found, remaining at this level throughout the growth cycle of the crop regardless of the bean variety (Figure 44). The level of parasitism was not affected by planting date, the use of granular insecticides or soil mulches.

Anagrus has a functional response of two days and its rate of parasitism levels off at 60% in four days which suggests a good search capacity (Table 61). However, observations of damage caused by *Empoasca* and low yields obtained with susceptible varieties (360 kg/ha Diacol Calima and 620 kg/ha for ICA-Bunsi) led to conclude that *Anagrus* does not have the capacity to keep leafhopper populations below the economic damage level.

Table 59. Effect of associating beans and sugarcane on number and height of sugarcane stems. (Mean of four replications.)

Relative planting date (days before beans)	Stems/plot	Height of stem (cm)
Sugarcane monoculture	3449.7a[1]	52.8a[1]
45 days	3044.7b	53.0a
30 days	2691.7c	66.3a
15 days	2353.0d	60.0a
0 days	2150.7d	54.1a

1 Figures within columns followed by the same letter are not significantly different at the 0.05% level.

Table 60. Yields of bean variety Diacol-Calima in monoculture and in association with sugarcane as influenced by different planting dates. (Mean of four replications); CV = 8.3%.

Cropping systems	Relative planting date (days after sugarcane)	Yield (kg/ha)
Beans	15	1800a[1]
Beans + sugarcane		1547b
Beans	0	1482b
Beans + sugarcane		1481b
Beans	30	1249c
Beans + sugarcane		926d
Beans	45	355e
Beans + sugarcane		301e

1 Figures within columns followed by the same letter are not significantly different at the 0.05% level.

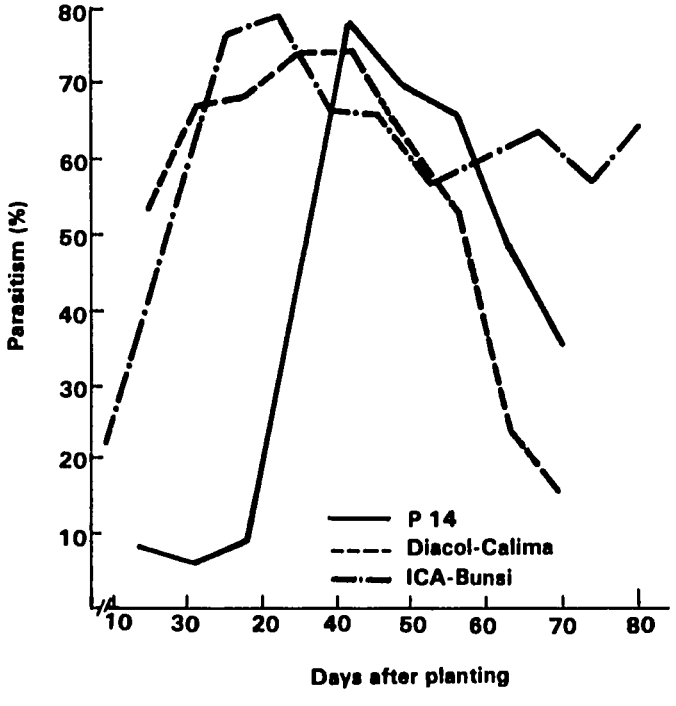


Figure 44. Parasitism level by *Anagrus* sp. on *Empoasca kraemeri* eggs on bean varieties P14, Diacol-Calima and ICA-Bunsi.

Other studies with *Empoasca*

This year the response of the leafhopper to colors and shapes of the surface surrounding the bean plant was studied again. White colors in all shapes and sizes were repellent, yellow shapes atracted leafhoppers independent of the surface area (Figure 45). These results were not confirmed when using yellow plastic mulches but served to design more efficient traps for studies on population dynamics of *Empoasca*.

Chrisomelids

Biology

Figure 46 illustrates the life cycle of *Cerotoma facialis*. Studies were initiated on damage caused by *Cerotoma* larvae to be compared with that of *Diabrotica balteata* (CIAT Annual Report, 1978).

Second and third instar larvae were most damaging to plants less than 47 days old (Table 62). When comparing both species it was found that both decreased leaf area when infesting plants less than 14 days old (Figure 47). Damage caused by *C. facialis* was always greater as this species seems better adapted to beans than *D. balteata*.

Table 61. Functional response of Anagrus sp. to Empoasca kraemeri populations under greenhouse conditions (28°C; 85% R.H.).

Days after Empoasca infestation	Mean No. Empoasca eggs/leaf	Parasitism by Anagrus (%)
1	11	0
2	18	0
3	17	37.0
4	15	28.5
5	17	64.5
6	21	61.4
7	37	54.3
8	26	64.7
9	20	67.7
10	23	62.2

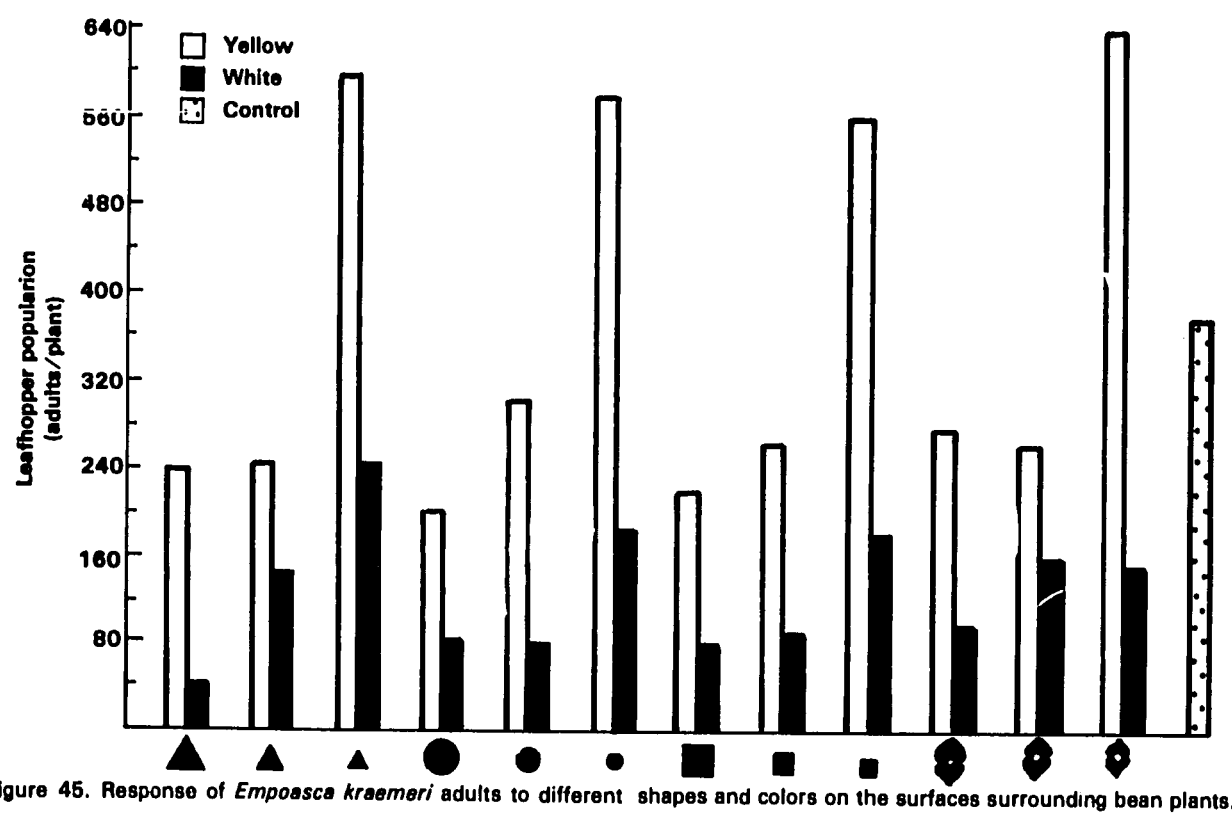


Figure 45. Response of *Empoasca kraemeri* adults to different shapes and colors on the surfaces surrounding bean plants.

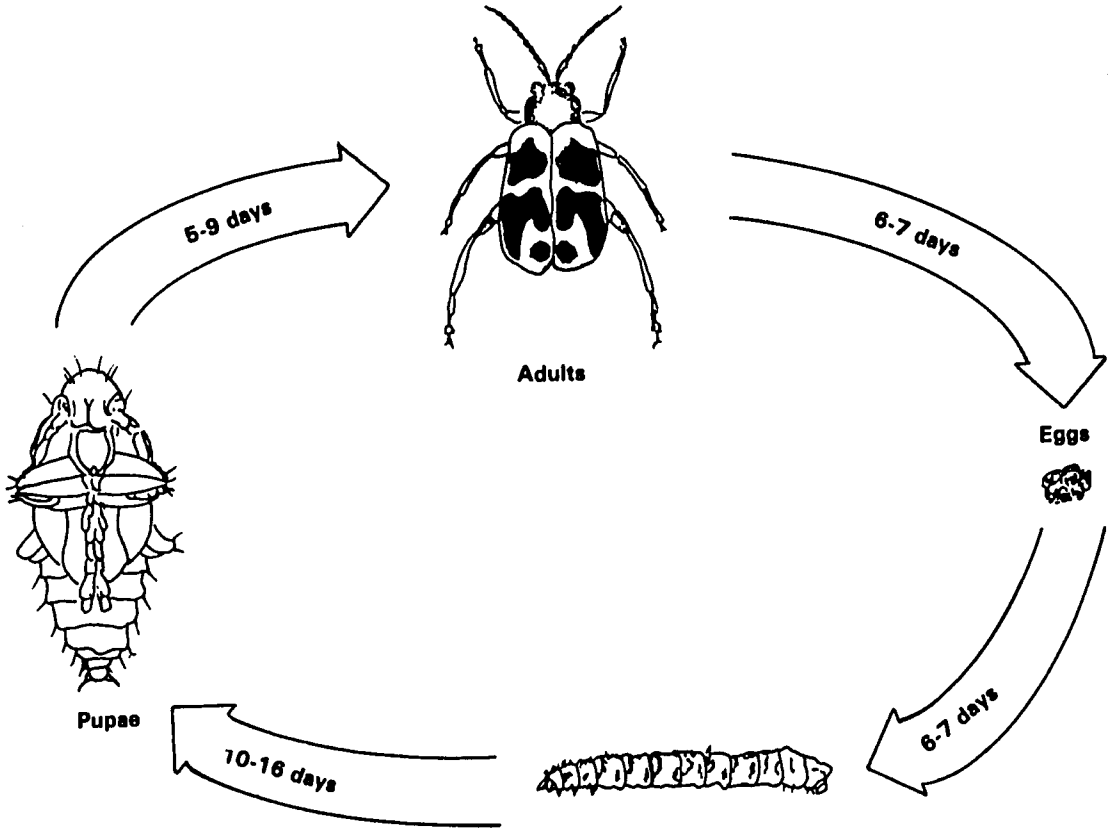


Figure 46. Life cycle of *Cerotoma facialis* Erichson.

Critical adult population levels

A critical adult population level affecting bean yields was established at 2-4 adults per plant during the early growth stage (8-15 days) and during the flowering period (29-36 days) (Table 63).

In experiments with *D. balteata* infestation levels of four adults per plant were critical at 8-15 and 8-22 days after planting when attacks occurred during one and two weeks, respectively (Table 64). Damage was most important during flowering with a two weeks infestation period.

Table 62. Damage (leaf area as percentage of control) caused by 10 Cerotoma facialis larvae of each instar infesting beans at different ages.

	Leaf area (% of control)						
	Day of infestation after planting						
Larval instar	0	1	4	7	14	21	Mean
First	102.5	88.1	77.9	100.6	94.9	110.5	95.8
Second	0	0	10.0	78.7	76.4	110.1	45.9
Third	0	3.4	5.7	28.7	86.2	87.7	35.3

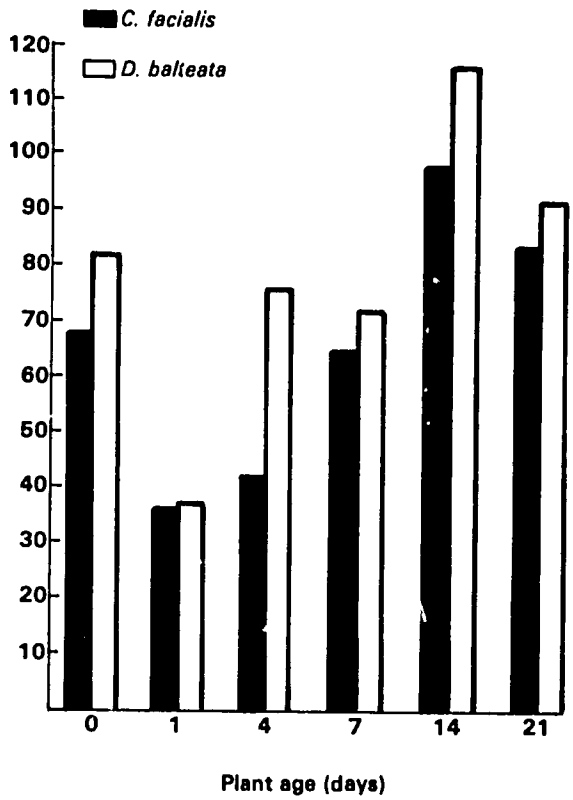


Figure 47. Percentage leaf area on bean plants 20 days after being infested with larvae of *D. balteata* and *C. facialis*.

Insect Pests of Stored Beans

Preliminary trials with vegetable oils for controlling *Acanthoscelides obtectus* showed a similar efficiency as reported for *Zabrotes subfasciatus*. Control was excellent with all vegetable oils tested (1-5 ml/kg of beans) both on beans infested with either adults or eggs (Table 65).

Sugarcane-Bean Association

Beans are mostly grown in association with other crops, predominantly with maize. However, in Latin America, small farmers also intercrop sugarcane with beans. The initial growth of sugarcane is slow and the canopy does not close before 2-3 months after planting. Sugarcane is planted in wide row distances, varying from 1.0 to 1.5 m, leaving sufficient space to intercrop with beans. In this way beans reduce weed growth and provide income during the early growth stage of sugarcane.

Relative Planting Dates

The bean variety Diacol Calima was planted 15, 30, and 45 days after sugarcane. Beans were seeded at 250,000 plants/ha and sugarcane at 10 nodes/m. Figure 48 illustrates the planting pattern used in this

Table 63. Effect of time and level of crisomelid infestation levels on yields of bean variety Diacol-Calima.

Infestation level (adults/plant)	Yield (g/m^2) Infestation period (days after planting)			
	8-15	15-22	22-29	29-36[2]
0	121.6a[1]	131.5a	141.7a	101.5ab
1	81.1ab	106.6a	134.9a	113.8a
2	56.6b	112.8a	99.1b	86.2ab
4	48.7b	106.6a	119.6ab	73.9b
Control with insecticide	89.6ab	89.6ab	89.6ab	89.6ab
Control without insecticide	69.2b	69.2b	69.2b	69.2b

1 Figures within columns followed by the same letter are not signficantly different at a 0.05 level.
2 No significant differences between treatments were observed in plants 36 days old.

Table 64. Effect of time and two levels of infestation of bean variety Diacol-Calima with *Diabrotica balteata* adults.

Infestation level (adults/plant)	Attack duration (days)	Age of plants (days)	Yield (kg/ha)
0	14	22-36	2048.7a[1]
Control with insecticide	-	-	2004.0a
0	7	36-43	1940.7a
0	7	8-15	1932.3a
0	14	8-22	1873.3a
0	7	22-29	1793.3ab
4	7	22-29	1793.2ab
0	7	15-22	1778.0ab
4	7	29-36	17 .2ab
Control without insecticide	-	-	1670.7abc
0	7	29-36	1656.7abc
4	14	22-36	1540.0abc
4	7	15-22	1496.7abc
4	7	36-43	1440.0abc
0	14	36-50	1426.7abc
4	14	36-50	1141.0bc
4	7	8-15	1072.7c
4	14	8-22	1009.3c

1 Figures within columns followed by the same letter are not significantly different at a 0.05 level.

Table 65. Control of *Acanthoscelides obtectus* attacking stored beans with vegetable oils.

Treatment (vegetable oil)	Application rate (ml/kg of beans)	Adults emerged[1]	
		Infestation with eggs[2]	Infestation with adults[3]
Maize	1	0	1.2
Maize	5	0	0
Soybean	1	0	0
Soybean	5	0	0
Mixture	1	0	0.6
Mixture	5	0	0
Control	-	64.2	172.0

1 Mean of five replications.
2 100 seeds infested with 1 egg/seed.
3 Seven pairs of adults per 100 g of seed.

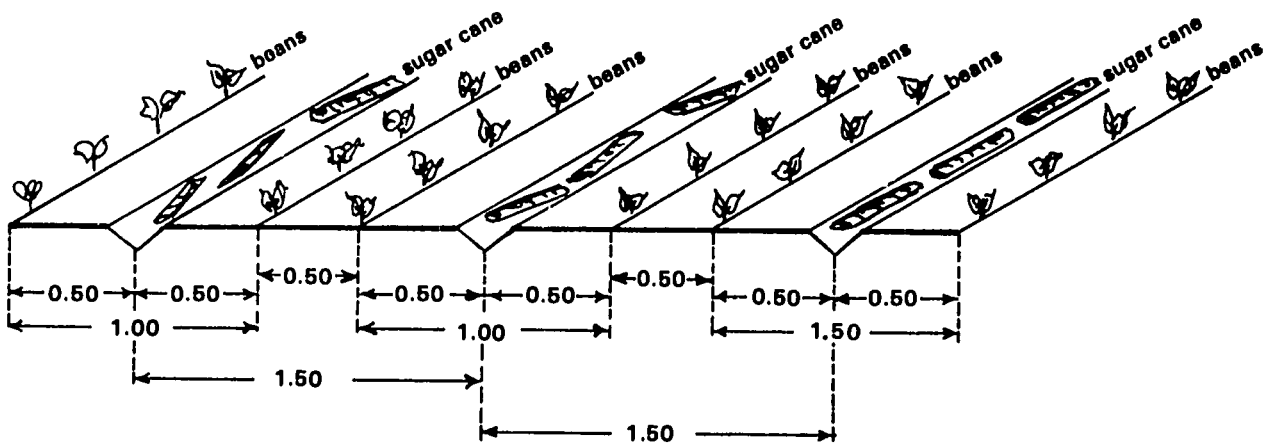


Figure 48. Planting patterm for bean-sugarcane intercropping studies.

experiment. Monoculture of beans and sugarcane at every planting date were included in the experiment.

As planting was delayed into the dry season, yields decreased due to increasing leafhopper populations (Figure 49 and Table 66) and no conclusions were drawn on the effects of relative planting dates on yields. However, the best relative planting date for bean appears to be 0-15 days after sugarcane.

Plant Densities

Beans were planted 10 days after sugarcane at populations of 10, 20, 40 and 40 plants/m². Bean yields in monoculture and intercropped tended to decrease as plant density increased. However percentage yield reduction due to association was higher at lower plant populations (Figure 50). In contrast to the first experiment, association with sugarcane reduced bean yield by 20%. Decreased bean yield were principally due to unfavorable spatial arrangement that

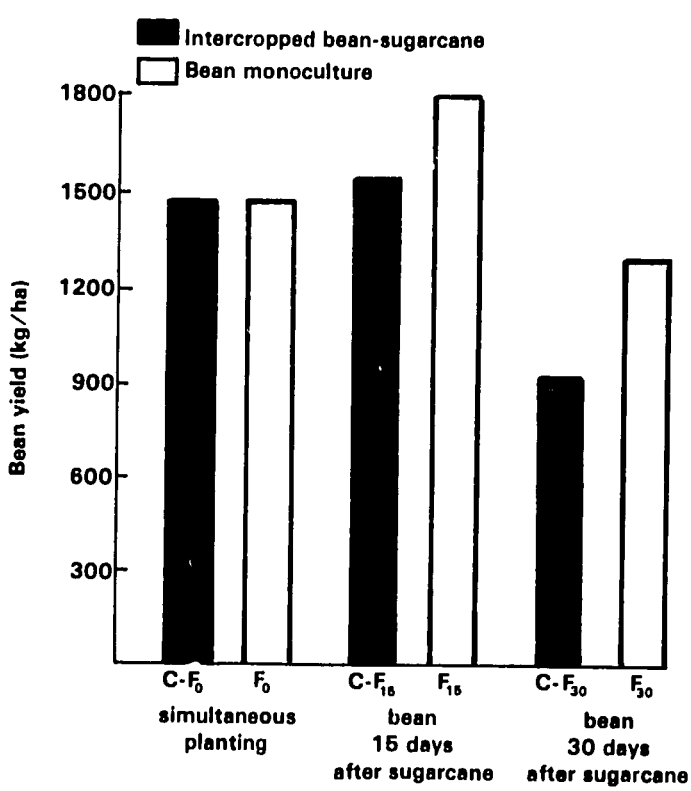


Figure 49. Effect of relative planting dates of intercropped beans and sugarcane on yields of bean variety Diacol Calima.

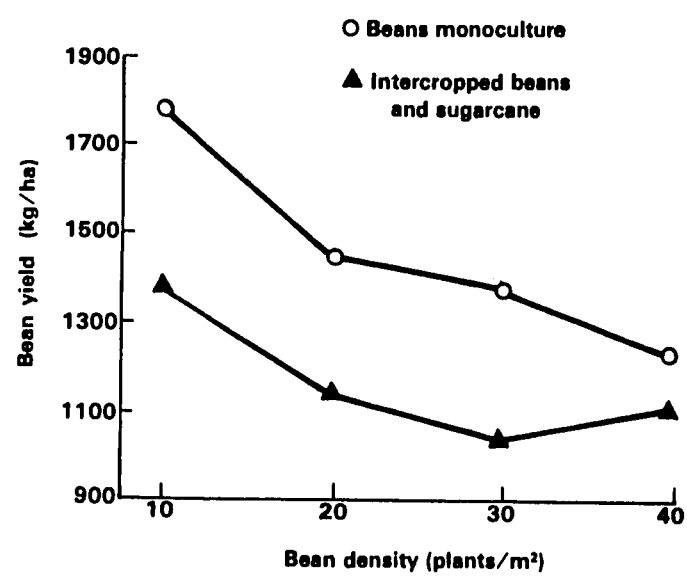


Figure 50. Effect of increasing bean plant population on bean yield in intercropped bean-sugarcane production systems.

Table 66. Yield of bean variety Diacol-Calima in monoculture and intercropped with sugarcane at different relative planting dates.

Relative planting date (days after sugarcane)	Bean yield (kg/ha)		Yield reduction (% of control)
	Monoculture	Intercropped	
0	1482b[1]	1481b	0
15	1800a	1547b	14
30	1249c	926d	26
45	355e	301e	15

1 Figures followed by the same letter are not significantly different at a 0.05 level.

led to strong competition between bean plants. The best spatial arrangement for the Diacol Calima growth habit I is approximately 40 cm between rows and 20 plants/m² (CIAT Annual Report, 1978), but due to restrictions in spatial arrangement from the sugarcane, higher populations were obtained by planting beans closer together within the row.

This experiment has been repeated by planting three rows of beans between every two sugarcane rows.

VALIDATION OF TECHNOLOGY IN ON-FARM TRIALS

The research system is not complete until improved germplasm or associated agronomic practices are tested at the farm level and this evaluation is often critical to respond to problems in the application of the new technology. Farm trials are designed to answer the following questions: (1) Is the new technology profitable? (2) Does it fit into the farmer's production system? (3) Are there differences between farms in natural or economic resources leading to different performance of technology or constraints to its production?

In this early stage of the Bean Program, the principal technologies with good experiment station or regional trial results were: Agronomic practices including higher density, disease or pest specific chemicals fertilizer, improved seed, inoculation, and herbicide. New germplasm was just beginning to become available in 1979.

Farm trials reported here are those carried out in Huila with monoculture bush beans (25 farms); the Restrepo region with monoculture bush beans (14 farms); and Antioquia with climbing beans in relay systems with maize (14 farms).

Huila

Southern Huila, in Colombia, is a diversified cropping area ranging in altitude on the plains from 800 to 1400 masl. Approximately 28% of Colombian bean production comes from Southern Huila principally from bush bean crops. Beans have been declining in importance in the region apparently due to substantial price fluctuation, low absolute yields, and the shifts to new coffee planting and other new crops. The maize-bush bean association predominates in the region; however, approximately 20% of the farmers produce beans in monoculture. Yields and income comparisons of

different systems production and technologies for these two crops are presented in Table 67. The yield levels for farmers' technologies were the mean values of the farm with farm trials in 1979. The improved agronomy yields are based upon the farm trial yields in 1978 and 1979 and were discounted to 1.5 t/ha for the differences between farmers' management and farm trials. Considering only farmers' practices the maize-bean association is more profitable than monoculture beans within the range of expected price ratios of maize and beans. However, new agronomic technology makes monoculture bean production more profitable than the association even at the very low bean: maize price ratio of 3:1.

Besides greater profitability with present technology, there are two other hypothesized reasons for a preference of farmers for the maize-bean association over monoculture. First, since farms need to produce maize for human and animal consumption, beans provide a good ground cover reducing erosion and leaching. Second, at low chemical input levels multiple cropping may reduce some insect and disease problems in both crops.

With higher bean prices and improved technology, a shift to monoculture bean production is expected as part of the shift to higher value products in southern Huila.

Effects of Different Factors in Huila On- Farm Trials

The 1979 farm trials were an extension of 1978A and included: (1) the use of farmers' seed with and without various seed treatments with thiram and carbofuran; (2) the application of herbicides; (3) the use of clean seed produced in Dagua, Valle del Cauca, under irrigation with rogueing and heavy chemical protection; and (4) the use of a new variety, BAT-47, selected as the best yielding red-seeded variety in the Bean Program's 1977 yield trials.

In 1979 farmers' yield for monoculture beans, (1172 kg/ha) were slightly higher than in 1978. The improved agronomy technology gave almost identical mean yields to those obtained in 1978. Better agronomy with farmers' seed increased yields 31% on farms with no fertility problems as compared with a 50% yield increase obtained last year. Better agronomy included higher density and improved weed control. In farms with low soil fertility, farmers' seed, 200 kg of 20-60-20 NPK fertilizer, and better agronomy increased yields 19% compared to a 43% for last year. Since curative spraying was not necessary this year in most farm trials (83%), the better agronomy had very low input costs especially on the majority of farms not requiring fertilizer (Figure 51).

Table 67. Farm income and yields of various bean production systems in southern Huila, Colombia.

	Maize yields (kg/ha)	Bean yields (kg/ha)	Farm income (Col. $)[1] 1978 (3:1 price ratio)	Farm income (Col. $)[1] 1979 (4.5:1 price ratio)
Farmers' fields				
Monoculture bush beans	-	1178	8,402	22,538
Maize-bush bean association	1990	780	16,098	25,458
Farm trials (1978A and 1979A)				
Bean monoculture				
New technology - improved agronomy	-	1500	18,973	36,973

1 Farm income is defined as total revenue minus variable costs including all labor costs priced at the market rate for hired labor. The 3:1 price ratio refers to Col. $24/kg of beans, and Col. $8/kg of maize (1978). In 1979 maize prices remained unchanged and beans went up to Col. $36/kg. The price for beans in 1978 was unusually low and in 1979 it was unusually high. Over the last 20 years in Colombia the price has fluctuated between these two ratios. (Col. $40 = US$1.00).

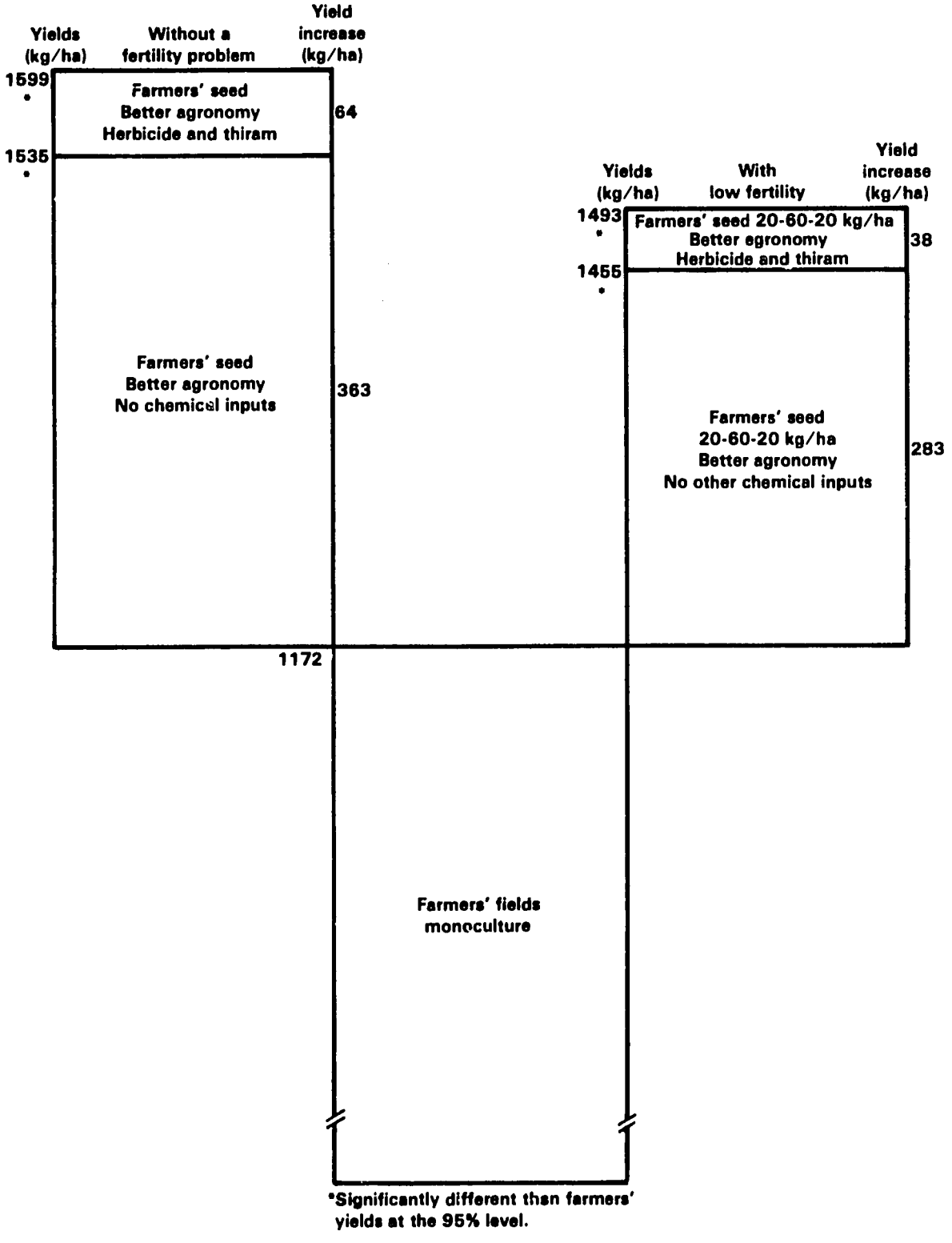


Figure 51. Effects of different factors on bean yields in the 1979A farm trials in Huila, Colombia.

Herbicide and a seed treatment with thiram had only a small effect on yields; however, the herbicide treatment also reduced the number of weedings. These inputs were profitable on both farm types and the return on investment was high even though the absolute increases in net income were small (Table 68).

There was a further yield increase from the use of the new variety BAT-47 on both soil types, with high levels of chemical inputs. However, there was a substantial price discount of 66% due to small seed size of this variety even though color is almost the same as that of farmers' seed. This discount was the subjective assessment of bean wholesalers in southern Huila. Taste preferences by seed size are clearly an important economic consideration.

There was no yield advantage to "clean seed" over farmers' seed. The additional yields from the fertilizer response above the 20-60-20 kg/ha rate on the low fertility soils and above zero on the other soils did not pay for the increased cost of fertilizer.

Introducing new technology

Utilizing linear programming, model farms of the two principal farm sizes producing beans were constructed. Besides present activities the model was allowed to choose new bean technologies. The income increase from improved bean agronomy is not as large as the increase from new coffee technology on the small farm. Moreover, the rate of return on capital was low (11%) for the new agronomic technology for beans (Tables 69 and 70).

One of the principal problems of bean production is the price collapse at harvest. In three weeks during the harvest period in 1978A, the purchase price for beans fell from Col.$32 to $20/kg. Bean seed in 1979A sold for over Col.$40. Low cost on-farm storage technology is available and has been farm tested in various regions. To interest farmers in the new agronomic technology it may also be necessary to introduce improved storage. With storage plus new agronomy in the models, income increases were substantial. Moreover, the rates of return on capital increased substantially to 33 and 69% in the two farm sizes with only 50% storage. Increased credit is necessary on both farm sizes to introduce the new technology.

In summary, the linear programming results indicate that profit maximizing farmers will choose new bean technology and if combined with storage and credit, substantial increases in income with high rates of return are possible.

Restrepo

The Restrepo region in the Valle del Cauca, Colombia, is not an important bean production area as beans and cassava are produced on a small scale principally for family consumption. The principal activity on Restrepo farm is coffee comprising from 85-

Table 68. Return on investment in new technologies for two different soil fertility conditions in southern Huila (1979A).

	Farmers seed Improved agronomy		Herbicide - thiram technology[1]	
	No soil problem	Soil Problem	No soil problem	Soil problem
Increased net income[2] (Col. $)	11,329	5,534	3,021	1,907
Increased costs (Col. $)	3,917	6,342	-333	-301
Return on additional investment:				
Increased net income / Increased cost	2.89	0.87		

1 The herbicide-thiram technology also includes farmers' seed and improved agronomy.
2 Increased net income = $\Delta Y.P$ - Increased costs, where ΔY is increased yields and P is the price received by farmers for beans.

Table 69. Potential income, credit requirements, and returns from various new technologies on small farms (typical size of 2.4 ha) in southern Huila determined by a linear programming model.

	Traditional cropping conditions	With improved technology[1]			
		A	B	C	D
Farm income (Col. $)[2]	76,796	106,881	118,319	134,519	155,219
Income increase (%)	-	39.0	11.0	14.0	15.0
Capital borrowing (Col. $)	9,333	18,593	26,532	30,000	30,000
Return on an additional unit of capital	-	0.11	0.11	0.33	0.69

1 Improved technology: A = caturra coffee high technology; B = A + monoculture beans and improved agronomy; C = B + 50% storage; and D = B + 100% storage.
2 Col. $40 = US$1.00.

92% of farm income. However, Restrepo is a marginal coffee area due to lesser rainfall than the primary coffee regions. With the on-going rapid diffusion of the higher yielding Caturra coffee variety in Colombia, and the impending decline of the world coffee price, a substantial realocation of coffee to the optimum coffee areas with the lowest production costs is expected. Hence, there is an increasing concern in Colombia for the 55% of the coffee farms located in marginal coffee areas*. The programming analysis here evaluated the income effect of a falling coffee price and of a shift out of coffee production into new bean technology for this type of marginal coffee area.

These estimates and most of the following information in this section were taken from M. Stabile, An Economic Analysis of Diversification in a Marginal Coffee Region. Unpublished MS thesis, University of Guelph, in process.

Table 70. Potential income, credit requirements, and return from various new technologies on medium farms (typical size of 15.8 ha) in southern Huila determined by a linear programming model.

	Traditional cropping conditions	With improved technology[1]			
		A	B	C	D
Farm income (Col. $)[2]	182,380	248,780	264,527	288,684	332,566
Income increase (%)	-	36.0	6.0	9.0	15.0
Capital borrowing (Col. $)	41,323	75,000	90,000	90,000	90,000
Return on an additional unit of capital	-	0.41	0.27	0.69	0.87

1 Improved technology: A = Expanded area of present activities; B = A + monoculture beans and improved agronomy; C = B + 50% storage; and D = B + 100% storage.
2 Col. $40 = US$1.00.

Marginal coffee areas appear to be prime areas for the expansion of bean production. They have adequate temperature and rainfall conditions for beans. The predominant small farmers have marketing knowledge, obtain credit, and utilize fertilizer and other chemicals on their coffee. Since beans generally require good management and moderate input use, this experience with coffee is more useful than experience with some other grains. Since coffee has very high labor requirements, the labor availability by season and the effectiveness of herbicide use on the beans need to be evaluated.

Factors potentially constraining bean production in Restrepo are disease (anthracnose, angular leaf spot, and rust), insects *(Empoasca kraemeri)*, soil fertility, low mean P levels of 2.5 ppm, and seasonal labor shortages during the coffee harvest.

Effects of Different Factors in Restrepo On-Farm Trials

Monoculture bean yields with farmer's practices were reasonably high (1 t/ha). A 34% increase in yield and net income was obtained when farmer's seed was combined with improved agronomy, which included higher plant density, application of micro-nutrients, timely weeding, and benomyl spray for anthracnose control (Table 71). The effect of improved agronomy was less in the Restrepo trials than in Huila, apparently due to the more pressing soil constraints in Restrepo.

At very low P levels in the soil in Restrepo there was an excellent response up to 500 kg of 10-30-10/ha of NPK. At the highest fertilizer level (the most profitable treatment) farm yields increased 94% (1.94 t/ha).

The herbicide results indicate the need for region specific herbicide trials before including this input in the farm trials as was done for Huila in 1978B. If the appropriate herbicide had been available for Restrepo giving the same yields as the equivalent treatment without herbicide, then according to the programming results, bean area in new technology would have increased by 0.1 ha on small farms, 0.4 ha on medium farms, and 1.65 ha on large farms, thereby increasing farm income 3.7-4.4% on the various farm sizes. There was no effect from clean seed apparently due to the inability to control the aphid carrier of BCMV by rogueing. In spite of seed production under irrigation and with rogueing the incidence of BCMV ranged from 25 to 40 percent.

Effect of New Bean Technology on Income

The programming model enables the selection of the profit maximizing farm plant including the new bean technology. With a falling coffee price new bean

Table 71. Yields, profitability, and costs of various technologies in Restrepo using the bean variety Diacol-Calima (1978B).

Technology level	Yield (kg/ha)	Net income (Col. $)	Input costs (Col. $)
T_0 farmers' practices	1000a[2]	13,752	16,257
T_1 farmers' seed - improved agronomy	1341ab	18,340	21,890
T_2 clean seed - improved agronomy	1254a	13,280	24,340
T_3 clean seed[1] - 50 kg P_2O_5/ha (167 kg/ha of 10-30-10)	1547abc	23,022	23,373
T_4 clean seed[1] - 100 kg P_2O_5/ha (333 kg/ha of 10-30-10)	1842bc	30,157	25,103
T_5 clean seed[1] - 100 kg P_2O_5/ha, herbicide	1531abc	21,757	24,173
T_6 clean seed[1] - 150 kg P_2O_5/ha (500 kg/ha of 10-30-10)	1942c	31,420	26,840

1 Also utilize improved agronomy practices: higher plant densities, micronutrient applications, and benomyl-sprays. Clean seed refers to seed production under irrigated conditions with rogueing.

2 Figures followed by the same letters are not significantly different at a 0.05 level.

technology can reduce but not eliminate the abrupt farm income decline (Table 72). On all farm sizes traditional coffee area is replaced by beans predominantly with new technology. Due to greater credit restrictions the small farmer does not use the highest fertilizer level whereas the medium and large farmers move rapidly into this high fertilizer alternative. The rates of return on this shift from old coffee into new bean technology are very high—130% on the small farm and 50% on the medium and large farms. The area increases of new bean technology are not dramatic but returns are substantial and occur on all farm sizes.

In summary, the agronomy and the programming results indicate the profitability of new technology in bean production in marginal coffee areas. This technology includes chemical control of anthracnose and *Empoasca*, higher plant densities, and high P levels in combined fertilizers. In 1979B the Federación Nacional de Cafeteros (FEDECAFE), CARE, and Abonos de Colombia (ABOCOL, a Colombian fertilizer company) are collaborating to support demonstration trials of this new bean technology in Restrepo.

Antioquia

El Carmen, in Antioquia, is the principal region

Table 72. Changes in income and bean and coffee areas, capital requirements and rate of return on capital on small, medium and large farms in a marginal coffee region with the availability of new bean technology.

	Farm size		
	Small farm (2.5 ha)	Medium farm (6.5 ha)	Large farm (16.5 ha)
Income increase[1]			
(Col. $)	14,350	23,000	56,250
(%)	23	32	59
Change in coffee area (ha)	- 1.35	- 1.4	- 3
Change in bean area (ha)			
First semester	+ .7	+ 1.4	+ 3.4
Type of technology	Farmers' technology	High fertilizer	High fertilizer
Second semester	+ .7	+ 1	+ 1.2
Type of technology	Moderate fertilizer	High fertilizer	High fertilizer
Change in capital requirements			
(Col. $)	21,800	49,400	112,800
(%)	51	32.5	36
Rate of return on capital	1.30	0.49	0.50

Source: Data from M. Stabile, An Economic Analysis of Diversification in a Marginal Coffee Region. Unpublished MS thesis, Guelph University, Guelph, Canada, 1980.

1 The income increases from the bean diversification should be compared with the income decreases from the falling coffee price of Col. $13,000 on the small farm, Col. $38,500 on the medium farm and Col. $64,000 on the large farm. Hence, the effect of diversification of a marginal coffee region is to moderate the impact of falling coffee prices. The net change in farm income considering both changes was +1.8%, -1.4%, and -4.8% on the three farm sizes. Hence, the new technology helped offset the falling coffee price but did not increase income except on the small farm.

producing beans in Colombia; Antioquia produces 28% of Colombian bean production. El Carmen is a small farmer region with a predominant rotation of two cycles of potatoes, two years of maize-bean relay cropping, and then back to potatoes. Potatoes are sometimes intercropped with peas, beans, and arracacha. Pastures is another important activity. There is much local variation in planting dates and crop systems.

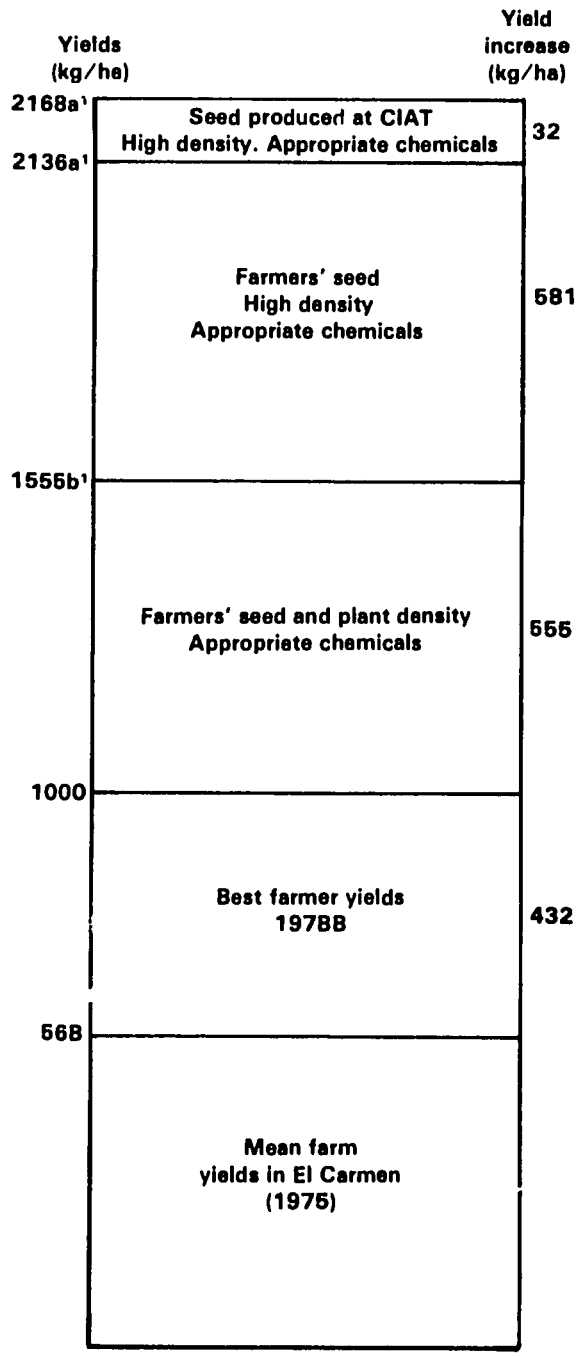
Cargamanto, the predominant local variety, is extremely vigorous so the maize system is strongly influenced by the need to support this aggressive climber. Maize is planted in holes at 0.9-1.0 m spacings with 3-4 plants per hole and 1 m between rows. A tall, strong-stemmed local maize is preferred over higher yielding new varieties because maize yields are not very important in this system where a price ratio of up to 7:1 exists for the bean:maize ratio. Bean density is low (22,000 plants/ha). High chemical and organic fertilizer levels are applied for building up soil fertility and improving texture. Anthracnose appears to be the principal constraint to increasing yields. BCMV, *Empoasca*, oidium, angular leaf spot and asochyta leaf spot are frequently observed. Farmers spray fungicides (maneb) and insecticides frequently, 4- 8 applications/crop cycle.

Effects of Different Factors in Antioquia On-Farm Trials

Surveys in 1975 indicated mean bean yields of 568 kg/ha for Antioquia (Figure 52). However, in El Carmen, the most fertile and best administered region in this bean production zone of Antioquia, yields are estimated at 1 t/ha. With better agronomy, principally the substitution of benomyl for maneb, mean yields of 1.55 t/ha were obtained. Combining higher density (66,000 plants/ha) with benomyl applications increased yields to 2.1 t/ha. The high plant density required a reinforcing with stakes and thus cultural operations became more difficult and disease risk was increased. Even with the application of benomyl and a lower than normal rainfall the incidence of anthracnose in 1978 was significantly correlated with the density actually achieved.

Changing the fungicide from maneb to benomyl is a very low cost innovation. However, input costs are high in this higher density system (Table 73). Increased plant density and improved agronomy doubles farm income from Col.$35,000 to $74,000 with an increase in input costs of $11,000. Since staking is the principal component of increased costs further economies may be possible with modifications in the spacing between maize holes from 90 to 45 cm instead of staking.

Both the new varieties and inoculation still have technical problems to be resolved before they will be competitive with the above practices.



¹ Figures followed by the same letter are not significantly different at a 0.05 level

Figure 52. Effects of improved technology on bean yields in the on-farm trials in El Carmen, Antioquia (1978B).

Table 73. Costs and benefits of present farmers' practices compared to those of improved technologies in El Carmen, Antioquia (1978B).

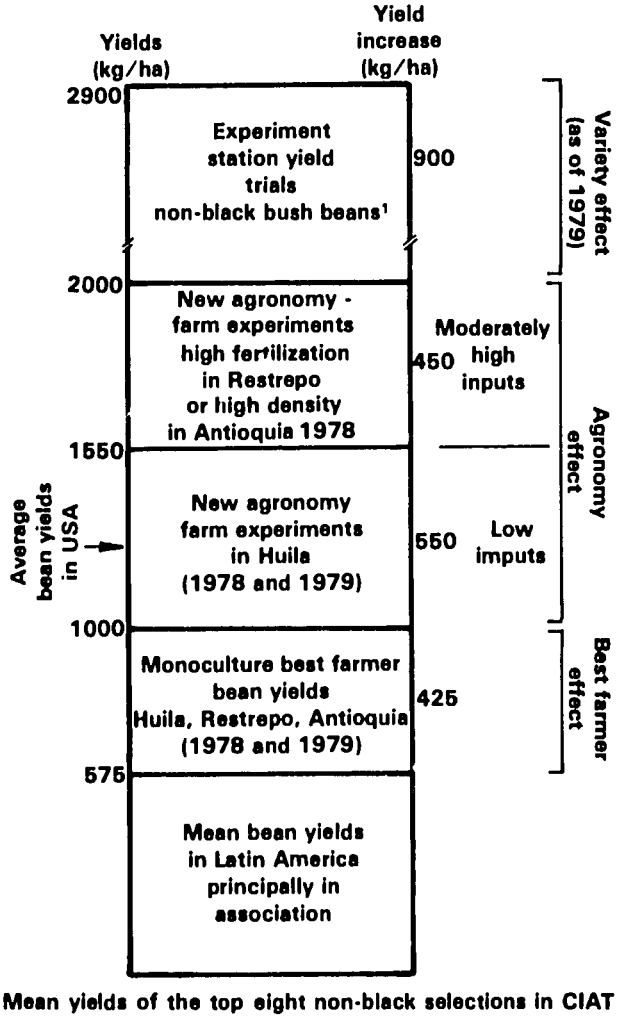
	Best farmers' practices	Farmers' density and seed appropriate chemicals	Farmers' seed, higher density + appropriate chemicals
Yields (kg/ha)	1,000	1,555	2,136
Gross revenue (Col. $)	45,000	69,975	96,120
Variable costs (Col. $)[1]	10,271	12,631	21,736
Net income (Col. $)	34,729	57,344	74,384
Increase in net income (Col. $)	-	22,615	17,040
Increase in costs (Col. $)	-	2,360	9,105

1 Included labor but no charge for land services or depreciation on the simple tools.

Conclusions

Improved agronomy involving low input use in Huila and moderately high input use in Restrepo and Antioquia was profitable and would be adopted by profit maximizing farmers according to the model results. After a year and a half of testing different types of improved seed including clean seed on farms in three regions over two seasons, it appears reasonable to conclude that without the BCMV resistance, clean seed has no economic importance, i.e., the observed yield gains do not justify the costs which would be incurred by national institutions in producing clean seed or other types of improved seed. With BCMV resistance in a new variety, it will be necessary to further evaluate the seed quality effect at the farm level.

The present yield gap between mean Latin American bean yields and CIAT experimental line yields in 1979 was almost 2.5 t/ha (Figure 53). With the farm trials this gap can be divided into three components. First, almost 0.5 t/ha can be explained as the difference between bean yields at low density in association (the system predominating in most regions of Latin America) and in monoculture with higher densities already found on better farms. Secondly, a 1 t/ha difference can be obtained from improved agronomy with the farmers' varieties. A 0.5 t/ha yield increase can be obtained principally with better agronomy without utilizing high input levels. Another 0.5 t/ha of the improved agronomy included relatively high input levels. Nevertheless, new experimental lines with resistances to diseases or insects or lower P re-



[1] Mean yields of the top eight non-black selections in CIAT in 1979.

Figure 53. bean yields in farmers' fields, on-farm experiments, and experimental station.

quirements could potentially substitute for some of the higher cost agronomic practices. Finally, the variety effect is another 0.9 t/ha as shown in the 1979B results.

Inoculation, incorporation of new experimental lines, and different cropping systems in bush beans are technological components that still remain to be evaluated.

SPECIFIC STUDIES

Temperature Adaptation

Two hundred and fifty selected germplasm accessions and advanced breeding lines from all four growth habits were planted at five Colombian locations (latitude range from 2-6°) with different temperature regimes, through adequate irrigation and fertilization, the physiological effects of temperature adaptation of *P. vulgaris* L. could be studied.

Table 74 summarizes selected yield data for the five locations. The yield of the five highest yielding materials at each location is shown for all five locations. These materials were chosen to illustrate the interactions and adaptation components that are occurring. Large breaks in adaptation occur at both temperature regime extremes (13 - 18° and 25 - 27°C). Target area study data (Figure 54) show that the majority of beans in Latin America are in fact grown between the temperature range (18 to 25°C) of the adaptation breaks observed. At the very low temperature site (Pasto) all adaptation groups produced a low or no yield. Only 67 of the 250 entries actually set seed with failure occurring at all reproductive stages. The break in adaptation was not as great for the high temperature site. In general, materials of growth habit Type IV produced higher yields than the other three growth habit types in the moderate and low temperature locations. Type I material performed well under the low temperature conditions and Type II at the high temperature location. Materials such as G02227 (IV) and G03451 (IV) are adapted well for moderate to low temperatures. Wide adaptation from low to high temperatures was found in G05653 (IV) which performed well at all three locations. Adaptation for very low and very high temperatures seems to be more specific. Of 600 materials planted in a recent experiment at Pasto, there are lines of Type I, II, and III exhibiting adaptation to very low temperature with experimental yields near to 2 t/ha.

A summary of the yield component data for the five adaptation groups is presented in Table 75. All the selected material showed a delay in flowering at low temperatures. Under these conditions, material adapted to moderate to high temperatures exhibited a greater delay than the low temperature material. It should be noted that the photoperiod was essentially equal at all locations. Since these lines vary in their sensitivity to photoperiod the data strongly suggest that an interaction between temperature and photoperiod exists which causes flowering delay. Future screening methods for delay in flowering should involve the two environmental conditions. A delay in physiological maturity occurred for all groups under lower temperatures not only due to late flowering but also by an excessive number of unfertile pods produced. This is evident from the data on the moderate adapted group where a large number of pods and few seeds per pod were produced at the low temperature locations. At the higher temperature sites the number of seeds per pod were high but yield was reduced due to few numbers of pods even though the plants had the same flowering period as in the moderate temperature site. This suggests that considerable flower abortion was occurring under high temperatures.

In general, all adapted groups tended to have the highest daily yield efficiency at the moderate temperatures; materials studied tend to be more adapted to moderate and high temperatures than to low temperatures.

Growth Habit Stability

Certain bean lines have been observed to be either indeterminate climbing (Type IV) or indeterminate non-climbing (Type II and III) depending upon the cropping location and season.

Table 74. Yield data for the highest yielding *Phaseolus vulgaris* L. materials from 250 entries at five locations having different temperature[1] regimes in Colombia.

Identification	Growth habit	Yield (t/ha) Santa Fé	Patía	Palmira	Popayán	Pasto
	Group 1: highest yielders at very high temperatures (Santa Fé)					
G02552	IV	2.23	2.84	3.11	3.10	0.00
G03689	II	2.22	2.93	2.42	2.72	0.00
G05213	II	2.14	2.52	3.26	2.63	0.00
G04461	II	2.14	2.77	2.59	2.66	0.00
FF036-3	II	2.12	2.39	2.71	2.87	0.00
	Group 2: highest yielders at high temperatures (Patía)					
G02115	IV	1.48	4.16	3.08	1.95	0.00
G05054	III	1.29	3.99	3.28	2.62	0.00
G03762	IV	1.57	3.60	3.49	2.84	0.00
G05653	IV	0.96	3.53	3.91	3.28	1.26
G03352	IV	1.43	3.50	4.44	2.78	0.27
	Group 3: highest yielders at moderate temperatures (Palmira)					
G02227	IV	0.96	2.08	4.45	3.21	0.14
G03352	IV	1.43	3.50	4.44	2.78	0.07
G02327	IV	1.52	2.57	4.33	3.16	0.00
G00685	IV	0.00	1.61	4.31	3.02	0.00
G02161	IV	2.07	2.77	4.26	2.78	0.00
	Group 4: highest yielders at low temperatures (Popayán)					
G03451	IV	1.22	2.92	3.41	3.32	0.00
G05653	IV	0.96	3.52	3.91	3.28	1.26
G03144	IV	1.53	2.70	3.66	3.27	0.19
G04524	II	2.10	2.56	3.74	3.22	0.00
G02227	IV	0.96	2.08	4.45	3.21	0.14
	Group 5: highest yielders at very low temperatures (Pasto)					
G04523	I	1.63	2.10	3.06	2.02	1.41
G05772	I	0.00	0.25	2.21	1.88	1.32
G08042	I	0.64	2.53	2.39	1.32	1.05
G05702	IV	0.00	0.34	1.36	1.83	0.94
G05701	IV	1.26	3.27	3.23	2.73	0.93
Location mean yield		1.26	2.26	2.57	2.38	0.43
LSD		0.47	0.80	0.63	0.69	0.26
CV %		23.5	22.3	15.2	17.9	37

1 Temperatures (°C): Santa Fé: mean = 26.7; max. = 31.3; min. = 22.1. Patía: mean = 25.5; max. = 29.7; min. = 21.5. Palmira: mean = 23.9; max. = 28.9; min. = 20.0. Popayán: mean = 17.9; max. = 23.9; min. = 11.0. Pasto: mean = 12.7; max. = 16.4; min. = 9.7.

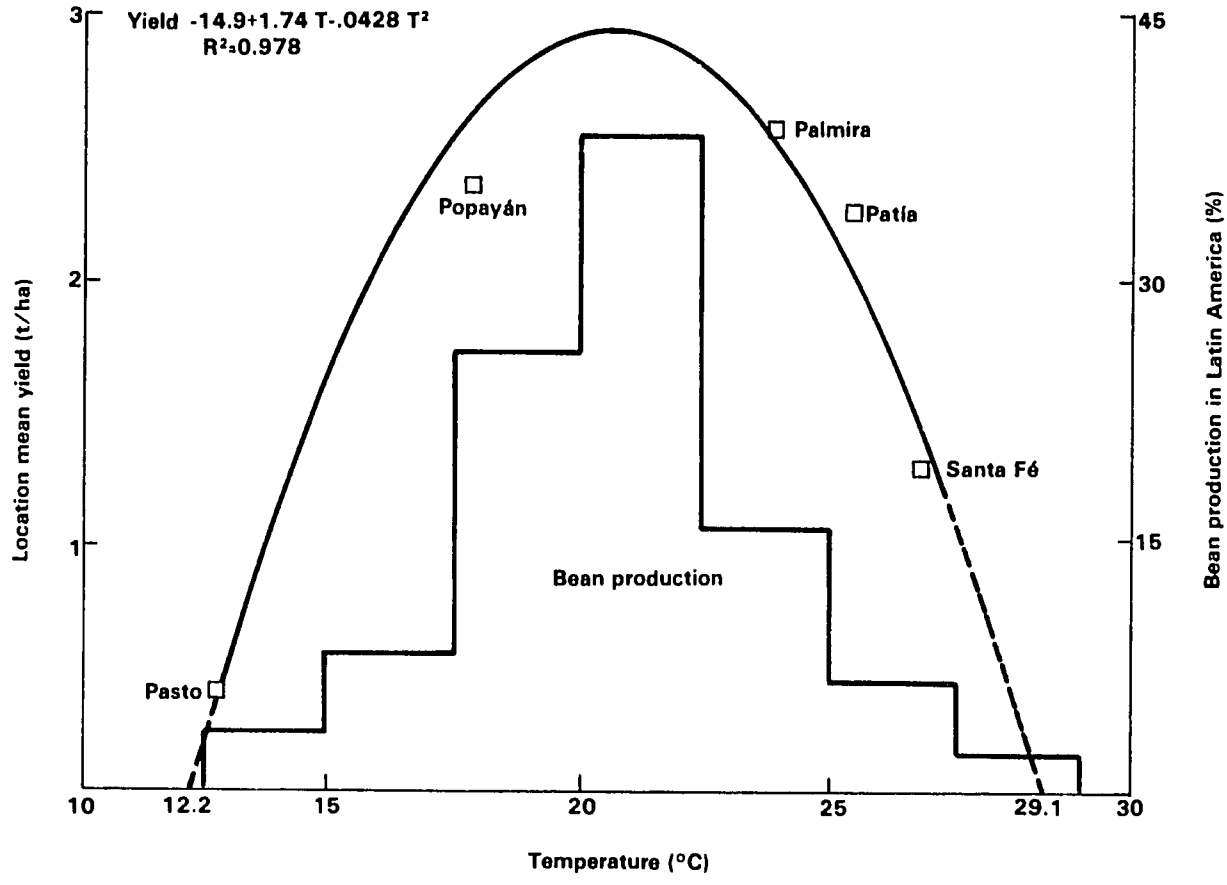


Figure 54. Mean yields of 250 materials at five Colombian locations with different temperature regions compared to bean production percentage, at mean temperatures in Latin America.

In controlled environmental chamber studies this change in morphology was due to a night break of red light (Figure 55). This response was nullified when red light was followed by far-red irradiation implying a photomorphogenic rather than a photoperiodic response. Research is continuing to study the feasibility of using a red light night break in the field to screen for growth habit stability.

Crosses were made of lines that exhibited growth habit instability to line G04454 that remained non-climbing under all red:far-red ratios. In the greenhouse and growth chamber, the climbing trait was controlled by one major gene based on segregation data in F_2 and backcross progenies from crosses to both parents. Red light stimulated the activity of this dominant allele and far-red light delayed it (Table 76). Genetic control of flowering sensitivity to long day photoperiod was independent of the gene for climbing *versus* non-climbing growth habits, suggesting that flowering and climbing are two genetically independent phytochrome-controlled responses.

F_2 and F_3 seeds from single plants, grown in the photoreversible experiments were planted at two locations which varied in altitude and temperature (Palmira 24°C, 1000 m; Patia 26°C, 600 m). Segregation studies from both locations for the parental, F_2 and F_3 populations deviated from the expected phenotypic ratios and indicated more nearly reversed dominance. Heterogeneity tests verified that these populations did not represent a set of samples from a single population, even though they were from a single population under controlled environmental conditions. This indicated that penetrance of the single gene observed under controlled conditions was highly dependent upon both environmental conditions und upon other genes in the genome.

Seedling Vigor

Research was conducted to develop an effective screening method for seedling vigor in the germplasm Twenty materials varying in seed size were used. Seed was selected for each variety within each size group

Table 75. Yield components of the five highest yielders from each adapted group of *Phaseolus vulgaris* L. selected from 250 entries at five locations at each temperature regime.

Adaptation groups[1]	Temperature regime				
	Very low	Low	Moderate	High	Very high
			Days to flower		
1	93	56	39	37	36
2	87	49	36	39	36
3	85	50	35	39	38
4	85	50	37	37	40
5	76	47	40	39	35
Location mean	76	51	37	36	35
LSD	4.0	2.5	2.0	1.5	1.9
			Days to physiological maturity		
1	159	103	82	84	84
2	159	99	86	92	92
3	157	105	90	95	100
4	157	99	88	90	94
5	151	100	84	95	100
Location mean	153	101	81	87	87
LSD	6	2.3	1.2	0.62	0.47
			Number of pods/m^2		
1	0	229	219	229	228
2	121	200	302	290	151
3	429	207	305	177	147
4	325	241	279	225	148
5	139	115	169	129	130
Location mean	197	193	219	199	160
LSD	196	82	62	81	145
			Number of seeds/pod		
1	0.0	5.6	6.1	5.5	5.0
2	1.4	4.4	4.5	4.5	4.5
3	0.5	4.7	6.1	5.1	5.1
4	1.0	5.0	5.3	4.9	4.5
5	2.0	4.0	3.9	3.3	3.0
Location mean	1.0	4.8	5.1	4.7	4.2
LSD	0.68	1.32	1.1	1.0	0.92
			Weight per seed (mg)		
1	0	192	177	188	190
2	218	279	239	256	208
3	240	279	246	251	224
4	198	250	228	228	210
5	396	402	333	313	303
Location mean	301	250	214	222	202
LSD	78	36	30	26	0.03
			Yield per day (g)		
1	0.0	2.7	3.7	3.2	2.6
2	0.3	2.7	4.3	4.2	1.5
3	0.1	2.9	4.8	2.7	1.2
4	0.2	3.3	4.4	3.1	1.4
5	0.8	2.0	2.9	2.0	1.0
Location mean	0.3	2.4	3.2	2.6	1.5
LSD	0.17	0.68	0.75	0.92	0.66

1 Group 1-5: groups of five highest yielders at very high temperature to very low temperature location, respectively.

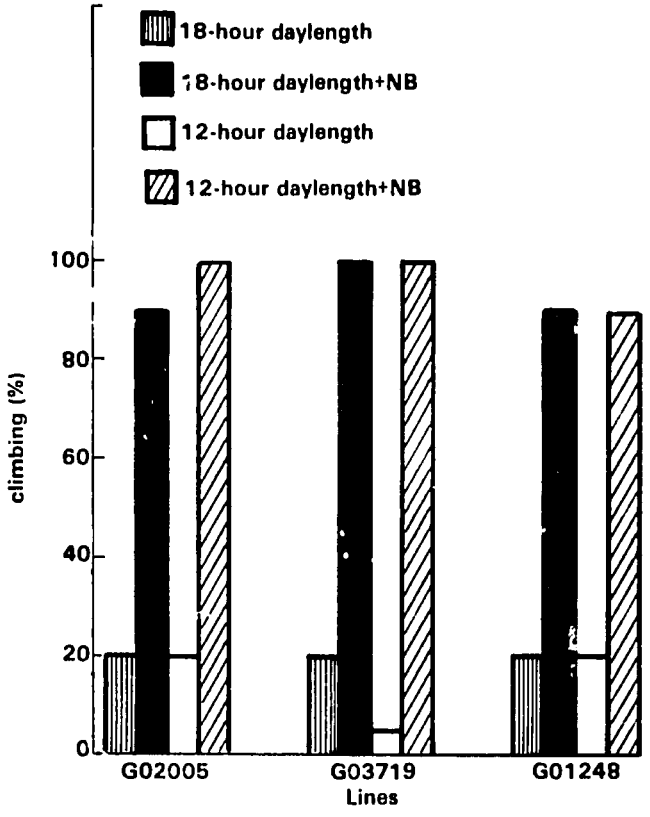


Figure 55. Occurrence of climbing habit in three bean lines under two daylengths with and without a red light night break (NB) of 15 minutes.

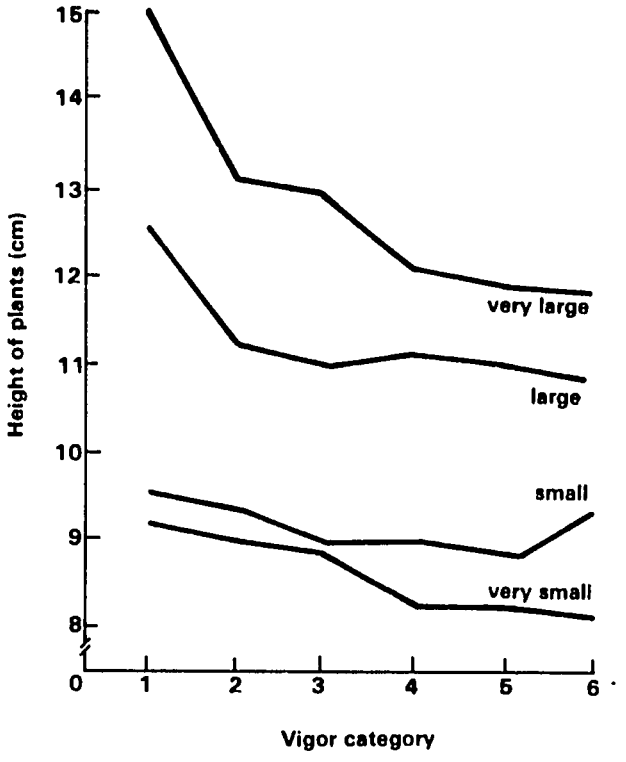


Figure 56. Height of plants (19 days after planting) *versus* vigor categories for four bean seed size groups.

Table 76. Number of climbing and non-climbing plants of parental and F_2 populations of beans grown under an 18-hour photoperiod with a 15-minute night break of red followed by far-red light.

Population	Red light		Red/far-red	
	Climbing	Non-climbing	Climbing	Non-climbing
Parent				
G03719	6	0	0	3
G01248	6	0	0	3
G02005	4	0	0	3
G04454	0	17	0	9
F_2				
G03719 x G04454	32	10	0	14
G04454 x G01248	22	7	0	14
G0445 x G02005	21	7	0	14

using a non-destructive seed conductivity method. This methodology separated seed within each size group into eight categories according to their vigor.

In general larger seeded lines produced taller plants 19 days after planting. The reverse was true for relative growth rate (RGR) and rate of germination index (RGI).

The equipment used (Model MSS-110, Agro Sciences Michigan) performed well in separating seed according to relative vigor measured by height of plant, RGR and RGI but not for net assimilation rate. Figures 56 and 57 show seedling vigor categories are independent to the seed size categories. A significant correlation existed for weight of seed *versus* height of plant (0.57) and significant negative correlations for both RGR (-0.89) and RGI (-0.75). Correlations between height of plant, RGR, and RGI *versus* seed vigor categories were -0.83, -0.97, and -0.90, respectively.

This methodology appears promising as a rapid means of seed selection for relative seedling vigor.

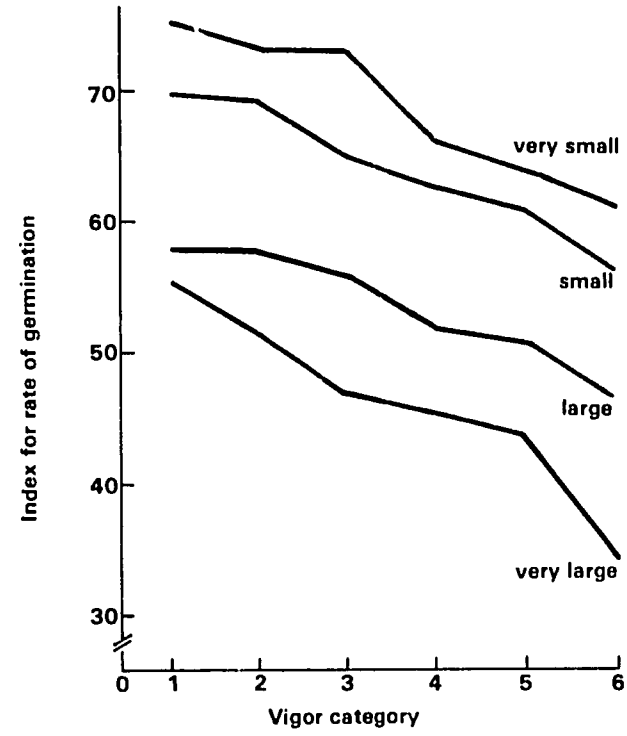


Figure 57. Germination index *versus* vigor categories for four bean seed size groups.

REGIONAL ACTIVITIES

Central America and the Caribbean

Activities focussed on strenghtening the research and technology transfer network in the region with CIAT's headquarters in Palmira, Colombia. Activities include selection of trainees, organization of meetings and workshops, germplasm distribution, and collaboration with national programs in specific projects. Outposted staff also assist in evaluation of nurseries and participate in the ICTA-CIAT collaborative project on development of BGMV resistant germplasm.

PCCMCA

The program had an active participation in the organization and realization of the Grain Legume Section of the XXV Annual Meeting of the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios, PCCMCA, in Tegucigalpa, Honduras

Short Course on Bean Production

The program aided in the organization of an intensive short course on Bean Production for local researchers in Honduras sponsored by the Programa de Maíz y Fríjol, PROMYF.

Lines Tolerant to BGMV

A meeting with bean leaders from Mexico, Central America, Panama, Haiti, and the Dominican Republic was organized to become familiar with the new lines tolerant to BGMV in Guatemala and El Salvador, and to coordinate future plans for the area. Three varieties developed from CIAT materials by the Instituto de Ciencia y Tecnologia Agricola (ICTA) of Guatemala were released.

Technology Transfer

Nurseries from CIAT for yield and adaptation tolerances to heat and drought, *Empoasca, Apion,* BGMV, and web-blight, and early and advanced

breeding lines were distributed to different countries for the February, May and September plantings. Approximately 1250 kg of seed were distributed throughout the region.

National programs were encouraged to form their own yield and adaptation nurseries VINAR. VINARs from Honduras, Guatemala and Costa Rica were distributed to the other national programs in the region. The VINAR from Guatemala was also sent to CIAT, Brazil, Jamaica, and Puerto Rico.

As a result of the work with these materials in collaboration with the national programs several varieties were adopted or released during the year (Table 77). It is the first time materials produced at CIAT are being considered for their release as new varieties.

ICTA/CIAT Collaborative Project

The most limiting bean disease in southeast Guatemala is Bean Golden Mosaic Virus. The virus is also an important production constraint in regions of El Salvador, Honduras, Cuba, Brazil, and the Dominican Republic. In cooperation with the Instituto de Ciencia y Tecnologia Agricola (ICTA) of Guatemala, a project has been advanced to search for host plant resistance to BGMV.

Local Guatemala varieties, such as Rabia de Gato, are highly susceptible to BGMV. During 1977 a breeding program was initiated, and 41 hybrid populations were evaluated. After several seasons of testing on experiment stations and in farm trials (Tables 78 and 79) in monoculture and in associated cropping systems, and at different levels of fertilizer and insecticide inputs, three advanced hybrid selections resistant to BGMV were named as new varieties by ICTA late in 1979 (Table 77).

Data from ICTA (Table 80) shows that one of the resistant lines, without chemical protection against the whitefly vector of the virus, yielded more than the treatment in which the local (susceptible) variety was protected by both granular pre-plant and foliar insecticides. ICA-Pijao and Turrialba 1, both parents of numerous BGMV crosses, have been released in southeastern Guatemala and frequently serve as resistant checks.

Table 77. Variety released in Central American or Caribbean countries from IBYAN materials including varieties or CIAT advanced breeding lines.

Line or variety	Name	Country
Line 32	ICA-Pijao (ICTA-Suchitan)	Cuba, Guatemala, Costa Rica
ICA-10103	Talamanca	Costa Rica, El Salvador
	Porrillo 1 (ICTA-Culma)	Guatemala
	ICA-Tui	Costa Rica
Br. 2	Bico de Ouro	Trinidad & Tobago
	Ex Rico 23	Trinidad & Tobago
DOR 41	ICTA-Quetzal	Guatemala
DOR 42	ICTA-Jutiapan	Guatemala
DOR 44	ICTA-Tamazulapa	Guatemala
FF11-10-1-CM-2-7	Acacia 6	Honduras

Table 78. Monoculture bean yields of experimental lines with or without high BGMV pressure (ICTA Regional Trials).

Line	Identification	Population	Disease rating[2]	Yield (kg/ha) With BGMV	Yield (kg/ha) Without BGMV	Relative yield (%)
DOR 44	FF2152-1-CM(7)	F_6	5.0	1486	2106	70
D-11	FF424-5-CB-1	F_8	5.0	1386	2039	68
D-34	FF1012-CB-CB	F_8	6.0	1314	1954	67
DOR 41	FF1006-4	F_8	5.0	1300	2478	52
D-82	FF2152-CM(3)	F_6	6.0	1288	2309	56
DOR 42	FF1012-CB-CB	F_8	5.0	1233	2420	51
D-33	FF972-2-CB	F_8	6.5	1217	2640	46
D-37	FF1012-3-CB	F_8	5.3	1207	2688	45
D-52	FF2175-M-4	F_7	6.0	1184	2421	49
D-51	FF2175-M-3	F_7	5.0	1177	2841	41
D-38	FF2158-M-CM(12)	F_7	6.3	1106	2284	40
D-50	FF2175-M-2	F_7	6.3	1050	1885	56
D-6	FF446-8-CB	F_8	6.7	1020	1846	55
D-55	FF2179-CM-3	F_7	6.5	989	1894	52
D-45	FF2160-M-4	F_7	6.3	956	3078	31
D-29	FF1006-3	F_8	6.0	932	2336	40
P675	ICA-Pijao	-	5.7	1111	2462	45
P709	Turrialba-1	-	5.7	651	2196	30
P9	Pecho Amarillo	-	8.0	546	2540	21
LSD (0.01)					903	
CV %					20.7	

1 High BGMV pressure in Monjas site, 1978; no BGMV pressure in San Jerónimo site, 1979.
2 BGMV rating in Monjas site, 1978: 1-3 = resistant; 4-6 = tolerant; 7-9 = susceptible.

Table 79. Reaction to BGMV and rust, and yields of bean lines in association with maize in on-farm trials, Guatemala.

Line	Identification	Population	Reaction to:[1] BGMV	Reaction to:[1] Rust	Yield (kg/ha)
DOR 44	Tamazulapa	F_6	T	T	1893
DOR 41	Quetzal	F_8	T	T	1555
D-51	FF2175-M-3	F_7	T	T	1521
P675	ICA-Pijao	-	T	T	1469
DOR 42	Jutiapan	F_8	T	T	1307
P709	Turrialba 1	-	T	T	1273
D-52	FF2175-M-4	F_7	T	T	1254
	PI 310739	-	T	S	1199
78-12		-	S	S	1114
78-10			T	S	880
	Rabia de Gato	-	S	S	264
LSD (0.01)					577
CV %					27

1 BGMV or rust rating: T = tolerant; S = susceptible.

Table 80. Yields of improved and traditional varieties with an without insecticide protection, and under BGMV pressure in on-farm trials in Guatemala.

Variety	Yield (kg/ha)		Yield increase (%)
	Without insecticides	With insecticides[1]	
Jutiapan (DOR 42)	2133	3443	62
ICA-Pijao (P675)	1678	3535	48
Rabia de Gato (P739)	280	1959	14

1 Includes 20 kg/ha carbofuran 5G and five applications of methamidophos.

Table 81. Results of 1979 preliminary yield trials under heavy BGMV pressure in Monjas, Guatemala

Line	Identification	Population	Reaction to BGMV[1]	Yield (kg/ha)
-	DR3757-8g-CM(11)	F_4	6.0	678
-	DR3757-5g-CM(7)	F_4	5.5	668
-	DR3737-1g-CM(8)	F_4	6.0	668
Jutiapan (DOR 42)	FF1012-CB-CB-CM(2g)	F_8	6.5	624
P675	ICA-Pijao (Suchitán)	-	7.0	585
P757	Porrillo 1	-	7.0	412
P488	Porrillo 70	-	7.0	357
P9	Pecho Amarillo	-	7.5	222
P709	Turrialba-1	-	7.0	220
P6	PI 313739	-	8.0	178
P712	51052	-	8.0	107
LSD (0.01)			1.1	360

1 BGMV rating: 1-3 = resistant; 4-6 = tolerant; 7-9 = susceptible.

Yield trials of selections from the second (1978) group of progenies included one of the three earlier lines (DOR 42) as the resistant check. Under severe BGMV pressure, several new lines appear even more promising than the recently named varieties (Table 81), suggesting that further gains may be obtained from intermating the most superior selections from diverse genetic backgrounds. Eighty seven F_2 populations from such intermatings, made at CIAT, were evaluated in Guatemala during 1979.

TRAINING AND COMMUNICATION ACTIVITIES

Training

In collaboration with CIAT's Training Office, which has major responsibilities in coordinating all CIAT training efforts, the Bean Program trained a total of 114 professionals from 23 countries in different areas of specialization (Table 82).

Conferences

Two major workshops were held this year at CIAT: the first from November 12-14 on Anthracnose, Angular Leaf Spot, and Common Bacterial Blight with the participation of 40 scientists from different countries; and the second, from November 19-23 on Bean Genetic Improvement, with 12 active breeders of 11 countries.

Audiotutorial Materials

The development of auto-didactic materials (audiovisuals accompanied by study guides) on bean technical information continued throughout 1979 in collaboration with CIAT's Communication Support Unit. These teaching sets are used by training participants as complementary aids of classroom, laboratory, and field work. During the year efforts were accelerated to disseminate these materials to research, extension, and teaching institutions throughout Latin America. These sets have proved to be effective in support of CIAT-sponsored in-country training courses. Table 83 shows the list of audiotutorial units on beans presently available.

Printed Media

New titles published in CIAT during 1979 are shown in Table 84. In collaboration with the Communication Support Unit the Bean Program developed a bimonthly newsletter entitled "Hojas de Fríjol". It is written to provide bean workers throughout the region with timely information activities within the various countries as well as in CIAT and other institutions around the world.

Table 82. Number of professionals trained in beans at CIAT in 1979 by discipline of specialization and category of training.

Discipline of specialization	Postdoctoral Fellows	Visiting Research Associates	Research Scholars	Postgraduate Research Interns	Postgraduate Production Interns	Special trainees	Short course participants	Total
Agronomy	-	1 (4.0)[1]	2 (13.0)	13 (47.5)	-	-	-	16 (64.5)
Biometrics	-	1 (3.0)	-	-	-	1 (1.0)	-	2 (4.0)
Crop mechanization	-	-	-	-	-	1 (1.0)	-	1 (1.0)
Economics	-	1 (12.0)	2 (14.0)	2 (5.5)	-	-	-	5 (31.5)
Entomology	1 (12.0)	-	-	5 (13.5)	-	-	-	6 (25.5)
Germplasm	-	2 (17.0)	-	1 (0.5)	-	-	-	3 (17.5)
Plant breeding	1 (12.0)	5 (34.0)	1 (12.0)	6 (13.5)	-	-	-	13 (71.5)
Plant pathology	-	2 (7.0)	3 (20.0)	5 (10.5)	-	-	-	10 (37.5)
Plant physiology	2 (15.0)	2 (11.0)	1 (11.0)	-	-	-	-	5 (37.0)
Production	-	-	-	-	-	-	66 (67.0)	66 (67.0)
Plant virology	1 (6.0)	1 (12.0)	-	2 (2.0)	-	1 (8.0)	-	5 (28.0)
Soil microbiology	-	-	1 (4.0)	3 (9.0)	-	-	-	4 (13.0)
Training	-	-	-	2 (3.5)	-	-	-	2 (3.5)
Total	5 (45.0)	15 (100.0)	10 (74.0)	39 (105.5)	-	3 (10.0)	66 (67.0)	138[2] (401.5)

Numbers in parenthesis are man-months of training.
The actual number of professionals trained during 1979 was 114. The 138 figure is inflated due to the fact that some trainees received further training in other categories. Countries of origin of professionals trained:

Argentina	(6)	Costa Rica	(8)	Guatemala	(9)	Perú	(6)	Sri Lanka	(1)
Bolivia	(3)	Cuba	(11)	Haití	(1)	Australia	(1)	Tanzania	(2)
Brazil	(28)	Dominican Republic	(5)	Honduras	(4)	Belgium	(3)	United States	(7)
Chile	(3)	Ecuador	(6)	Mexico	(9)	Holland	(1)		
Colombia	(12)	El Salvador	(7)	Nicaragua	(2)	Kenya	(3)		

Table 83. Audiotutorial units on beans available as of December 31, 1979 (only in Spanish).

Series	Title
04SB-05.01	Descripción y daños de las plagas que atacan el fríjol
04SB-05.03	Principales insectos que atacan el grano de fríjol almacenado y su control
04SB-06.01	Enfermedades del fríjol causadas por hongos y su control
04SB-06.02	Enfermedades del fríjol causadas por virus y su control
04SB-06.04	Técnicas para aislamiento, identificación y conservación de hongos patógenos al fríjol
04SB-06.06	La roya del fríjol y su control
04SB-08.02	Cruzamiento del fríjol
04SB-09.01	Morfología de la planta de fríjol común (Phaseolus vulgaris L.)
04SB-09.02	Diversidad genética del género Phaseolus
04SB-12.03	Semilla de fríjol de buena calidad

Table 84. Publications on beans issued in the established CIAT series during 1979.

Code	Title	Language	Pages	Press run
02E1B-79	Annual Report 1978	English	78	359
02S1B-78	Separata Informe Anual 1978	Spanish	85	1200
20S/EB3-79	Preliminary Trials (EP) 1979	Eng./Span.	32	600
20SB2-76	IBYAN/Fríjol Arbustivo (1976)	Spanish	202	600
20EB-1	International Bean Rust Nursery Results 1975-76	English	19	1200
20SB-1	Vivero Internacional de Roya del Fríjol Resultados 1975-76	Spanish		
20EB-2	International Bean Rust Nursery Results 1977-78	English	20	900
20SB-2	Vivero Internacional de Roya del Fríjol Resultados 1977-78	Spanish		
09EB-1	Bean Production Problems: Disease, Insect, Soil and Climatic Constraints of Phaseolus vulgaris	English	432	3000
09SB-1	Problemas de Producción del Fríjol: Enfermedades e Insectos y Limitaciones Edáficas y Climáticas de Phaseolus vulgaris	Spanish	432	2000
01NB-1	Directorio de Investigadores en Fríjol de América Latina y el Caribe	Spanish	92	750
08EB-4	Abstracts on Field Beans, Vol. IV	English		1500
08SB-4	Resúmenes sobre Fríjol, Vol. IV	Spanish		1500

FUTURE PLANS

The Bean Program has an efficient operational scheme for germplasm evaluation, improvement and distribution. Tolerance or resistance to most production constraints have been identified and are being incorporated systematically into lines with superior yield. Twenty one of these lines derived from CIAT's breeding and evaluation program are currently in various stages of on-farm trials in the Latin American network.

Large yield and profit increases were consistently achieved in farm trials in Colombia, with both bush and climbing beans by simple agronomic practices.

The program will continue the systematic development of lines with an increasing number of resistance factors. However, increased emphasis will be given to areas where resistance is lacking or where the team feels progress is not adequate.

Pyramiding resistance or tolerance to common bacterial blight will receive increased attention, as this disease is considered one of the most important production constraints in the warmer bean production zones. More detailed studies will be made on drought tolerance since the target area study has identified the importance of this factor. Tolerance to low P, soil acidity, and the combination of these two with low fertility will also need further efforts, especially for the Brazilian production situation. Screening for more stable rust resistance will continue receiving high priority.

Until now no traits have been identified that influence yield potential. Research in physiology based on genetic variability identified in morphology and other characteristics will receive increased attention. This is especially appropriate as genetic variability and methodologies are available for meeting the Bean Program's main objective of developing lines with multiple pest resistance.

The germplasm development flow will be further improved expecting national programs to participate more intensively.

With an intensive collaborative network presently operating in Latin America, the program intends to direct part of its efforts to Eastern Africa, the second most important bean production area in the tropics. This outreach activity will be based on results of a regional conference to be held in Malawi in March 1980 on bean production potential in that area.

APPENDIX A

Description of growth habits of *Phaseolus vulgaris* L. used in this Annual Report

TYPE I: Determinate growth habit; reproductive terminals on main stem; with no further node production on the main stem after flowering commences.

TYPE II: Indeterminate growth habit; vegetative terminals on main stem with node production on the main stem after flowering commences; erect branches borne on the lower nodes of the main stem; erect plant with relatively compact canopy; guide development variable depending on environmental conditions and genotype.

TYPE IIIa: Indeterminate growth habit; vegetative terminals on the main stem with node production on the main stem after flowering; relatively heavily branched with variable number of facultatively climbing branches borne on the lower nodes; main stem guide development variable but generally showing climbing ability.

TYPE IIIb: Indeterminate growth habit; vegetative terminals on the main stem with node production on the main stem after flowering; relatively heavily branched with variable number of facultatively climbing brances borne on the lower nodes; main stem guide development variable but generally showing climbing ability.

TYPE IVa: Indeterminate growth habit; vegetative terminals on the main stem with heavy node production after flowering commences; branches not well-developed compared to main stem development; moderate climbing ability on supports and pod load carried evenly along the length of the plant.

TYPE IVb: Indeterminate growth habit; vegetative terminals on the main stem with heavy node production after flowering commences; branches not well-developed compared to mainstem development; strong climbing tendency with pod load mostly borne on the upper nodes of the plant.

NOTES: The growth habit classification has been expanded for the climbing types since the 1977 Annual Report. Type III materials with some tendency to climb are now recognized as Type IIIb and Type IV has been divided on the basis of vigor and pod distribution.

The most important distinguishing features of the growth habits are as follows: terminal raceme on main stem for Type I; indeterminate with erect branches for Type II; indeterminate with prostrate branches for Type IIIa; indeterminate with semi-climbing mainstem and branches for Type IIIb; indeterminate with moderate climbing ability and pods distributed evenly up the plant for Type IVa; indeterminate with aggressive climbing ability and pods carried mainly on the upper nodes of the plant for Type IVb.

Growth habit is not necessarily a stable characteristic since changes in growth habit may occur from one location to another. The classification of growth habit for a particular genotype is only useful in a defined environment, particularly with regard to climbing ability.

Appendix B. List of CIAT accessions of Phaseolus referred to in the 1979 Bean Program Annual Report.

G number	Identification and/or local register	Source
00022	PI 136677	United States
00023	PI 136678	United States
00122	Jatu Rong (PI 163120)	United States
00124	PI 163372	United States
00159	Cali Fasulya (PI 165078)	United States
00445	Guz (PI 173766)	United States
00574	Tombul (PI 177032)	United States
00677	PI 181892	United States
00685	PI 182007	United States
00983	PI 224738	United States
01248	PI 200947	United States
01401	PI 224743	United States
01753	Negro (PI 308909)	United States
01821	F. Garbancillo (PI 309805)	United States
02005	PI 310739	United States
02006	PI 310740	United States
02047	PI 310805	United States
02115	PI 310878	United States
02165	PI 311781	United States
02227	PI 311861	United States
02258	PI 311904	United States
02303	PI 311959	United States
02326	PI 311991	United States
02327	PI 311992	United States
02333	PI 311998	United States
02402	F. Garrapato (PI 312092)	United States
02512	PI 313592	United States
02525	PI 313624	United States
02540	PI 313653	United States
02545	PI 313658	United States
02552	PI 313665	United States
02618	PI 313755	United States
02764	PI 317586	United States
02801	F. Almendrilla (PI 319597)	United States
02839	Amapolo de Camino (PI 319642)	United States
02858	F. Zacaticano (PI 319665)	United States
02959	Pecho Amarillo	Guatemala
03131	F. Negro	Guatemala
03144	Jamaica	Guatemala
03159	V. San Isidro Media Guía	Guatemala
03352	Puebla 151B	Mexico
03366	Puebla 240A	Mexico
03371	Puebla 298	Mexico
03445	Guanajuato 22	Mexico
03451	Guanajuato 116-A	Mexico
03467	Michoacan 31	Mexico
03607	C.C.G.B. 44	Venezuela
03627	S-182-R	Venezuela
03689	S-31552	Venezuela
03719	Mexico 12-1	Venezuela
03762	Negro de Guatemala	Venezuela
03781	Venezuela 22	Venezuela

Appendix B. cont.

G number	Identification and/or local register	Source
03790	Venezuela 46	Venezuela
03800	Venezuela 72	Venezuela
03807	Brasil 2	Venezuela
03834	51051	Venezuela
03843	Seminole	Venezuela
03872	Trujillo 3	Venezuela
04000	Nep-Bayo 22	Costa Rica
04017	Feijao Carioca	Costa Rica
04120	Iguacu	Costa Rica
04153	50580	Costa Rica
04211	Venezuela 66	Costa Rica
04346	Michoacan 50	Mexico
04421	S-630B	Costa Rica
04446	Ex-Puebla 152 (brown seeded)	Mexico
04445	Ex-Rico 23	Colombia
04452	ICA-Guali	Colombia
04454	ICA-Tui	Colombia
04459	Nep-2	Costa Rica
04461	Porrillo = 1	Costa Rica
04464	Turrialba 2N	Costa Rica
04489	Culiapa 72	Guatemala
04523	Linea 17	Colombia
04524	Linea 29	Colombia
04525	Lines 32	Colombia
04567	Ant. 130	Colombia
04637	Cun. 115C = Arbolito	Colombia
04682	Nar. 23 = Matahambre	Colombia
04835	Puebla 56C Blanco	Mexico
05054	H-1 Mulatinho	Brazil
05059	H-6 Mulatinho	Brazil
05066	BRZ-374	Brazil
05158	Bico de Ouro 1445	Brazil
05169	BRZ-976	Brazil
05201	Mexico 528	Brazil
05213	I-113	Brazil
05468	NH-697	Costa Rica
05652	Mexico 309	El Salvador
05653	Ecuador 299	El Salvador
05701	Rojo 70	El Salvador
05702	Cargamanto	Colombia
05712	Comp. Chimaltenango 3	Guatemala
05762	Jalisco 33	Mexico
05764	Mexico 6	Mexico
06533	Vermelho	United Kingdom (England)
08042	GPL-1	Kenya

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(as of December 31, 1979)

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