Specific Character Improvement

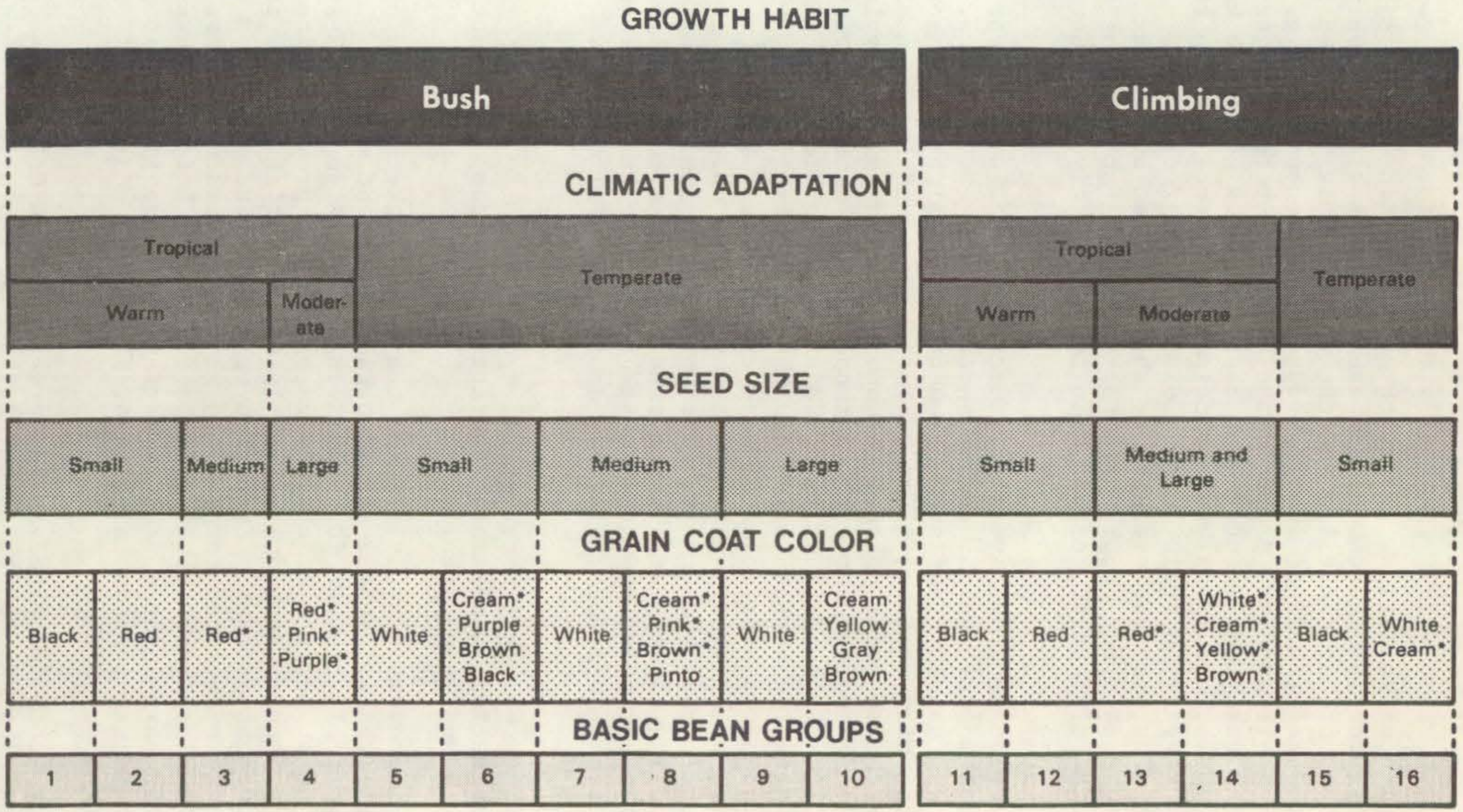
Very conspicuous variations in growth habits, grain colors, sizes and forms, etc., occur among commercial bean varieties grown in various production regions of Latin America and the world. This variation is sometimes due to preferences of local producers and consumers--e.g., mulatinho in the northeast vs. preto in the southern states of Brazil. In both these regions, small-seeded bush bean varieties of growth habits II and III are grown, and, thus, the principal difference between the two groups of varieties is grain color. Similarly, agroclimatic conditions, cropping systems, presence or absence of an overriding desirable trait, demand for export markets, and other factors also help determine the predominance of certain bean types in a given production region.

Bean-production problems are also enumerable. While some problems, e.g., bean common moscaic virus, common bacterial blight, Empoasca, rust, anthracnose, angular leaf spot, drought, etc., might be common across most production regions, great variation is found in the number, symmatry, and relative order of their economic importance. Screening and evaluation of germplasm for each of these factors generally require very specific climatic conditions. In addition, there are great variations in screening methodologies and the incompatibility of generating simultaneous artificial disease epiphytotics, insect infestation, simulation of drought conditions, and so on. Thus, it is difficult to handle more than two to three production limiting factors in a single breeding nursery at a given time. In order to identify desirable genetic variation and utilize it effectively and efficiently in bean improvement, therefore, CIAT has adopted the following two strategies:

1. Specific character improvement.
2. Recombination of desirable characters according to production regions and bean types.

The above improvement activities of the Bean Program evolved over a period of several years, but the formal organization and working conditions (Figure 1) were put forward during 1981. A continuous search for better and newer sources of characters across all growth habits, grain types, and bean-production regions is the essential part of the character-improvement process. Each of over a dozen and a half agronomic characters required for solving major production problems is being handled in a separate breeding project. The principal emphasis in each, however, is maximizing character expression, stability, adaptive range, and usefulness by recombining favorable genes, sources, mechanisms, and so on.

Breeding projects for problems not present within Colombia--e.g., bean golden mosaic virus (BGMV), Apion, Epilachna, web blight, drought, etc.--and those with wide pathogenic variation, such as rust, depend largely on collaboration from national programs and their natural occurrence.



* Includes solid as well as mottled, striped, and speckled types.

Figure 1. Criteria for establishing the basic groups for bean germplasm development and evaluation for Latin America.

The original and improved sources of desirable traits are available to all interested bean researchers, either through international nurseries or upon individual request.

Resistance to Viral Diseases

Bean Common Mosaic Virus (BCMV)

Screening of individual selections. A total of 5546 individual bush bean lines, involving approximately 112,000 plants, was inoculated this year with a mixture of the Florida and New York 15 strains of BCMV and evaluated for their resistance. The screening of climbing beans was intensified in 1981, reaching a total of 2217 selections or 24,410 plants individually inoculated and evaluated using the above-mentioned BCMV strain mixture. The screening of climbing materials was carried out under special planting conditions (lower density and improved soil fertility) and in a glasshouse where symptom expression was greatly enhanced.

Screening of selected grain types. Some important modifications to the screening methodology implemented in 1979 were introduced this year in order to detect materials that do not show disease symptoms after their inoculation with mosaic-inducing BCMV strains such as Florida and New York 15. Among these materials, the large red, red-mottled, canario (ochre), and pinto grain types have frequently been observed to escape detection. These materials are now being inoculated with BCMV NL3, a necrosis-inducing strain, to detect the presence of the dominant necrosis (I) gene, which confers resistance to systemic mosaic. A total of 1625 materials (23,680 plants) was inoculated this year with the BCMV NL3 strain under screenhouse and glasshouse conditions. The development of systemic or local vein necrosis was approximately the same in the two environments, but the inoculated primary leaves of some materials dropped off the plants at an earlier stage in the screenhouse, making the evaluation more difficult. This phenomenon of leaf abscission, characteristic in some BCMV NL3-infected bean plants, was delayed under glasshouse conditions.

Simultaneous mosaic and necrosis test. An inoculation technique was developed to achieve maximum infection and symptom expression with some bean-breeding materials selected to investigate the possibility of genetic linkage between grain color, size, and BCMV susceptibility. Each plant tested was simultaneously inoculated with the Florida (mosaic-inducing) and NL3 (necrosis-inducing) strains of BCMV, using one strain per primary leaf. Ten days later, the plants were evaluated for the presence of either mosaic or necrosis. The efficiency of detection of homozygous-resistant and of heterozygous- and homozygous-susceptible plants was 100% in the first test involving a total of 1080 plants (54 selected materials).

Evaluation of advanced breeding lines. The 191 entries selected for the 1980 Preliminary Trials (EP) were screened to confirm both their resistance to mosaic-inducing BCMV strains and the presence of the dominant I gene, which confers this resistance. For the evaluation, 20 plants were inoculated with the mosaic-inducing Florida strain and 20 plants with the necrosis-inducing NL3 strain of BCMV, for each entry. The results obtained were in complete agreement with those of previous evaluations, and the BCMV-resistant bean selections were demonstrated to carry the dominant I gene.

Breeding for black root resistance. The Bean Program continued its fourth year of collaboration with the Plant Breeding Institute (IVT) in the Netherlands to incorporate recessive genes, which protect against necrosis-inducing strains of BCMV, into commercial grain types already possessing the dominant hypersensitive resistance to mosaic-inducing strains of the virus. The first group of backcrosses, made in 1980, incorporated the recessive genes into tropically adapted lines. This year the second backcross was made. Breeding lines representing the major color groups of beans grown in Latin America were chosen to use as the backcross parent. The crosses are listed in Table 1.

In addition to the backcross program, 84 advanced families from crosses to especially difficult color groups (large red mottles and canario grain types) were tested for the presence of dominant I gene resistance. Sixteen families were homozygous-resistant to BCMV mosaic strains, while 18 families were segregating resistant and susceptible plants and 47 families were fully susceptible to the combination of mosaic strains used. The resistant families are being used as parents in the crossing program.

Yield reduction due to BCMV. Resistance to BCMV is almost nonexistent in traditional highland varieties, and yet the disease is not commonly observed in most highland areas. This may be due either to a lack of vectors or to reduced symptom expression in varieties adapted to cool temperatures. In order to study the potential importance of BCMV in highland varieties, a trial was conducted in Popayan with the variety Cargamanto, inoculated at the primary leaf stage with a mixture of the two strains Florida and New York 15. The trial was planted at the end of the wet season to encourage symptom expression and, consequently, yields were low. An average of 42% of the plants in the inoculated plots showed symptoms. The yield in inoculated plots was 520 kg/ha, compared with 659 kg/ha in the uninoculated plots (LSD = 58 kg/ha, 15 reps), representing a 21% yield reduction. The results are similar to those previously obtained for variety Calima in a warm climate (1979 Annual Report). Severity of the disease is potentially just as great in the highlands, therefore, but incidence is generally reduced and restricted to dry areas. Incorporating resistance to BCMV into highland materials has involved crossing with lowland-adapted varieties. A limited number of lines combining cold tolerance with BCMV resistance are now available in the VEF.

Table 1. Lines involved in second cycle of backcrosses with IVT bean lines, 1981.

F_2 family	Cross	F_3 [a]	Seed color
MC 7222	BAT 1155 x (BAT 338 x (F_3 IVT 7233 x IVT 7214))	0	
MC 7223	BAT 1235 x (BAT 338 x (F_3 IVT 7233 x IVT 7214))	2	Cream striped, cream spotted
MC 7226	ICA L-24 x (BAT 338 x (F_3 IVT 7233 x IVT 7214))	1	Black
MC 7208[b]	BAT 93 x (BAT 338 x (F_3 IVT 7233 x IVT 7214))		
MC 7212[b]	BAT 448 x (BAT 338 x (F_3 IVT 7233 x IVT 7214))		
MC 7214[b]	BAT 561 x (BAT 338 x (F_3 IVT 7233 x IVT 7214))		
MC 7219[b]	BAT 1061 x (A 23 x (F_3 IVT 7233 x IVT 7214))		
MC 7221[b]	BAT 1155 x (G 5066 x (F_3 IVT 7233 x IVT 7214))		
MC 7227[b]	ICA L-24 x (G 5066 x (F_3 IVT 7233 x IVT 7214))		

a. Number of F_3 selections made containing recessive and dominant BCMV genes, according to Dr. Eelco Drijfhout, Plant Breeding Institute (IVT), Netherlands.
b. Results of the test crosses are pending.

Combined Bean Common
and Bean Yellow Mosaic Resistance

The incorporation of multiple resistance genes against the known bean common and bean yellow mosaic virus strains present in Latin America is being pursued in cooperation with the Chilean National Institute of Agricultural Research (INIA). The project involves, initially, the production of F_1 and/or F_2 seed from crosses made at CIAT between susceptible Chilean cultivars and the IVT lines 7214 and 7233, which carry multiple resistance genes against the BYMV and BCMV strains present in Chile. The hybrid seed is sent to Chile at this stage to make possible an early selection for adaptation and resistance to the prevalent virus strains.

So far, F_1 and F_2 seed of six crosses each between Chilean cultivars and IVT 7214 and IVT 7233 were sent to Chile this year. In addition to the above sources of resistance, other bean varieties, such as Great Northern, Pinto, and Monroe, have been observed to possess resistance against the Chilean BYMV strains. A number of crosses were made between Great Northern 31 or Monroe and selections of Chilean cultivars, and the F_2 seed will be sent to Chile in time for the upcoming planting season.

The 1979 EP was also evaluated at the Quilamapu INIA Experiment Station, at Chillan, Chile, seeking resistance sources to bean yellow mosaic virus. Of the 196 entries, 97 (49.5%) did not show symptoms in the field. However, some of these materials, selected at random, proved susceptible to the virus in artificial inoculations. The nature of this phenomenon is being investigated. All the EP lines proved to be resistant to BCMV under field conditions in Chile.

Bean Chlorotic Mottle

Bean chlorotic mottle reached epidemic proportions for the first time in Latin America, namely, in Argentina. The incidence of this whitefly-borne disease was up to 100% in many bean fields and covered an area of approximately 20,000 ha, primarily in the Provinces of Tucuman and Santiago del Estero in northwestern Argentina. The epidemic level of this disease was directly associated with the high populations of whiteflies on beans and, indirectly, with the presence of nearby soybean plantings where the insect breeds. The disease affected the local bean cultivars as well as most of the entries included in the 1980 black IBYAN. Two IBYAN entries, however, ICTA-Jutiapan and -Quetzal, remained symptomless in areas where the problem was severe. It is interesting to note that these two ICTA lines were developed for their resistance to another whitefly-borne disease, bean golden mosaic. Of the two materials, ICTA-Quetzal, (DOR-41) showed better adaptation and yield potential, and, consequently, it is being increased for larger trials to be conducted next year.

Bean Golden Mosaic Virus

In 1981, black grain types continued to show higher levels of resistance to BGMV relative to nonblack grain types. For these black grain types, CIAT continues to emphasize multiple-factor breeding, especially to combine BGMV, *Empoasca*, and *Xanthomonas phaseoli* resistance with high yielding ability. CIAT's efforts for nonblack grain types are primarily directed toward increased levels of BGMV resistance within each specific color group. Advances in resistance are especially evident in small Pompadour and small red grain types. A number of red and black selections currently being evaluated by ICTA-CIAT show more promise than do the resistant checks, Jutiapa, Quetzal, and Tamazulapa.

Crosses in process continue to emphasize multiple-factor incorporation into blacks and now into red grain types also. Early-generation progenies will be progressively selected for *Xanthomonas* and *Empoasca* resistance at CIAT, and subsequently for *Apion*, BGMV, and local adaptation in Central America.

The Program also continues to research for new sources of resistance. This year, 144 lines of *P. vulgaris silvestris* were screened for BGMV resistance. Six of these lines showed high levels of resistance and acceptable adaptation and are currently being crossed to locally adapted BGMV-resistant materials. In addition, several selections from interspecific crosses between resistant accessions of *P. coccineus* with *P. vulgaris* appear to have very high levels of resistance, but these are still considered in the early stage of improvement.

Consistent with the decision taken by the Bean Team to offer national programs advanced breeding materials to select for location-specific constraints prior to the establishment of IBYAN nurseries, a 1981 EP nursery was set up in Central America to screen for golden mosaic resistance. Among the 191 EP entries tested, two lines, A 171 and A 174, were determined to be the most resistant to BGMV. Both lines had good intermediate levels of resistance under strong disease pressure. This was unexpected in that neither of the two unrelated lines have parentage with known resistance to BGMV. Though they still need to be retested for resistance, this finding indicates that within tropically adapted *P. vulgaris* there probably are still more unidentified sources of resistance to the pathogen.

Materials are now being increased for a 1982 IBGMV nursery, which is to be distributed in February 1982. Some very promising materials from Brazil, the Dominican Republic, and other Central American locations are among those being increased. In the 1981 EP and various breeding nurseries, we observed evidence of location/variety interaction for resistance to BGMV, indicating the existence of pathogenic variation in BGMV. The wide selection of materials for the 1982 IBMVN will help clarify the extent of pathogenic variation.

Resistance to Fungal and Bacterial Diseases

Anthracnose and Angular Leaf Spot

Over 13,000 bean accessions from the CIAT germplasm bank were evaluated for their resistance to anthracnose caused by *Colletotrichum lindemuthianum* and angular leaf spot caused by *Isariopsis griseola* in the period between March 1978 and October 1981. Initially, all the accessions were planted in hill plots in Popayan and inoculated with local isolates of both pathogens; those accessions with resistance or variable reaction to anthracnose and/or angular leaf spot and with general good adaptation were selected for further evaluation and verification of reaction in the field and greenhouse. Progenies from individual plant selection were evaluated until uniformity of resistance was obtained. Along with some anthracnose-differential cultivars, all selections were planted and inoculated in Popayan in two- to three-row plots, each 2 m long, for final evaluation in the March and September plantings of 1980. Resistant accessions were also evaluated sequentially in the greenhouse against a mixture of *C. lindemuthianum* isolates from Popayan, a mixture of isolates from other parts of Colombia, a mixture of known European races, an isolate (C 236) from Guatemala, and an isolate of the race Alpha Brazil of the anthracnose fungus. Similarly, the accessions were evaluated in the glasshouse with a mixture of *I. griseola* isolates from Popayan. Inoculum preparation, field and glasshouse-inoculation procedures, and disease-evaluation scales have been reported previously (CIAT Annual Report 1978, 1979).

The germplasm-evaluation strategy is based on the assumption that populations of local isolates of the anthracnose and angular leaf spot pathogens can effectively be managed in the field and as a greenhouse screening tool to evaluate large quantities of bean germplasm and, in the process, eliminate germplasm accessions and breeding progeny that are susceptible or resistant only to some of the races of these two pathogens. The remaining resistant and agronomically desirable materials can be evaluated again in the field to local isolates and in the glasshouse to local and other isolates of both pathogens. In this manner, it is possible to select genotypes that have broad resistance against a very wide range or all known races of the anthracnose fungus and to Colombian isolates of the angular leaf spot pathogen. The pathogenic spectrum inherent within isolates of *C. lindemuthianum* found in the field in Popayan is very diverse and complementary to those from other parts of Colombia, Latin America, and Europe (Table 2), thus providing the screening mechanisms required to identify more localized as well as broad sources of resistance to anthracnose.

Anthracnose. A total of 162 accessions were resistant or intermediate to the Popayan isolates of *Colletotrichum lindemuthianum*. Of these, 27 accessions had either resistant or intermediate anthracnose reaction to all known and available races from Europe and other highly virulent isolates from Colombia and other parts of Latin America. Table 3 shows selected bean accessions resistant or intermediate to all known races and other unclassified isolates of *C. lindemuthianum* and their reaction to the angular leaf spot pathogen. All 27 accessions had resistant reaction to C. lindemuthianum isolates from areas of Colombia other than Popayan and resistant or intermediate reaction to a mixture of Popayan isolate 10-76 and race Alpha Brazil, both able to overcome the resistance of Cornell 49-242, a much utilized source of anthracnose resistance throughout the world. Similarly, 21 accessions had resistant and 37 intermediate reaction to the race Alpha Brazil of C. lindemuthianum. Of these 58 entries, 29 had either resistant or intermediate reaction to all the races and isolates previously mentioned.

It should be noted that although there was adequate variation for grain type and growth habit, there was a preponderance of growth habit III. Except for very few accessions, most originated from Latin American countries in which anthracnose is a serious production problem. This strongly emphasizes the importance of the search for desirable traits among germplasm collected from its center of genetic diversity.

From crosses made in 1978, 15 experimental lines involving six different sources of resistance to anthracnose were developed this year.

Table 2. Reaction[a] of selected sources of resistance and differential lines of Phaseolus vulgaris L. to known races and other isolates of Colletotrichum lindemuthianum at various locations in Colombia, Latin America, and Europe.

Entry	Reaction in the field (Popayan)	Reaction in the glasshouse[b]					
		1	2	3	4	5	6
AB 136	R	R	R	R	R	I/V	R
BAT 93	R	R	R	R	R	S	R
BAT 841	R	R	R	R	R	R	R
BAT 76	S	S	R	S	S	S	S
Coco a la Creme	R	R	R	R	R	S	R
Cornell 49-242	S	S	R	S	R	S	S
Mexico 222	R	R	R	R	R	R	R
Michigan D.R.K.	S	S	S	S	R	R	S
Michelite	S	S	S	S	S	S	S
P.I. 207262	R	R	R	R	R	R	R

a. R = resistant; S = susceptible; I/V = intermediate/variable.

b. Treatment: 1 = all Popayan isolates used for field evaluation; 2 = same as 1, but excluding isolate 10-76, which overcomes the resistance of Cornell 49-242; 3 = isolates from areas of Colombia other than Popayan; 4 = isolate of an Alpha Brazil race obtained from France; 5 = isolate C 236 from Guatemala; and 6 = mixture of European races including Kappa, Lambda, and Iota.

Table 3. Reaction[a] of selected germplasm bank accessions of *Phaseolus vulgaris* L. to all known races and other isolates of *Colletotrichum lindemuthianum* and their reaction to angular leaf spot.

CIAT accession no.	Country of origin	Growth habit	Grain		Anthracnose reaction[b]					Angular leaf spot reaction
			Size	Color	1	2	3	4	5	
G 983	Mexico	III	Medium	Black	R	R	I	R	R	S
G 2327	Mexico	IV	Small	Black	R	R	I	I	R	S
G 2333	Mexico	IV	Small	Red	R	R	I	I	R	S
G 2338	Mexico	IV	Medium	Black	R	R	R	R	R	I
G 2696	Venezuela	II	Small	Black	R	R	I	R	R	S
G 3367	Mexico	IV	Small	Cream	R	R	I	R	R	S
G 3991	Costa Rica	IV	Small	Cream	R	R	R	R	R	R
G 4010	Costa Rica[c]	III	Medium	Cream striped	R	R	I	R	I	S
G 4032	Costa Rica	IV	Small	Cream	R	R	R	R	R	R
G 4108	Costa Rica[c]	III	Small	Black	R	I	I	R	R	S
G 4360	Mexico	III	Medium	Brown striped	R	R	R	R	R	S
G 4391	Mexico	III	Medium	Brown striped	R	I	R	R	R	S
G 6220	Venezuela	II	Small	Black	R	R	I	R	R	S
G 6769	Mexico	III	Medium	Gray	I	R	R	I	R	S
G 7199	Venezuela	III	Small	Black	R	I	I	R	R	R
G 8519	Guatemala	III	Small	Black	R	I	R	R	R	I
G 11680	Nicaragua[c]	II	Medium	Pink mottled	R	R	R	R	R	S

a. R = resistant; S = susceptible; I = intermediate.

b. Treatment: 1 = field evaluations after inoculation with local isolates from Popayan; 2 = glasshouse evaluations with all Popayan isolates used for field evaluations; 3 = glasshouse evaluations with the race Alpha Brazil of *C. lindemuthianum*, which overcomes the resistance of Cornell 49-242; 4 = glasshouse evaluations with isolate C 236 from Guatemala; 5 = glasshouse evaluations with a mixture of European races including Kappa, Lambda, and Iota.

c. Indicates the country of procedence.

Also, 34 additional crosses among 35 parental sources of resistance were made. The objective thus far has been to combine as many sources of resistance to anthracnose as possible. In the screening and selection of progenies, local isolates of the anthracnose pathogens from Popayan have been utilized; however, attempts will now be made to sequentially screen in the CIAT-Palmira glasshouse all lines with resistance reaction in the field to non-Colombian isolates.

An international bean anthracnose nursery is being organized and will shortly be distributed in the major bean-growing areas of the world for testing all new sources of anthracnose resistance along with the anthracnose differential lines.

Angular leaf spot. Unlike for anthracnose, only a few accessions showed resistant or intermediate reaction to the Colombian isolates of *Isariopsis griseola*. A total of 37 accessions had resistant and 88 intermediate reaction to angular leaf spot; however, many of these accessions were susceptible to the Popayan isolates or other isolates of *Colletotrichum lindemuthianum* when tested simultaneously. Of the 162 accessions with resistant or intermediate reaction to the Popayan isolates of *C. lindemuthianum*, 47 possessed similar reaction for angular leaf spot. Table 4 shows selected bean accessions with resistant or intermediate reaction to *I. griseola* and their reaction to the anthracnose pathogens. The usefulness of these sources of resistance cannot be determined until these accessions are further tested in other locations and to other isolates of the angular leaf spot pathogen from Latin America and other parts of the world.

The segregating population of the crosses made during 1979 and 1980 to incorporate sources of resistance to angular leaf spot as well as halo blight and powdery mildew are being evaluated at the CIAT-Popayan and ICA-Obonuco farms.

Pathogenic variation studies. Many of the pathogens that cause diseases in beans are notorious for their pathogenic variation; therefore, a major effort is dedicated to obtain cultivars with as broad and stable resistances as possible. To this purpose in the disease screening, the pathogenic spectrum of the isolates utilized is widely-based. Experimental work was conducted at CIAT to determine the extent of pathogenic variation of the Colombian isolates of three pathogens: *Colletotrichum lindemuthianum*, the anthracnose fungus; *Isariopsis griseola*, the causal agent of angular leaf spot; and *Pseudomonas phaseolicola* (= *P. syringae* pv. *phaseolicola*), the halo blight pathogen.

During 1981, in order to monitor pathogen populations of *C. lindemuthianum* in Colombia, all new sources of anthracnose resistance and differential cultivars were planted in the CIAT-Popayan and ICA-La Selva experimental fields. In addition, several isolates of the anthracnose pathogen from different areas of Colombia were collected and tested in the CIAT-Palmira glasshouse, against the differential cultivars. Several of the isolates studied were similar in that they attacked Cornell 49242 in the same manner of *C. lindemuthianum* races

Table 4. Reaction[a] of selected germplasm bank accessions of *Phaseolus vulgaris* L. to Colombian isolates of *Isariopsis griseola*, the angular leaf spot pathogen, and their reaction to anthracnose (*Colletotrichum lindemuthianum*).

CIAT accession no.	Country of origin	Growth habit	Grain		Angular leaf spot reaction	Anthracnose reaction[b]				
			Size	Color		1	2	3	4	5
G 735	Guatemala	IV	Small	Yellow	R	I	I	I	R	R
G 2676	Mexico	II	Small	Black	R	I	R	S	R	I
G 3353	Mexico	III	Medium	Black	R	R	R	S	S	R
G 4129	Costa Rica	III	Small	Black	R	R	R	S	S	R
G 5653	Ecuador	IV	Medium	Pink	R	R	I	I	R	R
G 6975	Brazil	III	Small	Black	I	R	I	I	R	R
G 11060	Mexico	III	Medium	Gray	I	I	R	I	R	I

a. R = resistant; S = susceptible; I = intermediate.

b. Treatment: 1 = field evaluation after inoculation with local isolates from Popayan; 2 = glasshouse evaluations with all Popayan isolates used for field evaluations; 3 = glasshouse evaluations with the race Alpha Brazil; 4 = glasshouse evaluations with isolate C 236 from Guatemala; 5 = glasshouse evaluations with a mixture of European races including Kappa, Lambda, and Iota.

Kappa, Iota, and C 236; however, when these isolates were tested against a set of European differentials, provided by Dr. E. Drijfhout of IVT, the Netherlands, they appeared to be different from all races of C. lindemuthianum previously reported (Tables 5 and 6).

Similarly, experimental work was conducted to confirm the existence of pathogenic variation in I. griseola. Some workers in the past have noted variation among the different isolates of this pathogen; however, there is no experimental evidence to confirm it. Twenty isolates from different parts of Colombia were used in this experiment. Table 7 shows the reactions of some bean cultivars and lines to a group of selected isolates. Pathogenic variation was observed among the isolates used. Some isolates from the same geographical area varied in pathogenicity. The isolates from Popayan could be separated into three groups based on their ability to attack the cultivars tested. In addition, some of the isolates from the same pathogenicity group varied with respect to disease severity on susceptible cultivars common to them.

Halo Blight

A total of 30 isolates of Pseudomonas phaseolicola from various parts of Colombia were separated into race 1 and race 2 based on their pathogenicity on standard bean cultivar Red Mexican UI-3. Standard isolates of both races obtained in the United States were compared. All 20 isolates from Pasto, a region where halo blight is prevalent, were classified as race 2, whereas seven isolates from Popayan, two isolates from Tenerife, and one isolate from Palmira were classified as race 1.

Table 5. Reaction[a] of standard anthracnose differentials to some isolates of Colletotrichum lindemuthianum from Colombia.

Differential variety	Isolates of Colletotrichum lindemuthianum					
	I-81	52-26	10-76	S-81	G-81	B-81
Michelite	+	+	+	+	+	+
Aguille Vert	+	+	+	+	+	+
Michigan D.R.K.	+	+	+	-	-	-
Sanilac	+	+	+	-	-	-
Perry Marrow	+	+	+	-	-	-
Coco a la Creme	-	+	-	-	-	-
P.I. 167399	-	-	-	+	-	+
P.I. 165426	+	+	+	+	+	+
Cornell 49-242	-	-	+	+	+	+
Evolutie	-	-	-	-	-	-
Mexico 222	-	-	-	-	-	-
AB 136	-	-	-	-	-	-

a. + = susceptible; - = resistant.

Table 6. Proposed standard range[a] of differentials for the identification of races of <u>Colletotrichum lindemuthianum</u>, according to E. Drijfhout, IVT, Holland.

Differential variety	Alpha	Beta	Delta	Epsilon	Gamma	Kappa	Lambda	Iota	Alpha Brazil	C 236
Michelite	+	+	+	+	+	+	+	+	+	+
Aguille Vert	+	+	+	+	-	+	+	+	+	+
Michigan D.R.K.	-	+	+	-	+	+	+	+	-	-
Sanilac	-	+	+	-	-	+	+	+	-	+
Perry Marrow	-	-	+	-	+	+	+	+	-	-
Coco a la Creme	-	+	-	-	+	-	+	+	-	+
P.I. 167399	+	+	-	-	-	-	+	-	+	-
P.I. 165426	-	-	-	+	-	-	-	-	+	+
Cornell 49-242	-	-	-	-	-	+	-	+	-	+
Evolutie	-	-	-	-	-	-	-	+	-	+
Mexico 222	-	-	-	-	-	-	-	-	+	-
AB 136	-	-	-	-	-	-	-	-	-	-

a. + = susceptible; - = resistant.

Table 7. Differential reaction[a] of *Phaseolus vulgaris* L. cultivars and lines to inoculation with isolates of *Isariopsis griseola* from Colombia.

		Cultivar/line reaction				
Isolate	Origin	G 2575-10P-2C	Alabama	ICA-Duva	Caraota 260	G 1805-1P-1C
IG 14-80	La Selva	S	R	S	R	R
IG 21-80	Pitalito, Huila	S	R	S	R	S
IG 8-79	Popayan	S	S	R	R	R
IG 1-77	Popayan	S	S	S	S	R
IG 9-79	Popayan	S	S	S	S	S

a. Foliar disease reaction: R = resistant (no apparent disease symptom); S = susceptible (varying degrees of disease severity).

Rust

Rust. Bean rust caused by Uromyces phaseoli is a major disease of beans through Latin America and other bean-growing regions of the world. The pathogen is reported to have much pathogenic variation. Many cultivars are resistant in one or a few areas, but few cultivars are resistant over a wide range of locations throughout the world or over long periods of time.

One of the CIAT Bean Program objectives is to identify new rust-resistance mechanisms that are stable in time and space. Through the International Bean Rust Nursery (IBRN), the Program deploys rust-differential varieties and new sources of resistance to the major bean-growing areas of the world where rust is an important factor. Table 8 shows the reaction of several CIAT bean lines from the 1979-1980 IBRN that were resistant over a wide range of locations during those 2 years. The results are from evaluations conducted in 22 sites in 10 countries. It should be noted that the rust-monitoring entry Pinto 650 was susceptible in 20 of the 22 sites. Several of the CIAT lines were either resistant or intermediate to the different rust populations that may exist in Latin America and other areas of the world. Many of these lines could be utilized as sources of rust resistance in a bean-improvement program. Thus, breeding efforts continue to emphasize the incorporation of bean rust resistance from several sources into CIAT breeding lines. Crosses made from three and four rust-resistant parents continue to be evaluated in CIAT-Palmira under adequate levels of rust inoculum. The 1981-1982 IBRN, now in distribution, includes 41 standard rust-monitoring entries along with some of the most widely resistant bean lines from the 1979-1980 IBRN as well as new rust-resistant lines.

During 1980, at the CIAT-Palmira Station, inheritance studies of the bean rust-resistance reaction were made. Known rust-susceptible lines were crossed to lines having a resistant reaction and with lines with small and necrotic pustule types. Results from these crosses indicate that the rust-resistant reaction of BAT 41 is controlled by a single dominant gene; the small pustule of G 05066 and the necrotic pustule of BAT 153 are both controlled by single recessive genes. Results also suggest the possible existence of an allelic series in which the resistant reaction is dominant over susceptible and the latter dominant over the necrotic pustule type; however, further work is necessary to confirm these results.

Rust reaction type vs. yield. Studies were conducted to compare the yield of several bean cultivars possessing different rust reactions, under chemically protected and nonprotected conditions. The materials were chosen on the basis of their pustule type or types and rust incidence they exhibit under CIAT-Palmira conditions (Table 9). The progress of the disease was monitored throughout the entire growing season. Standard split-plot experimental design was utilized with three replications. The experiment included protected and nonprotected plots--both noninoculated--and plots inoculated directly with rust uredospores collected locally. There were no significant yield differences between the rust-inoculated and the nonprotected plots.

Table 8. Rust reaction of selected CIAT bean lines from the 1979-1980 International Bean Rust Nursery evaluated in 22 sites in 10 countries.

Entry	Grain color	Growth habit	Rust reaction in 22 sites[a] (no. lines)			
			Immune	Resistant	Intermediate	Susceptible
Pinto 650	Cream-mottled	III	0	2	0	20
V 3249	White	IV	6	13	3	0
G 3834	Brown-mottled	I	6	10	6	0
BAT 76	Black	II	4	13	5	0
BAT 66	Black	II	5	9	8	0
BAT 261	Black	II	7	8	7	0
BAT 445	Black	II	5	8	9	0
BAT 67	Black	II	6	8	7	1
BAT 93	Cream	II	4	10	7	1
BAT 248	Black	III/II	5	11	5	1
BAT 308	Black	III	5	9	7	1
BAT 424	Black	II	6	6	9	1
BAT 429	Black	II	4	8	9	1
BAT 447	Black	II	5	7	9	1
BAT 504	Black	II	6	8	7	1
BAT 520	Black	II	6	10	5	1
EMP 9	Black	II	6	8	6	2
G 3874	Black	IV	4	9	7	2
BAT 72	Black	II	4	10	6	2
BAT 73	Black	II	4	9	7	2
BAT 89	Cream-mottled	II	7	6	6	2
BAT 256	Brown	II	4	12	4	2
BAT 347	Cream	II	4	6	9	3

a. IBRN evaluations were held in Colombia (6), United States (3), Brazil (3), Ecuador (2), Mexico (2), Republic of South Africa (2), Peru (1), Costa Rica (1), Dominican Republic (1), and Tanzania (1).

Table 9. Rust reaction, mean yields of chemically protected and nonprotected plots, and yield losses in selected bean lines under CIAT-Palmira conditions.

Entry	Pustule type[a]	Rust reaction[b]	Mean yield (kg/ha)		Yield loss (%)
			Protected	Nonprotected	
Ex Rico 23	LP	HI	1283	331	74.2
BAT 308	SP	MI-HI	1823	1488	18.4
BAT 153	MP-LP	HI	1085	614	43.4
BAT 93	SP	LI	1041	844	18.9
BAT 527	MP-LP	HI	845	439	48.0
Pinto 650	LP	HI	627	240	61.7
Jamapa	LP	HI	1251	689	44.9
BAT 883	MP-LP	HI	1508	611	59.4
BAT 41	SP	MI-HI	978	1019	1.7
BAT 256	MP-LP	HI	818	310	62.1
EMP 81	SP	MI-HI	1114	1049	5.5

a. SP, MP, and LP denote small, medium, and large rust pustule type, respectively.
b. LI, MI, and HI denote low, medium, and high rust incidence, respectively.

Experimental lines in the inoculated and nonprotected plots with large pustule types and high rust incidence suffered yield losses of up to 74%. Yield of lines with the small pustule reaction was not reduced by more than 18% despite the high rust incidence in some lines. Similar epidemiological and yield work will be conducted again to determine if some of the rust-resistance mechanisms under study are stable in time and space and to determine their heritability.

Web Blight

Under the warm-moist environment of the humid lowland tropics of Central America and the Caribbean, web blight is traditionally considered a major constraint to bean production as it can destroy entire crops. However, recently this disease has been identified as a limiting factor to bean production at higher altitudes. During the first semester of 1981, web blight reached epidemic levels in Popayan and in many bean fields in the mountains of Colombia where coffee is generally grown. Beans in this area are planted in between young coffee trees and figure in the coffee growers' association crop-diversification plan. To this extent, CIAT, in collaboration with ICA and the Colombian Coffee Federation, has conducted regional bean trials to identify materials with commercial acceptance and adapted to the zone. In several of these bean trials during the first half of 1981, web blight appeared to be the most yield-limiting factor, particularly to local cultivars with high susceptibility to web blight. In all trials where web blight was severe, three CIAT lines--BAT 1230, 1235, and 1295--were superior to local cultivars under heavy disease pressure (Table 10). No cultivar was immune to the disease, however.

Web blight normally reached epidemic levels in two locations in Costa Rica, San Isidro, and Esparza, where the 191 entries of the EP trial, along with some IBYAN entries, local cultivars, and progenies, were evaluated for their reaction to this disease. Several entries appeared to have good to intermediate levels of resistance. Among the lines with intermediate resistance were, again, BAT 1230 and 1235.

From both locations in Costa Rica, 33 EP entries and some selections made locally were chosen for further web blight evaluation in Colombia, Costa Rica, El Salvador, and Nicaragua.

Due to the increasing importance of this disease in several countries and with the identification of materials with intermediate levels of resistance, a new emphasis is being placed on this disease. This year, in addition to the international testing of the most resistant EP entries in Central America, a large trial will be conducted in Darien, Colombia, in a field where web blight occurs. Here, materials identified as web blight-resistant from CIAT and Central America, as well as progeny from crosses between BAT 1235 and other lines, will be evaluated for their web blight reaction. Similarly, growth room studies aimed to develop a suitable screening methodology that corroborates field results will continue. So far, results obtained in growth room studies do not differentiate web blight-resistance levels observed under field conditions in Colombia or Costa Rica.

Table 10. Web blight disease reaction of some CIAT and ICA lines compared to local cultivars of Phaseolus vulgaris L. evaluated in the coffee zone of Colombia, June 1981.

Bean line or cultivar	Disease reaction[a]			
	La Marquesa, Caicedonia	La Primavera, Armenia	Montenegro, Armenia	Mean
BAT 1230	2.0	2.0	2.5	2.1
BAT 1235	3.0	3.0	2.5	2.8
BAT 1295	2.5	2.5	2.0	2.5
IVA L-24	3.5	3.0	3.5	3.3
ICA L-23	4.0	4.5	3.5	4.0
Uribe Rosado[b]	4.0	3.5	4.0	3.8
Calima[b]	4.5	3.5	4.0	4.0

a. Rating: 1 = no apparent disease; 5 = killed by disease.
b. Local cultivar.

Common Bacterial Blight

Efforts to develop common bacterial blight-resistant materials in all bean types and grain colors with commercial acceptance continue. During 1981, new methodology was also developed for the evaluation of resistance in beans to Xanthomonas phaseoli (= X. campestris pv. phaseoli), the CBB pathogen. The new procedure is a variation of the razor blade technique previously reported (Annual Report, CIAT, 1979). In the new procedure, a bacterial cell suspension is placed in a plastic bottle capped with a rubber stopper with two small perforations in which pieces of sponge are placed to allow the inoculum to pass slowly. Two surgical steel blades are placed in the rubber stopper next to the perforations, and both, the rubber stopper and blades, are enveloped in a piece of cheesecloth to hold them in place (Figure 2). This new procedure and the razor blade procedure were compared in the field and greenhouse using six bean cultivars known for their CBB reaction. It was determined that the surgical blade is a faster procedure, easier utilized, and very uniform; however, it does not discriminate as well as the razor blade procedure among levels of resistance.

An earlier experiment in which bean lines were inoculated with single isolates of the CBB pathogen was repeated in 1981 (CIAT, Annual Report 1980). The results corroborate past experiments that demonstrate the existing variation in virulence within the X. phaseoli isolates from different areas of the world. Based on these and past results, the screening of bean germpalsm will continue with the single most virulent isolate of X. phaseoli previously collected at CIAT. CIAT expects to increase the levels of foliage resistance in locally adapted, agronomically desirable germplasm.

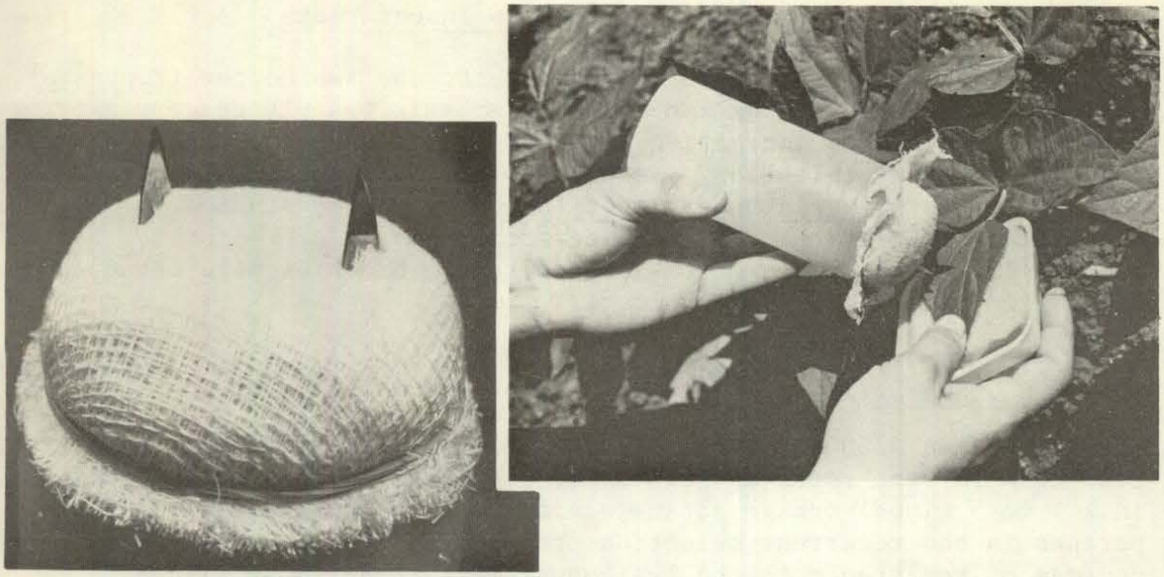


Figure 2. The surgical blade technique is used to inoculate bean plants with common bacterial blight (top right). The plastic bottle is equipped with a rubber stopper and two steel surgical blades, enveloped in a piece of cheesecloth (bottom left).

This year, 106 CIAT early-generation and advanced breeding lines, previously rated as resistant to Xanthomonas, were evaluated in a replicated trial to determine their relative foliar resistance. The materials were inoculated at the first three-trifoliate stage using the new surgical blade technique and evaluated 12 days after inoculation. Of the lines inoculated, 27 were rated 2.0 to 2.5 (1 = immune, 5 = susceptible) relative to 3.0 of our resistant check, BAT 93. Among the best 27 lines were both small red brilliant and black opaque breeding lines with good reproductive adaptation. These are color groups to which we previously had difficulty transferring Xanthomonas resistance.

In our effort to search for higher levels of resistance to pathogens, 19 F_2 populations from interspecific crosses between P. vulgaris and Xanthomonas-resistant accessions of P. coccineus were evaluated for their CBB resistance in the second semester 1981. Several highly resistant selections from each cross are being advanced. In addition, 67 accessions of P. acutifolius and 41 of wild P. vulgaris were evaluated for resistance to Xanthomonas. Sixteen of the P. acutifolius accessions were rated nearly immune to the pathogen, although all the wild P. vulgaris accessions were determined to be susceptible.

With these successes, we are beginning to place more emphasis on incorporating multiple resistances, including resistance to Empoasca and rust, into blight-resistant germplasm.

Resistance/Tolerance to Insect Pests

Germplasm evaluations for resistance to the leafhopper (Empoasca), spider mites, and bruchids continued. Emphasis was placed on verifying progress obtained in increasing levels of resistance to the leafhopper through recurrent selection. Mechanisms of resistance to Empoasca in both Phaseolus vulgaris and P. acutifolius are being studied. Significant progress was made in increasing levels of resistance to the pod weevil. High levels of resistance to the bruchids were detected among wild accessions of P. vulgaris.

Empoasca kraemeri

More than 5300 lines from various nurseries were evaluated in 1981. Less than 1% were rated as resistant, receiving a score of less than 3 in a 1 to 5 visual damage rating scale. Some of the best were used as parents in the recurrent selection program. As in previous years, no sources of resistance to the leafhopper were found among wild P. vulgaris accessions (131 materials tested).

New leafhopper materials were included in the international Empoasca nursery, which was distributed to Argentina, Chile, Cuba, Dominican Republic, Mexico, Nicaragua, and Venezuela. This nursery has now been evaluated in practically all countries of Latin America; a 65% return of the data has allowed us to use widely adapted materials as parents in the breeding program. The most outstanding materials have been G 00124 (white), G 01549, G 05144, EMP 40 (all black), and EMP 83 (cream).

As stated before (Annual Report, CIAT, 1980), significant progress in breeding for resistance to the leafhopper had been made. A series of modifications in selection procedures had also been put into practice. To further test the changes introduced and verify progress obtained in the third cycle of recurrent selection, three consecutive yield trials were conducted. The combined analysis of the results was most encouraging. New selection parameters, such as the reproductive adaptation scores introduced in 1980, correlated much better with unprotected yield (rank correlation coefficient = 0.73**) and with percentage yield reduction (r_s = 0.59**) than did visual damage scores and insect population counts, which were not significantly correlated. In terms of unprotected yield and percentage of yield reduction, the results (Figure 3) confirmed the superiority of materials such as EMP 81, EMP 84, EMP 86, EMP 83, and others over the susceptible check (BAT 41). The importance of yield expression under Empoasca stress as a parameter for selection was thus reconfirmed.

When F_4 families from the fourth cycle of intermating were yield-tested, more progress was detected (Table 11). Not only were higher levels of resistance obtained, but there was also a gain in terms of color diversity. Several of these materials have commercial grain type and are significantly superior to the susceptible checks and, in some cases, to the improved check (EMP 81). These results will need reconfirmation in 1982.

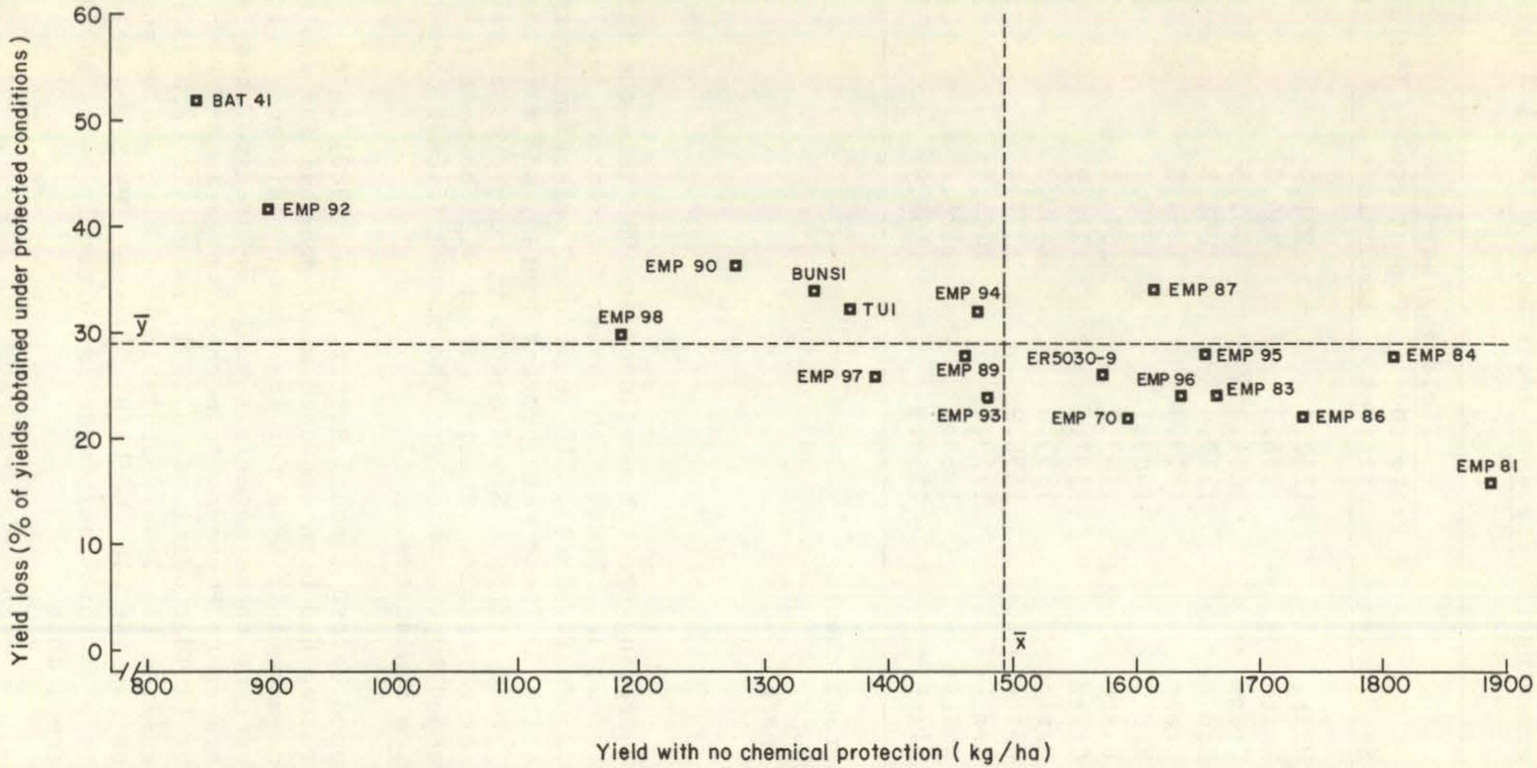


Figure 3. Performance of F_4 bean lines selected from the third cycle of intermating for resistance to Empoasca kraemeri at CIAT-Palmira, 1981. (Yields under protected conditions are not shown.)

Table 11. Mean yields of chemically protected and unprotected plots and yield losses in F_4 materials selected from the fourth cycle of intermating for Empoasca resistance (CIAT, 1981B).

Material	Seed color	Yield (kg/ha) Protected conditions	Yield (kg/ha) Unprotected conditions	Yield losses (%)
EMP 114	White	1252.7	1221.9	2.4
EMP 102	White	1296.3	1239.0	4.4
EMP 81[a]	Cream	1684.4	1463.5	13.1
EMP 116	Red	1279.4	1088.8	14.9
EMP 104	Cream	1819.9	1494.8	17.8
EMP 105	Red	1489.1	1210.1	18.7
EMP 84[a]	Black	2109.2	1694.8	19.6
EMP 110	Cream	1597.4	1276.9	20.0
EMP 119	Carioca	1855.0	1430.3	22.9
EMP 112	White	1658.9	1271.4	23.3
BAT 41[b]	Red	1729.4	1064.3	38.4
ICA-Bunsi[b]	White	1988.4	1126.7	43.3
ICA-Tui[c]	Black	2559.9	1168.9	54.3

a. Improved resistant check.
b. Susceptible check.
c. Intermediate check.

The Empoasca breeding project continued in 1981 into the fifth and sixth cycle of intermating. Under high insect infestation levels (5.2 nymphs/leaf and 6.2 adults/plant), 310 individual selections were made among 94 F_2 populations. These were progeny-tested, and more than 30 were selected for yield trials. Simultaneously, more crosses were made emphasizing nonblack materials. Special effort will be made in selecting large-seeded types, which are the most difficult ones to improve for Empoasca resistance.

It was mentioned before (Annual Report, CIAT, 1980) that significant differences had been detected among nymphal and adult populations in some materials bred for leafhopper resistance. It was stated then that some of these materials would be used to study the mechanism of resistance to Empoasca in both P. vulgaris and P. acutifolius. Under field conditions in 1981, materials such as EMP 94 and EMP 82 had significantly lower populations of both adults and nymphs (Figure 4) than the susceptible check (BAT 41) and EMP 81, a tolerant material. The nature of this resistance is currently being studied under greenhouse conditions.

In P. acutifolius, the results of three field trials and four greenhouse studies suggested that nonpreference might be responsible for highly significant differences in leafhopper populations between

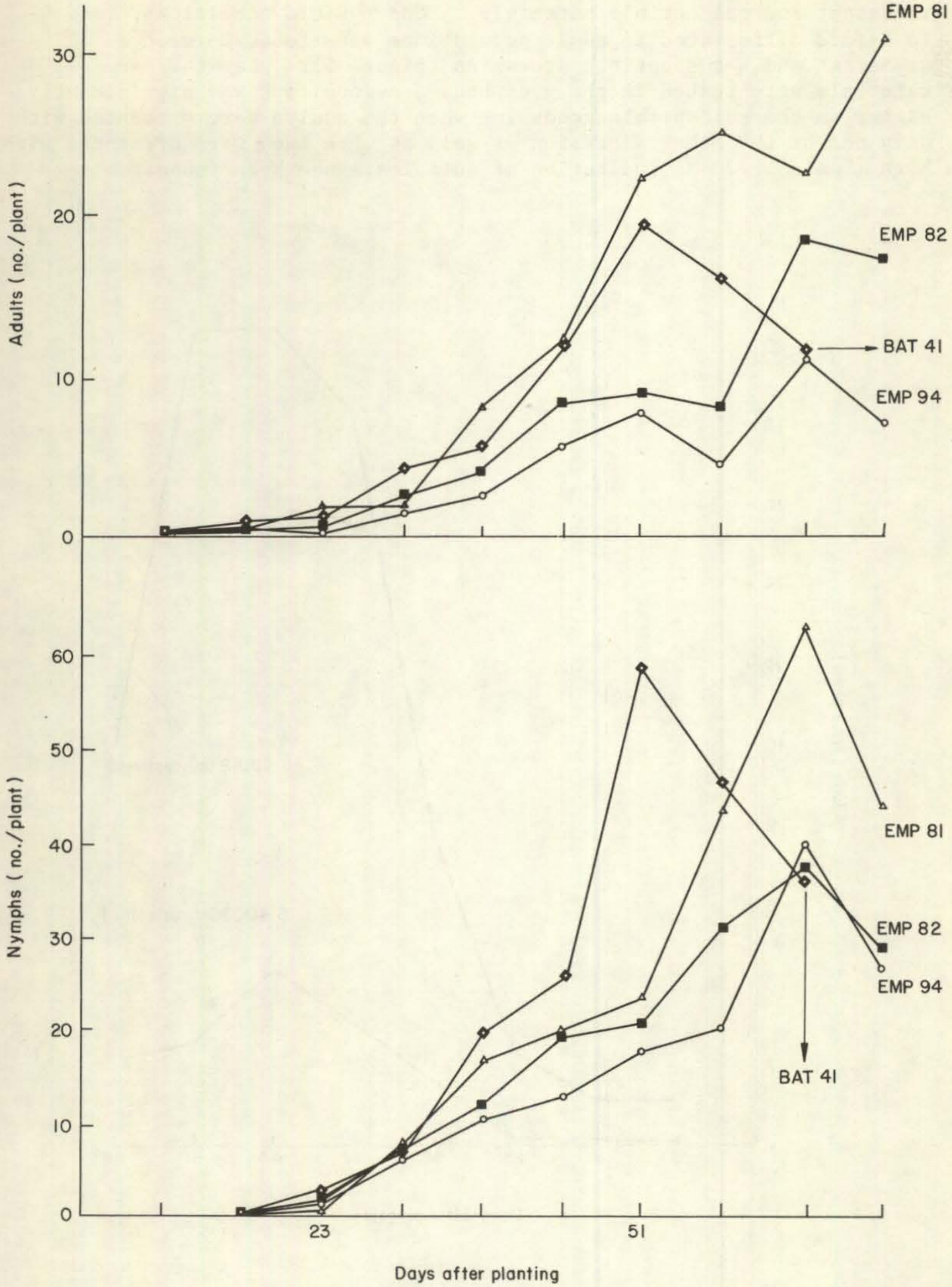


Figure 4. Adult and nymphal population levels of Empoasca kraemeri on four bean varieties (average of four replicates).

resistant and susceptible materials. Under field conditions, from 4- to 6-fold differences in adult populations were found between a resistant and a susceptible accession (Figure 5). When the same materials were tested in the greenhouse, oviposition was significantly higher on the susceptible accession when the adults were presented with only one or the other accession as well as when they were presented with both (Table 12). No indication of antibiosis has been found.

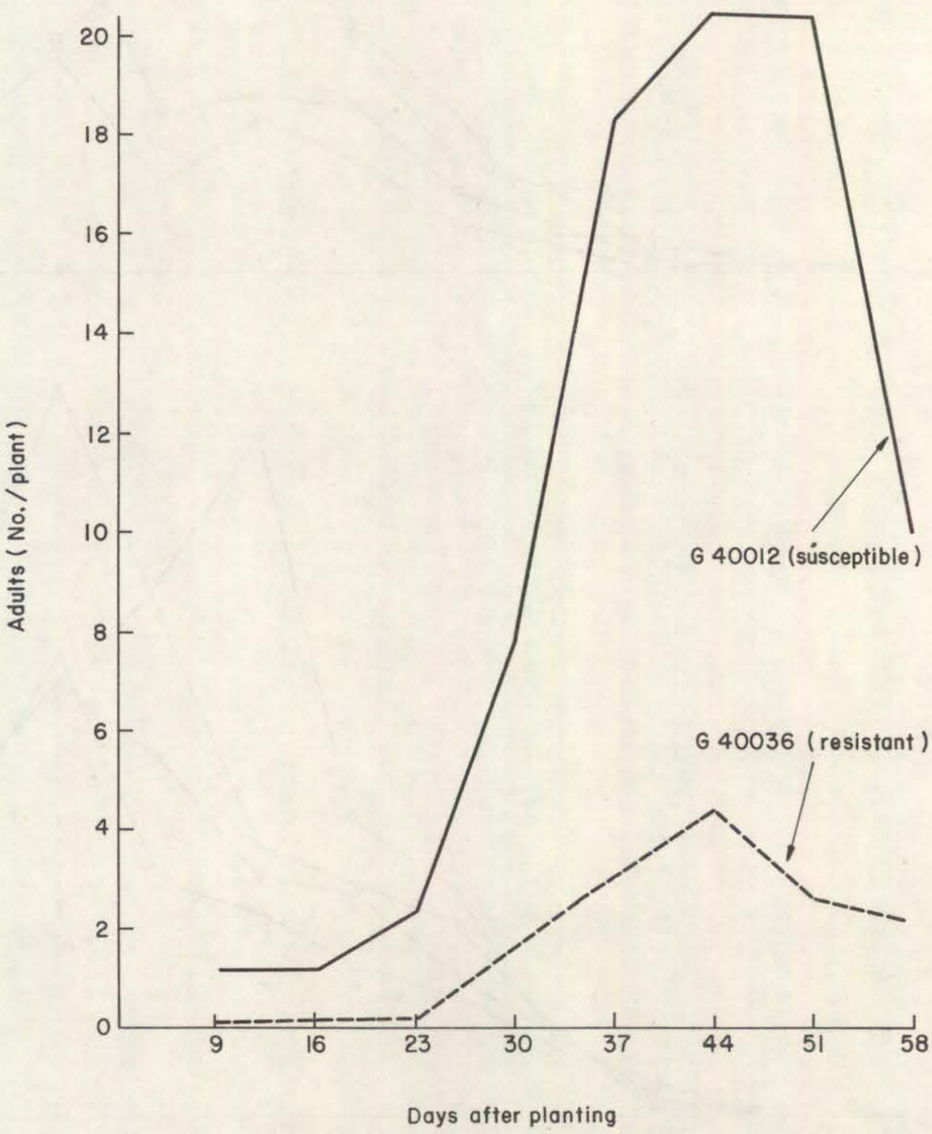


Figure 5. Adult Empoasca kraemeri population levels on a susceptible and a resistant Phaseolus acutifolius accession (field conditions).

Table 12. Adult leafhopper oviposition on susceptible and resistant *Phaseolus acutifolius* materials (greenhouse conditions), tested twice.[a]

Material	Both materials present		Only one or the other material present	
	Rep 1	Rep 2	Rep 1	Rep 2
G 40012 (susceptible)	202 a	1363 a	3298 a	776 a
G 40036 (resistant)	153 b	888 b	1638 b	164 b

a. Means within columns followed by the same letter are not significantly different at the 5% level.

Bruchids

More than 5600 cultivated bean materials were evaluated for resistance to the Mexican bean weevil (*Zabrotes subfasciatus*) between 1975 and 1981; almost 1000 were evaluated for resistance to the common bean weevil (*Acanthoscelides obtectus*). It was concluded that levels of resistance among cultivated materials were too low to be of economic importance. However, excellent sources of resistance were found among 206 wild bean accessions evaluated in 1981 (Table 13). Materials such as G 12952 reduced the survival rate of immature stages, lengthened the duration of the life cycle, and reduced dry weight of the progeny. This was confirmed by studying the emergence pattern of the bruchid when it was reared in a highly resistant wild cultivar (G 12952) as compared to the commercial check, Diacol Calima (Figure 6). High levels of resistance were also found when the materials were exposed to the common bruchid, *Acanthoscelides obtectus*. Crosses have been made to attempt to incorporate these genes into cultivated accessions.

Apion godmani

Significant progress was made in the incorporation of resistance to the pod weevil for Central America. The international *Apion* nursery was distributed to El Salvador, Guatemala, Honduras, Mexico, and Nicaragua in 1981. Better site selection and careful nursery evaluations allowed us to reconfirm the best sources of resistance and to detect important progress in this breeding project. Table 14 illustrates some of the results. Evidently, the *Apion* lines were highly superior to the commercial check. This work is most promising.

Table 13. Development of *Zabrotes subfasciatus* in selected wild bean accessions.[a]

CIAT accession no.	Adults produced/ replicate (no.)	Life-cycle duration (days)	Emergence (%)	Adult weight (mg x 10^{-4})	Classification
G 10019	7.0 e	37.6 ab	3.6 d	8 c	Resistant
G 12880	39.0 d	32.9 c	17.6 c	10 bc	Resistant
G 12891	87.0 c	47.6 b	27.8 c	8 c	Resistant
G 12952	8.7 e	67.3 a	3.3 d	7 c	Resistant
G 13021	137.7 b	31.6 c	55.3 b	11 b	Susceptible
Check:					
Diacol Calima	306.3 a	30.6 c	81.8 a	16 a	Susceptible

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

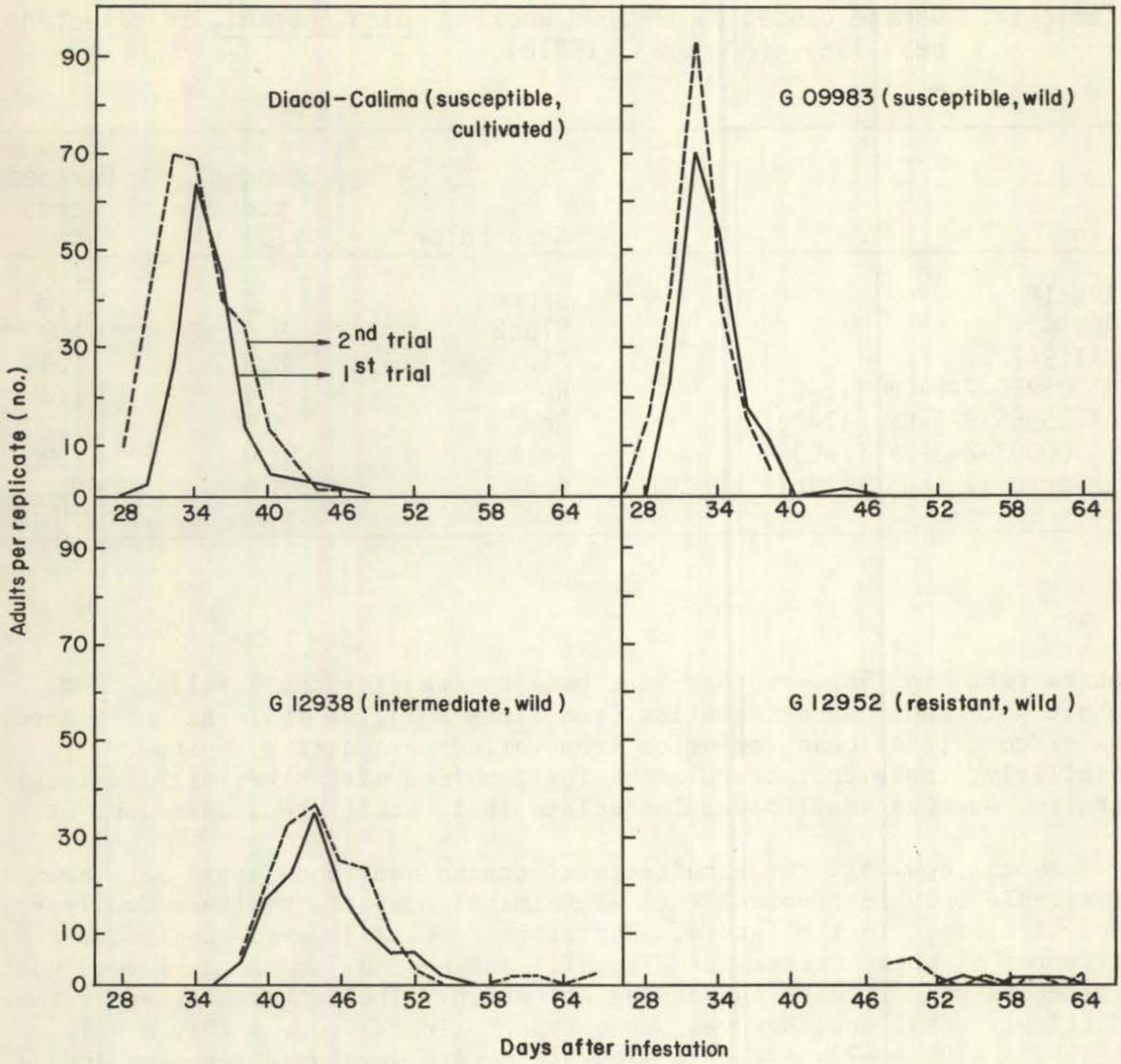


Figure 6. Emergence patterns of Zabrotes subfasciatus reared in four bean accessions (CIAT, 1981)

Yield and Plant Architecture Improvement

Incorporation of resistance to BCMV in the very small podded accession G 7460 was completed and line A 207 was developed. Unlike G 7460, which is a Type III, line A 207 is a Type I. Similarly, a true breeding line, A 209, with the lanceolate leaf characteristic discovered in 1978, was developed with BCMV resistance. New crosses have been made with A 207 and A 209 to study the inheritance and combine these unique characters with other agronomically desirable traits. Line A 209 seems to be partially sterile, a trait probably associated with the lanceolate

Table 14. Damage caused by the pod weevil, Apion godmani, to selected bean lines (Honduras, 1981B).

Line	Seed color	Damaged pods (%)	Damaged seeds (%)
APN 18	Brown	4.6	1.6
APN 42	Black	9.0	1.8
BAT 947	Pink	8.9	1.9
AT 05965-7-5-CM (12-B)	Red	1.6	1.3
AT 05965-9-6-CM (11-B)	Red	4.5	1.2
AT 06003-2-3-CM (7-C)	Yellow	10.0	2.9
Desarrural (susceptible check)	Red	78.6	50.4

character. In 1981, crosses were made to transfer small foliage and short internode characteristics from lines A 132, A 154, and A 156 into major commercial bean varieties from various production regions. Similarly, these characters are being combined with other architectural traits, such as small pods, lanceolate leaf, stiff stem, uniculum, etc.

Until now, all the architectural traits mentioned above have been available only in tropically (CIAT-Palmira) adapted, small-seeded Type I and II lines. In the future, adaptation to CIAT-Popayan conditions and transfer of these traits into Type III and medium- and large-seeded bush varieties will receive increasing attention. The latter has been rather difficult until now; however, some Type I lines--e.g., A 201, A 464, A 469, A 470, A 472, A 472, A 476, etc.--were developed for some Andean regions this year. Each of these has medium-sized seed and possesses relatively small foliage, and the latter four lines bear ten or more nodes on the main stem. These lines require further improvement in architectural traits, however, in comparison with their best small-seeded counterparts.

Tolerance to Moderately Acid Soils

Three groups of materials were screened this year for tolerance to moderately acid soils:

1. The 1980 EP was tested at CIAT-Popayan in 1980B.
2. After initial multiplication, the accessions from the Costa Rican Germplasm Bank were screened at CIAT-Quilichao in 1981A.
3. The breeding lines, including parents and experimental lines, were screened at CIAT-Quilichao in 1980B.

CIAT-Popayan Screening for Low Soil Phosphorus

The soil at CIAT-Popayan does not have sufficient aluminum and manganese content for screening purposes. Aluminum content never exceeds 3.0 meq/100 g soil, and manganese content lies below 10 ppm. Interestingly the calcium content is very high for this type of Inceptisol, a Typic Dystrandept. On the screening site, calcium content reached as high as 2.0 meq/100 g soil, and the saturation of aluminum was around 60%; no aluminum or manganese toxicity symptoms were observed, however. This is explained by the presence of 38% organic matter, which provides a very high buffering capacity of this soil for beans.

In this semester, the 1980 EP breeding lines and some commercial Brazilian varieties were screened simultaneously for low soil phosphorus tolerance. The experiment was carried out under protection against diseases. The results are shown in Table 15 for the EP, Brazilian, and other commercial varieties. The average yield of the 10 best EP lines under low soil phosphorus were much higher than the average Brazilian commercial variety or the commercial varieties from other countries. However, neither the breeding lines nor the Brazilian commercial varieties could outyield Carioca, which was used as the check. Most of the breeding lines tested in the 1980 preliminary yield trials did not have in their pedigree parents resistant to moderately acid soil. That is why none of them could outyield the check.

CIAT-Quilichao Testing

Many of the current commercial bean varieties in Brazil trace back to the Germplasm Bank of Costa Rica. Rio Tibagi, Rico 23, Costa Rica, and Iguaçu, are a few examples. In order to search for better low soil P-efficient beans, a series of Costa Rican black bean accessions was screened in 1981A at the Quilichao Station using recently multiplied seed. The results are shown in Tables 16 and 17. Many materials outyielded the best check, Carioca, but did not have BCMV resistance. Only two materials (one having two different accession numbers) could be classified as tolerant to moderately acid soil (having the best performance under both stress conditions).

In 1980B, the first CIAT lines from crosses involving one parent tolerant to acid soils were screened at the CIAT-Quilichao Station. Most of these lines fulfill the Brazilian grain type requirements, and, in addition, each possesses one or two additional disease resistances. Carioca was planted as the check. The semester 1980B was dry and irrigation was needed. Some common varieties showed a negative response to high phosphorus. The results are shown in Table 18 for phosphorus and in Table 19 for aluminum and manganese tolerance. Only a few materials outyielded Carioca in stress to phosphorus and stress to aluminum and manganese, but in this group several lines were classified as tolerant to moderately acid soil. These are A 97, A 83, and A 118.

Table 15. Response to low levels of applied P for the most efficient, low soil P materials on soil with less than 10% Al saturation (CIAT-Popayan, 1980B).

Rank	Entry	Seed color	Growth habit	Bean yield (kg/ha) 22 kg P added/ha 50 kg P added/ha	131 kg P added/ha 300 kg P added/ha	P response factor
			EP 1980 lines			
1	G 00101	Cream	I	1621	1585	-0.14
2	Col 168	Cream	IV	1483	1592	0.44
3	Cena 164-1	Cream	III	1471	1932	1.84
4	BAT 1088	Cream	II	1380	1463	0.33
5	A 21	Red	II	1333	1653	1.28
6	BAT 919	Black	II	1288	2613	5.30
7	E 00926	White	II	1282	1295	0.05
8	Preto 132	Black	II	1272	1513	0.96
9	BAT 76	Black	II	1250	2600	5.40
10	BAT 1090	Brown	II	1247	1025	-0.89
	Average			1363	1727	
			Brazilian Commercial Varieties			
1	Preto 132	Black	II	1272	1513	0.96
2	Rico Pardo	Brown		1236	1865	2.52
3	Roxinho	Red		967	1397	1.72
4	Tayhu	Cream		961	1571	2.44
5	Aete 2	Cream	III	943	1455	2.05
6	Roxinha	Cream		904	1276	1.49
7	Rio Tibaji	Black	II	893	1627	2.93
8	Jalo	Yellow		826	1296	1.88
9	Parana 1	Brown		732	546	-0.74
10	Aroana 7	Brown		571	613	0.17
11	Americano Precose	Yellow		539	695	0.62
12	Goiano Precose	Yellow		473	533	0.24
13	Pirata 1	Cream		369	701	1.33
14	Iguacu	Black		230	197	-0.13
15	Chumbinho	Brown		159	475	1.26
	Average			738	1051	
			Commercial Varieties			
1	Puebla 152	Black	III	1062	1886	3.3
2	Jamapa (G 4456)	Black	II	836	2151	5.26
3	Diacol Calima	Red-mottled	I	751	925	0.70
4	ICA-Guali (G 4452)	Red-mottled	I	671	815	0.57
5	ICA-Pijao (G 4525)	Black	II	320	394	0.30
6	ICA-Tui (G 4454)	Black	II	299	222	-0.31
7	Porrillo Sintético	Black	II	234	367	0.53
	Average			596	966	
			Checks			
1	Carioca (G 4017)	Cream striped	III	1801	2401	2.40
2	H1 Mulatinho (G 5054)	Cream	II	1305	1547	0.97
	Average			1553	1974	

Tolerance to Water Stress

The Bean Program continued in 1981 with large-scale screening for water stress tolerance. The technique of chain block designs was followed as before (Annual Report, CIAT, 1980) and proved successful in eliminating much field variation. Two trials were run in 1981: trial 8019 was planted in December 1980 for the Jan./Feb. 1981 stress period and trial 8101 to catch the August 1981 stress period. Results from 8019 were disappointing, due to heavy rains soon after flowering, which reduced the number of stress days to about 1 week; stress was measured using the temperature differential technique on only 5 days. Analysis

Table 16. The ten most tolerant materials and their checks to moderate Al and Mn levels in the soil with a 65% aluminum saturation (CIAT-Quilichao, 1981A, Costa Rican Bean Germplasm).

Rank	Entry	Seed color	Growth habit	Bean yield (kg/ha) 65% Al saturation	10% Al saturation	Limiting response factor
1	P.V. 104 N Criollo Pacuar 2	Black		1728	2635	15.5
2	P.V. 1 N Guatemala 174	Black		1670	1771	1.7
3	P.V. 95 N Mexico 488	Black		1546	2005	7.7
4	P.V. 299 N Cuba 168	Black		1508	2432	15.4
5	P.V. 156 N Col 122	Black		1487	1647	2.7
6	P.V. 211 N Honduras 182	Black		1487	1968	8.0
7	P.V. 210 N Salvador 217	Black		1473	1634	2.8
8	P.V. 387 N M-12-1[a]	Black		1473	2275	13.4
9	P.V. 3 N 353 A[a]	Black		1438	2439	16.7
10	P.V. 55 N Salvador 268	Black		1436	2660	20.4
			Average	1525	2147	
Checks						
1	G 5054	Cream	III	1494	1890	6.6
2	H6 Mulatinho (G 5059)	Cream	II	1131	2495	22.7
3	Pecho Amarillo (G 2959)	Black	III	1080	2576	24.9
4	Carioca (G 4017)	Cream	III	829	2274	
			Average	1134	2309	

a. Materials also efficient in low soil P.

Table 17. The ten most efficient materials and their checks to low soil P with a 10% aluminum saturation (CIAT-Quilichao, 1981A, Costa Rican Bean Germplasm).

Rank	Entry	Seed color	Growth habit	Bean yield kg/ha: 22 kg P added/ha 50 kg P added/ha	Bean yield kg/ha: 131 kg P added/ha 300 kg P added/ha	P response factor
1	P.V. 110 N Veranic 2	Black	II	2263	2170	-0.4
2	P.V. 62 N Black Turble Soup	Black	II	2126	1925	-0.8
3	P.V. 109 N Salvador 263			2038	1763	-1.1
4	P.V. 167 N Salvador 208			2037	1890	-0.6
5	P.V. 145 N Salvador 221			1990	2252	1.0
6	P.V. 106 N Mexico 30			1979	2092	0.5
7	P.V. 417 N M-12-1[a]			1978	2275	1.2
8	P.V. 3N 353 A[a]			1899	2439	2.2
9	P.V. 310 N			1882	2610	2.9
10	P.V. 89 N Preto Camaru			1864	2544	2.7
		Average		2006	2196	
Checks						
1	Carioca (G 4017)	Cream	III	1903	2274	1.5
2	Pecho Amarillo (G 2959)	Black	III	1628	2576	3.8
3	H1 Mulatinho (G 5054)	Cream	II	1441	1890	1.8
		Average		1657	2247	

a. Materials also tolerant to moderate Al and Mn levels in the soil.

Table 18. The five experimental lines most efficient to low soil P with less than 10% aluminum saturation (CIAT-Quilichao, 1980B).

Rank	Entry	Growth habit	Bean yield (kg/ha) 22 kg P added/ha 50 kg P added/ha	Bean yield (kg/ha) 131 kg P added/ha 300 kg P added/ha	P response factor
1	A 90	III	1239	1086	-0.61
2	BAC 61	II	1108	1173	0.25
3	A 97[a]	II	1085	1442	1.43
4	A 83	II	1056	1570	2.06
5	A 118[a]	III	1036	1111	0.30
	Average		1105	1276	
Checks					
1	Carioca (G 4017)	III	1277	1280	0.013
2	Iguacu (G 4821)	III	750	1277	2.107
	Average		1014	1279	

a. Materials also tolerant to moderate Al and Mn levels in the soil.

of the results showed, however, that considerable reductions in yield had taken place. It was deemed wise not to rely on these results until further corroboration could be obtained. Trial 8101 endured almost 30 days of strong water stress and hence could serve as a good comparison with some 120 common cultivars in the previous trial.

It was decided that the practice of selection on the criterion of proportional yield reduction due to stress could be counterproductive, because of the likelihood of selecting generally low yielding cultivars. Alternative selection schemes were examined (Figure 7) and the theoretical direction of selection examined for each. As can be seen from Figure 7, the most productive selection criterion is the geometric mean of stress and control yields (Scheme D). Schemes A and B have been widely used, with extra selection criteria based on either stress or control yield being above a critical minimum. There is little value in this approach since, if selection must be made on two values, the simplest method is using raw control and stress yields.

In experiment 8101, stress yields of 180 entries ranged from 2.9 to 0.3 t h^{-1}, while control yields ran from 3.9 to 1.7 t h^{-1}. The precision of the trial was good, with coefficients of variation of 17.5% for the yield index and 17.8% for the temperature differential. There was a low correspondence with the results of 8019, and it was concluded that trials with a short period of stress followed by rain are not representative and will be discounted in the future.

Table 19. The five experimental lines most tolerant to moderate Al and Mn levels in the soil with a 65% aluminum saturation (CIAT-Quilichao, 1980B).

Rank	Entry	Growth habit	Bean yield kg/ha: 65% Al saturation	Bean yield kg/ha: 10% Al saturation	Limiting response factor
1	A 97[a]	II	1060	1441	6.37
2	A 118[a]	III	1056	1111	0.91
3	A 79	III	938	1015	1.30
4	A 74	III	891	1034	2.36
5	A 83[a]	II	830	1570	12.33
	Average		955	1314	
Checks					
1	Carioca G 4017 (improved)	III	751	1280	8.8
2	Iguacu G 4821	III	837	1277	7.2
	Average		794	1279	

a. Materials also efficient with low soil P.

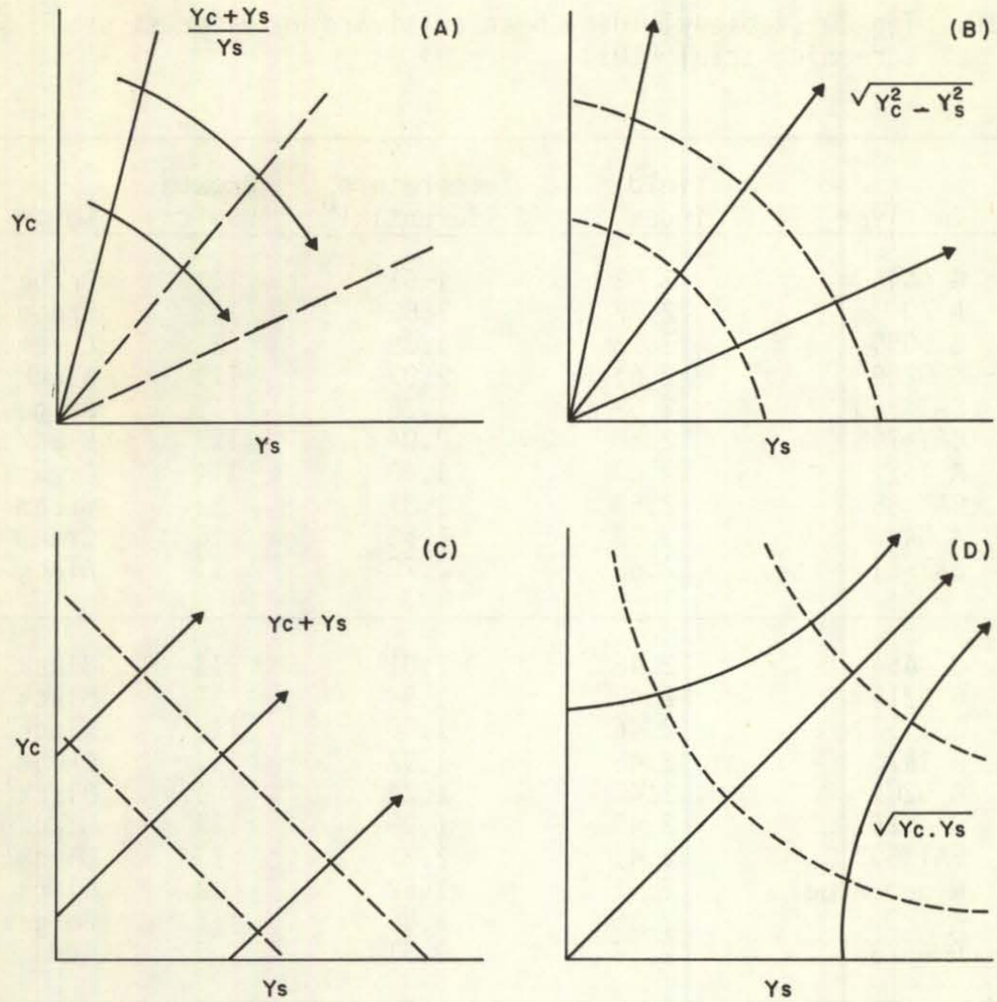


Figure 7. Alternative selection schemes for lines tolerant to water stress. Direction of selection (solid lines) and contours of equal weight (broken lines) under various schemes of combining control yield (Y_C) with stress yield (Y_S).

A highly significant negative relationship (r = -.685) was found between the canopy temperature differential and yield index. In general, this indicates that high-yielding, stress-stable cultivars tend to maintain transpiration water flow under stress; however, there is considerable variation from this rule, and some cultivars are evidently achieving stable yields under stress by alternative strategies. It should be noted that all the top 20 stable-yielding cultivars had temperature differentials less than the experimental average (Table 20).

The results broken down by grain color (Table 21) not only show the superiority of black and cream-colored genotypes but also reflect the high proportion of these colors in the trial (black, 65; cream and beige, 84; all other colors, 31).

Table 20. Top 20 stable-yielding bean cultivars in water stress screening trial 8101.

Rank	Cultivar	Yield index[a]	Temperature differential[b]	Growth habit	Color
1	G 4446	2.93	1.61	III	Beige
2	A 70	2.77	1.65	III	Cream red
3	G 5059	2.73	1.39	II	Cream
4	G 5208	2.61	2.07	III	Black
5	BAT 868	2.59	1.28	II	Beige
6	BAT 798	2.58	2.04	III	Black
7	A 162	2.57	1.00	III	Cream
8	BAT 85	2.53	1.87	II	Cream
9	A 54	2.53	1.63	II	Cream
10	BAT 51	2.52	2.73	II	Black
11	G 4454	2.48	2.01	II	Black
12	G 4215	2.47	1.94	II	Black
13	BAT 53	2.46	1.00	III	Black
14	A 147	2.45	1.92	III	Cream
15	G 5201	2.42	1.74	I	Black
16	G 4525	2.42	1.98	II	Black
17	BAT 502	2.41	2.31	II	Black
18	Negro Argel	2.41	1.52	II	Black
19	A 120	2.39	1.88	II	Beige
20	G 4523	2.37	0.51	I	Red
Range:	High	2.93	4.81		
	Mean	1.87	2.77		
	Low	0.64	0.51		
SE		0.107	0.243		
C.V.		17.5%	17.8%		

a. Geometric mean of control yield (Yc) and stress yield (Ys) ($\sqrt{Yc.Ys}$ t ha^{-1}).
b. Mean canopy temperature difference (°C).

Increased Nitrogen Fixation

Breeding for Enhanced Nitrogen Fixation

Breeding for enhanced nitrogen fixation in agronomically acceptable bush bean cultivars was continued in 1981 with two additional cycles of glasshouse selection and field evaluation undertaken.

Table 21. Leading entries by color group in water stress screening trial 8101.

Rank		Entry	Yield index[a]	Temperature differential[b]
			Black	
1		G 5208	2.61	2.07
2		BAT 798	2.52	2.04
3		BAT 51	2.52	2.73
4		G 4454	2.52	2.01
5		G 4215	2.46	1.94
6		BAT 53	2.46	1.00
7		G 5201	2.42	1.74
8		G 4525	2.42	1.98
Group range			1.19-2.61	1.0-4.17
			Cream, beige, etc.	
1		G 4446	2.93	1.61
2		A 70	2.77	1.65
3		G 5059	2.73	1.39
4		BAT 868	2.59	1.28
5		A 162	2.56	1.01
6		BAT 85	2.53	1.87
7		A 54	2.52	1.64
8		A 147	2.45	1.92
Group range			0.64-2.92	1.01-4.81
			Other colors	
1	Red	G 4523	2.37	0.51
2	Gray	G 4000	2.36	1.75
3	Red	BAT 258	2.25	1.36
4	White	Seaway Conguia	2.24[c]	1.60
5	White	G 4445	2.14[c]	1.83
6	Yellow	BAT 1170	2.03[c]	3.73
Group range			0.84-2.37	0.51-4.55

a. Geometric mean of control yield (Yc) and stress yield (Ys) ($\sqrt{Yc.Ys}$ t ha^{-1}).
b. Mean canopy temperature difference (°C).
c. Within one standard deviation of experimental mean, but leading from color group mean.

In the 1981B semester, 114 F_3/F_4 lines from the breeding program were evaluated for nitrogen fixation in Popayan. While control plots of the cultivars BAT 76 and BAT 332, used here as relatively active in nitrogen fixation, averaged $N_2(C_2H_2)$ rates of only 25.76 µmol C_2H_4 produced/plant/hour at flowering, the average for the 114 lines was 38.62 and five lines from cross 4823 averaged 53.98. Unfortunately, much of the material with enhanced nitrogen fixation was of unsatisfactory seed coat color, the reason a deliberate effort is being made to introduce additional promising material into the recurrent selection program for nitrogen fixation. Selections made from 96 F_2 populations tested in 1981A are currently in the field and, generally, are more acceptable in seed coat color. A total of 164 F_2 populations selected as high yielding and active in nitrogen fixation in the glasshouse are also being tested under field conditions in Popayan.

Validation of Breeding Methodology

The breeding methodology currently being used to enhance nitrogen fixation depends on early-generation screening of hybrid materials under conditions free from combined nitrogen in the glasshouse. Because of this unusual combination of features, efforts were undertaken in 1980-81 to confirm that this method permits the selection of material active in nitrogen fixation with mixed inoculant strains of Rhizobium.

Inoculated F_1 plants from the breeding population, grown under nitrogen conditions in the glasshouse, and so completely dependent on fixed nitrogen, were evaluated at flowering for growth and vigor and at maturity for yield. Selections were made for both high and low extremes in these traits. Ten F_2 seeds from each of 40 single-plant selections were then planted in the glasshouse and their yield without nitrogen again estimated. Plants selected in the F_1 for high yield and vigor under conditions of no nitrogen showed variation in yield in the F_2 significantly greater than that of plants selected for poor yield or low vigor (Figure 8). Yields of the F_2 and subsequent F_3 were also strongly correlated (r = 0.92) (Figure 9).

To confirm that there was a reasonable correlation between the glasshouse and field performance of lines selected for high potential to fix nitrogen (and also as part of the EP testing program), the 191 lines of the 1981 EP were grown both in the field at Popayan and in sand culture in the glasshouse. Yield was determined at both locations; nodule dry weight from a 10-plant sample per line at flowering was also determined in the field. Yield in the glasshouse varied from less than 1 to 16 g/plant, with appreciable differences evident between growth habit and color groups (Table 22). There was a strong correlation (r = 0.81) between yield when dependent on nitrogen fixation in the glasshouse and nodule dry weight at flowering in the field (Figure 10), and a surprisingly good correlation (r = 0.45) between glasshouse and field yields (Figure 11).

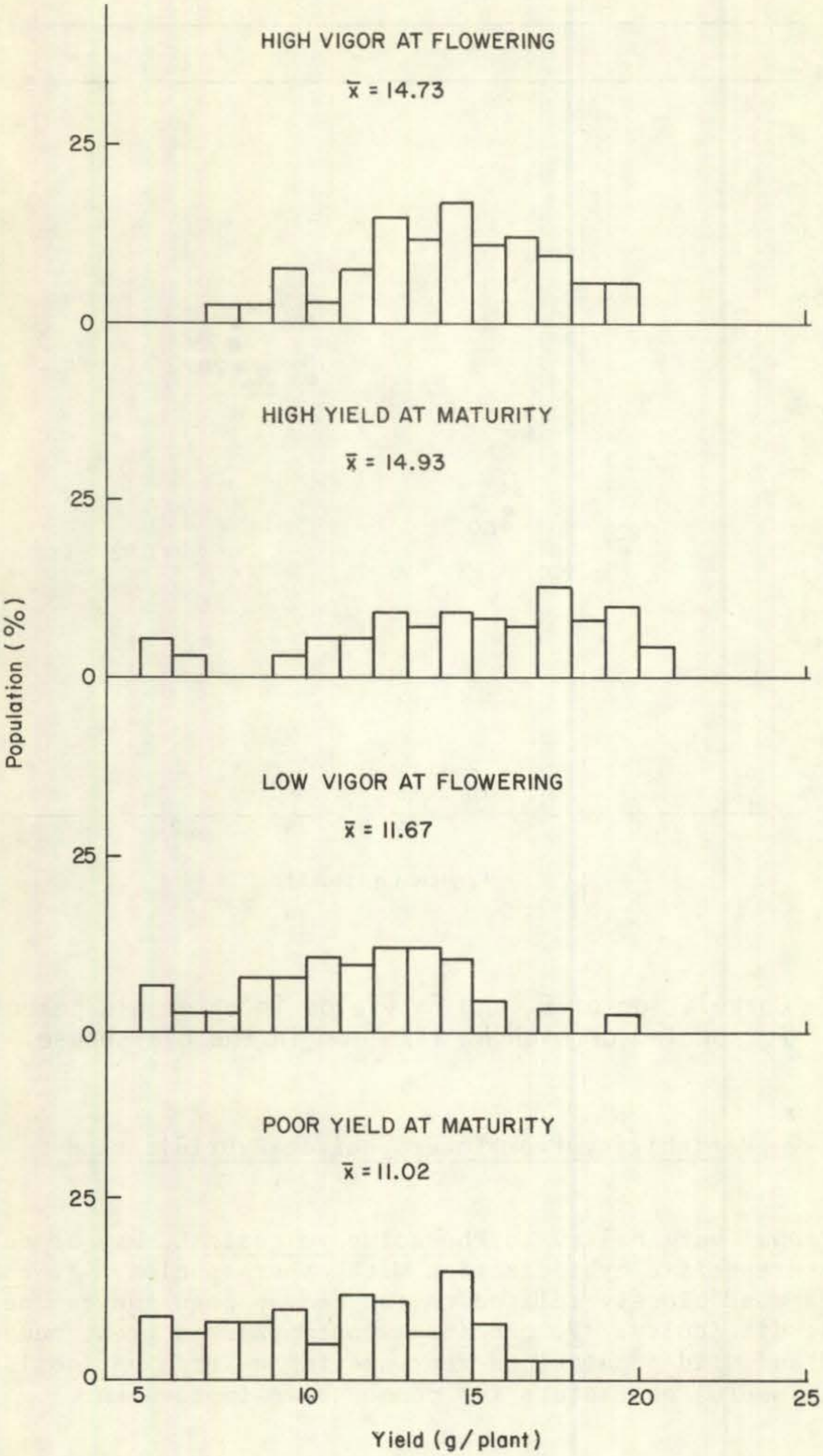


Figure 8. Effect of method of selection of F_1 plants (under conditions of no nitrogen) on yield in F_2 populations.

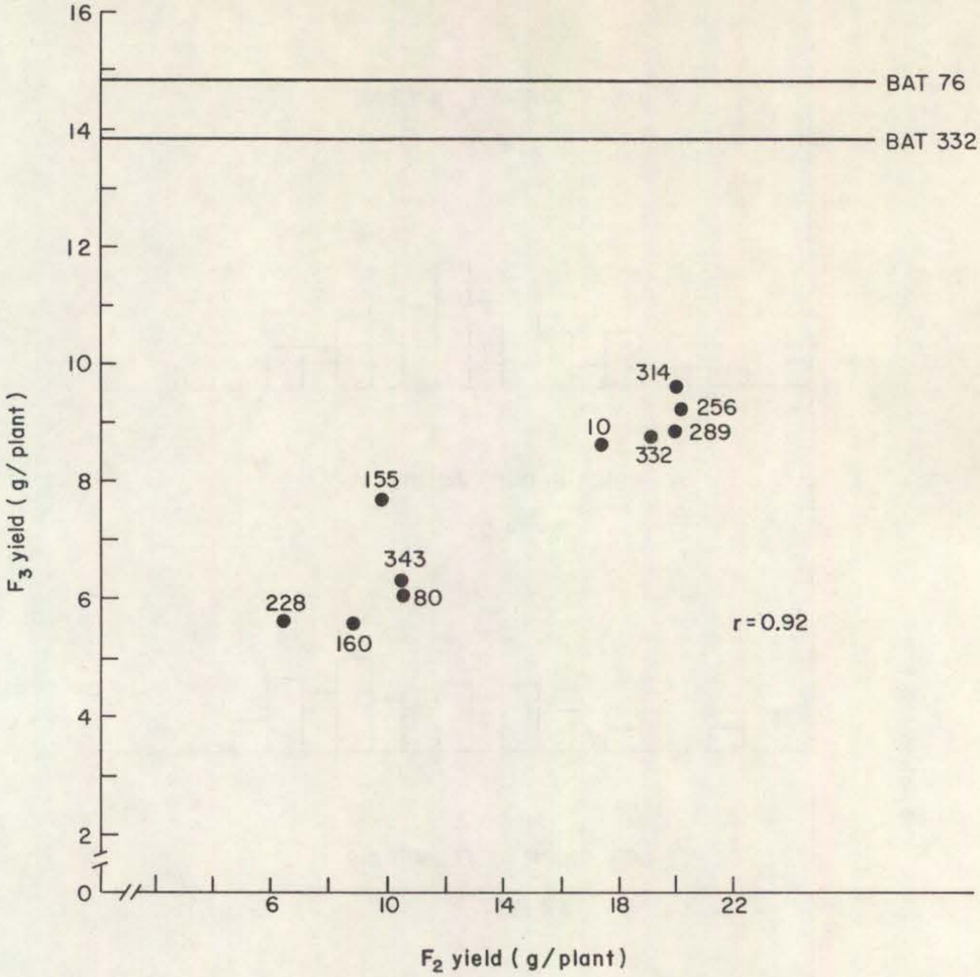


Figure 9. Correlation of F_2 and F_3 yields in materials selected in the F_2 for low or high N_2 fixation in the glasshouse.

Variability from Interspecific Hybridization

Additional variability in Phaseolus vulgaris L. may be derived through interspecific hybridization with other species. P. coccineus is the species most closely related to the common bean and can be crossed with little difficulty. P. coccineus encompasses a great number of cultivated and wild populations representing a large variability of potentially useful characters for common bean improvement.

Viability and Fertility in Interspecific Crosses

Both viability and variability in early generations were discussed in reports from the last 2 years (CIAT, Annual Reports 1979, 1980).

Table 22. Distribution of yield (g/plant) of 191 EP accessions (in the glasshouse) when dependent on fixed N_2 for growth.

Group	No. of lines yielding: < 1.0 g	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	16	Total entries
Black bush	0	0	0	0	0	0	22	11	11	22	11	22	0	0	0	0	9
Red bush--P	0	0	6	6	6	0	0	12	25	25	6	6	0	6	0	0	16
Red bush--M	8	0	8	0	0	8	0	16	16	16	8	16	0	0	0	0	12
Red bush--S	21	0	0	4	4	12	8	21	12	0	4	12	0	0	0	0	24
White bush	14	0	0	0	0	14	0	14	28	28	0	0	0	0	0	0	7
Gray bush	50	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	2
Bush, Type M	0	0	0	16	0	16	0	16	33	0	0	0	16	0	0	0	6
Bush, Type B	6	2	2	6	2	6	12	8	12	21	12	2	2	0	0	2	47
Bush, others	16	0	8	8	0	0	8	16	25	0	16	0	0	0	0	0	12
Climber, black	9	0	0	0	0	0	0	4	18	13	18	9	13	9	0	5	22
Climber, red	35	0	0	7	7	7	0	7	14	7	0	14	0	0	0	0	14
Climber, others	25	0	5	0	0	0	5	15	0	0	10	20	5	0	5	10	20

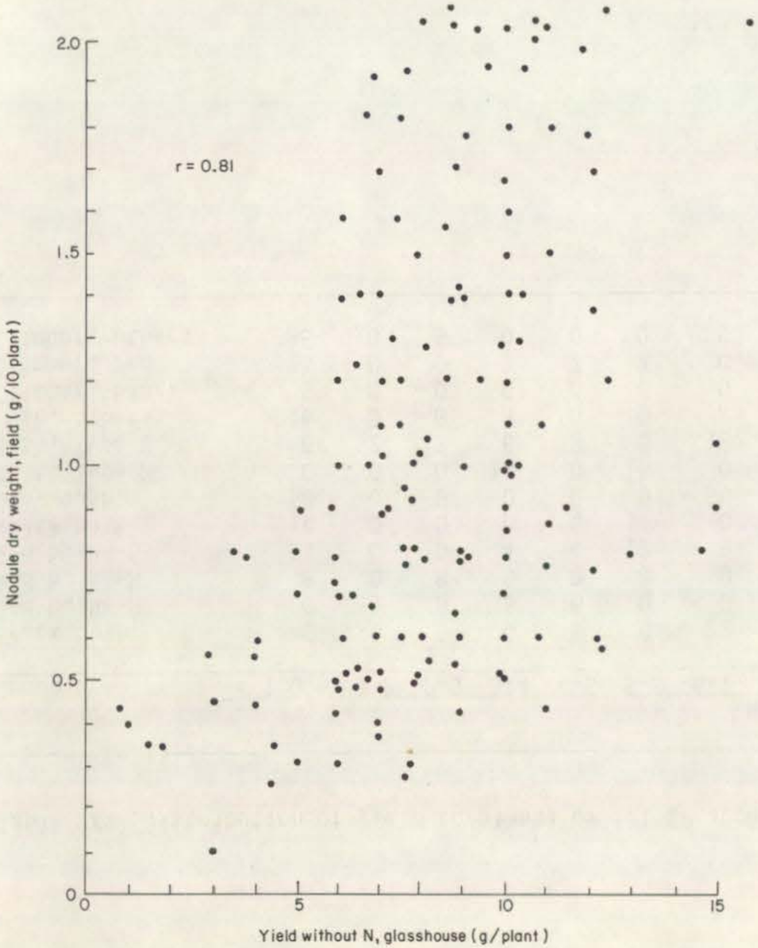


Figure 10. Correlation for lines of the 1981 EP between yield when dependent on fixed N_2 in the glasshouse and nodule dry weight at flowering in the field (Popayán).

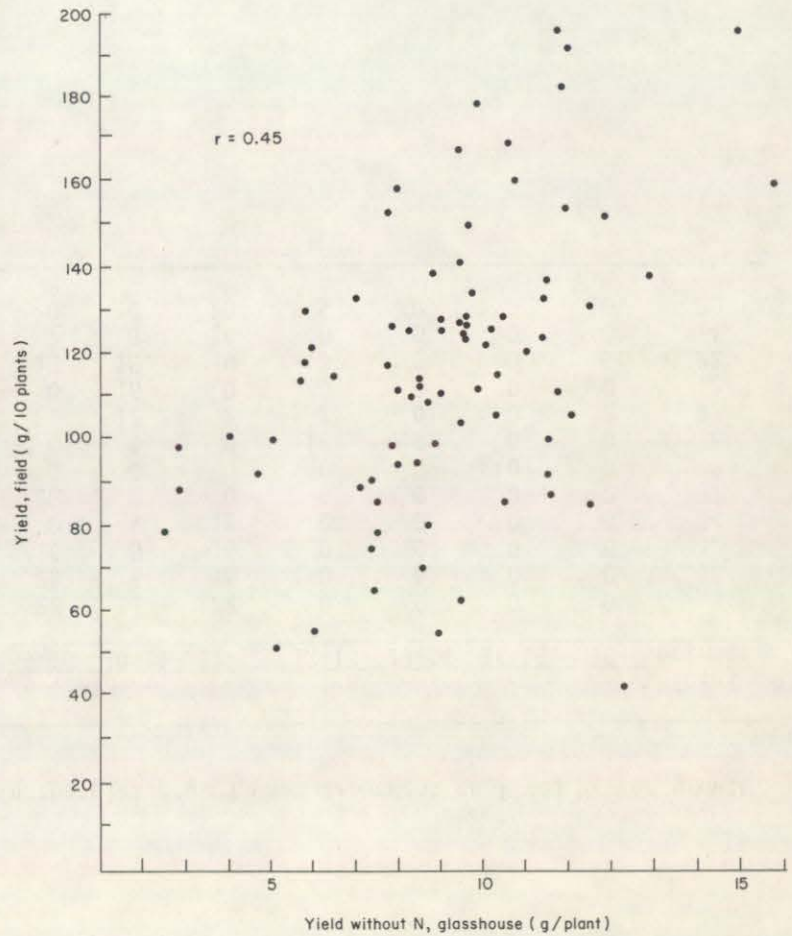


Figure 11. Correlation for lines of the 1981 EP between yield when dependent on fixed N_2 in the glasshouse and yield in the field at Popayan.

Early generations are characterized by a reduced viability and fertility, but these reductions are higher in progenies from the crossing of P. vulgaris with P. coccineus subsp. coccineus progenies than in those from P. vulgaris with P. coccineus subsp. polyanthus. Reduced viability and fertility also varies according to the combination of parents involved. In subsequent generations, a progressive restoration of viability and fertility has been observed.

In early generations, only a variable percentage of plants have a reduced viability (B and T dwarfs), but the other plants are remarkably vigorous. F_1 interspecific crosses using polyanthus as the male parent do not show any dwarfing; however, this is not true in the later generations.

Variability of Progeny

The experiments of Lamprecht (1941) and Walk and York (1957) showed that the early generations of crosses of P. vulgaris with P. coccineus subsp. coccineus are characterized by a return to P. vulgaris with a simultaneous loss of P. coccineus subsp. coccineus characters. Based on the previous findings between crosses of P. vulgaris with P. coccineus subsp. polyanthus, a study was carried out to compare the segregating populations of those two crosses. Such characters as bracteole length and width and number of veins per bracteole were chosen for their high discriminant power among the three parents involved in the crosses.

In crosses of P. vulgaris with P. coccineus subsp. coccineus very different segregating patterns were observed, depending on the combination of parents. The proportion of characters looking like those of P. coccineus subsp. coccineus varied according to the cross. Moreover, transgressive forms were observed. In crosses of P. vulgaris with P. coccineus subsp. polyanthus fewer differences were observed among the segregations. The F_2 populations were intermediate between both parents, and no transgressive forms were observed. The low coefficients of correlation in crosses of P. vulgaris with P. coccineus subsp. polyanthus indicated that the recombination among the observed characters was generally more important than in crosses formed from P. vulgaris and P. coccineus subsp. coccineus (Table 23).

The genetic meaning of these segregations has still to be determined, but the results indicate the important role that the combination of parents plays in the segregations from P. vulgaris and P. coccineus subsp. coccineus and the higher possibilities of recombination of characters in P. vulgaris with P. coccineus subsp. polyanthus.

Specific crossing projects are underway and some materials have already been selected for including architecture characters in common bean improvement and some plants with red seeds presented tolerance to bean golden mosaic virus.

Table 23. Segregation of bracteole length, width and number of veins per bracteole in *P. vulgaris* x *P. coccineus* crosses.

Cross	Coefficient of correlation		
	Length-width	Width-veins	Length-veins
P. vulgaris x *P. coccineus* subsp. *coccineus*			
C63 S-630-B x P.I. 201.297	0.97	0.67	0.34
Puebla 87 x P.I. 201.297	0.80	0.44	0.32
Nep 2 x P.I. 165.421	0.79	0.49	0.54
Junin 25 x Hammond's Dwarf	0.67	0.72	0.39
P. vulgaris x *P. coccineus* subsp. *polyanthus*			
C63 S-630-B x NI 373	0.46	0.72	0.22
Brasil 2 x NI 373	0.40	0.49	0.04

Special Studies

Heterosis

A study was initiated in 1978 to determine the heterosis and combining ability within and among bush bean varieties of different growth habits, seed sizes, geographical origins, etc. Four lines each of the three growth habits (Type I, II, and III) from the CIAT germplasm bank and the bean improvement program were selected to generate a total of 24 F_1 crosses: four within each growth habit and four for each of the three possible combinations among different growth habits. Due to hybrid dwarfism and subsequent death of several F_1 crosses involving two bank accessions, 11 crosses and two parents were dropped from the initial study.

Ten parents and their 13 crosses were grown in a randomized complete block design with three replications. The trials were conducted at CIAT-Palmira in 1979, 1980, and 1981. In 1981, the trial was also grown at CIAT-Popayan, but several hybrids and parents were lost due to their excessive susceptibility to anthracnose, angular leaf spot, white spot, and ascochyta leaf spot. Results of all 3 years have not yet been processed, but, from the 1979 trial, it appears that there is general lack of heterosis for days to flowering, flowering duration, pod-filling period, maturity, seeds per pod, and seed weight among bush bean varieties. On the contrary, heterosis for grain yield ranged from -8% for the cross Brazil 2 x G 5066 to 58% for A 23 x G 7148, with most F_1 crosses showing high and positive heterotic values. In part, this could be due to small plots and spaced plantings where hybrids probably utilized better than the parents the available space, nutrients, sunlight, etc. Of the four parents showing the lowest and highest heterosis, Brazil 2 is a small-seeded Type I; G 5066 is Type II with medium-sized seed; and G 7148 and A 23 are small-seeded Types III and II, respectively. The latter is a CIAT-bred line and the other three are accessions selected from the germplasm bank.

Hybrid Dwarfism

Hybrid dwarfism is characterized by the reduced and stunted growth of the F_1 hybrids which often do not flower and produce pods (Figure 12). Breeders at CIAT and elsewhere have observed this phenomenon in the past and referred to the plants as "cripples." In 1980, Mok et al. reported that the crippled character was controlled by two complementary dominant genes whose expressivity was temperature-dependent. As utilization of accessions from the germplasm bank in our crossing program has increased in recent years, so has the frequency of hybrid dwarfism. From the beginning, we have catalogued all the F_1 crosses showing hybrid dwarfism. In 1980, a study was undertaken to determine the extent of distribution and geographic origin of the genes controlling this character. From the parental lines resulting in hybrid dwarfism, four locations of origin were established: Brazil (4 lines), Colombia (5 lines), Turkey (6 lines), and West Germany (3 lines).

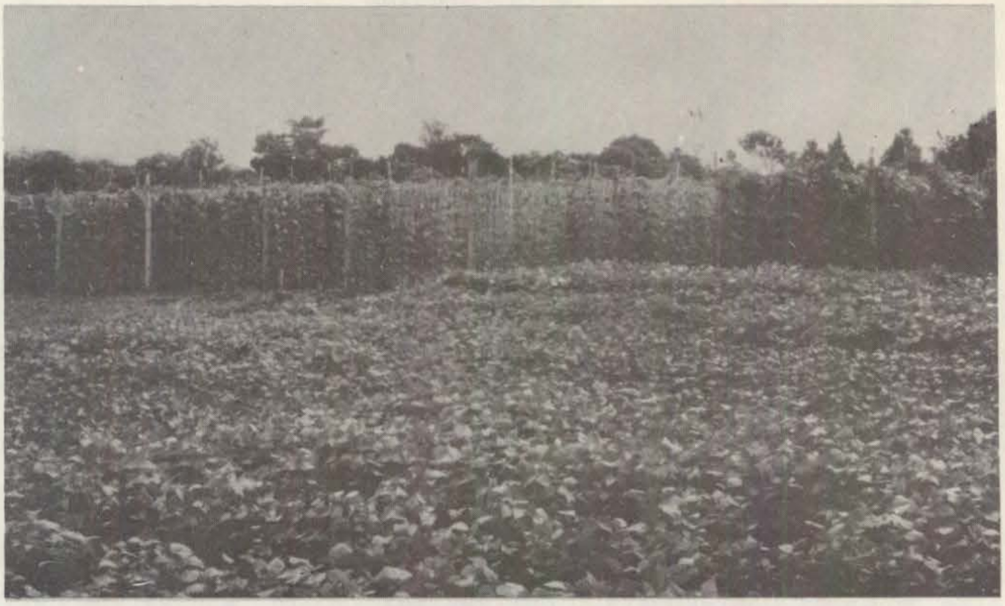


Figure 12. The climbing bean variety Cargamanto on a trellis system. The central plot was not inoculated with Rhizobium and shows deficient growth, compared to plots on the right and left, which were inoculated and grew vigorously.

All possible diallel crosses among parents within each group and a few selected crosses between different groups were made. Also, all lines were crosses with two common testers, one of small- and another of medium-sized seed. All parents and crosses were grown at both the CIAT-Palmira and Popayan farms. Hybrid dwarfism was observed in the F_1 crosses between or within groups only when a small-seeded line, e.g., BAT 332, BAT 1061, Carioca, G 7148, etc., was crossed with medium- and large-seeded types, e.g., ICA L 23, G 5066, etc. In our routine breeding program, not all such combinations show this problem. None of the crosses within either small- or medium- and large-seeded types have thus far been observed with hybrid dwarfism.

Data from recent EP and IBYAN trials strongly indicate the yield superiority of small-seeded lines over those possessing medium and large seeds in bush beans. In general, the latter forms demonstrate adaptive superiority over the former in cold climates and moisture stress conditions. The genetic barrier between these two distinct groups presumably arose early in the evaluation of different forms of *Phaseolus vulgaris* in order to keep these isolated from each other and thus capitalize on their individual characteristics of adaptive advantage and relative fitness in contrasting environments. Medium and large forms of *Phaseolus vulgaris* are predominant in the highlands of the Andes, and small types are more prevalent in the coastal areas of Mexico and Central America.

Starch Accumulation for Stress Tolerance

A collaborative project with Michigan State University was begun in 1981 to investigate starch accumulation in the stem and roots of selected bean lines. The technique used is that described by Adams et al. and can be used to screen large numbers of materials in the field fairly rapidly. The objective is to discover whether the ability to store starch and later mobilize it into the pods is related to the ability to withstand stresses, in particular the stress from shading when beans are associated with maize and stress due to drought. Evidence exists that seed-filling rate and yield are reduced less under shade in variety NEP-2 (starch storer) than in Sanilac (nonstorer) (MSU Bean Research Project, 1980). To identify lines adapted to the tropics and later to study their contrasting behavior in association and monoculture, a preliminary screening was carried out; results are summarized in Table 24. Relatively few varieties were found that stored starch. Varieties of various grain colors were found with contrasting behavior. The accumulation of starch in the stems was negatively correlated with days to flowering ($r = -0.54*$).

Table 24. Preliminary screening for starch content at flowering, 12 observations per variety.

Entry	Color	IKI score	
		Root	Stem
Nonstarch storers:			
V 7918	Red	2.08	1.83
V 79119	Red	1.79	1.63
V 7920	Red	1.75	1.50
G 2525 (P 589)	Pink	2.38	1.29
G 3873 (P 16)	Black	1.17	1.08
G 2540 (P 364)	White	1.79	1.21
G 1098	Cream	1.63	1.25
Sanilac (Control)	White	1.67	2.42
Starch storers:			
V 7933	Red	3.75	3.08
V 7844	Red	2.92	3.08
Carioca (G 4017)	Cream/beige	2.63	2.21
G 1253	Beige	3.63	2.71
Nep-2 (Control)	White	3.88	3.21
LSD		0.95	0.80