an program
1977/CIAT

Cover: CIAT research staff discuss observations made during evaluations of new breeding materials.

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 1977 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) and the governments of Australia, Belgium, the Federal Republic of Germany, Japan, the Netherlands, 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.

02E1R - 77
September 1978

Bean Program
1977 Report

This publication is a reprint of the Bean Program section, 1977 CIAT Annual Report

Centro Internacional de Agricultura Tropical (CIAT)
Apartado Aéreo 6713, Cali, Colombia, S.A.

PERSONNEL OF THE BEAN PROGRAM

(As of 31 December 1977)

CIAT General Direction

Senior staff
John L. Nickel, PhD, Director General
Alexander Grobman, PhD, Associate Director General, International Cooperation
Kenneth O. Rachie, PhD, Associate Director General, Research

Other professional staff
Cecilia Acosta, Administrative Assistant

Bean Program

Senior staff
Aart van Schoonhoven, PhD, Entomologist (Coordinator)
***Charles A. Francis**, PhD, Agronomist
Guillermo Gálvez, PhD, Regional Coordinator for Central America (stationed in San Jose, Costa Rica)
Peter H. Graham, PhD, Microbiologist (on study leave)
****Reinhardt Howeler**, PhD, Soil Scientist
Douglas Laing, PhD, Physiologist
Silvio Orozco, PhD, Plant Breeder (attached to ICTA, Guatemala)
John Sanders, PhD Economist
Howard Schwartz, PhD, Plant Pathologist
Shree Singh, PhD, Plant Breeder
Steven Temple, PhD, Plant Breeder
Oswaldo Voysest, PhD, Agronomist
Kazuhiro Yoshii, PhD, Plant Pathologist (attached to ICTA, Guatemala)

Visiting scientist
Oghenetsevbuko Todo Edje, PhD, Seed Physiologist

Postdoctoral fellows
Jeremy Davis, PhD, Agronomy
***Fred Eskafi**, PhD, Entomology
***Yoshihiko Hayakawa**, PhD, Physiology
Richard Swindell, PhD, Plant Breeding

Visiting specialist
***Robert Burns**, MS, Germplasm

Research associates
Camilo Alvarez, MS
***Luis Alberto Rojas**, MS

Research assistants
Ricardo Campos, Ing. Agr.
Mauricio Castaño, Ing. Agr.
Jorge García, Ing. Agr.
***Luis A. Gómez**, Ing. Agr.
Pablo Guzmán, Ing. Agr.
Nora Ruiz de Londoño, Ing. Agr.
Nelson Martínez, Ing. Agr.
Carlos J. Medina, Ing. Agr.
***Jorge E. Parra**, Ing. Agr.
Martín Prager, Ing. Agr.
José Restrepo, Ing. Agr.
Rosmira Rivera, Ing. Agr.
Juan C. Rosas, Ing. Agr.
Fernando Takegami, Ing. Agr.
Gerardo Tejada, Ing. Agr.
***Rafael Valderrama**, Ing. Agr.
***Guillermo Valencia**, Ing. Agr.
Silvio Vitery, Ing. Agr.
Silvio Zuluaga, Ing. Agr.

* Left during 1977
** Assigned to two programs

CONTENTS

Bean Program

With the arrival of the second breeder for the Bean Program, the importance of varietal development activities by the team greatly increased. Large numbers of new crosses were inititated and the first CIAT hybrids entered the international yield testing program this year. At this level, they will compete with germplasm accessions and entries from various national programs.

The results of the first International Bean Yield and Adaptation Nursery (IBYAN) showed a 35 percent yield difference between the five best entries furnished by CIAT and the five best local materials, in favor of the former group.

The yield differences observed in the first IBYAN were equal in the tropical as well as in the temperate zones. These nurseries showed that wide adaptation to environments exists within *Phaseolus vulgaris*. This testing regime greatly increased the intensity of the Program's Latin American network. The 1977 IBYAN was composed of two different sets, according to seed coat color preference — that is, a black-seeded nursery and a non-black nursery, each containing 25 entries.

In physiological experiments, it appeared that large vegetative structures leads to increased yields if lodging resistance can be found. Lodging resistance is also thought of as an important mechanism for disease avoidance.

Also in 1977, the second pathologist arrived and greater attention was given to moving segregating populations through a set of pest resistance nurseries as well as screening them for wide adaptation. The close collaboration with national program virologists in El Salvador, Guatemala, the Dominican Republic and Brazil identified sources of germplasm resistance to bean golden mosaic virus. The first multiple-country testing of hybrids between golden mosaic-tolerant parents resulting from respective breeding programs showed transgressive segregation and gave promise of future reduction of this increasingly important virus disease in Central America and Brazil.

Sources resistant to bacterial blight in tests in the United States were rated susceptible in tests at CIAT due to lack of adaptation. Adapted, moderately tolerant germplasm was located.

Vegetable oils, at a dosage of only 5 millimeters per kilogram of bean seed, appeared to effectively control insect pests of stored beans. This method is safe, cheap and easily adapted to household use.

Training again formed an important part of the Bean Program activities. The second intensive course for bean research scientists was held; 30 Latin American professionals participated. The program was also active in training individuals at the postgraduate intern levels and several MS and PhD thesis research requirements were fulfilled with projects done in the Program. A total of 71 professionals were trained in 1977.

Breeding

Major nurseries were planted at CIAT during the 1977 rainy seasons and a seed increase *Empoasca* resistance nursery was planted in the intervening dry season. Nurseries were planted in collaboration with other program disciplines and the Instituto Colombiano Agropecuario (ICA) in four locations outside CIAT.

Selected families were evaluated in replicated yield trials and multilocation observation nurseries were planted to select progenies for international testing in 1978. With the addition of a second breeder to the program in mid-1977, increased emphasis was given to breeding for improved plant architecture, yield, and adaptation. Also, with improvements in screenhouse facilities the program reached a capacity of 1500 crosses/year.

MAINSTREAM BREEDING

Parental Selection and Hybridization

Parents which consistently gave a high frequency of good offspring, most of which were validated by Agronomy in yield tests, were emphasized in planning crosses. Priority was given to identifying better non-black parents for hybridization (Table 1). With mechanized field operations the chances were increased of getting a larger volume of hybrid progenies and a greater number of segregating plants per population and to obtain non-black segregants with multiple resistance factors. A large number of parents and progenies have been discarded (especially those susceptible to Problem X) based on more complete information provided by program disciplines to the information system (SIFRI).

Progeny Management—Early Generation Screening

The breeding program has modified the previous system of progeny management (CIAT Annual Report, 1976) such that program disciplines contribute to genetic improvement through the screening of selected bush bean progenies (Fig. 1).

Table 1. **Frequencies of crosses within and among black and non-black parents[1] for the periods 1974-1976 and 1976-1977.**

	Blacks	Black x Color	Colors
1974-Nov. 1976	1111 (36%)	1712 (56%)	259 (8%)
Nov. 1976-Nov. 1977	152 (22%)	216 (31%)	336 (48%)

[1] Does not include 402 intermatings of progenies.

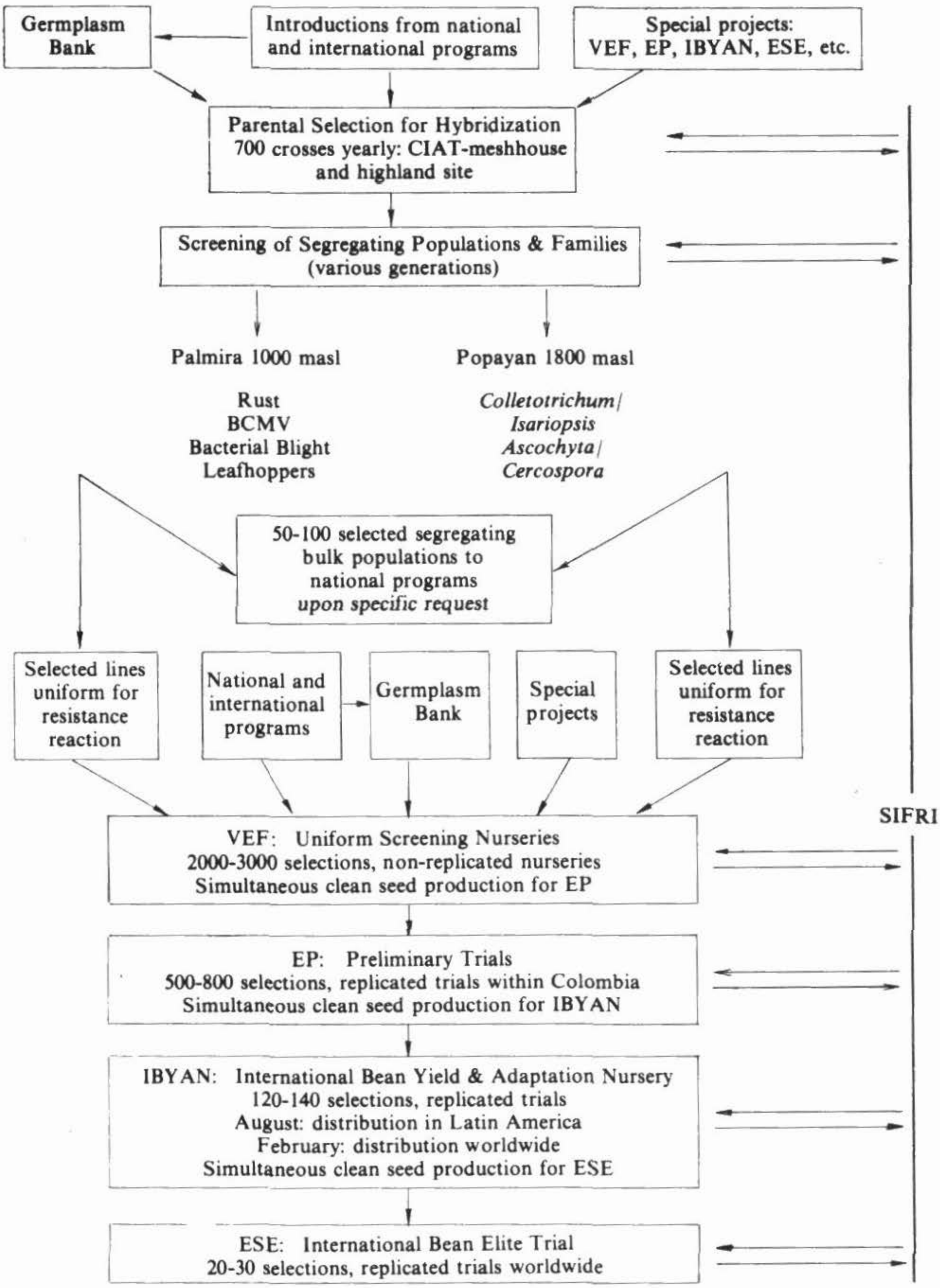


Figure 1. **Program for simultaneous and sequential development and evaluation of bean germplasm.**

Large plantings were inoculated with bean common mosaic virus (BCMV) rust and infested with *Empoasca* (see Fig. 3, Pathology). Also, angular leaf spot and bacterial blight tolerance were recently elevated to a high priority. Selections for multiple disease and insect resistance were made in a range of agronomic types and seed color combinations. Homogeneity is being sought for field tolerance to rust and anthracnose, rather than homozygosity for specific gene resistance. Progeny evaluations for anthracnose, angular leaf spot, and root rot resistance also began in the latter part of 1977.

A relatively remote combination of parents produced red-seeded progenies with reasonably erect, indeterminate growth habit combining resistance to BCMV and rust, which demonstrated the value of massive crossing. A number of populations and selections from crosses of promising bush type parents x climbing donors were given to the climbing bean section for evaluation.

Progeny Testing (Colombia)

Relatively homogeneous families selected at CIAT or Popayán from mainstream, disease-insect resistance and architectural-yield breeding, and from the national programs enter preliminary testing. This includes replicated yield trials by Agronomy, multilocation observation nurseries in contrasting environments; and screening by the program disciplines for all principal disease, insect and edaphic factors (Fig. 1). Summarized data from SIFRI is used to select entries that progress to international progeny testing, and to plan future crosses.

Yield trials of selections from earlier crosses in the program were conducted in each rainy season during 1977 but results were unreliable due to persistence over several semesters of the disturbance, Problem X.

International Progeny Testing

During 1977, breeding distributed to national programs a total of 646 F_2 and F_3 populations, and 526 early and advanced generation selections for evaluation. All selections and seed from F_2/F_3 populations originating from the breeding program are accompanied by information from the SIFRI regarding parents and their key characteristics.

SPECIAL BREEDING PROJECTS

Bacterial Blight Tolerance

Segregating populations and selected families were evaluated for bacterial blight tolerance to select parents for the first cycle of intermating. In greenhouse studies, narrow-sense heritability estimates of 0.68 and 0.27 were obtained from leaf clipping inoculation of progenies from crosses of P566 x P698, and P712 x P684, respectively. This suggested that selection for existing levels of tolerance in tropically-adapted progeny of tolerant x susceptible crosses will be easier than selection to increase existing tolerance levels.

Bean Golden Mosaic Virus Tolerance

Black-seeded progenies from crosses of parents identified by the 1976 IBGMV nursery performed very well in Central America. As a result, crosses were made among the best non-black entries in the 1977 IBGMV nursery and a recurrent selection and intermating effort was initiated with the collaboration of scientists in Guatemala, El Salvador, the Dominican Republic, and Brazil.

Bean Architecture, Yield and Adaptation Breeding (BAYAB)

CIAT bean breeding initially concentrated on the improvement of bean yield through breeding for resistance to the principal bean diseases and insects in Latin America. Selection for morpho-agronomic characters in the segregating populations was also practiced to maintain or improve current levels of yield potential.

With the arrival of a second breeder, improved bean plant architecture and lodging resistance, maximization of adaptation to climatic and edaphic factors and upgrading of yielding ability were further emphasized. In the F_2 (or equivalent) populations, emphasis was placed on selection for architectural characters. Grain yield and adaptation selection criteria will be imposed on the F_3 and F_4 generations. Presently, parents from germplasm collections, introductions, breeding nurseries, etc. are being sought.

The importance of other characteristics are also being determined. Root phyllotaxy of 36 selected parents of growth habits I, II, and III was studied to understand the variation of important characteristics within and between growth habits and to determine if any root characters are associated with resistance to lodging, drought, early vigor, and stability.

Ten seeds from each of 36 lines with three different growth habits were grown in seed germinators for seven days. Differences within and between growth habits were found only for total number of first order lateral roots and length of the primary root (Table 2). The value of these characters is being assessed.

Fourteen lines were selected for more extensive evaluation in sand culture. The factors considered were: number of first order laterals; length of the primary root; weight of roots and shoots; and shoot/root ratio. Five plants of each genotype were harvested at 10 and 24 days after planting. The greatest differences were in the number of first order laterals and total root and shoot weights of growth habit I lines as compared to those of growth habit II and III. The latter two showed similar patterns of growth.

BREEDING STUDIES

Earliness

A special project was conducted in which a series of crosses were made to generate early maturing material and to obtain heritability/inheritance estimates for earliness in three tropically-adapted F_4 populations. Eighteen superior, black-seeded F_4 lines were selected combining earliness with good yielding ability. Days to flowering and days to physiological maturity were both found to be highly heritable (Table 3). Crosses from 2 of the 3 donors demonstrated a single dominant gene for earliness, with no maternal effects

Table 2. **Mean values for five root characteristics of seven day-old seedlings of bush bean lines grown in a seed germinator.**

Growth Habit	No. of Entries Tested	Days to Radicle Emergence	Days to Appearance of First Order Laterals	No. of Positions of First Order Laterals	No. of First Order Laterals	Length of Primary Root (cm)
I	21	2	3	4	11.1	160.3
II	12	2	3	4	9.2	150.1
III	3	2	3	4	9.4	181.5
Mean		2	3	4	9.9	164.0

Table 3. **Inheritance and heritability of earliness in three tropically-adapted source populations[1].**

Cross	Pedigree	Days to Flower	Days to Maturity	Hb[2] Flower	Hb[2] Maturity	Hn[3] Flow	Fit to 3:1 Ratio[4]	Maternal Effects
18, 19	P569 x P721	30	60	.80	.87	.77	No	Yes
16, 17	P739 x P721	32	70	.73	.70	.72	Yes	No
20, 21	P780 x P721	30	55	.72	.80	.60	Yes	No

1 Values represent means of reciprocal crosses.
2 Broad-sense heritability, based on variances.
3 Narrow-sense heritability, based on parent-offspring regressions.
4 One major gene, earliness dominant to lateness.

(Fig. 2) while earliness in the third parent was controlled by two or more genes, with evidence of partial dominance for earliness and maternal effects. Data suggest that modifier genes were present in some crosses. The coefficient of genetic variation was high in all crosses, and days to first flower and days to physiological maturity were always highly correlated. Thus, selection for earliness could be practiced from the F_2 generation using a combined pedigree-bulk method. Transgressive segregation was observed for days to physiological maturity.

Evaluation of the Honeycomb Design

An experiment was designed to test the feasibility of using the screening honeycomb design in early generation yield testing. Forty-seven pure lines of beans were compared in two sets of four randomized complete blocks and in screening honeycomb designs with 1.15 and 0.70 meters between plant spacing. All varieties occurred randomly once within each of eight replications.

Results (Table 4) showed that there was

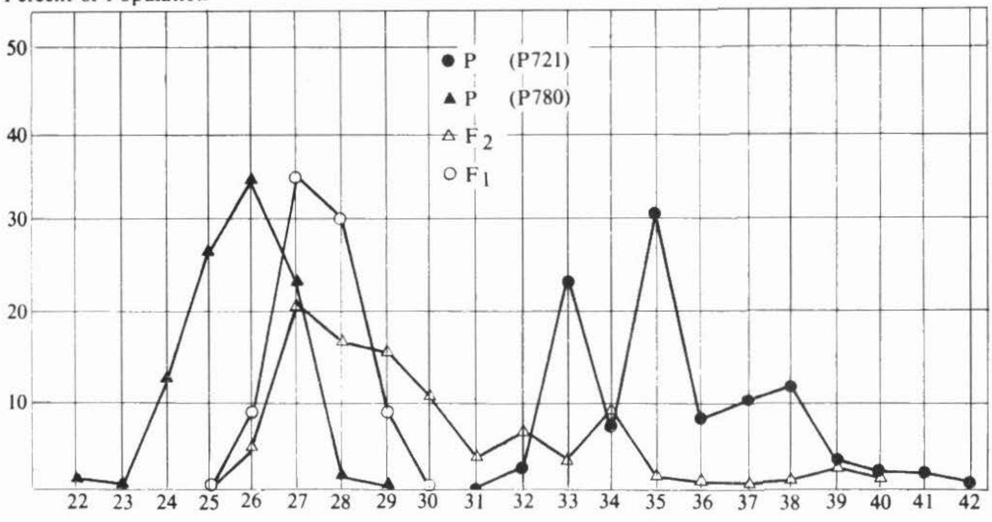


Figure 2. **Frequency distribution (percent) for parents, and F_1 and F_2 progenies from the cross P721 x P780.**

Table 4. Correlations between mean yields of 47 varieties (as a group and separated by growth habit) from randomized complete blocks and mean yields, modified and unmodified, from 8 replications of a simulated screening honeycomb design with 1.15 m. and 0.70 m. between plant spacing.

	Spacing	Unmodified Mean Yields from Honeycomb[1]	Mean Yields Corrected (Triangle)	Mean Yields Corrected[2] (Hexagon)
Yield[2] of 47 Varieties in RCB's	1.15	0.36*	0.36*	0.40*
	0.70	0.48**	0.43*	0.47**
Yield[2] of 23 Determinate Varieties in RCB's	1.15	0.48*	0.53*	0.51*
	0.70	0.49*	0.37	0.53**
Yield[2] of 24 Indeterminate Varieties in RCB's	1.15	0.29	0.24	0.36
	0.70	0.52**	0.49**	0.47*

[1] Yields of individual spaced plants in the honeycomb modified either as a percent of the surrounding triangle of controls (see Fig. 1) or as a percent of the surrounding equidistant hexagon of 5 random varieties and 1 control.

[2]*, ** Significant at the 0.05 and 0.01 level, respectively.

no advantage in employing the honeycomb design (in which mean yield was expressed as a percent of the surrounding hexagon or control triangle) over the randomized complete block design.

Competitive Ability *vs.* Yield

Studies of competition were initiated to optimize the effectiveness of CIAT bean breeding methodologies. If the best yielders in pure stands were also the best yielders in mixtures, bulk breeding for yield could be used. If not, another method using spaced plants would have to be used.

Six determinate and six indeterminate varieties were evaluated for their competitive ability in separate tests. Between plant spacing was 6.7 cm and between row spacing was 0.6 m in a split plot design with all possible ij $(i \neq j)$ combinations as main plots, and two pure stands and three proportions of i and j as subplots. Table 5 shows mean values for yields in pure stands and in mixtures over two replications and three proportions.

Correlations between the yield of a variety in pure stands and its average yield over mixtures were 0.94** for the indeterminate and 0.83* for the determinate varieties, if the yield of the pure stand (the mixture of a variety with itself) were not included among the values used to calculate the means over mixtures. The yield rank order for mixtures and pure lines was identical for the indeterminate varieties (if P46 which was heavily infected with BCMV, were not considered). Although rank order was not the same for mixtures and pure stands among the determinate varieties, the top three and the lower three varieties were the same.

Table 5. **Matrices of yields in mixtures for the 6 determinate and the 6 indeterminate varieties, based on means over 2 replications and 3 (1:3, 1:1, and 3:1) proportions for the mixture plots and means over 10 individual plots for the pure lines[1].**

Determinate varieties

	Associates						
	P89	P560	P623	P635	P637	P788	Variety Mean
P89	562.1	265.7	461.8	546.2	342.8	632.7	468.5
P560	482.1[2]	623.4	515.5	862.0	625.3	955.7	677.3
P623	255.1	110.4	205.9	297.4	107.8	232.6	201.5
P635	730.7	501.7	542.0	628.0	421.2	577.0	566.8
P637	958.4	650.9	721.1	731.5	649.6	1000.7	785.4
P788	567.0	268.3	480.4	475.8	360.2	588.5	456.7
Mean of Associates	592.6	403.4	487.8	590.1	417.8	664.6	

Indeterminate Varieties

	Associates						
	P246	P498	P524	P566	P643	P698	Variety Mean
P246	201.6	225.8	149.9	160.6	194.9	147.0	180.0
P498	198.4	442.2	279.8	382.3	243.3	515.8	343.6
P524	599.3	683.0	613.1	597.0	619.3	1099.2	701.8
P566	780.9	722.2	619.5	665.5	681.0	1018.5*	747.9
P643	493.4	476.3	508.5	545.9	470.0	885.6	563.3
P698	175.6	138.5	58.4	76.2	128.1	306.2	147.2
Mean of Associates	408.2	448.0	371.5	404.6	389.4	662.1	

1 All values adjusted to a grams 80 plant basis; means for pure lines based on 800 plants, means for mixtures based on 720 plants.
2 This value (482.1) is the average yield of P560 when grown in mixtures with P89.

Correlations between yields in mixtures and the average yields of associates grown with each competitor were -0.675 (n.s.) for the indeterminate varieties and -0.420 (n.s.) for the determinate varieties. However, when P246 was removed from the analysis of the indeterminates, as well as the aberrant variety (which produced normal growth but almost no seed due to Problem X) analysis of the determinate varieties, correlations between yields in mixtures and yields of associates became -0.884* and -0.973** for the indeterminate and determinate types, respectively.

This experiment strongly suggests that the best yielding bush beans in pure stands are the best competitors in mixed stands at high densities. These results suggest that bulk breeding may prove to be the most effective methodology for yield improvement. Results are being retested in segregating hybrid populations from crosses between parents with contrasting plant architectures.

Pathology

VIRAL DISEASES

Bean Common Mosaic Virus (BCMV)

Strain Evaluation. Several isolates of BCMV, obtained from infected seeds of several varieties in the CIAT germplasm bank originating in Latin American countries and the United States, were increased in the susceptible variety, Bountiful. Fifteen to 21 days after inoculation, the virus from Bountiful was inoculated onto a set of differential varieties developed by Drijfhout in Holland and Silbernagel in the United States.

The most common strain found was BCMV-1 (NL-1, Westlandia or type strain) (60%) followed by: BCMV-3 (NL-6, Florida, Western, Idaho, B, or Colana); BCMV-4 (NL-8); BCMV-2 (NL-7); and BCMV-5 (NL-2, New York 15 or Imuna). Strains BCMV-6 and 7 were not registered.

Epiphytotic of BCMV. An epiphytotic of black-root (systemic necrosis) occurred in June, July, and August at CIAT during which abnormal drought conditions raised temperatures above the average 24°C. This coincided with a high population of aphids, the natural vectors of BCMV During this epiphytotic, many segregating materials showed a hypersensitive reaction to BCMV as evidenced by vascular necrosis of the roots, stems, leaves, and pods, which produced rapid death of the plant, thus demonstrating the presence of the dominant *I* gene.

To determine which BCMV strains were present, field and greenhouse tests were done with infected sap from plants containing the dominant *I* gene and showing systemic necrosis. The virus was mechanically inoculated on the following varieties: (1) P458, P459, P566, P675, and P714 with the dominant *I* gene for tolerance; (2) Great Northern 123 with the recessive *i* gene; and, (3) the susceptible varieties P634, P645, and Stringless Green Refugee.

Table 6 shows the results of isolation of the virus from field-infected plants with systemic necrosis. Table 7 shows the results of inoculation with sap from BCMV systemically infected plants (Table 6) which had been previously infected with sap from field-infected plants. A comparison of Table 6 and 7 shows that while the susceptible varieties presented mosaic symptoms, Great Northern 123 with the recessive *i* gene was immune to the virus strain. On the other hand, varieties with the temperature sensitive, dominant *I* gene showed leaf vein necrosis and many plants died from systemic necrosis. The low number of plants with localized or systemic symptoms (Table 6) was due to the low concentration of the virus in the inoculum source plants with systemic necrosis. It was concluded that systemic necrosis was caused by BCMV, probably by strain BCMV-1, NL-1 or type strain.

Purification and Stability of the Virus. To obtain maximum infectivity of the BCMV strain for later use in field infections and to produce an antiserum with a higher titer specific to the virus, stability experiments were done in the greenhouse with different buffers, at different molarities and pH's, and combined with reducers, oxidizers, and chelating agents. Infectivity was 95-100 percent when sap was extracted with water from mechanically infected plants. When buffers were used, molarities superior to 0.5 reduced infectivity 25 percent. The virus was more stable with a sodium citrate buffer, 0.05M, pH 7.5.

Methods of Mechanical Inoculation. Various mechanical inoculation systems were tested. Mechanical inoculation was tried with a pestle, index finger and thumb,

Table 6. **Reaction of susceptible and tolerant varieties after inoculation with sap from field-infected plants with black-root in the greenhouse at 28-30°C.**

Variety	Type of Resistance	No. of Plants Inoculated	No. of Plants with Vein Necrosis	No. of Dead Plants	No. of Plants with Typical BCMV Symptoms
P458 (Tui)	*II*	145	24[1]	28	0
P459 (Jamapa)	*II*	155	35	39	0
P566 (Porrillo Sintético)	*II*	30	0	1	0
P675 (ICA-Pijao)	*II*	149	30	25	0
P714	*ii*	43	19	11	0
Great Northern 123	*II*	44	0	0	0
Stringless Green Refugee	Susceptible	60	0	0	14
P634 (Duva)	Susceptible	43	0	0	14
P645 (Nima)	Susceptible	28	0	0	3

[1] Web-type necrosis of the veins on the inoculated leaves.

sponge, hand brush, or an airbrush at 40 kg/cm^2 of pressure. While all were equally effective, the index finger and thumb were more practical for mass screening. However, the airbrush method required less inoculum, and reduced the possibility of contamination by other mechanically transmissible viruses.

Selection for Resistance. Some 789 naturally inoculated, promising materials were evaluated of which 234 were resistant and 555 susceptible.

In Popayán (1800 msl), BCMV-1, was mechanically inoculated on 724 promising materials; 296 were resistant and 428 susceptible. While it was thought that symptoms would develop better with the lower temperature, and contamination by the bean rugose mosaic virus (BRMV) would be avoided, appearance of symp-

Table 7. **Reaction of susceptible and tolerant varieties inoculated with sap from BCMV systemically infected plants (Table 6) originally inoculated with virus from field-infected plants.**

Variety	Type of Resistance	No. of Plants Inoculated	No. of Plants with Vein Necrosis	No. of Dead Plants	No. of plants with Typical BCMV Symptoms
P458 (ICA-Tui)	*II*	20	20[1]	5	0
P459 (Jamapa)	*II*	21	21	17	0
P566 (Porrillo Sintético	*II*	21	21	4	0
Great Northern 123	*ii*	30	0	0	0
P634 (Duva)	Susceptible	13	0	0	12
P645 (Nima)	Susceptible	15	0	0	15
Stringless Green Refugee	Susceptible	24	0	0	24

[1] Web-type necrosis of veins on the inoculated leaves.

toms was delayed, and they were not as clear as those in CIAT.

Bean Golden Mosaic Virus (BGMV)

Presence of BGMV in America and Africa. The presence of BGMV was confirmed in Brazil, Cuba, Dominican Republic, Mexico, Venezuela and Nigeria. While different concentration levels were registered in the different isolates, the presence of different strains of the virus was not suggested. However, further analyses will be made.

Characterization of the Virus. To improve efficiency and reliability of screening progenies for BGMV tolerance under controlled conditions, a special project was initiated on characterization of BGMV, its concentration in the plant and stability in plant tissues.

It was found that viral infectivity was preserved up to 30 days in dissected leaves or sap when stored at 4°C. However, when leaves or sap were frozen, infectivity was lost at five days.

When samples were taken at 10, 15, 20, 25, 30, and 40 days after inoculation, maximum concentration and infectivity of the virus were obtained 20 days after inoculation in both susceptible and tolerant varieties. However, the concentration was much greater in the susceptible plants, and in the leaves above the third trifoliate if the primary leaves were inoculated. The first two trifoliates showed only slight disease symptoms indicating a correlation between concentration of the virus and symptom severity. Analytical density-gradient centrifugation also demonstrated that tolerant varieties which did not show as severe symptoms as susceptible ones had a lower concentration of the virus. The tolerance rating in descending order for the accessions tested were as follows: P709, P458, P704, P675, P635, and P714.

Selection for Resistance. Some 1150 germplasm accessions were preliminarily evaluated in El Salvador and Guatemala. Some red, cream, brown, and white accessions were identified as tolerant to the virus and include: G651, G716, G729, G738, G765, G843, G1069, G1080, and G1157. The black bean varieties (G951, G1018, and G1257) showed the highest tolerances so far. In Brazil, local materials, Rio Tibagi and Gioianio Precoce and a mutant, TMD-1, showed low tolerance levels.

Selection for Resistance in Different Species of *P. vulgaris*. Under greenhouse conditions, 141 CIAT accessions were mechanically inoculated and evaluated. Seven species of *Phaseolus*, 6 of *Vigna*, *Macroptilium lathyroides*, *Glycine max*, *Lens culinaris*, and *Cajanus cajan* were tested. All accessions of *P. lunatus*, *P. coccineus*, *M. lathyroides*, and *V. sesquipedalis* tested were susceptible. Resistant materials of *P. acutifolius:* PI 310,800; PI 313,205; PI 319,443; and PI 307,805 will be included in a program of interspecific crosses (see Breeding). No accession of *P. vulgaris* was resistant to BGMV; only tolerance was found.

International Bean Golden Mosaic Virus Nursery (BGMN). The 190 entries in the 1977 BGMN were sent to 3 locations in Brazil, 2 in Mexico, and 1 each in the Dominican Republic, El Salvador, Guatemala, and Nigeria. Accessions previously classified as tolerant in Central America (Puebla 441, Guatemala 388, P488, P545, P704, and P709) were also tolerant in Brazil and Africa. Tolerance was defined by symptom intensity compared with susceptible and tolerant local controls.

Chrysomelid Transmitted Bean Viruses

Chrysomelid beetles are the most important vectors of bean viral diseases whose characteristic symptoms are mosaics associated with malformations and leaf rugoses or yellow or green mottles. They are often confused with symptoms of the bean common mosaic virus (BCMV). The extent of their presence in Latin America and the Caribbean is unknown. However, bean rugose mosaic virus (BRMV) cultures from Costa Rica, Colombia, Guatemala, and El Salvador were analyzed in pathogenicity trials and with specific antisera and the existence of strains of the virus was determined, confirming results by Gamez in Costa Rica.

Bean Southern Mosaic Virus (BSMV). The symptoms of systemic infection of the bean southern mosaic virus (BSMV) on some varieties under certain environmental conditions are similar to those induced by the bean rugose mosaic virus (BRMV) or the bean common mosaic virus (BCMV), depending upon the virus strain and the bean variety. Frequently, it does not show any symptoms on beans. Since BSMV is seed transmitted, it interferes with screening for other bean viruses. Serology was done on the cotyledon, testa, embryo and whole seed and a 25 percent seed transmission rate was obtained (Table 8).

Bean Yellow Stipple Virus (BYSV). This virus was isolated from beans in Turipaná, Colombia and its symptoms were similar to those caused by BGMV but not as intense. The virus was easily isolated and purified from beans and also from cowpea *(V. anguiculata)* and *M. lathyroides* which appear to be its natural hosts and principal inoculum sources. While the symptoms are easily identifiable, no resistant bean varieties have been found. However, BYSV does not appear to cause major yield reduction in *P. vulgaris*.

Seed Pathology

Clean Seed Production. During 1977, production of pathogen-free seed continued on 351 accessions in the screenhouse and 400 accessions of promising materials multiplied in the field.

Serology of Seed-Borne Viruses. Depending on the variety and environmental conditions, there are several viral diseases which do not express disease symptoms — remaining latent in their hosts. One of these is the bean southern mosaic virus (BSMV). This is a limiting factor in a seed cleaning or seed certification program. However, by soaking bean seed overnight, the presence of the bean southern mosaic virus (BSMV) could be determined by immunodiffusion serology. Bacterial seed pathogens could also be detected.

Table 8. **Seed transmission of the bean southern mosaic (BSMV) shown by agar gel serology.**

Varieties	Seed				Plants	
	Whole	Cotyledon	Testa	Embryo	No.	%
Bountiful (CIAT)	+	+	—	—		
Bountiful (Burpee's)	—	—	+	—	1300	25
P714 (Topcrop, CIAT)	—	+	—	—		
P714 (Topcrop, Burpee's)	+	+	+	—	100	0
Improved Tendergreen (Burpee's)	—	+	—	—		
Stringless Green Pod (Burpee's)	—	—	—	—		
P704 (Porrillo 1)	+	+	—	—	1000	0
P634 (ICA-Duva)	—	—	—	—		

FUNGAL DISEASES

Bean Rust

Over the past two years, no cultivar or line was immune or resistant to *Uromyces phaseoli* at every International Bean Rust Nursery (IBRN) location. However, some entries were resistant or tolerant at many locations and were incorporated into the 1977 IBRN along with recent CIAT accessions (Table 9). The highest proportion of susceptible IBRN entries occurred at locations in the Dominican Republic, Costa Rica, Mexico and CIAT. These sites should be useful to screen hybrid materials for resistance to diverse populations of rust races.

At CIAT, field nurseries were planted to simultaneously screen hybrid progeny for resistance to the bean common mosaic virus (BCMV) and rust. Progeny were hand-inoculated with BCMV as seedlings (CIAT Annual Report, 1976) and then rust epidemics were generated on the BCMV resistant plants before flowering and pod-setting. Two-three weeks before planting of nursery entries, a mixture of 10-15 rust spreading cultivars which were susceptible, intermediate and resistant to rust were planted four rows wide and parallel to every 20 rows of nursery entries (Figure 3). Three to four weeks after germination, spreader plants were inoculated (Figure 4) with a composite of rust races collected during previous epidemics (Figure 5). The mixture of varieties maximized survival of all pathogenic variability inherent within the local bean rust population.

Germplasm and progeny were evaluated according to the following scale: resistant = no infection or a few minute pustules; intermediate = few to many small pustules, usually present only on the lower leaf surface, or pustules with limited necrotic development; or susceptible = few to many large pustules on the lower and/or upper leaf surfaces.

A total of 1643 germplasm accessions were evaluated for rust reactions in the field: 89 were resistant; 69 were tolerant

Table 9. **Reactions of the most widely resistant entries to bean rust (*Uromyces phaseoli*) in the 1975 and 1976 International Bean Rust Nursery (IBRN). Data on number of locations where the entries received disease ratings[1].**

Promising Lines	Identification	Number of Locations									
		1975					1976				
		I	R	INT	S	ND	I	R	INT	S	ND
P793	Compuesto Chimaltenango 3	4	3	2	1	5	5	9	2	1	0
P709	Turrialba 1	4	3	2	3	3	3	7	6	1	0
P675	ICA-Pijao	3	1	4	3	4	3	6	7	1	0
P699	Mexico 309	6	5	1	0	3	6	3	3	2	0
	Mexico 235	2	1	2	0	10	6	4	4	2	1
P509	San Pedro Pinula 72	4	3	3	2	3	4	6	5	2	0
P693	Ecuador 299	5	7	1	0	2	3	6	6	2	0
P685	Cornell 49-242	3	5	4	1	2	2	4	9	2	0
P239	P.I. 226-895	4	6	2	0	3	1	5	7	2	2

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

Figure 3. **Bean Common Mosaic Virus- Rust Nursery design with 4 rows of rust spreader cultivars planted parallel to every 20 rows of nursery entries.**

and 1194 were susceptible. The remaining 291 accessions were variable in their reaction and provided additional sources of resistance/tolerance.

Anthracnose

Greenhouse techniques were developed

Figure 4. **Inoculation of bean rust spreader rows 4 weeks after plant emergence.**

Figure 5. **Rust inoculum (mixture of races) stored with calcium chloride. Inoculum (2-3 ml) mixed with 20 drops Tween 20 in 4 liters distilled water and sprayed onto plants.**

this year to screen for resistance to races of anthracnose prevalent in Colombia. A spore suspension, primarily of beta and gamma races at 1.2 x 10^6/ml (Fig. 6), was sprayed on leaves and injected into stems of seedlings which were incubated in a moisture chamber at 19-24°C and 90-100 percent RH. Materials were evaluated as: resistant = no infection on leaves or stems; intermediate = small, limited lesions on leaves with little development on stems; or susceptible = large lesions on leaves and stems, often causing plant death. Approximately, 100 promising lines resistant to anthracnose races in field nurseries in Popayán were also tested at other Colombian locations to identify candidates for an International Bean Anthracnose Nursery.

Root Rots

This year, experiments were initiated to develop field techniques for screening for resistance/tolerance to various root rot pathogens, principally to *Fusarium solani* f. sp. *phaseoli* and also to *Rhizoctonia solani, Sclerotium rolfsii* and *Pythium* sp. Individual pathogen nurseries were developed by inoculating seed and furrows with a mixture of isolates grown on sterilized media such as rice hulls. Optimum inoculum concentration, plant density and reliable rating scales for evaluation of segregating progeny are still being determined. However, preliminary data indicate that various accessions exhibit resistant/tolerant reactions to many or all pathogens tested (Table 10).

Some 240 accessions were also planted for field evaluation at Popayán under natural infestation with *Fusarium* and *Rhizoctonia:* 32 percent were resistant/tolerant but 10 percent of these entries contained a mixture of susceptible plants. Promising selections will be

Figure 6. **Hypodermic inoculation of bean seedling with a distilled water suspension (1.2 x 10^6 spores/ml) of bean anthracnose isolates.**

Table 10. **Evaluation of root rot reactions[1] on promising germplasm selections at CIAT in 1977.**

Promising Line	*Fusarium*	*Rhizoctonia*	*Sclerotium*	*Pythium*
P009	INT	INT-R	S	INT
P168	S	INT	INT	INT
P432	S	R	R	R
P458	R	S	R	R
P461	INT-R	S	R	INT
P566	R	R[2]	R	R
P622	R	S	INT	R
P646	INT-R	INT	S	R
P718	R	S	R	R
P746	R	R	R	R
P775	INT-R	INT-R	R	INT

1 INT = intermediate; R = resistant; S = susceptible.
2 P566 has been moderately susceptible in other tests at CIAT.

retested in artificially inoculated field nurseries at CIAT to determine their range of reactions to root rot pathogens.

Angular Leaf Spot

Greenhouse techniques to screen germplasm for resistance/tolerance to angular leaf spot were developed. Seedling leaves were spray-inoculated in the greenhouse with a spore suspension at 2 x 10^4/ml and incubated in a moisture chamber (90-100% RH) for 24-48 hours at 19-24°C. Symptoms appeared 12-14 days after inoculation. Field inoculations (2 x 10^4 spores/ml) were done at Popayán and an evaluation scale is being developed.

Web Blight

This year, techniques were worked out to screen germplasm for resistance/tolerance to web blight in the greenhouse at temperatures above 28°C with 95 percent RH. The fungus was grown on potato dextrose agar (PDA) and after four days, transferred to potato yeast dextrose agar (PYDA). After five more days, the fungus was then mixed in sterile soil to produce abundant quantities of basidiospores. Eight to fifteen days after germination, plants were spray-inoculated, incubated and evaluated five days later according to the following scale: 1 = no symptoms; 2 = little growth, chlorosis around the inoculation point; 3 = vein necrosis, with 33 percent leaf chlorosis; 4 = vein necrosis, 50 percent leaf chlorosis; and 5 = complete leaf necrosis. P17, P358, P488 and P566 were highly tolerant to web blight.

BACTERIAL DISEASES

Common Bacterial Blight

Greenhouse experiments were done to determine if pathogenic variation of common bacterial blight at CIAT were due to distinct races or variations in isolate virulence. The primary leaves of six cultivars with different degrees of tolerance or susceptibility were clip-inoculated at 5 x 10^7/ml with isolates from Latin America and the United States. Virulence between isolates and tolerance of the cultivars

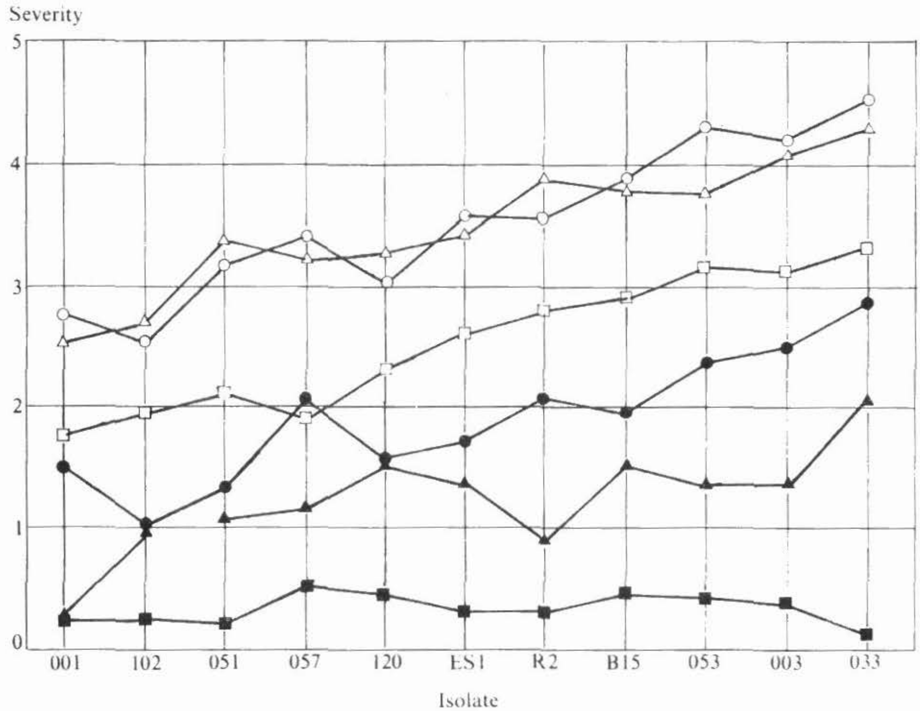


Figure 7. **Interaction between common bacterial blight isolates with different levels of virulence and bean cultivars with different levels of tolerance.**

varied, but there was no interaction at the P = 0.05 level between isolates and cultivars to imply the presence of races (Figure 7). These isolates and others from different locations in the Americas were then inoculated onto a susceptible cultivar, ICA-Pijao, to recover and estimate frequency of highly virulent isolates in natural populations (Table 11). Isolates from nearly every location were as virulent as

Table 11. **Frequency of virulent common blight isolates collected from different locations in Latin and North America, and clip-inoculated onto primary leaves of susceptible ICA-Pijao.**

Isolate Origin	Number of Isolates Tested	Number of Isolates as Virulent as XP 123	Range in Virulence[1]
Colombia, Cauca Valley	13	1	1.4- 9
Colombia, Restrepo	9	6	7.4-10.9
Colombia, other	5	0	5.0- 7.5
Puerto Rico	12	5	1.8-13.3
Mexico	8	3	4.6- 9.6
El Salvador	7	2	6.7- 8.9
Brazil	10	6	7.1-10.2
U.S.A., Michigan	2	0	5.7- 7.6

Data normalized to isolate XP 123 with a virulence rating of 10 ($LSD_{.05}$ = 1.5).

XP 123 from Colombia. Therefore, the bacterial blight screening will use the most highly virulent isolate in local populations of the pathogen to evaluate germplasm for resistance/tolerance.

Several varieties tolerant to common bacterial blight *(Xanthomonas phaseoli* and *X. phaseoli* var. *fuscans)* in temperate zones are susceptible under tropical conditions at CIAT. This makes parental selection and progeny screening more difficult. Therefore, studies were initiated in 1977 to investigate the influence of plant adaptation and environmental factors upon disease reaction, and to develop reliable greenhouse and field techniques to evaluate common blight tolerance at CIAT.

Five cultivars were selected which were susceptible, tolerant, and varied for photoperiod sensitivity (Table 12). The poorly adapted cultivars, P684 and P698, were treated with supplemental lighting to simulate temperate zone lighting and to extend time to flowering. Beginning at 20 days after germination, plants were inoculated at weekly intervals by water-soaking with bacterial cells of a highly virulent Colombian isolate, CIAT XP 123 (5×10^7/ml). At 22 and 33 days after initial inoculation, the light treatment significantly delayed flowering and leaf senescence, increased foliage development and produced a tolerant response in the non-adapted P698. These differences were also confirmed with yield data, thus demonstrating the effect of poor plant adaptation on common bacterial blight tolerance. The CIAT breeding section will select parents with bacterial blight tolerance and/or incorporate tolerance from poorly adapted parents within an agronomic background well-adapted to tropical conditions.

DISEASE OBSERVATION TRIALS

In collaboration with the Instituto Colombiano Agropecuario (ICA), CIAT bean breeding and pathology planted nurseries in several areas of Colombia to simultaneously evaluate germplasm for plant adaptation and disease resistance. Several promising accessions possessed multiple disease resistance or tolerance to various plant pathogens such as rust, anthracnose, web blight, powdery mildew, gray spot, *Ascochyta* blight and common bacterial blight (Table 13).

Table 12. **Effect of different environments on common blight (*Xanthomonas phaseoli*) reactions.**[1]

		Common Blight Reaction		
		Temperate	Tropical	
Promising Lines	Adaptation at CIAT	Normal Photoperiod	Normal Photoperiod	Extended Photoperiod[2]
P684	Poor	S	S	S
P698	Poor	T	S	T
P498	Good	S	S	S
P566	Good	S	S	S
P597	Good	T	T	T

[1] S = susceptible; T = tolerant

[2] 18 hour day; supplementation with incandescent lights in field.

Table 13. **Promising lines with multiple disease resistance or tolerance to fungal and bacterial pathogens in various field nurseries in Colombia.**

Promising Lines	Disease Reaction[1]					
	Rust	Anthracnose	Web Blight	Powdery Mildew	Gray Spot	Common Blight
P167	INT	R	S	S	INT-R	S
P168	INT	R	S	S	INT-R	T
P179	R	R	T	N	N	T
P189	R	R	S	S	INT-R	S
P203	INT	R	S	S	S	T
P204	R	INT	S	S	INT-R	T
P256	INT	INT	S	INT-R	S	S
P334	INT	R	T	S	INT-R	S
P349	INT	S	S	INT-R	S	S
P507	INT	R	T	S	T	T
P631	R	R	S	S	INT-R	S
P670	R	R	T	S	S	S
P782	INT	R	T	S	INT-R	T

[1] R= resistant; T= tolerant; INT= intermediate, S =susceptible, INT-R= resistant during natural epidemics, require controlled tests to confirm resistance. N= P Line not observed for reaction to specific pathogen.

Entomology

Moderate to low levels of resistance to *Empoasca,* mostly based on tolerance, were identified in the germplasm bank and recurrent selection initiated to increase resistance levels. Cultural control of leafhoppers also appears promising. The biology of the Chrysomelid species, *Diabrotica balteata,* was studied in the laboratory and damage of the different life stages to beans at different levels of maturity. Treatment of stored beans with vegetable oils was found to be a cheap and effective method of protection against *Zabrotes subfasciatus.*

LEAFHOPPERS

Screening for Resistance

Additional sources of resistance to the leafhopper, *Empoasca kraemeri,* were found in new germplasm accessions. The International Bean Rust Nursery (IBRN) contains several entries — e.g. G05942 and Turrialba 1 — with promising resistance to *Empoasca.*

To test the feasibility of screening segregating populations for resistance based on individual plant damage scores, 38 promising lines having known and varying resistance levels identified in previous replicated trials were used to simulate resistant x susceptible crosses of an F_2 population. Individual damage scores taken twice weekly, and yield per plant in one replicate were correlated with the other seven replicates. Rank correlation coefficients between individual and replicated scores were highly significant (Table 14), indicating that selection of

Table 14. **Correlation coefficients of individual plant damage scores in 1 replicate with the 7 remaining replicates for simulated F_2 of 38 P lines scored twice weekly for leafhopper damage (damage scale 0-5).**

Evaluation Method	No. Observations	Spearman's Rank Correlation Coefficient
Visual damage score	13	0.592
Visual damage score	7	0.574
Visual damage score	5	0.549
Visual damage score	3	0.533
Visual damage score	1	0.441
Visual damage score with more weight given to later observations		0.653
Seed yield		0.585
Combined visual dam. score and yield		0.639

single plants in the F_2 generation may be an acceptable screening method.

Scoring leafhopper damage once a week was as accurate as scoring damage twice a week while yield data supplement damage scores. Yield regression between unprotected and protected plants was significant. Average yield/plant decreased from 10.42-2.63 g, respectively, but individual lines deviated significantly indicating variety x treatment interactions, i.e. genetic differences in resistance.

A 15 x 15 diallel cross was made and F_2 plants and their F_3 progeny families were evaluated in the same manner as the simulated F_2 population (calculated for 50% of the 925 F_2 selections). Heritability estimates (regression of F_3 family mean on F_2 plant value) of six crosses with black and non-black parents were low (Table 15). This may have been due to limited genetic variability and relatively large non-additive, genetic variation. Few F_3 families from superior F_2 plants demonstrated a uniformly high tolerance level to *Empoasca;* most showed wide segregation.

Capture of leafhopper nymphs on hooked epidermal hairs is an important resistance mechanism against *Empoasca fabae*. Therefore, the effectiveness of pubescence as a resistance mechanism against *E. kraemeri* was studied. Maximum capture rate of 24 percent was observed only once on Redcloud and the best average rate of nymphal capture was 5 percent on Calima, followed by 4.7 percent on Redcloud. While hairless, black-seeded varieties already have superior *E. kraemeri* resistance, nymphal capture ranged from 0.8-1.4 percent indicating that incor-

Table 15. **Correlations between individual F_2 plant damage scores of 50 plants per cross and their F_3 family damage score in 6 selected crosses using resistant and susceptible parents.**

Cross	Spearman's Rank Correlation Coefficient	Narrow Sense Heritability	% Significance Level of Herit. Estim.
P512 x P478	0.127	0.28	5
P682 x P692	0.155	0.14	31
P720 x P681	0.221	0.40	0.4
P560 x P458	0.257	0.18	20
P420 x P692	0.274	0.21	14
P682 x P681	0.422	0.22	13

porating pubescence into black-seeded varieties may further increase resistance.

Economic Damage

Studies were conducted to determine the economic threshold of leafhopper populations on Diacol-Calima, a standard susceptible control. Table 16 shows nymphal populations permitted per leaf before initiating chemical control, bean yields, production costs and sale value. As nymphal populations per leaf were reduced to nearly zero, production costs were estimated to increase exponentially with the number of chemical applications. A linear relationship between production (total returns) and nymphs per leaf was assumed and an asymptotic relationship between the number of nymphs and production costs.

The highest profit was made at 0.81 nymphs per leaf. Therefore, the economic threshold population of leafhoppers was defined as the level which allows maximum profit and not as the level at which cost of control equals expected value of yield loss (Fig. 8).

Two experiments were done to determine at which growth stage the bean plant is most susceptible to leafhopper damage. The growing season of susceptible Diacol-Calima was divided into 18 day periods and during each of these four periods plants were protected with monocrotophos or left unprotected in the control (Table 17).

In both trials, yields were highest when beans were protected during flowering and podset at 26 to 44 days but in the first experiment in which leafhopper attack came later than in the second experiment, the period from 44-62 days was most critical. The presence of leafhoppers on the plants from 8-27 days or from 62 days on did not influence yields.

These results have important implications. First, early chemical control, i.e. carbofuran as a soil treatment, is less effective and protection by mulching does not have maximum influence as the plants are already large when the most susceptible growth stage begins. By that time, plants have mostly covered the mulch.

Table 16. **Yield value of harvest and cost of production (average of four replicates) with various leafhopper nymphal populations on Diacol-Calima when sprayed with monocrotophos at 0.25 liter a.i./ha/application.**

No. of Nymphs/Leaf					
Planned	Observed to initiate Spraying	No. of Sprays	Yield (kg/ha)	Value of Product[2] (Col $)	Cost of Production (Col $)
0	0.63	5	1294a	20.704	10.572
1	1.22	4	1118b	17.888	10.257
3	3.55	2	670c	10.720	9.629
5	5.07	1	641cd	10.096	9.314
7	7.45	1	503d	8.048	9.314
Control	8.67[1]	0	38e	608	9.000

1 Maximum population at 44 days; counts from 29-49 days after planting were mostly above 5 nymphs/leaf.

2 1 kg beans valued at $16.00.

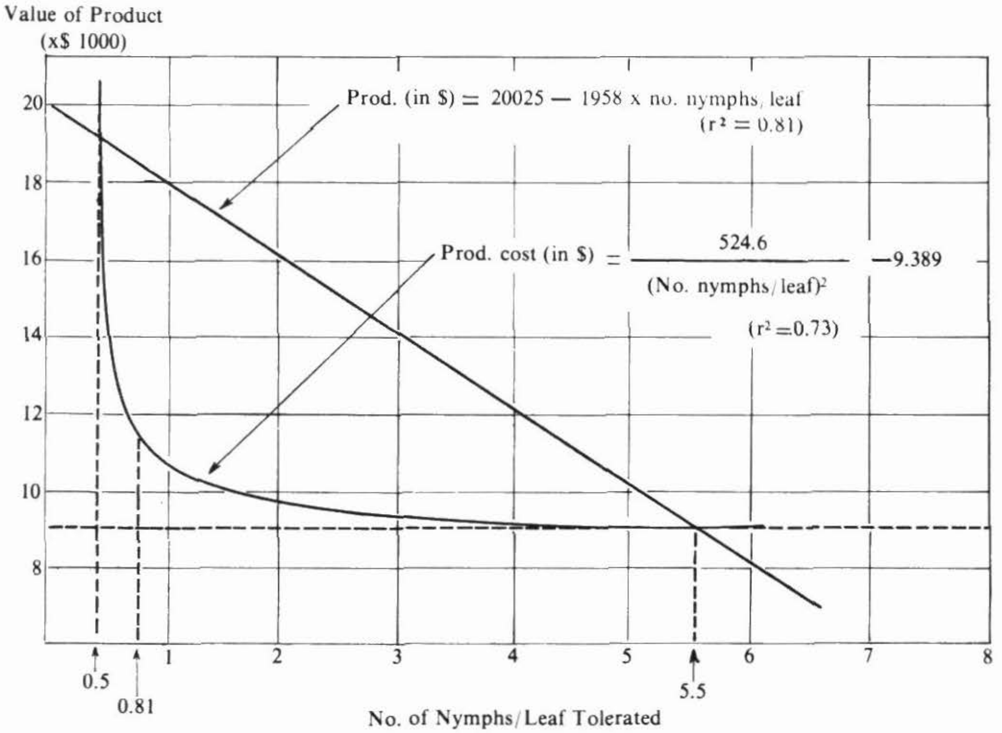


Figure 8. **Relationship between leafhopper nymphal population, value of product and production cost (in Col.$).**

Table 17. **Yield of dry beans of Diacol-Calima following insecticide treatments during different plant growth stages. (Avg. 4 replicates).**

Chemical Protection Period (in days after planting)	No. of Insecticide Applications	Dry Bean Yield (kg/ha)	
		First Experiment	Second Experiment
8-80	4	1359bc[1]	1411a
8-62	3	1385bc	1550a
8-44	2	1327bc	1241a
8-26	1	1073d	553b
Untreated	0	1002d	475b
27-80	3	1655a	1467a
45-80	2	1549ab	847b
63-80	1	1012d	583b
27-62	2	1480ab	1276a
8-27 and 62-80	2	1181cd	532b

[1] Treatments followed by the same letter were not significantly different at $P < 0.05$.

Table 18. **Yield of Diacol-Calima with different mulches providing leafhopper control (avg. 4 replicates).**

Treatment	% Light Reflection	Dry Bean Yield (kg/ha) Insecticide Protected	Dry Bean Yield (kg/ha) Unprotected
Rice straw mulch	8.0	1671d	861b
Aluminum foil mulch	20.3	2312e	1296c
Black plastic mulch	5.2	1725d	395a
Control	5.4	1753d	416a

Mulching

Studies continued on the influence of straw and aluminum foil mulches on leafhopper populations and bean yield. When beans were chemically protected and mulched, yields increased 32 percent with aluminum foil mulch (Table 18), probably due to increased light intensity. (Aluminum foil reflected 20 percent of incident light compared to 5 percent reflected in non-mulched and black plastic-mulched plots.) Yields in the non-mulched plots and the black plastic-mulched plots were very low due to heavy insect pressure, but doubled by rice straw mulching. Aluminum foil mulch tripled yield as compared with the control plots. It appears that light reflection and/or color contrast are the principal factors involved in reducing leafhopper populations.

In another experiment with susceptible Diacol-Calima and P-14, a resistant variety, the nymphal populations in straw-mulched and aluminum foil-mulched plots were 30 and 17 percent of the control, respectively, during the first half of the growing season (Table 19). However, later populations were higher on mulched plots

Table 19. **Plant dry weight, dry bean yield and average nymphal populations per leaf on the leafhopper susceptible variety, *Diacol-Calima*, and P-14, a resistant variety, following different insect control treatments.**

Treatment	Diacol-Calima		P-14	
	Dry Weight at Flowering (g/plant)			
Control	4.26		11.07	
Insecticide-treated	6.78		15.25	
Straw mulch	7.65		15.97	
Aluminum foil mulch	9.95		15.50	
	Nymphs/Leaf			
	Up to 41 days	After 41 days	Up to 41 days	After 41 days
Control	3.39	2.85	2.20	5.41
Insecticidal treated	0.06	0.01	0.11	0.01
Straw mulch	1.01	3.64	0.75	4.87
Aluminum mulch	0.59	2.46	0.59	4.76

due to increased plant vigor and reduced leafhopper damage during earlier stages. However, plant dry weights at flowering for the mulched plots were equal to or higher than plant weights in non-mulched insecticide protected ones. Yields were generally very low, due to unusually hot weather during the flowering period, but dry bean yields of the resistant variety on non-protected plots were nine times those of the susceptible variety, confirming the value of plant resistance to the leafhopper.

CHRYSOMELIDS

While *Neobrotica variabilis* is most commonly found in flowering beans at CIAT, the Chrysomelid, *Diabrotica balteata*, the banded cucumber beetle, is generally more common in the fields and its biology was studied in the laboratory. Eggs of *D. balteata* hatched in seven days in the laboratory and the three larval stages required 12 to 14 days. Pupation also took 12 to 14 days. Although bean root damage from Chrysomelid larvae is common in the field, larvae could not be reared on bean roots or nodules in the laboratory. However, rearing was successful on maize roots. When larvae were fed maize roots for three days, then placed on beans, survival greatly increased (Table 20). Older

Table 20. ***D. balteata* larval survival on bean and maize roots.**

Days after Hatching and Infestation	Food Medium		
	Maize Roots	Bean Roots	Bean Root Nodules
0	200	200	200
3	189	87	0
6	178	14	-
9	170	1	-
12	162	0	-
Adults obtained	95	0	0

larvae were often found dead on the hooked trichomes of the hypocotyles.

The effect of larval feeding on seedling development was also tested. When young larvae attack beans prior to plant emergence, feeding on primary leaves and cotyledons, primary leaves emerge with perforations, resembling symptoms of adult feeding. When seeds were infested with older larvae, one day after planting, severe damage to cotyledons and stems occurred, often impeding plant emergence or reducing plant growth. First instar larvae were most damaging to seeds when infested one day after planting. However, second and third instar larvae caused more damage, especially when seeds were infested at planting (Table 21).

Table 21. **Leaf area of Diacol-Calima beans measured 10 days after planting as percentage of leaf area of control plants, after infestation with *Diabrotica balteata* larva on three dates after planting.[1]**

No. of Larvae/Plant	Larval Stage	Leaf Area Infested as % of Control on days after Planting		
		0	1	4
5	1st instar	93.3	89.3	96.8
	2nd instar	22.3	37.3	76.0
	3rd instar	0	10.8	2.0
10	1st instar	95.3	53.4	84.2
	2nd instar	12.1	9.1	31.7
	3rd instar	0	0.5	0.8

[1] Plants grown in the greenhouse (18°-35°C avg. 23.3°C; RH 65-100%, avg. 98.5%). Average of 20 replicates for 1st instar and 10 replicates for 2nd and 3rd instars.

Table 22. **Relationship between infestation level, bean leaf area and yield (avg. 3 replicates Diacol-Calima).**

Feeding Period (days after planting)	Estimated Infestation Level (adults/plant)	Remaining Leaf Area as % of Control	Yield as % of Control
8 -15	0.9	82.9	96.1
	1.4	67.0	79.8
	3.0	52.5	72.4
15-22	1.2	83.7	113.8
	1.4	71.2	111.4
	3.7	58.3	70.1
22-29	1.1	89.0	89.8
	1.0	77.4	75.7
	3.7	53.1	48.8

The effect of adult feeding on bean yield was also studied. Preliminary results showed that up to 22 days after planting, 19 percent defoliation or up to 1.4 adults per plant can be tolerated without significant yield loss (Table 22). From 22 to 29 days after planting, one adult per plant significantly reduced yields.

BROAD MITES

In the CIAT Annual Report 1975, the Tarsonemid mite, *Polyphagotarsonemus latus,* was reported to cause up to 56 percent yield losses. Fifteen pesticides were tested for *P. latus* control, in which beans were sprayed with dimethoate to protect them from leafhopper attack and which enhances *P. latus* attack according to the literature and previous observations at CIAT. Results of the best eight compounds are shown in Table 23. Bean yield was highest following endosulfan treatment but kelthane and hostathion were also effective. Tetradifon was highly effective

Table 23. **Damage grade, mite population and dry bean yield following treatment by different insecticides (avg. 3 replicates, ICA-Pijao).**

Product	Dosis (a.i./ha)	Avg. Dam. Grade (0-3) of *P. latus* 7 Days after 1st Applic.	No. of *P. latus* 5 Days after 1st Applic.	No. of *T. desertorum* 10 Days after 2nd Applic.	Yield (kg/ha)
endosulfan	1.23 liter	0.1g	95e	178bc	2015a
dicofol	0.84 liter	0.8efg	124de	30c	1783ab
triazophos	0.40 liter	0.5fg	115de	127c	1765ab
omethoate	0.50 liter	1.5cde	35b	119bc	1711b
carbaryl	1.60 kg	1.0ef	223bcde	894a	1664b
Amitraz	0.06 liter	1.5cde	104e	42c	1648b
monocrotophos	0.28 liter	1.8cd	264bc	286bc	1578b
carbofuran	0.12 kg	2.1bc	318bc	617a	1540b
Control	—	3.0a	349b	237bc	1155c

Table 24. **Effect of different vegetable oils tumbler-applied on Bruchid biology on beans (avg. 5 replications, 100 g each, infested with 7 pairs of adults).**

Oil	ml oil/ kg seed	% Adult Mortality after Application at Days		No. Eggs/ Replic.	No. Emerged Progeny Adults/ Replic.
		2	7		
Soybean	1	15	52.9	107.8	6.4
	5	100	100	0	0
	10	100	100	0	0
Mixed	1	9	84.3	121.6	13.0
	5	100	100	0	0
	10	100	100	0	0
Maize	1	22.5	88.6	89.0	13.2
	5	100	100	0	0
	10	100	100	0	0
Control		0	1.4	318.8	208.0

against *Tetranychus* sp. mites but not against *P. latus*. By contrast, carbaryl was effective against *P. latus* but caused a *Tetranychus* outbreak. Elosal may be more effective by increasing the dosage.

STORED GRAIN INSECTS

About 2000 germplasm bank accessions were tested for resistance to the Bruchid, *Zabrotes subfasciatus*. In the three trials, there were variations in resistance for each entry but selections P364 and P507 maintained a low resistance level. This resistance was expressed in reduced oviposition and emergence, or prolonged development period for *Zabrotes*.

Vegetable oils were tested for control of Bruchids infestations in stored beans. Three cooking oils were tumbler-applied to the beans which were then infested with *Z. subfasciatus* (Table 24). At 5 ml/kg, 100 percent adult mortality was observed.

Table 25. **Seed germination and water absorption following treatment with maize oil and storage for 1 or 180 days (avg. 5 and 3 replicates, of 50 seeds and 100 g, respectively).**

ml oil/ kg beans	Percent Germination of Seed Stored after Oil Treatment for:		Percent Weight Increase by Soaking for 24 Hrs. after Oil Treatment and Storage for:	
	1 day	180 days	1 day	180 days
1	88.7	85.9	107.8a	103.8b
5	87.1	82.4	102.2b	102.2b
10	88.7	77.6	100.3b	103.5b
Control	90.0	79.6	107.7a	107.7a
Sign. level	n.s.	n.s.		

Additionally, when beans heavily infested with larvae were treated with 5 ml of cottonseed oil/kg of beans, adult emergence was also significantly reduced, indicating that the oils also affected Bruchids after their penetration in the seed. Tumbler applications were more effective than manual applications; only 1 to 2 ml of oil tumbler-applied gave complete control while up to 5 ml were required when applied manually. Oil applications did not affect seed germination or water absorption (Table 25).

Physiology

Physiological studies continued on yield limiting factors and adaptation components of *Phaseolus vulgaris* germplasm at CIAT and Dagua (altitude 830 msl) and at Popayán (altitude 1,900 msl) during 1976-1977.

GROWTH AND YIELD OF PORRILLO SINTETICO

In 1975 Porrillo Sintético was selected as a representative variety to study yield limiting factors under tropical conditions. Results are now available for 12 growth analysis experiments conducted at CIAT from 1974-1977 under irrigated and protected conditions. Yield and other parameters studied are presented in Table 26. Results for experiment 7616 are included where Porrillo Sintético was grown at four distances from a line of incandescent lights with a 16 hr 30 min daylength, causing progressive lengthening of the growth cycle due to the photoperiod sensitivity of the variety. The highest yield (4.1 t/ha) in the series was recorded for the plots adjacent to the light source (CIAT Annual Report, 1976).

Yield variability for the 12 cycles was associated with factors summarized in Table 27. Lodging, bacterial blight (chemical control was not effective) and soil factors such as high sodium saturation in one field were probably most important although the relative importance of these factors cannot be accurately indicated yet. The sum of the severity scores for the six factors in Table 27 was highly correlated with yield ($r = -0.94$). Mean radiation and temperature data recorded during the experiments (Table 28) show extremely low climatic variability.

Yield variation for one variety at one location over a number of seasons provides a useful means of evaluating the importance of various physiological parameters in yield determination. The highly significant correlation of pods/m^2, total dry matter at maturity and maximum node number, shown at the bottom of Table 26 supports the preliminary conclusions (CIAT Annual Report, 1976) that crops with larger vegetative structure have higher yields. Increased dry matter production (correlation with yield $r = 0.96$) and a relatively constant harvest index ($r = -0.28$) were associated with this yield trend. Increasing node structure increased leaf area index resulting in higher levels of photosynthate supply at least up to ceiling leaf area which was from 4.1 to 4.2 m^2/m^2 in this variety under non-lodged conditions. Further increases in leaf area in the upper nodes after flowering were balanced by leaf area loss due to senescence at the lower nodes.

Leaf area duration (LAD), the integrated leaf area available over a particular period of the growth cycle, is a measure of the total availability of green leaf area with time. Figure 9 shows the linear relationship of maximum node number to LAD for the whole growth period (emergence to physiological maturity) for the 12 cycles.

Table 26. **Yield and yield components for Porrillo Sintético in growth analysis experiments at CIAT from 1975-76.**

Experiment	Yield[1] in g/m² at 14% Moisture	Days to Flowering[2]	Days to Maturity[2]	Yield[3]/Day in g/m²/day	Pods[4]/m 1/m²	Beans/Pod 1/pod	Bean Size in mg/bean	Total[4] Dry Matter in g/m²	Harvest[5] Index in %	Maximum Node No. 1/m²
7616	412 (37)[6]	51	95	4.12	314	5.71	197	698	52	1010
7630	355 (25)	33	69	4.79	276	5.49	200	503	61	732
7616	347 (39)	43	84	3.99	255	5.79	201	562	53	806
7707	312 (28)	33	75	3.90	256	5.72	182	475	56	572
7616	298 (37)	36	71	3.92	215	5.69	208	474	54	560
7609	295 (26)	32	72	3.83	220	5.65	204	410	62	545
7616	277 (39)	36	69	3.74	202	5.59	210	409	58	549
7541	277 (4)	34	72	3.59	208	5.93	191	384	62	576
7612	265 (20)	33	76	3.27	204	5.97	186	381	59	607
7629	232 (26)	34	81	2.69	180	5.29	214	349	57	492
7503	227 (20)	32	74	2.87	210	4.87	191	343	57	598
7622	219 (30)	33	67	3.04	192	5.52	176	337	56	612
Mean	293	36	75	3.64	227	5.60	197	444	57	638
Stand. Dev.	(57)	(5.6)	(7.6)	(0.59)	(39.3)	(0.30)	(12)	(106)	(3.3)	(145)
r (*vs.* yield)		0.74	0.85	0.85	0.94	0.41	0.17	0.96	-0.28	0.81

1 Yield measured on 7 to 10 m² harvested area per replication, 4 replications per trial.
2 Days from emergence.
3 Yield/day from planting to physiological maturity.
4 Data corrected by ratio of yield of main plot: yield in 1m² component subsample.
5 Ratio yield: total dry matter at harvest (minus leaves and petioles at maturity).
6 Standard deviation.

Table 27. **Severity scores[1] for possible limiting factors in each of the growth analysis experiments with Porrillo Sintético at CIAT from 1975-77.**

Experiment	Lodging	Bacterial Blight[2]	*Heliothis* sp.	Mites[3]	Soil Salinity[4]	Poor Drainage	Total Score
7630	1	1	1	1	1	1	6
7707	1	1	1	1	1	1	6
7609	1	1	1	1	2	1	7
7541	2	3	1	1	1	1	9
7616	2	1	3	1	1	1	9
7612	3	1	1	3	1	1	10
7629	4	1	1	1	1	3	11
7503	5	2	3	1	1	1	13
7622	4	1	1	1	4	1	12

1 Severity score: 1 = factor not present; 5 = factor at high level of severity; estimates based on global experience in physiology experiments at CIAT.
2 Bacterial blight control was ineffective with available chemicals.
3 Mite resistance to various materials was encountered.
4 Maximum salinity: 2-3% Na saturation in exchange complex.

Table 28. **Data for mean solar radiation and mean temperature for growth analysis experiments[1] (for period from emergence to physiological maturity) with Porrillo Sintético at CIAT from 1975-77.**

Experiment	Radiation in cal/cm²/day	Temperature in °C
7616 (a)	497	23.1
7630	496	23.3
7616 (b)	506	24.1
7707	472	23.4
7616 (c)	504	24.3
7609	496	23.3
7616 (d)	503	24.3
7541	426	22.0
7612	460	23.2
7629	483	23.1
7503	444	22.9
7622	473	23.0
Mean	480	23.4

1 Data Source: ICA Meterological Station, Palmira.

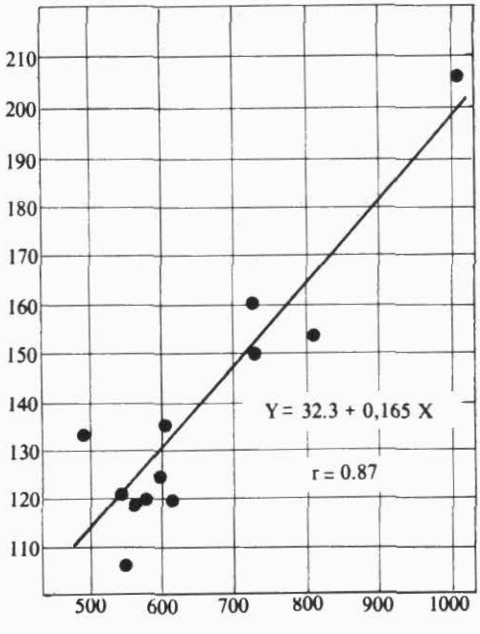


Figure 9. **Regression of LAD (leaf area m² days/m² land area) from emergence to physiological maturity on maximum vegetative node number measured after flowering for Porrillo Sintético in 12 growth analysis experiments at CIAT from 1976-77.**

Crops with a larger total node structure maintained leaf area at a higher level throughout the growth cycle. Increased LAD is in turn correlated with final yield (Figure 10). However, the relationship was somewhat influenced by lodging. Three of the crops in the bottom left of Figure 10 were heavily lodged (experiments 7629, 7503, and 7622) which resulted in an apparent decrease in the efficiency of the leaf area available. This suggests that an increase in leaf area duration without a concurrent improvement in lodging resistance will not produce higher yield levels due to the inefficient use of solar radiation by lodged canopies.

The influence of lodging on canopy height for two typical experiments is shown in Figure 11. Experiment 7622 lodged immediately prior to flowering during a heavy storm while 7609 suffered a gradual decrease in canopy height as the crop approached maturity. The most common type of lodging does not involve stem bending *per se* but rather root lodging which causes the whole plant to fall over.

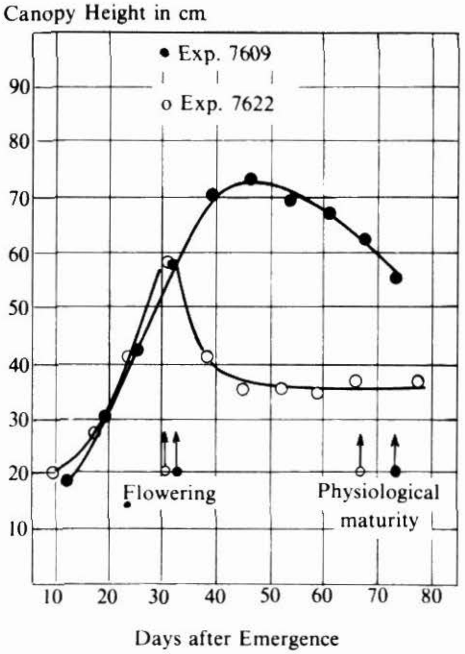


Figure 11. **Effect of lodging on canopy height in two growth analysis experiments with Porrillo Sintético.**

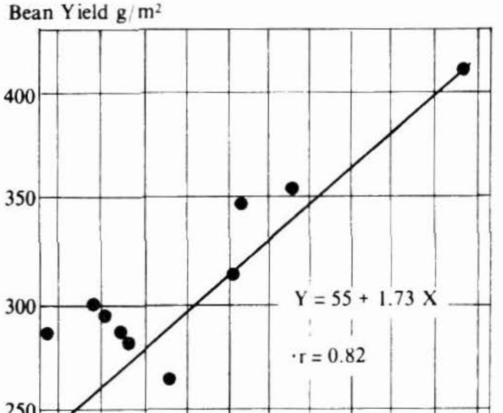


Figure 10. **Regression of grain yield (14% moisture basis) on LAD (leaf area m² days/m² land area) from emergence to physiological maturity for 12 growth analysis experiments for Porrillo Sintético at CIAT from 1975-77.**

The regression of yield on LAD for various periods of growth are shown below:

Yield (Y) *vs.* LAD (emergence to maturity): $Y = 55 + 1.73X, r = 0.82$
Yield (Y) *vs.* LAD (emergence to flowering): $Y = 155 + 3.49X, r = 0.80$
Yield (Y) *vs.* LAD (flowering to maturity): $Y = 45 + 2.94X, r = 0.78$

From these data, it is obvious that a general increase in leaf area at all growth stages may be necessary rather than particular emphasis on the post flowering period. It is also obvious from the overall data that a high LAD before flowering normally means a high LAD after flowering. This also implies that an increase in

LAD and presumably photosynthate supply, leads to increased sink size and also to increased post-flowering source to fill the available sink.

The relationship of crop growth rate (CGR, $g/m^2/day$) of Porrillo Sintético for the above-ground portion of the crop to leaf area index (LAI) is an important consideration with respect to the above conclusions. Crop growth rate was calculated from the weekly total dry matter samplings up to 56 days from emergence (heavy leaf loss after 56 days prevents an assessment of CGR for the whole crop during the maturation phase). The data (Figure 12) show a curvilinear relationship to mean LAI with a mean maximum growth rate of ~ 12 $g/m^2/day$ at LAI between 3.0 and 4.0. Up to a mean weekly LAI of ~ 4.0 m^2/m^2 there is no real suggestion of an optimum type response in these data. Variability of CGR within a particular LAI range was probably associated with lodging, solar radiation received, and other factors. Research is continuing on the factors associated with this variability. Any improvement in maximum LAI above average levels may not be associated with increases in CGR at higher LAI values. However, if lodging resistance can be improved, increased maximum leaf area should result in the maintenance of a higher LAD.

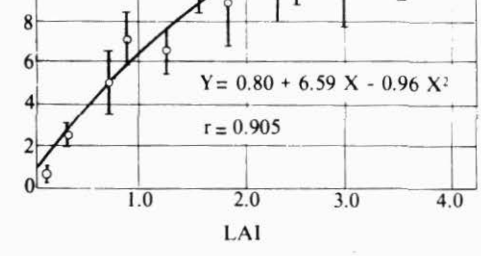


Figure 12. **Relationship of CGR ($g/m^2/day$) to mean LAI. Mean of weekly samplings in 12 growth analysis experiments with Porrillo Sintético at CIAT, from 1975-77.**

High yields in experiments 7616, 7630 and 7707 were associated with either (a) an increased length of the growth cycle by manipulating the flowering date using photoperiod response (for 7616), or (b) were within the normal growth cycle for this variety (for 7630 and 7707). In the latter case, both crops had little lodging and disease, insect and soil problems were minimal (*Table 27*).

GROWTH AND YIELD IN RELATION TO GROWTH HABIT

A summary of growth analysis data for five varieties, representative of the four growth habits defined at CIAT is presented in Table 29. Mean yield range in the data is typical for the varieties at CIAT under monoculture conditions. Mean data for Porrillo Sintético from Table 26 is included for comparison (treatments in experiment 7616 which were influenced by artificially increased daylength have been excluded).

While less data is available for these growth habits the conclusions which can be drawn are similar to those for Porrillo Sintético. Increased node structure and leaf area are strongly related to yield. The comparative earliness of the determinate varieties (P635 and P788) apparently limits the maximum leaf area and thus the LAD. Mean yield per day is slightly lower than in Porrillo Sintético.

Leaf area efficiency (bean yield/LAD) for the four nonclimbing varieties is very similar ranging from 1.95 to 2.12 g/m^2 $days/m^2$. This strongly suggests that the differences in canopy type in these lines does not greatly influence the yield capacity of the photosynthetic system. However, leaf area efficiency for the

Table 29. **Mean yield and other parameters measured for five cultivars from four types in growth analysis experiments at CIAT, 1975-77.**

Parameters	P635 I	P788 I	P566 II	P498 III	P589 IV	r[1]
	Cultivar and Growth Habit					
Mean yield (14% moisture), g/m²	230	242	273	322	365	
Number of experiments	3	2	9	3	3	
Pod number/m²	142	246	216	265	294	-
Bean per pod	2.55	3.20	5.56	4.36	5.69	-
Bean size, mg/bean	544	272	195	240	185	-
Maximum node number/m²	363	413	587	923	864	0.94
Maximum leaf area index	3.03	3.43	3.57	4.14	5.99	0.94
LAD[2] (E-F)[3]	23	18	36	41	81	0.93
LAD (F-M)	95	96	94	123	180	0.91
LAD (E-M)	118	114	130	164	261	0.93
Days to flowering (E-F)	25	25	33	33	41	0.95
Days to maturity (E-M)	64	67	73	81	89	0.99
Yield/day (planting to maturity)	3.31	3.36	3.51	3.73	3.88	0.83
Yield/LAD (E-M)[4]	1.95	2.12	2.10	1.96	1.40	-

[1] Correlation with yield (r)
[2] LAD m² days/m²
[3] E = emergence, F = flowering, M = physiological maturity.
[4] Leaf area efficiency, g/m² days/m² land area.

climbing variety used here was much lower even when supported on a trellis, possibly due to excessive leaf area development (maximum LAI 5.99) which caused self shading of the lower leaves. This conclusion is supported by yield profiles by node reported for P589 in the CIAT Annual Report, 1976.

Crop growth rate data for the limited number of cycles with P589 suggests a lower rate of growth at higher LAI values than was the case with P566. Further data will be needed to reach firm conclusions.

CROP MANIPULATION

Carbon Dioxide Fertilization

In the first experiment carbon dioxide supplementation (1200 ppm) was applied to Porrillo Sintético growing in 1 m² open-topped, ventilated chambers over two growth periods: (a) Period 1(-5 to +15 days from flowering); and (b) Period 2(-5 to +35 days from flowering). The objective was to evaluate the relative importance of increased photosynthate supply during the period after first flowering when final pod number is being determined (Period 1) compared to the whole of the flowering, pod set and bean filling period up to physiological maturity (Period 2). A 40 percent yield increase was obtained in Period 1, compared to 43 percent in Period 2 (Table 30). The benefits of increased photosynthate supply appear to be of primary importance during the immediate post-flowering period due mainly to increased pod set and mature beans/pod. An additional 20 days of CO_2 supplementation in Period 2 produced only a 3 percent yield increase over Period 1.

Table 30. **Effect of carbon dioxide fertilization[1] applied over two periods on yield and other parameters of Porrillo Sintético at CIAT.**

Period[2]	Treatment	Yield in g/m^2 (14% moisture)	No. Pods/ m^2	No. Beans/ Pod	Mean Bean Wt. mg/bean	Node No. Maturity $1/m^2$	Total Dry Weight	Harvest Index
-5 to +15	CO_2	340 (140)	264	5.63	195	545	494	(59.1)
	Control	243 (100)	221	5.11	185	507	367	(56.9)
-5 to +35	CO_2	446 (143)	328	5.44	215	542	660	(58.3)
	Control	311 (100)	244	5.16	213	535	466	(57.4)
L.S.D. 0.05		33	25	0.32	11	53	54	(2.1)
C.V.%		9.0	8.9	4.4	3.9	7.8	8.0	(3.7)

[1] Applied to $1m^2$ ventilated open-topped chambers in the field at 1200 ppm CO_2 (approx. 900 ppm above ambient CO_2 levels); control chambers ventilated at ambient CO_2 level.

[2] Days from flowering.

Increased photosynthate supply did not significantly alter final node number suggesting that overall canopy structure was not altered. The increased dry matter production was divided between vegetative and reproductive parts with a slight increase in harvest index in the CO_2 treatment in both periods.

The results strongly suggest that photosynthate supply in the immediate post-flowering period controls pod set and yield in this variety. An improvement in photosynthate supply should be possible by either increasing leaf area and leaf area duration or by increasing the photosynthetic efficiency of the available leaf area. Both will be aided if stem erectness and lodging resistance can also be improved.

Carbon Dioxide/Major Element Fertilization

A second experiment was conducted to test the hypothesis that foliar application of major nutrients (N, P, K and S) to the canopy could increase yield although the crop had been fertilized with all the critical elements at sowing. Research in soybeans in the United States had suggested this possibility. The possibility of an interaction between increased photosynthate supply and increased nutrient supply was also evaluated. The results of a 2x2 factorial experiment with the appropriate treatment combinations are presented in Table 31. The overall yield increase due to CO_2 fertilization from -5 to +35 days from flowering was only 21 percent (Treatment 1) compared to 43 percent in the first experiment. The crop was well grown and lodging was not a problem: leaf area of adjacent control crops approached $4.0m^2/m^2$. Probably, the control canopy was more efficient in this experiment suggesting that photosynthate supply was not as limiting. The effects of NPKS fertilization were entirely additive with no suggestion of a positive interaction. A 6 percent increase in yield was recorded for NPKS application with or without CO_2 fertilization. In this experiment, the yield increase due to CO_2 supplementation was related almost entirely to an increase in pod set which emphasizes the importance of photosynthate supply during this phase.

Foliar Fertilization at Different Growth Stages

An experiment was also conducted to

Table 31. **Effect of carbon dioxide fertilization (-5 to +35 days from flowering) and foliar application of NPKS on yield and parameters of Porrillo Sintético at CIAT.**

Treatment[1]	Yield g/m²	Pods/ m²	Beans/ Pod	Bean Weight in mg/bean	Node Number 1/m²	Total Dry Matter g/m²	Harvest Index %
CO_2	471(121)	328	5.64	219	605	706	57.4
NPKS	412(106)	286	5.73	216	501	608	58.3
CO_2 + NPKS	493(126)	330	5.83	220	505	716	59.2
Control	390(100)	273	5.59	219	504	574	58.4
Field plot	353(90)	248	5.78	212	527	510	59.5
L.S.D. 0.05	45	36	0.52	13	62	63	3.8
C.V. %	6.6	6.5	4.8	3.1	6.2	5.4	3.4

1 Treatments 1-4 in 1m² chambers; CO_2 treatments 1200 ppm CO_2; NPKS equivalent to 80:12 23:5 kg/ha in 5 foliar applications; field plot and control yield without chambers.

evaluate the effects of NPKS application at different growth stages and with increasing applications up to a maximum of 80: 12:23:5 kg/ha of NPKS, respectively. Yield data is presented in Table 32. Most treatments produced a slight but non-significant increase (mean 5.2 percent) in yield which supports the results of the

Table 32. **Yield and yield components of Porrillo Sintético for 10 foliar spray application treatments[1] of NPKS applied at 5 different growth stages at CIAT.**

Total Nutrient Application NPKS kg/ha	Stages[2] of growth	Yield (14%) g/m	No. Pods 1/m²	No. Beans/ pod	Bean Wt. in mg/bean	N % Beans
Control	-	312 (100)	239	5.71	228	4.21
80:12.0:33.0:5.0	1,2,3,4,5	323 (104)	252	5.51	232	4.02
16: 2.5: 6.6:1.0	1	339 (109)	253	5.70	235	4.10
16: 2.5: 6.6:1.0	2	313 (100)	231	5.72	236	4.14
16: 2.5: 6.6:1.0	3	333 (107)	257	5.59	239	4.08
16: 2.5: 6.6:1.0	4	332 (106)	249	5.33	234	4.10
16: 2.5: 6.6:1.0	5	320 (103)	244	5.26	237	4.22
32: 5.0:13.2 2.0	1,2	328 (105)	255	5.49	233	4.11
48: 7.5:19.8:3.0	1,2,3	339 (109)	280	5.13	223	4.18
64:10.0:26.4:4.0	1,2,3,4	324 (104)	250	5.39	237	4.18
L.S.D. 0.05		39	36	0.59	16	0.20
C.V. %		8.2	9.5	7.5	4.8	3.3

Applied as urea, potassium sulphate and potassium polyphosphate neutralized with phosphoric acid and applied in aqueous solution at the rate of 16:2.5:6:1 kg/ha of NPKS per growth stage.
Growth stages: 1=-7 days from flowering; 2= day of flowering; 3=+7 days; 4=+14 days; 5=+21 days.

previous experiment. While further research may be necessary, it appears that when a bean crop is well provided with soil-applied nutrients at planting there does not appear to be any real response to the use of foliar-applied soluble nutrients during the growth cycle. On the other hand, where definite soil deficiencies exist, foliar applications could be of value when applied at critical growth stages.

ADAPTATION COMPONENTS

Research continues on physiological components of adaptation considered important in determining the range of adaptation of germplasm. Screening methods are being developed to select suitable parents with desirable characteristics. The components under evaluation include: photoperiod sensitivity, excess soil water tolerance, water stress resistance, temperature (altitude) adaptation, planting density response and growth habit stability. The latter is under study at Cornell University in a collaborative research project; work in this area at CIAT will begin in 1978.

Screening for Photoperiod Response

Photoperiod screening of all promising lines has been completed by studying the phenology of the material under the lights (18 hr/day) compared to that of controls grown at the normal day length (12hr 20 min). The field light system for screening was altered prior to the last two screenings to accommodate more materials. The new system utilizes an overhead light bank (83 x 300 w incandescent bulbs mounted 2.5 m over an area 25 m x 25 m). The system accommodates 500 different materials grown in staked hill plots (1 m x 50 cm) in two replications per treatment.

A comparison of the earlier linear light system with the new overhead method for 10 test varieties is presented in Table 33. The close agreement between methods suggested that the results for all four screenings could be combined. A summary of the combined data for 808 materials, mostly P lines, is presented in Table 34. Forty-one percent of the lines tested were photoperiod insensitive (< 4 days flowering delay in 18 hr days). The data also

Table 33. **Comparison of two systems to screen for photoperiod response at CIAT: comparison of data for number of days of flowering delay in 18 and 12hr 20 min photoperiods for 10 control varieties.**

Promising Line Tested/ Experiment	Days of Flowering Delay			
	Linear Light Source		Overhead Light Source	
	Experiment 7501A	Experiment 7501B	Experiment 7617	Photoperiod[1] Classification
P005	17	10	15.5	3N
P006	0	1	1.5	1N
P008	15	15	15	3N
P012	-1	2	0.5	1N
P302	1	-2	0	1N
P306	23	21	23.5	4N
P459	7	3	0.5	1N
P566	14	10	13.5	3N
P514	29	18	16.5	3N
P540	16	16	17	3N

1 1N =<4 days delay; 2N = 4-10 days delay; 3N = 10-20 days delay; 4N = 20-30 days delay; 5N = 30 days delay. N = absence of abnormal flower abscission in long days.

Table 34. **Summary of combined data for photoperiod response screenings by growth habit of germplasm selections at CIAT, from 1975-77.**

Growth Habit	Classification of Photoperiod Response					Total
	1	2	3	4	5	
	< 4[1]	4-10	11-20	21-30	> 30	
I	97	22	59	30	18	226
	(43)[2]	(10)	(26)	(13)	(8)	(100)
II	163	40	67	17	7	294
	(55)	(14)	(23)	(6)	(2)	(100)
III	61	26	41	38	40	206
	(30)	(13)	(20)	(18)	(19)	(100)
IV	15	7	18	10	32	82
	(18)	(9)	(22)	(12)	(39)	(100)
Total	336	95	185	95	97	808
	(41)	(12)	(23)	(12)	(12)	(100)

[1] Days of flowering delay at 18hr days as compared to natural daylength of 12hr 20 min.
[2] Data in table gives number and percent of genotypes within growth habits

confirmed the tendency reported earlier for a lower proportion of insensitive materials in growth habits III and IV. In particular, the very high proportion (39 percent) of extreme sensitivity (>30 days delay) in the Type IV material is an interesting feature of these data. Evaluation of possible reasons for this tendency is somewhat hampered since the exact origin of the original germplasm material is often unknown.

The importance of photoperiod insensitivity in beans with respect to wide adaptation has not yet been fully evaluated, but when complete results of the first IBYAN have been analyzed a clearer picture should emerge. One of the objectives of Ideotype B breeding (CIAT Annual Report 1976) at CIAT is to increase the preflowering period. While the search for lateness to flower in photoperiod insensitive and acceptable agronomic types in the germplasm bank has not proved very fruitful to date, lateness for higher latitudes (i.e. > 15ºN or S) could be improved by using parents with intermediate levels of sensitivity. Provided the relevant cropping system allows production during long days (i.e. > 12 hours), an increase in the preflowering period should result, relative to photoperiod insensitive material.

Screening for Tolerance to Excess Soil Water

Bean production in some parts of the world is limited by heavy rainfall leading to water logging in poorly drained soils. Two experiments evaluated a possible screening method for tolerance to excess soil water under CIAT conditions. A suitable site was leveled and banks constructed so that water could be maintained in furrows at a height of 5 to 8 cm below the crest of two row beds (1 m center to center). Water was maintained at this height from 12 days after emergence until physiological maturity. In the first experiment 25 P lines were

Table 35. **Yield[1] data for first experimental screening at CIAT for excess soil water tolerance for selected varieties.**

P Line	Name	Growth Habit	Yield g/m Control	Yield g/m Excess Water	% Yield Reduction
P566	Porrillo Sintético	II (B)[2]	240	207	14
P757	Porrillo 1.	II (B)	228	175	23
P675	ICA-Pijao	II (B)	260	190	27
P458	ICA Tui	II (B)	243	175	28
P511	S-182N	II (B)	241	141	41
P302	PI 309 804	II (B)	248	135	46
P643	Nep 2	II (W)	219	117	47
P788	PI 284 703	I (Y)	216	115	47
P737	Jamapa (VEN)	II (B)	268	142	47
P459	Jamapa (CRI)	II (B)	271	141	48
P692	Diacol Calima	I (R)	242	112	54
P637	Línea 17	I (R)	252	109	57
P512	S-166 AN	III (B)	297	118	60
L.S.D. (Var x Treat.) 0.05			49.9		
C.V. %			16.2%		

1 Mean of three replications per treatment
2 Seed color: B= black; W =white; Y=yellow; R = red.

evaluated and 100 lines in the second. The results suggest that large genetic differences exist for resistance to excess water in the material evaluated. Table 35 shows that the 'Porrillo' types (P566, P757, P675) showed excellent tolerance while the 'Jamapa' type material (P302, P737, P459) had a relatively uniform yield reduction of 46 to 48 percent. The largest yield reduction in the first experiment (60%) was for the black-seeded P512. While black Type II varieties showed the highest tolerance level, it is clear that the response is not related to seed color *per se*. A summary of the screening results for the second experiment is presented in Table 36.

Table 36. **Results[1] of the second excess water tolerance screening experiment at CIAT: data for the number of varieties within three tolerance classifications by growth habit.**

Growth Habit	Percent Yield Reduction[2] Low <40%	Moderate 40-68%	High > 68%	Total
I	6	14	1	21
	(29)	(67)	(4)	(100)
II	4	26	5	35
	(11)	(74)	(14)	(100)
III	2	19	6	27
	(7)	(71)	(22)	(100)
Total	12	59	12	83[2]
	(14.0)	(71.1)	(14.4)	(100)

1 100 varieties screened, 17 excluded due to the virus symptoms.
2 Percent yield reduction: Yield Control-Yield Treatment/Yield Control (in percent); mean percent yield reduction 54 ± 14.

Screening for Water Stress Resistance

In previous stress screenings, many materials were poorly adapted to Peruvian coastal plain conditions at La Molina. An experiment was conducted at CIAT to evaluate a possible screening method using infrared thermometry. A hand-held thermometer, sensitive to ± 0.2.ºC, with a target zone of 20 to 30 cm diameter was used to evaluate the canopy temperature differential (△T) between irrigated plots and those experiencing water stress during a drying cycle following irrigation. Stomatal closure during the onset of stress normally results in higher canopy temperatures up to a limit determined by the reradiation characteristics of the leaves. Varieties experiencing progressively higher △ T values during a drying cycle suffer higher levels of tissue water stress. Measurements were initiated at approximately maximum leaf area index (7 days after previous irrigation) at 1100-1230 daily in 44 varieties (growth habits I,II and III). Results are available for five days of measurements before the first rains of the wet season in September 1977 forced early termination of the study. Data in Figure 13 show △ T values for two extreme

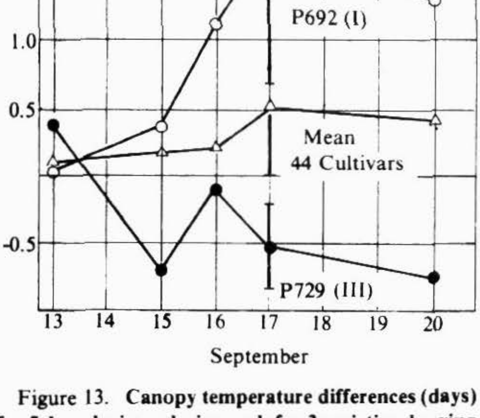


Figure 13. **Canopy temperature differences (days) for 5 days during a drying cycle for 2 varieties showing contrasting responses and the mean of 44 cultivars.**

Table 37. **Summary of canopy temperature screenings of 44 materials according to the numbers of materials in each growth habit within differential canopy temperature ranges.**

Growth Habit	Differential <0.20	Canopy 0.20-0.40	Temperature >0.40	ºC Total
I	3	4	7	14
II	8	4	3	15
III	6	5	4	15

genotypes P692 and P729. Measurements for P692 indicated that it suffered greater stress which was also verified by visual observation. P729, which was previously identified in Peru (CIAT Annual Report, 1975) as having possible stress resistance, had a stressed canopy temperature slightly below the control plot. Table 37 summarizes the △ T readings over five days according to growth habit. There is a definite tendency for higher "stress" in Type I materials compared to the indeterminate types which was also verified in field observations.

The results are promising for quickly and quantitatively evaluating water stress resistance on large numbers of materials without relying on the subjective method of visual scoring or other more time-consuming methods. Dry season research at CIAT is planned to correlate the results of the method with yield reductions in stress treatments. The method could provide a useful tool for screening of advanced material.

Screening for Temperature Adaptation

In uniform yield trials by the agronomy group at various altitudes in Colombia and Ecuador certain germplasm selections showed good adaptation over a range of altitudes, from 14-1,900 msl. On the other hand, other materials showed poor adaptation at lower altitudes. Forty contrasting genotypes (10 from each growth habit) were selected for physiological evaluation at four altitude/temperature regimes. Soil fertilization and liming were applied to reduce the influence of adverse soil conditions. Disease control was also effected to avoid interactions with respect to differential disease resistance in the material.

Experimental data are available for the first three locations. Of the 40 varieties, data for 8 were not included due to severe virus symptoms at CIAT. In addition, the trial at Popayán suffered water stress at various growth stages due to lack of irrigation facilities and overall yields were low.

The data in Table 38 gives yield of cultivars in Types I and IV where the largest cultivar x temperature interactions were measured. In Type I, P637 showed above average yields at each location while Diacol Andino proved poorly adapted at lower altitudes but very well adapted at the highest altitude, almost equalling yield of P637 at 1900 msl. This same pattern was repeated for P589 in the Type IV group which showed excellent adaptation at all altitudes, while P590 (Cargamanto) produced virtually no yield at the lower altitude locations. Although P590 plants were vegetatively vigorous, they produced only isolated pods with very few seeds. The cultivars P759 (I) and P260 (IV) showed some tendency to decrease relative yields with increasing altitude but this could be related to the dry conditions at Popayán in the latter part of 1976 rather than to temperature conditions *per se*. The experiments are being repeated this year and the physiological factors associated with these interactions are being evaluated.

The data in this and other trials including the 1976 IBYAN show that *Phaseolus* germplasm has quite a wide

Table 38. **Yield of selected varieties from temperature adaptation experiments at three altitudes in Colombia: CIAT; Las Guacas, Cauca; Dagua, Valle.**

Location	Dagua	CIAT	Las Guacas
Altitude, m	825	1001	1850
Temperature mean °C	25.1	23.9	19.1
Temperature max. °C	29.7	28.7	24.7
Temperature min. °C	20.6	19.2	13.5
Identification	Bean Yield in g/m² (14% moisture)		
Growth Habit I			
P637	198(120)[1]	314 (113)	169 (115)
Diacol Andino	36 (22)	200 (72)	166 (113)
P759	206 (124)	316 (114)	115 (78)
Mean of G.H. I (n = 8)	165 (100)	278 (100)	147 (100)
Growth Habit IV			
P589	402 (142)	382 (130)	197 (113)
P590	7 (2)	20 (7)	150 (86)
P260	323 (114)	298 (102)	161 (92)
Mean of G.H. IV (n=8)	282 (100)	293 (100)	175 (100)

[1] Percent of the mean yield within each growth habit.

adaptation with respect to temperature conditions within a range 18-26ºC mean growing season temperature.

Screening for Response to Planting Density

Results reported in 1976 showed a variety x density interaction in bush beans. Recommendations for ideotype development at CIAT include Ideotype C with expected adaptation to low density production conditions typical of most small farms in Latin America. One-hundred promising materials were screened at two densities (8 plants/m^2 and 30 plants/m^2) in early 1977 to evaluate parents for this ideotype. Results suggest that there are differences in density response characteristics. The field variability encountered was very high and the experiment is being repeated. Results of density trials at CIAT were heavily influenced by lodging and to some extent, by "Problem X" which appears to be density dependent for its expression. Symptom severity is highly variety-dependent.

Microbiology

This year, varietal differences in nitrogen fixation and cultural factors affecting active nitrogen fixation were emphasized. Computer programs for data storage relating to the *Rhizobium* collection were also developed (see also Microbiology section, Beef Program and Biometrics Unit reports).

VARIETAL DIFFERENCES IN NITROGEN FIXATION

During 1977, more than 700 P lines were evaluated for symbiotic nitrogen fixation with CIAT 1057 at Popayán. Although cultivars were generally poorly adapted to the lower temperatures, determinate, early flowering cultivars such as P635 consistently fixed less nitrogen than indeterminate cultivars in Types III and IV. While this experiment is still being analyzed, these varietal differences were confirmed in other studies undertaken this year.

In Popayán, Type I and II cultivars were evaluated for nitrogen fixation potential in relation to Types III and IV. Eleven cultivars of *P. vulgaris* analyzed included: Type I — P243, P403, P536, P635, P637, and P692; and Type II — P561, Seafarer and Nep 2. P498 (Type III) and P590 (Type IV) were the controls. As in previous studies P590 proved stronger in N_2 fixation than the other cultivars (Fig. 14) with a peak N_2 fixation of 37.7 *u*moles C_2H_4 produced/plant/hour, six weeks after planting. When corrected for diurnal variation in N_2 fixation and using the hypothetical 3: 1 ratio for C_2H_2:N_2 conversion, this cultivar fixed the equivalent of 73.7 kg/ha of nitrogen/cycle (Table 39). This was considerably higher than had been obtained with this cultivar in previous studies. P498, a bush cultivar, also achieved a relatively high fixation rate

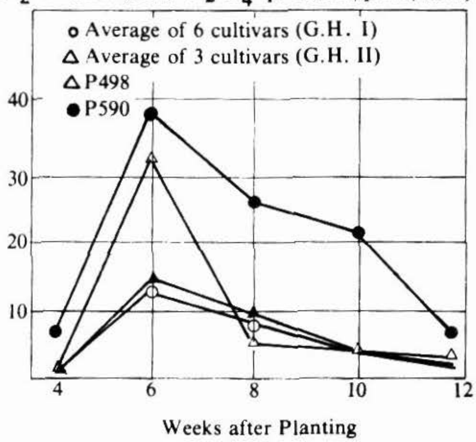


Figure 14. Varietal differences in nitrogen fixation in relation to growth habit.

Table 39. **Parameters of nitrogen fixation in 11 cultivars of *Phaseolus vulgaris*, 6 weeks after planting.**

Identification	Nodule Dry Weight mg/plant	SNA[1]	Acetylene Reduction[2]	Theoretical N_2 Fixation/ha	Growth Habit	Days to Flowering	Days to Maturity	Yield kg/ha
P243	24	371	8.9	12.2	I	45	110	2.200
P635	32	349	11.2	13.5	I	44	104	2.200
P692	35	318	12.8	27.6	I	47	104	1.900
P637	41	383	15.8	25.1	I	47	114	2.300
P402	59	339	20.1	25.1	I	47	110	2.300
P536	34	294	10.0	18.2	I	41	114	2.800
P561	34	257	8.8	19.8	II	43	110	3.000
Seafarer	33	539	17.6	21.2	II	45	120	1.900
NEP-2	29	447	12.9	26.0	II	53	116	2.600
P498	75	431	32.2	34.5	III	50	104	3.600
P590	106	355	37.7	73.7	IV	66	130	3.800

1 μmol C_2H_4 produced/g nodule dry weight/hour

2 μmol C_2H_4 produced/plant/hour

but no other Type I or II cultivar approached this level. It is often inferred that cultivars active in nitrogen fixation will be poor yielders. Here, P498 had both higher yield and more active nitrogen fixation than other bush cultivars.

In this experiment, the soluble carbohydrate content of nodules and concentration of soluble carbohydrates were greater in P590 than in P498 (Fig. 15). Further studies with these two cultivars are underway.

DENSITY EFFECTS ON NITROGEN FIXATION

The effect of planting density on nitrogen fixation in P498, P590 and P635 was studied using the Bleasdale parallel row design. Between and within row spacings were varied on a 1.1/1.0 ratio and plant densities increased from 5.5 to 120 plants/m².

At 39 days after planting, the effect of population density on nitrogen fixation varied according to cultivar. On a per plant basis, N_2 fixation of P590 peaked at 8.5 plants/m² and rapidly declined at higher densities (Fig. 16). P498 reached a maximum at 18.5 plants/m and slowly declined

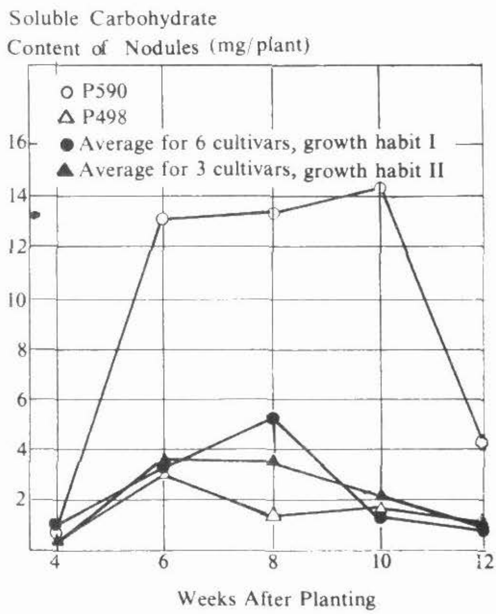


Figure 15. **Differences in the soluble carbohydrate content of nodules in 11 cultivars of *Phaseolus vulgaris*, in relation to growth habit.**

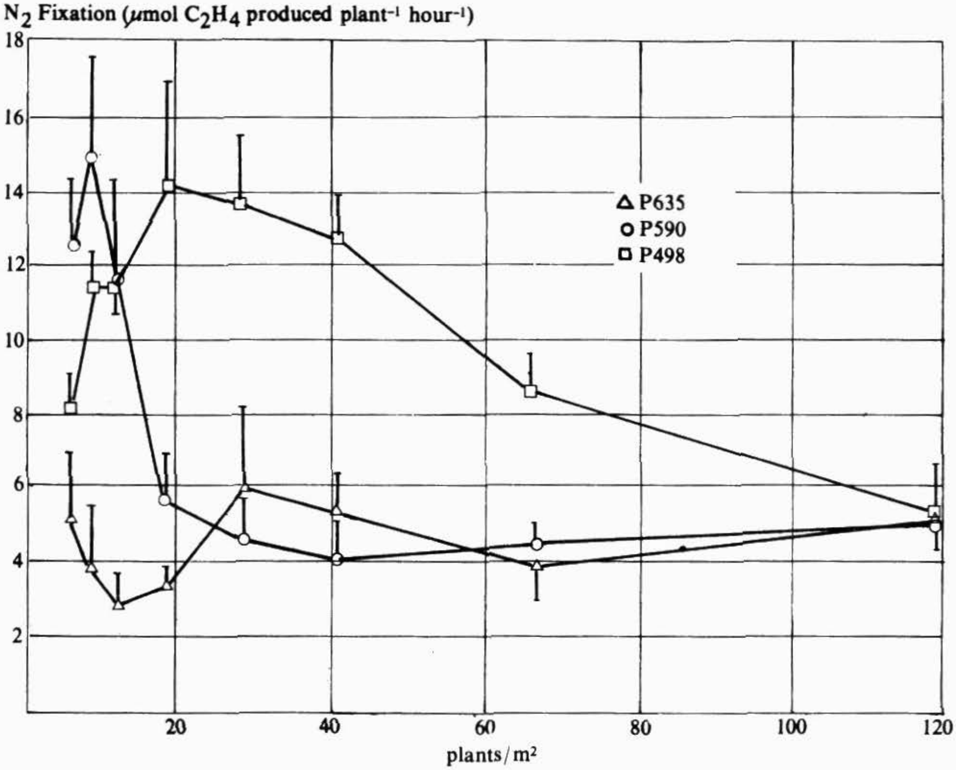


Figure 16. **Influence of planting density on nitrogen fixation in 3 cultivars of *Phaseolus vulgaris*, 39 days after planting.**

at higher densities. However, N_2 fixation per unit land area showed that all three varieties had maximum fixation at the highest density (Fig. 17a). The relative insensitivity of nitrogen fixation in P498 to plant density parallels yield-density responses in this cultivar (CIAT Annual Report, 1976).

Although some variation in specific nodule activity (SNA) was detected (Fig. 17b), much of the difference in fixation was attributable to change in nodule fresh weight/plant (Fig. 18). Increasing density also changed the pattern of nodulation in all three cultivars. At the higher plant densities, nodules contained both an increasing proportion of the total plant carbohydrate (Fig. 19) and somewhat elevated concentrations of soluble carbohydrate (Fig. 20).

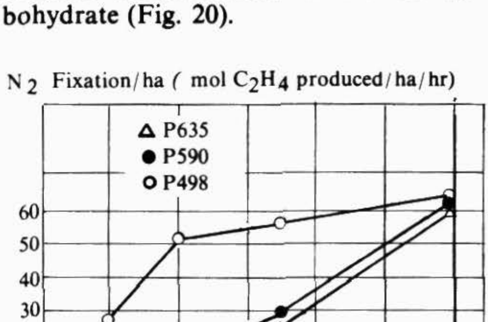


Figure 17a. **Effect of planting density on nitrogen fixation in 3 cultivars of *Phaseolus vulgaris*.**

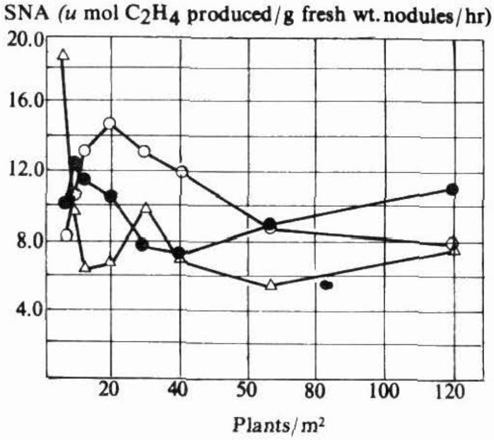


Figure 17b. **Effect of planting density on specific nodule activity in 3 cultivars of *Phaseolus vulgaris*.**

EFFECTS OF BEAN/MAIZE ASSOCIATION ON BEAN NITROGEN FIXATION

The influence of a bean/maize association on bean nitrogen fixation was evaluated using bean cultivars P590 and P526 and two maize populations — one a vigorous type used on small farms and the other similar to improved maize types.

Bean plant and pod weight/plant for P590 in monoculture, or associated with the two maize populations is shown in Figure 21. When P590 was grown with Amarillo Tropical, plant growth and pod development was not significantly different from that obtained in monoculture, even at 92 days after planting. However, plant and pod development was reduced when P590 was associated with the more vigorous landrace maize. Plant development for the bean cultivar P526 was inhibited by association with the landrace maize (Fig. 22) as early as 50 days after planting. Although monoculture maize plots were not planted for com-

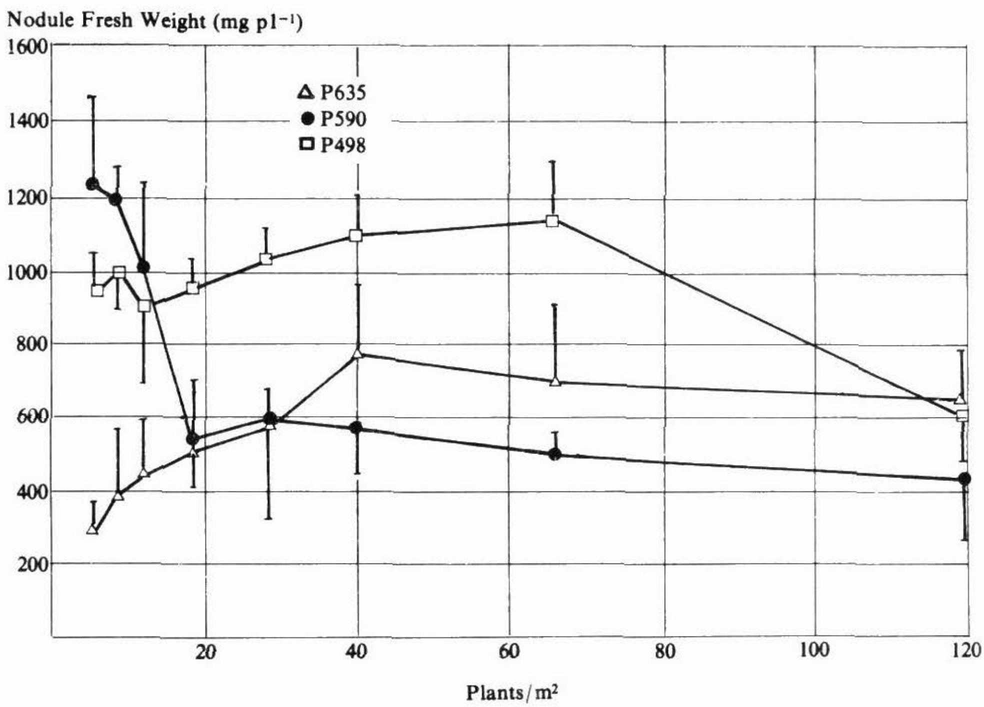


Figure 18. **Influence of planting density on nodule fresh weight in 3 cultivars of *Phaseolus vulgaris* 39 days after planting.**

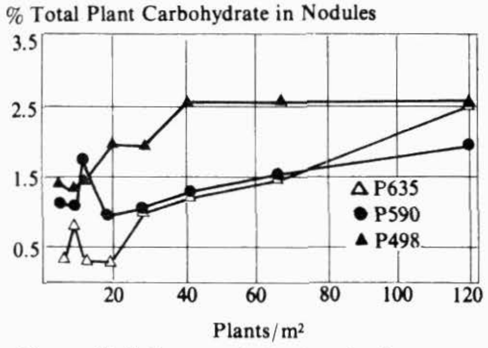


Figure 19. **Influence of planting density on the percentage of total plant carbohydrate recovered in nodules of 3 cultivars of *Phaseolus vulgaris*.**

parison, both maize populations tested developed less vigorously in association with the more aggressive P590 than with P526.

Figure 23 shows seasonal profiles of N_2 fixation for P590 and P526, grown in monoculture or associated with maize. With P590, fixation reached a maximum of 20.6 μmoles/plant/hour, 68 days after planting and declined rapidly thereafter. No difference was detected between fixation levels and duration in monoculture or associated with maize. In the symbiotically weaker P526, maximum fixation in monoculture occurred 50 days after planting. Fixation was reduced slightly by association with either maize. By the 68 day harvest, fixation in all P526 treatments had declined, and no further differences were apparent. It appears therefore that while competition for light and/or nutrients limits plant development in maize/climbing bean associations, this

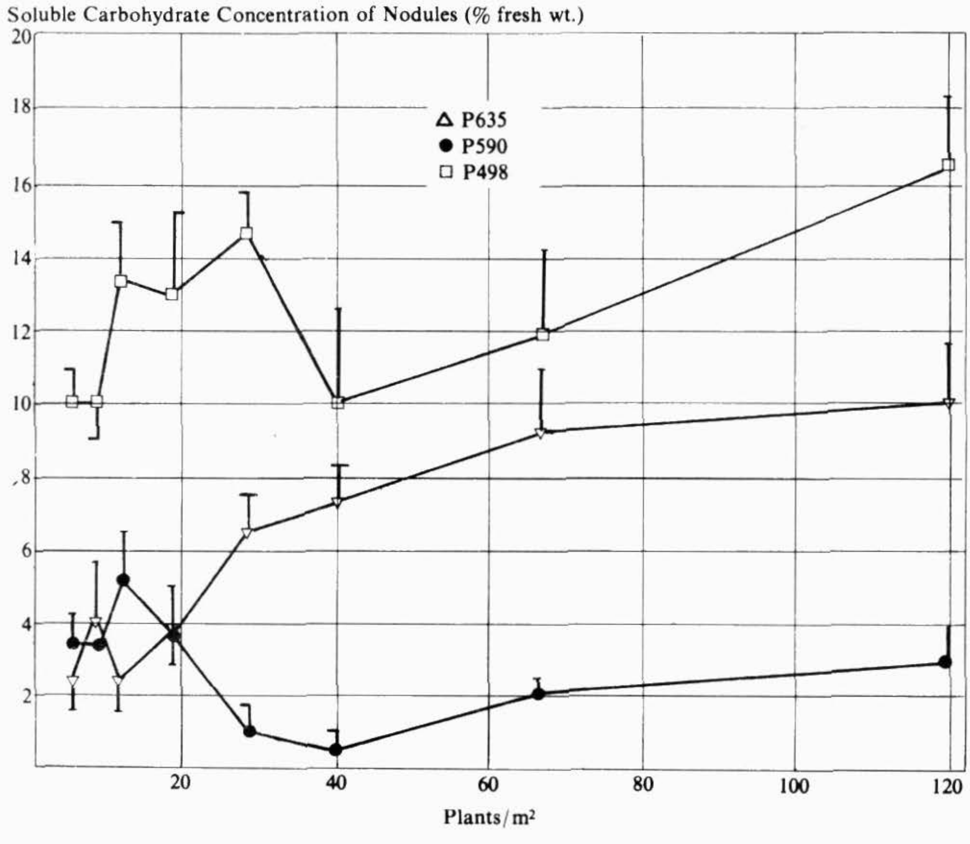


Figure 20. **Effect of planting density on the ethanol soluble carbohydrate content of nodules in 3 cultivars of *Phaseolus vulgaris*.**

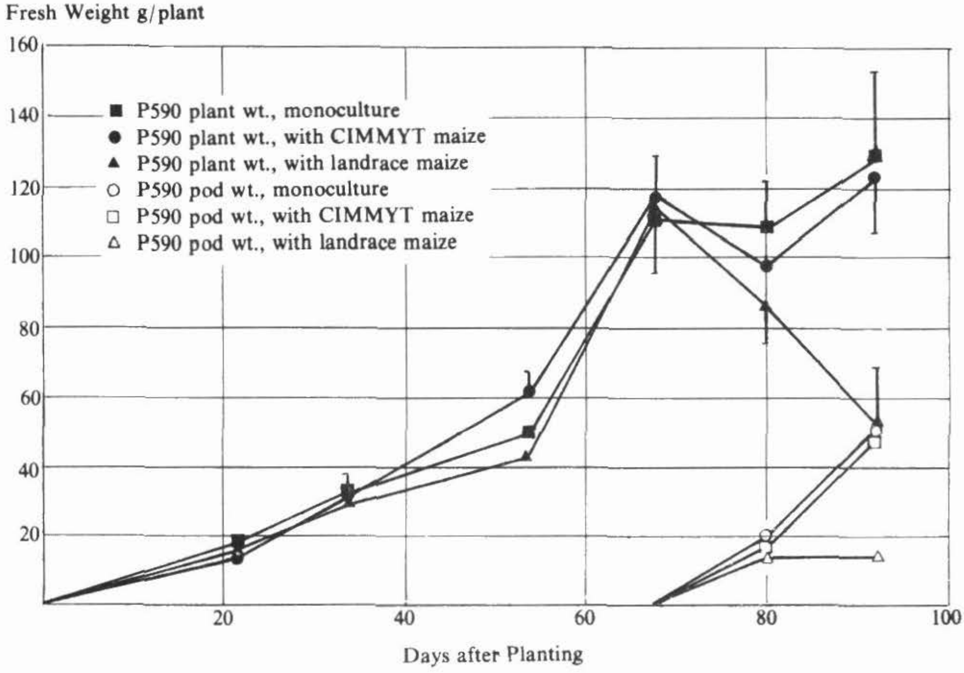


Figure 21. **Bean plant weight and pod weight for the cultivar P590 grown in monoculture or associated with a landrace or CIMMYT maize.**

growth limitation does not normally occur during the period of active nitrogen fixation. Studies are in progress to evaluate fixation in maize/bush bean associations.

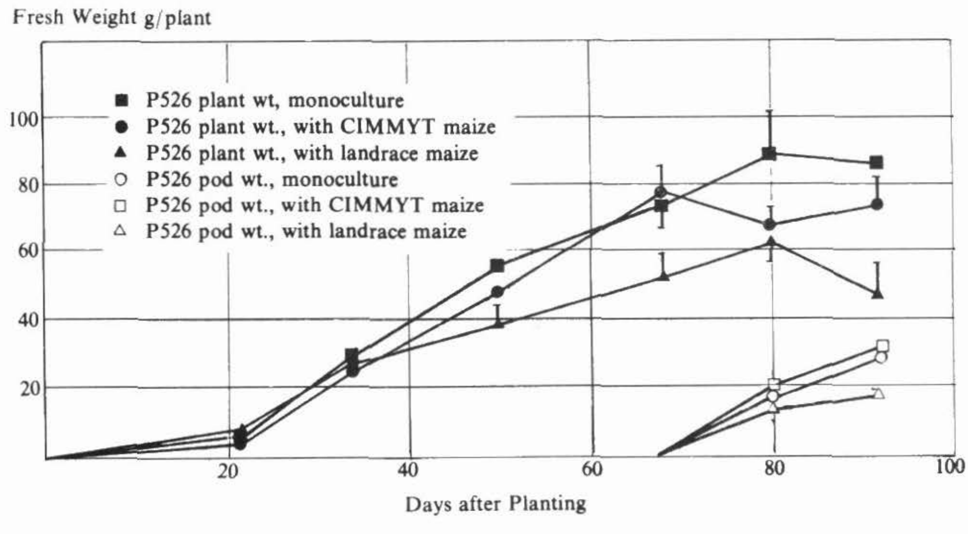


Figure 22. **Bean plant weight and pod weight/plant for the cultivar P526 grown in monoculture or associated with a landrace or CIMMYT maize.**

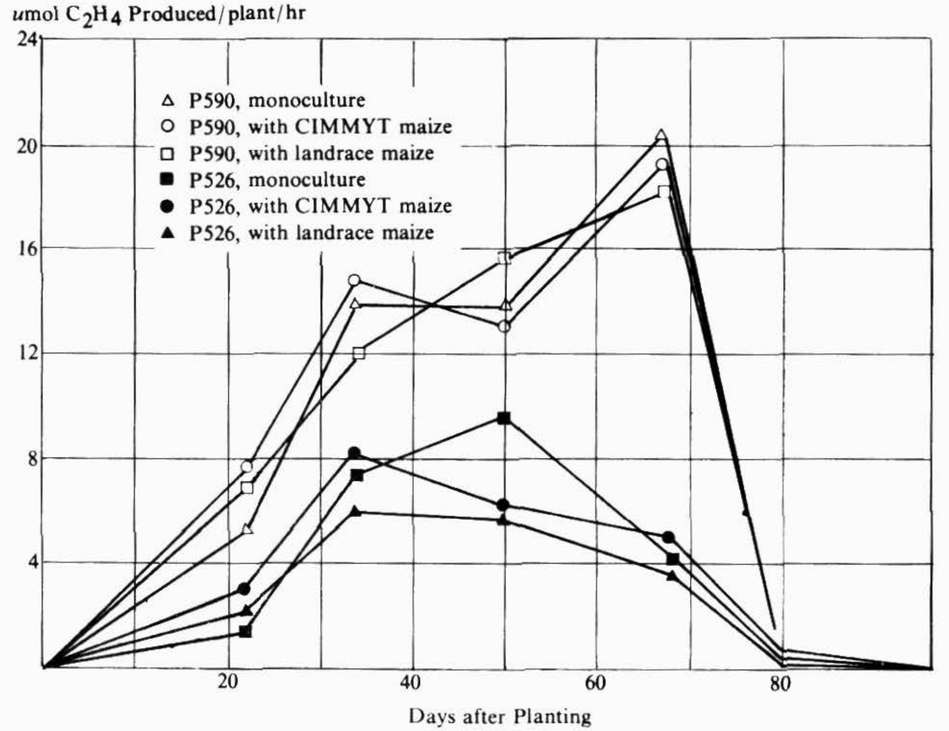


Figure 23. **Seasonal profiles in N_2 fixation for P590 and P526 grown alone or associated with a landrace or CIMMYT maize.**

PHOSPHORUS FERTILIZATION AND NITROGEN FIXATION

The CIAT Annual Report for 1976 showed tested black beans slightly more tolerant to low soil phosphorus than colored cultivars. This year, cultivar-phosphorus interactions and their influence on nitrogen fixation were studied. A continuous phosphorus gradient was established in which fertilization with triple superphosphate varied from 0-750 kg/ha in increments of 50 kg/ha. Thirty cultivars of *P. vulgaris* were sown along the P gradient and evaluated at flowering and maturity for plant development, phosphorus uptake and nitrogen fixation.

As shown in Figure 24, nodule fresh weight at flowering in each type increased with increasing levels of phosphorus. Type III and IV cultivars consistently produced more nodule tissue/plant.

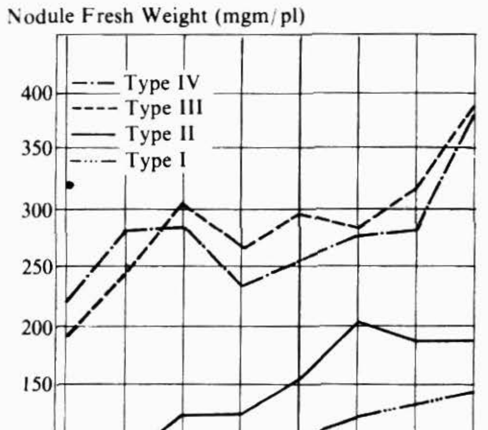


Figure 24. **Response in nodule fresh weight development to P fertilization as influenced by growth habit. (Data taken at flowering.)**

Nodule fresh weight increased from 28 to 257 mgm/plant and percent of nodule phosphorus from 0.20 to 0.27 percent with increasing phosphorus but root fresh weight increased from 941 to only 2211 mgm/plant and from 0.14 to 0.16 percent P content. Thus increasing P levels increased the percent of P in the nodules and leaves more than in the roots (Fig. 25 a, b).

N_2 fixation at flowering was also markedly influenced by phosphorus supply, though not all cultivars reacted equally. Figures 26 and 27 show nodule fresh weight and fixation increases in four cultivars of *P. vulgaris* relative to the mean for all 30 cultivars. These differences were not due to the production of more nodule tissue per mgm of P in the nodules; to differences in specific nodule activity; nor to the plants' ability to provide a greater percentage of the available phosphorus to

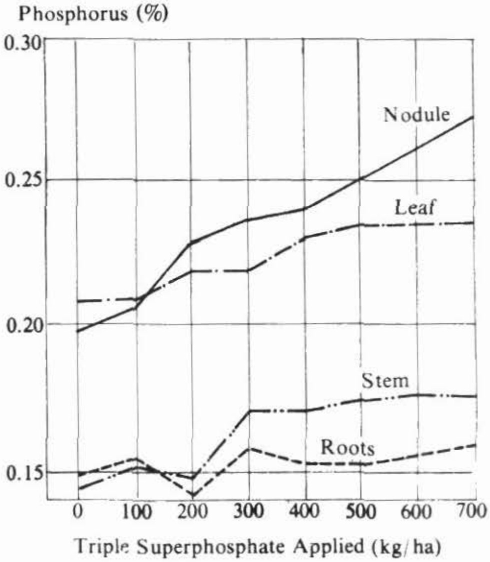


Figure 25b. **Increase in % phosphorus in plant parts as a consequence of increasing P fertilization. (Average of 30 cultivars.)**

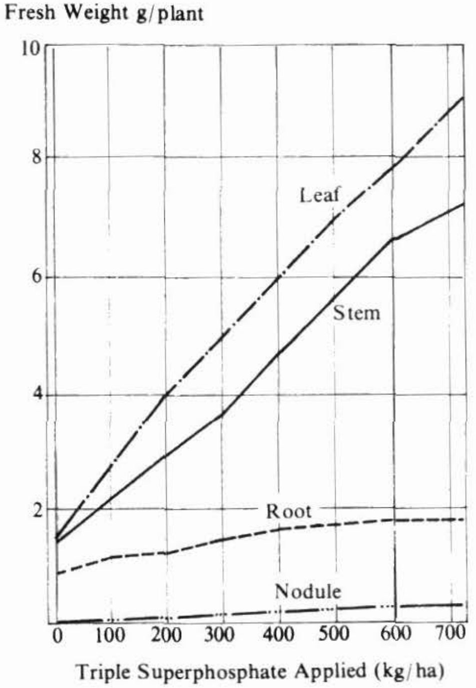


Figure 25a. **Fresh weight increases in individual plant parts as a consequence of increasing P fertilization. (Average of 30 cultivars).**

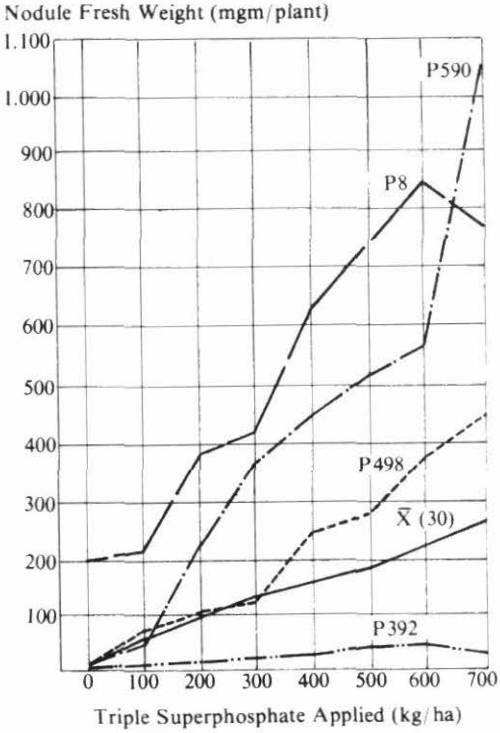


Figure 26. **Nodule fresh weight increases in cultivars of *Phaseolus vulgaris* as influenced by increasing P fertilization. (Data taken at flowering.)**

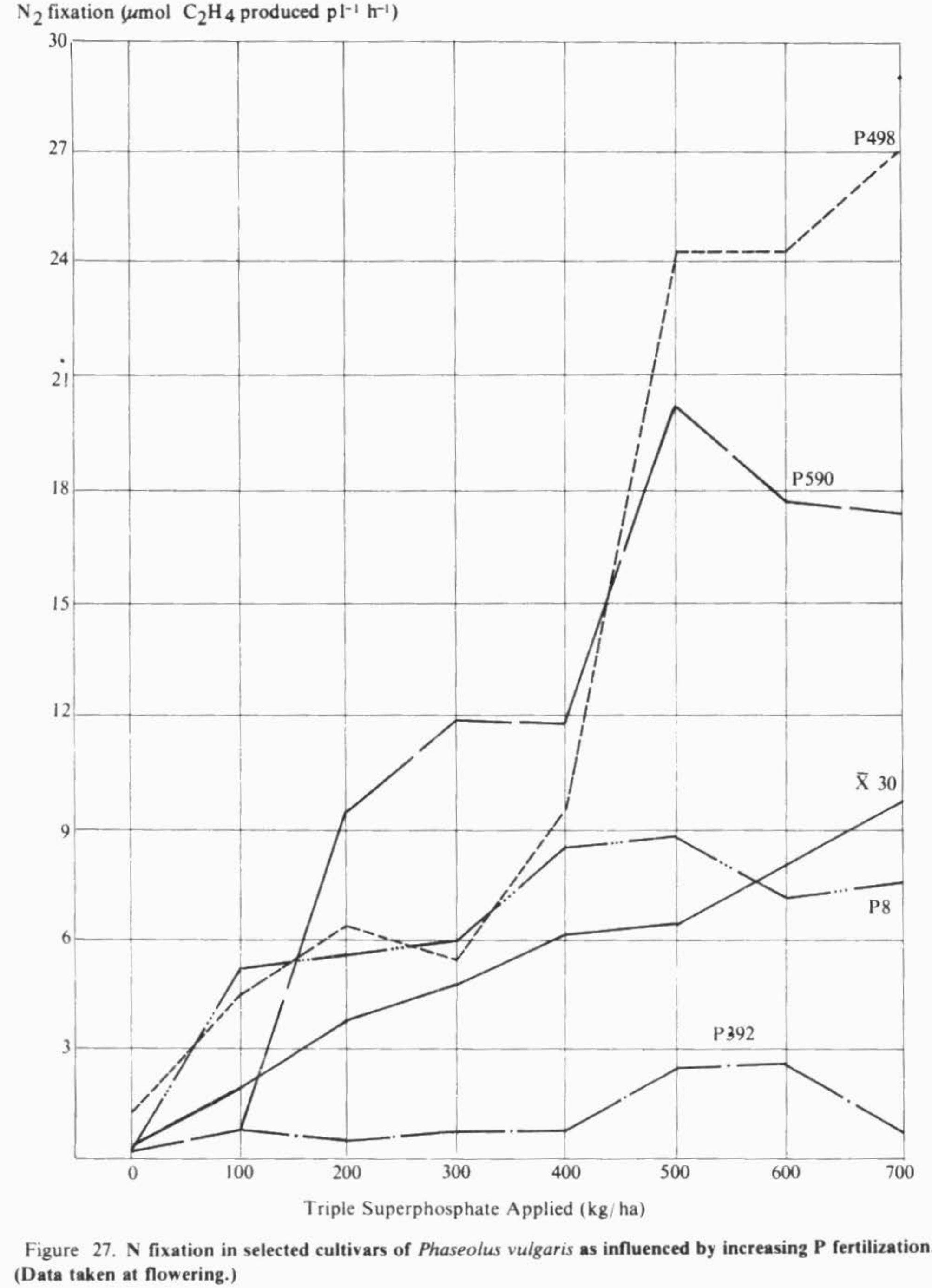


Figure 27. **N fixation in selected cultivars of *Phaseolus vulgaris* as influenced by increasing P fertilization. (Data taken at flowering.)**

the nodules. Although P8 and P498 grew proportionately better at low phosphorus than most cultivars, P590 was below average. Further studies are being done.

Soils and Plant Nutrition

Research continued on major and minor element nutrition of beans; germplasm accessions were screened for tolerance to low soil phosphorus; plant phosphorus requirements were estimated; methods of application and sources of phosphorus were tested. Nitrogen fertilization and the management of alkaline soils were also studied.

SCREENING FOR TOLERANCE TO LOW SOIL PHOSPHORUS

Germplasm selections continued to be screened for tolerance to low phosphorus levels in Popayán. Since previous work indicated that the zero P level was too severe a stress to screen varieties for P tolerance, germplasm was screened at 50 and 300 kg P_2O_5/ha, band-applied as triple superphosphate (TSP) under the seed. Some 432 varieties were planted in single rows with two replicates in each of two plantings. The same P levels were reapplied for the second planting.

Since the direct yield ratio at low/high P levels tended to select varieties with low yields at the high P level due to poor adaptation, a tolerance index was calculated by multiplying yield ratio with the relative yield at the low P-level.

In the first screening, average yields were 85 and 189 g/m² at the 50 and 300 kg P_2O_5/ha, respectively, giving an average tolerance index of 15. Germination was poor due to severe drought after seeding, and plants suffered from water stress throughout the growth cycle. However, 11 varieties yielded over 200 g/m² at the low P level and 4 varieties yielded over 350 g/m² at the high P level.

Table 40 shows the yields of the 10 most P-tolerant varieties and their tolerance

Table 40. **Yield and tolerance index of the 10 most P-tolerant varieties selected in two field screenings in Popayán.**

	1976B Yield in g/m² kg P_2O_5/ha				1977A Yield in g/m² kg P_2O_5/ha		
Variety	50	300	Tolerance Index[1]	Variety	50	300	Tolerance Index[1]
P178	259	249	104	P744	256	173	130
P401	219	201	92	P438	229	183	99
P743	193	163	88	P678	201	145	96
P194	255	302	83	G-04231	236	230	83
P289	235	296	72	P649	291	351	83
P10	188	201	68	P439	231	229	80
P211	196	231	64	P778	199	187	73
P169	122	094	61	P763	214	220	71
P589	186	222	60	P779	161	130	68
P699	206	281	58	P259	204	221	65

[1] tolerance index $= \frac{(\text{Yield low P})^2}{\text{Yield high P}} \times \frac{\text{Yield low P}}{\text{Highest yield low P} \times 100} \times 100\%$

index. P178 gave the highest yield at low P and had the highest tolerance index. This was followed by P401 and P743. Thus, it can be seen that several varieties may yield as well or better at a low P level than at a high rate of application.

For the second set of varieties tested, yields were 121 and 181 g/m^2 at the 50 and 300 kg P_2O_5/ha levels, respectively, giving an average tolerance index of 28 percent (Table 40). Due to better climatic conditions and residual effect of P applied in the first screening, yields of the second set were considerably higher. There were 29 varieties yielding over 350 g/m^2 at the high P level. The highest yielding varieties were: P507, P167, P495, P639, and P468.

EXTERNAL P REQUIREMENT OF BEANS

Conventional soil analysis provides a relative measure of phosphorus availability, but does not indicate the P fertilization level required to obtain certain yield levels since this depends on the crop's P requirement, i.e. the P concentration in soil solution to obtain nearly maximum yield, as well as the P fixing capacity of the soil. The latter can be determined by shaking soil for six days with 0.01 M $CaCl_2$ of various P concentrations and analyzing the supernatant solution for P. From this the P-sorption isotherm can be calculated, indicating the amount of P to be applied to a certain soil to obtain a specific P concentration in soil solution.

To determine the P requirement of beans, the variety ICA-Huasano was planted in Popayán in plots to which TSP was applied and incorporated at eight levels ranging from 0 to 2060 kg P_2O_5/ha corresponding to a soil solution concentration range of 0.01 to 0.112 ppm P. The plots were limed at 2 t/ha and received 100 kg N, 5 kg Mg, and 1 kg B/ha, and two bean crops were planted. The second crop measured the residual effect of applied P.

Figure 28 shows the response to applied P for both plantings. While plants suffered from severe drought during the first planting, yields increased from 500 kg/ha without P to 3.7 t/ha at 2060 kg P_2O_5/ha. Although no additional P was applied in the second planting more favorable climatic conditions produced higher yields with a maximum of 3.7 t/ha with the initial application of 870 kg P_2O_5/ha.

Figure 29 shows the relative yield of the two bean plantings in relation to the P concentration in soil solution. The external P requirement of the crop was defined as the P concentration at which 95 percent of maximum yield was obtained. Thus, the requirement for beans was calculated as 0.08 ppm for the first and 0.054 ppm for the second planting, which is comparable to the 0.06 ppm determined for corn in Hawaii. Although both crops have similar P requirements for maximum yield, bean yields (especially during the drought-affected first seeding) were much more affected by a lack of P than corn. This indicated the high susceptibility of beans to P deficiency.

A critial P content in the leaves of 0.38 percent was determined, which agrees with

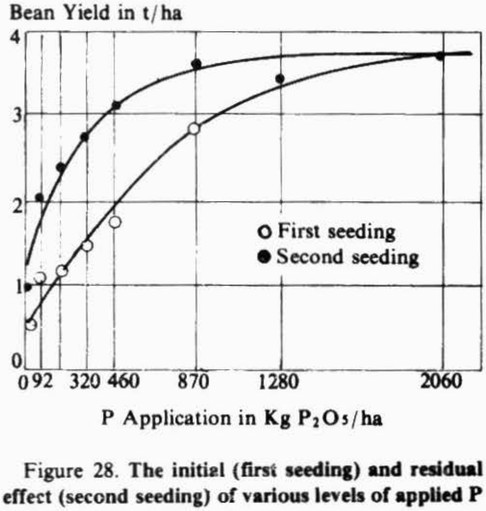


Figure 28. The initial (first seeding) and residual effect (second seeding) of various levels of applied P on bean yields in Popayán.

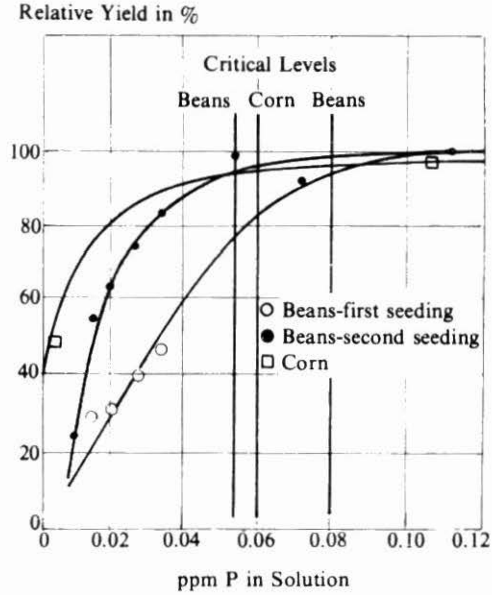


Figure 29. **The relative yield of corn and two seedings of beans as affected by the P concentration in solution as determined from sorption isotherms. Corn data are from two volcanic ash soils in Hawaii.**

the 0.34 - 0.40 percent reported in 1976. Similarly, the critical level of Bray II extractable soil P was found to be 14 ppm.

Soil analysis after each harvest showed that high P application increased soil pH from 4.7 to 4.9 and from 4.5 to 4.8 in the first and second planting, respectively. However, in these two consecutive bean plantings, pH declined 0.4 units and Al increased 0.4 me Al/100 gm. This decrease in pH may be counteracted by application of about 400 kg/ha of lime at each planting. High P applications (especially of basic slag or rock phosphates) are also effective.

APPLICATION METHOD

In soils with high P fixation, the application method is as important as the level of application — the optimum method often varying with the P source. The P concentration in soil solution depends on the rate of P release of the source and the rate of P fixation by the soil: slow release sources require good soil-fertilizer contact to dissolve and should be broadcast and incorporated, but banding is recommended for water soluble P sources to reduce fixation. The optimum application method for each source may be something between broadcast and banding, depending on the release and fixation rates.

To determine the optimum application method, three P fertilizers — TSP, basic slag, and Huila rock phosphate — were applied in small triangles as shown below Figure 30; the triangle base simulated broadcast application; the tip, band application; and the intermediate section, strip application. Fertilizers were applied at the rate of 75, 150, and 300 kg P_2O_5 / ha.

Figure 30 shows the response to the different application methods for the three levels and sources. Yields were significantly better when TSP was band-applied than when broadcast or strip-applied, especially at the higher rates. Seventy-five kg P_2O_5 /ha band-applied was as effective as 300 kg/ha broadcast. Thus, minimum soil-fertilizer contact increased efficiency by reducing fixation of this highly soluble source. Application method did not affect efficiency of basic slag, but that of rock phosphate was slightly higher when incorporated. Basic slag gave slightly higher yields than TSP while both were significantly better than the rock phosphate.

The second trial was reseeded in the same rows as the first without disturbing or reapplying the P treatments. Figure 31 shows the average response for the initial and residual effect. In the second seeding, application method had no effect on the efficiency of any of the P sources. Thus, banding TSP was beneficial for the first planting, but was not subsequently effective for maintaining a high P concentration. In the residual plots, yields were almost twice those of the first planting,

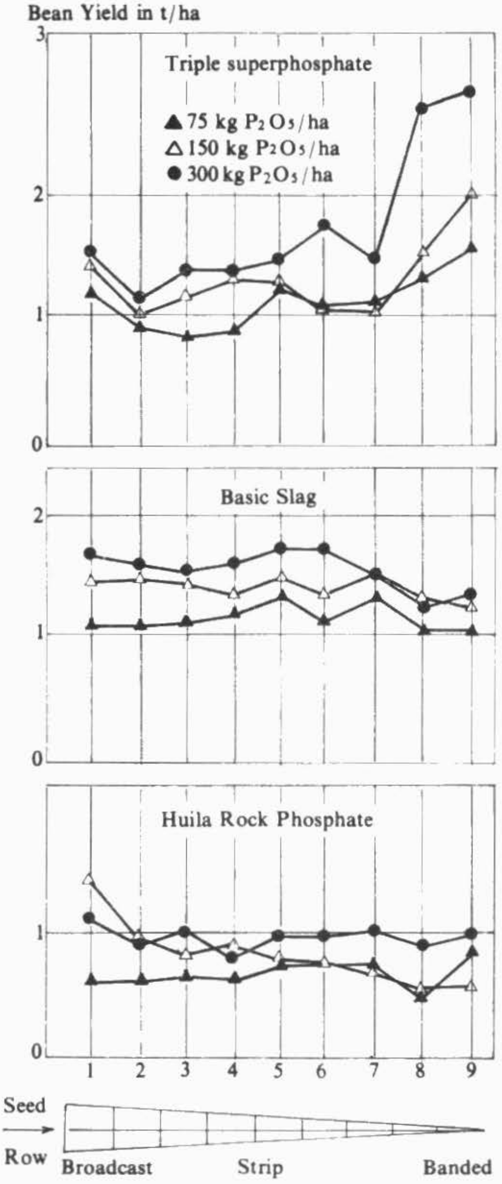


Figure 30. **The effect of fertilizer distribution, applied at three levels and sources of phosphorus, on bean yield in Popayán.**

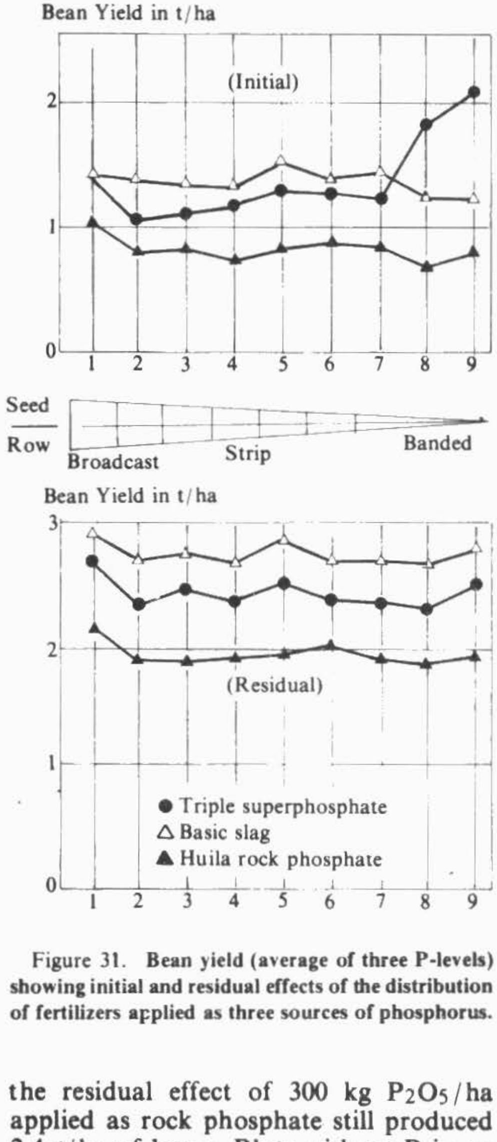


Figure 31. **Bean yield (average of three P-levels) showing initial and residual effects of the distribution of fertilizers applied as three sources of phosphorus.**

indicating the importance of the residual effect of these P fertilizers and improved moisture supply. Basic slag was significantly superior to TSP which in turn was superior to the rock phosphate. However, the residual effect of 300 kg P_2O_5/ha applied as rock phosphate still produced 2.4 t/ha of beans. Plots without P in an adjacent trial produced only 930 kg/ha.

PHOSPHORUS SOURCES AND LEVELS

The 1976 Annual Report reported the response of beans to various application levels and sources of rock phosphate. This year, the same trial was repeated in two consecutive plantings to measure the residual effect of the P sources. Of two

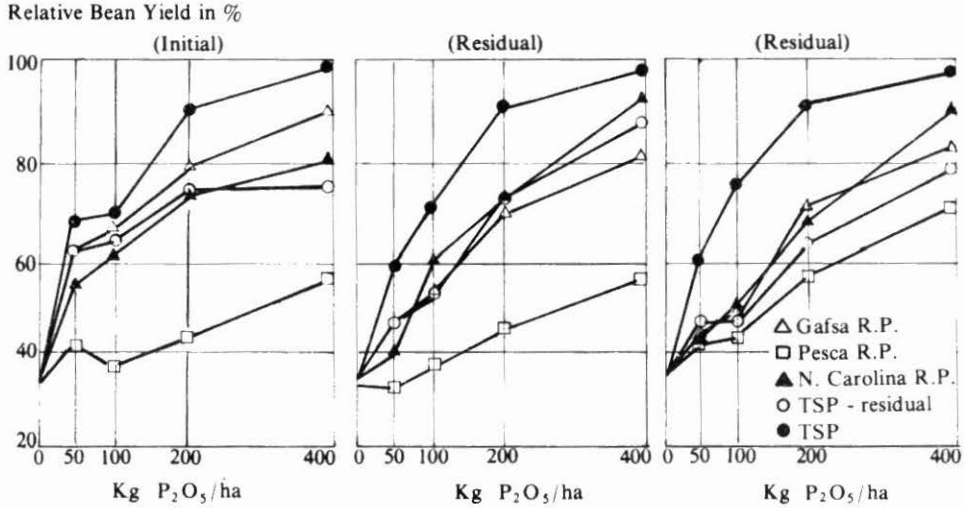


Figure 32. **Relative yields of beans in three plantings after applications of various levels and sources of phosphorus, Popayán.**

original TSP treatments, one was used as an optimum control in which the same amount of P was reapplied at every planting and the other measured residual effect.

Figure 32 shows the relative yields of various sources during the three seedings. In the first seeding last year responses varied significantly according to the citrate-solubility of the source. In subsequent plantings, less soluble sources such as Pesca and Tennessee became relatively more effective, while the very soluble sources such as TSP and Gafsa rock became relatively less effective. Thus, the large initial differences in effectiveness between sources tended to disappear with time. For all sources, beans responded positively to applications of 400 kg P_2O_5/ha, without reaching a yield plateau. For the residual effect plots, the response was nearly linear up to that level. Therefore, relatively cheap rock phosphates may effectively replace the more expensive TSP in acid, high P fixing soils.

A critical P content of 0.33 percent was obtained by relating bean yields to P contents of upper leaves at flower initiation. Similarly, the relation of yield and Bray I extractable soil P indicated a critical level of 9 ppm P, Bray I, in both the second and third plantings. The critical level defined by the Cate-Nelson method is 4.5 ppm P, Bray I (Fig. 33). The Bray II

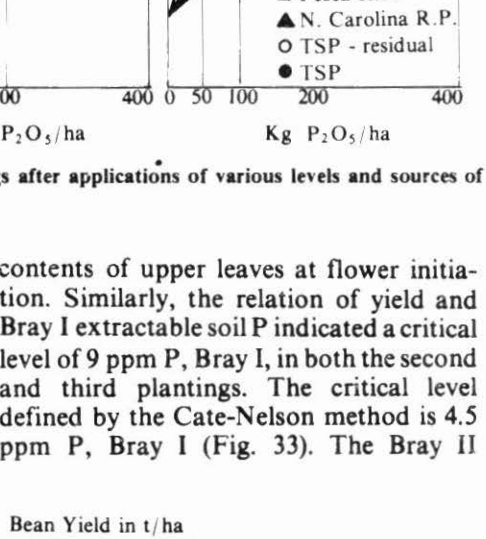


Figure 33. **The relation between bean yield and soil phosphorus as determined at Popayán by Bray I. Arrows indicate critical levels according to the Cate, Nelson and the 95 percent maximum yield methods.**

extractant cannot be used for rock phosphate treated soil as the acid dissolves more P than is available to the plant.

METHOD AND LEVELS OF NITROGEN APPLICATION

Nitrogen experiments in Ecuador (Annual Report, 1975) showed a positive response of beans up to 200 and 400 kg N/ha and broadcast application was superior to banding. However, in three consecutive plantings in Popayán no significant N response was obtained except for a slight negative response at the highest N level.

After the first planting, N was reapplied

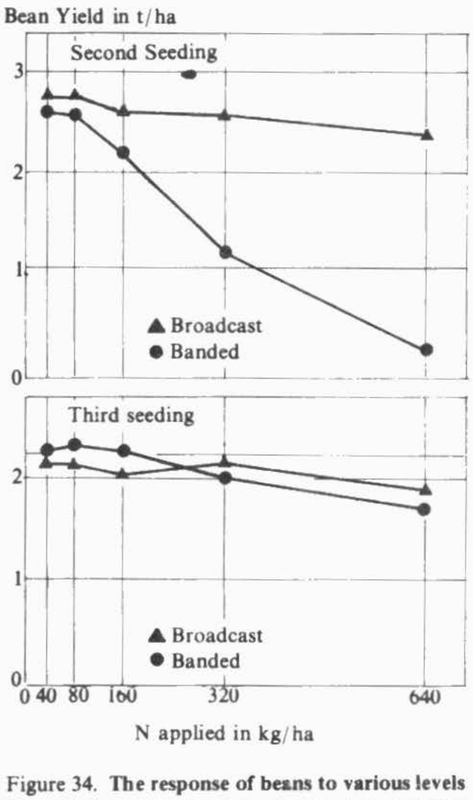


Figure 34. **The response of beans to various levels of N applied as urea either broadcast or in bands. The indicated N levels were reapplied before the second seeding, and measured as residual effect in the third seeding.**

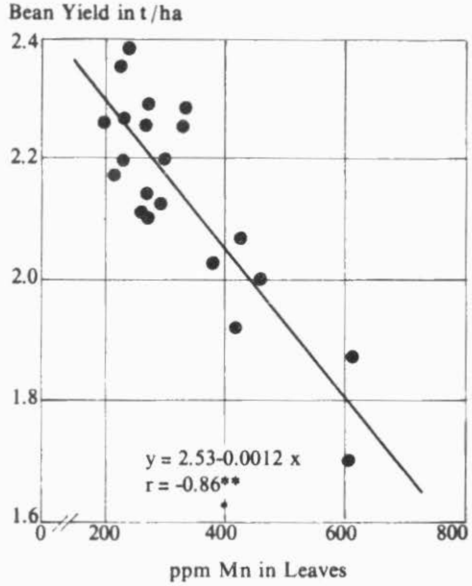


Figure 35. **Relation between bean yield and Mn content of upper leaves at flower initiation.**

to 1/2 of each plot to measure the recent as well as the residual effect of N. Germination was poor at band-applied N levels of 160, 320, and 640 kg/ha due to fertilizer burn caused by dry weather. This produced a marked negative response to high levels of banded N, while broadcast application only slightly affected yield (Figure 34).

When the residual effect was measured in the third seeding, germination was normal but yields were depressed by high levels of banded N, from 2.26 to 1.71 t/ha at levels of 160 and 640 kg N/ha, respectively. This was apparently due to N-induced Mn toxicity at high levels of banded urea. Reapplied banded N decreased the soil pH from 4.8 to 4.1,consequently increasing exchangeable Al and available Mn. Figure 35 shows that bean yields in the third seeding decreased linearly from 2.4 to 1.7 t/ha as the Mn content in bean leaves increased from 200 to 600 ppm. Although toxicity symptoms were only observed at more than 400 ppm Mn, yields were affected when the Mn was above 200 ppm in the leaves.

MINOR ELEMENT FERTILIZATION

Beans grown on alkaline soils at CIAT may suffer from boron and other minor element deficiencies. Foliar sprays of Zn, Fe, Mn, and B were applied singly or in combination as 1 percent $ZnSO_4$, 2 percent Fe-sequestrene-330, 2 percent $MnSO_4$ and 1 percent Solubor, respectively. The varieties ICA Guali and Porrillo Sintético were sprayed at the second trifoliate leaf stage and one week before flowering. Control plots also included soil applied Zn, Fe and Mn (10 kg/ha each) dissolved in water and band-applied below the seed.

Plants without foliar- or soil-applied Zn were stunted, showing severe interveinal yellowing of upper leaves, which later spread throughout the whole plant. Porrillo Sintético recuperated markedly after flowering but ICA Guali remained stunted with many necrotic lower leaves. In Porrillo Sintético, foliar-applied Mn prolonged indeterminate growth without flowering and pod-set. Foliar analysis indicated that plants in all treatments were B-deficient except for those with soil-applied B. Foliar-applied Mn and Zn induced a more severe B deficiency than other treatments.

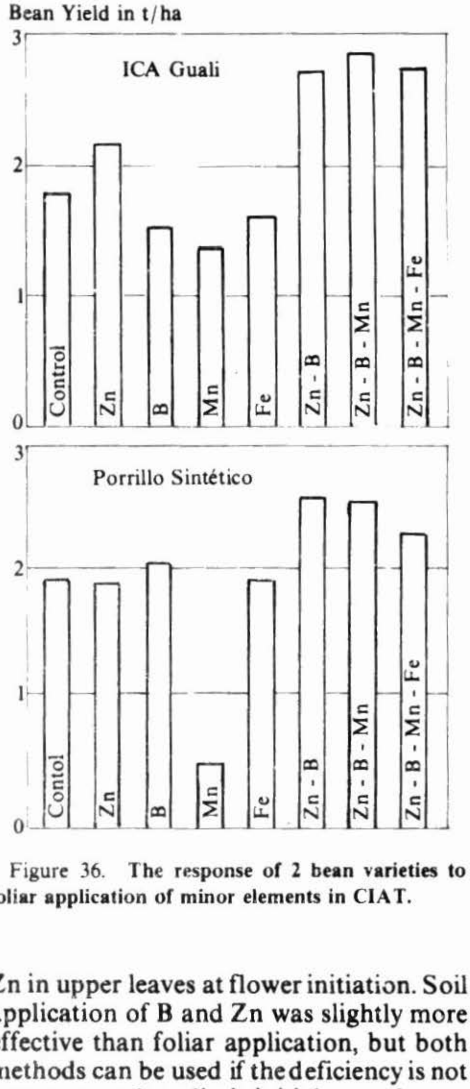


Figure 36. The response of 2 bean varieties to foliar application of minor elements in CIAT.

Figure 36 shows the yield response of selected treatments. ICA Guali responded mainly to Zn alone or combined with B. Porrillo Sintético responded to B alone or combined with Zn. There was a marked negative response to foliar-applied Mn, especially in Porrillo Sintético. Thus, the indiscriminate application of various minor elements to soils deficient in only one or two elements, may actually induce more severe deficiencies.

As observed previously (CIAT, Annual Report 1975); black-seeded varieties like Porrillo Sintético are more susceptible to B deficiency than the red-seeded ICA Guali, while ICA Guali is more susceptible to Zn deficiency. The critical level of Zn deficiency in both varieties was found to be 17 ppm Zn in upper leaves at flower initiation. Soil application of B and Zn was slightly more effective than foliar application, but both methods can be used if the deficiency is not severe enough to limit initial growth.

MANAGEMENT OF ALKALINE SOILS

At CIAT, bean yields may be affected by a combination of high pH, high Na saturation, salinity, poor drainage and deficiency of one or more minor elements. To test the susceptibility of beans to alkaline conditions, six varieties were grown in plots, used previously for cassava, which had been treated with

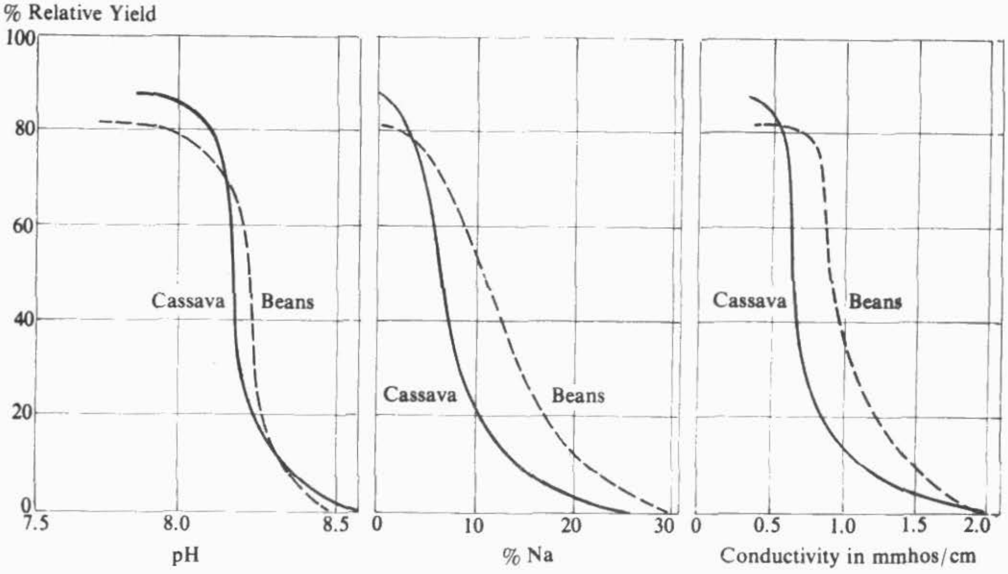


Figure 37. **The relative yield of beans and cassava as affected by soil pH, percent sodium saturation and conductivity of saturation extract.**

gypsum, elemental sulphur, sulphuric acid, rice straw, Zn, Fe, and Cu.

Yields of P498 (Puebla 152) were extremely low because of B deficiency. Average yields of the remaining five varieties responded to application of 1 and 2 t/ha of S, 5 t/ha of gypsum and to 10 kg zn/ha. Figure 37 shows the relation between the relative yield of P788 and pH, percentage Na saturation, and electrical conductivity compared with M Col 22, the most tolerant of the three cassava varieties previously studied in the plot. There was little difference in response among three bean varieties. Bean yields decreased drastically as pH increased above 8.2, when Na saturation increased above 5 to 10 percent and the conductivity increased above 0.75 to 1.0 mmhos/cm. Beans were considerably more tolerant than M Col 22 but bean yields were drastically reduced at levels far below the 15 percent Na saturation and 2 mmhos/cm conductivity that define "sodic" and "saline" soils, respectively.

Agronomy

Agronomic research in monoculture and in associated maize/bean systems continued at CIAT and Popayán. Monoculture bush bean research concentrated on: (1) preliminary yield evaluation of germplasm selections and advanced breeding lines; (2) uniform yield trials in Colombia; and (3) the International Bean Yield and Adaptation Nursery (IBYAN). Further agronomic studies continued on maize/bean associations and preliminary yield evaluations of climbing bean (Type IV) germplasm selections.

BEAN MONOCULTURE TESTING

Preliminary Yield Trials

Two preliminary yield trials at CIAT evaluated 117 non-black, bush bean (Type

I, II, III) selections (Table 41). Yield levels for Type I varieties such as P776 and P788 were outstanding. (P788 has the characteristics of Swedish Brown which has been widely utilized as a parent in the United States.)

Another preliminary yield trial at CIAT also evaluated 25 advanced breeding lines according to color (Table 42). Among the non-black materials, five white and brown lines showed excellent yield compared to the highest yielding variety in the control group. (P302). In almost all cases the pedigrees included the high-yielding black Type II selection, P459 (Jamapa). However, in the black-seeded group yield levels were similar to the best of the controls suggesting that there were higher yield gains in brown and white-seeded material than in black-seeded lines.

Table 41. **Yield of the best entries in two Preliminary Yield Trials[1] at CIAT.**

Identification	Name	Growth Habit	Seed Color	Yield kg/ha
Preliminary Trial No. 1				
P776	Tortolas	III	Beige	3213
P788	PI 284-703	I	Yellow	3168
P153	PI 179-715	I	Brown (m)[2]	3155
P138	PI 176-694	I	White	2980
Controls				
P692	Diacol Calima	I	Red (m)	2731
P458	ICA Tui	II	Black	2388
P675	ICA Pijao	II	Black	2372
Mean of 81 materials				2376
L.S.D. .05				494
C.V. %				13
Preliminary Trial No. 2				
P684	PI 207-262	III	Beige	2925
P766	Aurora	II	White	2774
P622	PI 211-412	III	Beige	2720
Controls				
P675	ICA-Pijao	II	Black	3052
P756		II	White	2875
P692	Diacol Calima	I	Red (m)	2345
Mean of 36 materials				2112
L.S.D. 0.05				440
C.V. %				13

[1] Trial 1: 81 lines in a 9x9 lattice, 3 reps. Trial 2: 36 var., in a 6x6 lattice, 3 reps.

[2] m = mottled

Table 42. **Yield of the most promising advanced breeding materials in the Preliminary Yield Trials[1] at CIAT.**

Identification	Generation	Pedigree	Growth Habit	Seed Color	Yield Kg/ha
Non-Black Materials					
FF 12-13-1	F5	P459 x P567	II	White	3114
FF 11-6-1	F5	P459 x P008	III	Brown (d)[3]	2897
FF 16-3	F5	P459 x P004	II	Brown (d)	2845
FF 16-26-3	F5	P459 x P004	III	Brown	2822
FF 17-4-4	F5	P566 x P004	III	Beige	2739
Controls[2]					
P302	PI 309 804		II	Black	2764
P459	Jamapa		II	Black	2739
P675	ICA Pijao		II	Black	2679
Mean of 11 controls					2513
Mean of 36 entries					2465
L.S.D.					440
C.V. %					11.2
Black Materials					
FF 6-9-1	F5	P566 x P459	II	Black	2954
FF 49-1-1	F4	(P459 x P008) (P008 x P568)	III	Black	2827
FF 4-13	F5	P459 x P568	II	Black	2812
FF 2-6-3	F4	P459 x P006	II	Black	2806
FF 24-9-1	F4	(P459 x P488) (P459 x P568)	II	Black	2793
Controls[2]					
P675	ICA Pijao		II	Black	2958
P758	Puebla 152		III	Brown	2637
P498	Puebla 152		III	Black	2630
Mean of 11 controls					2410
Mean of 36 entries					2540
L.S.D. 0.05					457
C.V. %					11.2

1 36 Varieties in a 6 x 6 lattice with 3 reps., including 11 control varieties for each trial.
2 Yield of three highest yielding controls in each trial.
3 d = dark brown.

Uniform Yield Trials

Results are available for uniform yield trials planted in the second semester of 1976 at CIAT and Popayán with black and non-black varieties. Generally, the more recent selections were not superior to the best control varieties (Table 43). Results are also available for uniform yield trials at CIAT with black and non-black lines in which both germplasm selections and advanced breeding lines were compared with control varieties (Table 44). Two black, advanced breeding lines (also included in Table 42) were superior to the best controls. Within the non-black group some of the germplasm selections also showed high yield levels. Uniform yield

Table 43. **Yield of the most promising black and non-black materials in the Uniform Yield Trials at CIAT and Popayán.**

	CIAT			Popayan	
Identification	Seed Color	Yield Kg/ha	Identi-fication	Seed Color	Yield Kg/ha
Non-Black Materials[1]					
G4826	Cream (m)[2]	2700	G01224	Brown	1980
P788	Yellow	2478	P017	Brown	1874
G1212	Red	2469	G00805	Red	1565
G6391	Cream (m)	2388			
Controls					
P692	Red (m)	2726	P524	Cream	2477
P756	White	2645	P459	Black	2422
P392	White	2418	P756	White	2064
Mean of 16 materials		2378			1544
L.S.D. 0.05		279			675
C.V. %		8.5			25.7
Black Materials[3]					
P014	Black	2451	P009	Black	2937
P422	Black	2269	P226	Black	2801
P199	Black	2247	P437	Black	2763
Controls					
P459	Black	2238	P675	Black	2830
P675	Black	2229	P459	Black	2600
P566	Black	2013	P566	Black	1639
Mean of 25 materials		1988			2271
L.S.D. 0.05		350			674
C.V. %		12.7			18.6

1 16 varieties, 4x4 lattice, 3 reps.

2 m = mottled

3 25 varieties, 5x5 lattice, 3 reps.

Table 44. **Yield of the most promising entries in two Uniform Yield Trials[1] at CIAT.**

Identification	Pedigree	Growth Habit	Yield Kg/ha	Identi- fication	Growth Habit	Yield Kg/ha	Seed Color
	Black-seeded material				**Non-black-seeded material**		
FF 2-6-3	P459 x P006	II	2617	P141	I	2831	Red (m)[2]
P455		II	2531	P138	I	2732	White
FF 6-9-1	P566 x P459	II	2458	P708	I	2536	Beige
P533		II	2404	P060	I	2467	Brown (m)
P280		II	2403	FF 17-4-4[3]	II	2163	Beige
			Controls				
P675		II	2162	P756	II	2446	White
P459		II	1950	P675	II	2153	Black
P498		II	1924	P692	I	1929	Red (m)
Mean of 36 entries			2096			2039	
L.S.D. 0.05			381			448	
C.V. %			11.3			13.7	
Efficiency of lattice design			12%			106%	

1 36 lines in each trial, 6x6 lattice, 3 replications.

2 m= mottled with secondary color

3 Pedigree: P566 x P004

trials at other locations will evaluate yield stability of this material across environments and promising lines entered into the IBYAN program for 1978.

International Bean Yield and Adaptation Nursery (IBYAN)

Results for the 1976 IBYAN are available for 41 locations which range in latitude from 1°S to 55°N. Twenty varieties including a range of seed colors were selected for all locations.

Mean yield of the five best IBYAN entries (in both tropical and temperate zones) for the first 41 sites (Table 45) was 35 percent higher than the mean of the five local entries. This suggests that germplasm material selected under tropical conditions has a wide adaptation range. The four highest yielding materials across locations were the black-seeded Type II varieties: P302 (PI309-804); P459 (Jamapa); P560 (51051, I-1138); and P675 (ICA-Pijao). Some of which were also outstanding in previous CIAT yield trials at altitudes up to 2000 msl in Colombia and Ecuador and in earlier research by the Programa Cooperativo Centroamericano de Mejoramiento de Cultivos Alimenticios (PCCMCA) in Central America.

Mean yield for both IBYAN and local

Table 45. **Mean yield of 20 common and 5 local entries in the 1976 IBYAN at 31 tropical and 10 temprerate locations.**

Group	Zone	Yield in kg/ha		
		Group Mean	Mean of 5[1]	Mean of Highest yielder[2]
IBYAN entries	Tropical	1392	1758(135)	1959(118)
	Temperate	2078	2601(135)	2768(116)
IBYAN entries	Tropical	—	1303	1660(100)
	Temperate	—	1925	2391(100)

[1] Mean of five highest yielders at each location among IBYAN entries and mean of five local entries at each location.
[2] Mean of highest yielding variety at each location within each zone.

entries in the temperate zone was higher than that of the tropics where disease development was severe in some locations. The factors associated with yield variation between locations will be evaluated when the full data set is available.

Data in Table 46 shows the frequency of

Table 46. **Frequency of moderate (1500-1999 kg/ha) to excellent yields ($\geq$ 3000 kg/ha) achieved by the lines tested in the first International Bean Yield and Adaptation Nursery (IBYAN).**

Lines	Seed Color	Growth Habit	Frequency of Yields				Total
			≥3000	2500-3000	2000-2499	1500-1999	
P566	Black	II	1	1	7	19	28
P512	"	II	-	4	6	15	25
P302	"	II	3	2	9	10	24
P459	"	II	1	4	8	11	24
P458	"	II	1	4	8	11	24
P675	"	II	-	4	11	8	23
P560	"	II	3	2	9	8	22
P402	Brown	I	1	3	5	13	22
P524	Cream	II		2	8	9	21
P498	Black	III	1	5	8	7	21
P539	"	II	1	5	8	6	20
P757	"	II	-	6	5	9	20
P643	White	II	-	3	7	10	20
P755	Red	I	-	4	3	13	20
P756	White	II	1	2	6	10	19
P758	Brown	III	1	3	7	7	18
P637	Red	I	1	2	5	8	16
P692	"	I	1	2	2	10	15
P759	"	I	-	2	4	9	15
P392	White	I	-	2	5	7	14

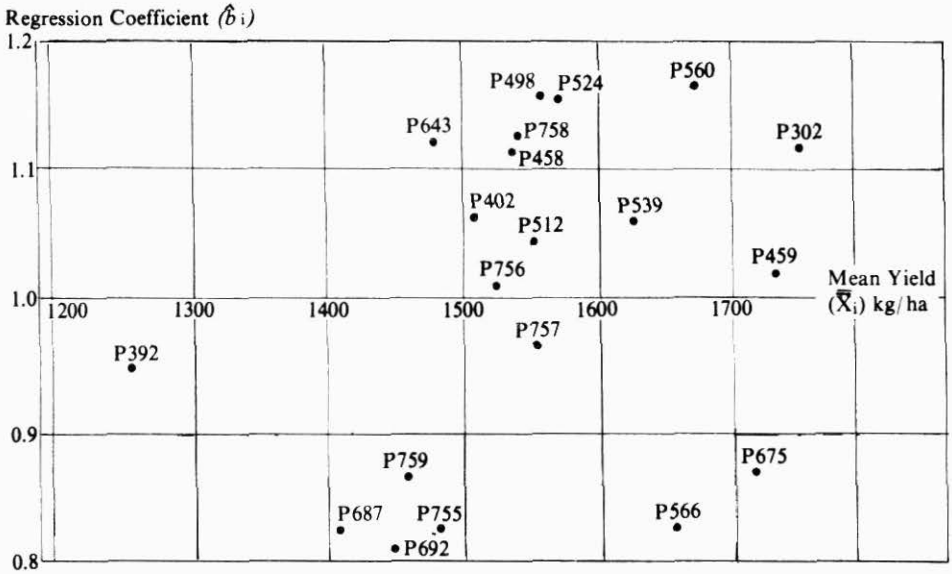


Figure 38. **Plot of regression coefficient($\hat{b}_i$) vs mean yield across locations for 20 common IBYAN entries (3 highest yielding entries/location) in 39 sites in temperate zones.**

yield over 1500 and more than 3000 kg/ha at 41 locations. The wide adaptation of the black-seeded, Type II entries is notable. The poorer performance of lines such as P755 (Pompadour 2); P637 (Linea 17); P692 (Diacol Calima); P759 (Redcloud) and P392 (Sanilac) appears to be associated with the determinate Type I and possibly the comparative earliness of these lines.

A regression analysis of mean cultivar yield/location on site mean yield (including zero yields where these occurred) for the first 39 locations (Fig. 38), shows that five black Type II varieties (P302, P459, P675, P560, and P566) had the highest average yield (1.6 t/ha) but with wide variation in $\hat{b}$ values. P566 was better adapted to the lower yielding sites ($\hat{b}$ = 1.13). The lowest yielding group ($\leq$ 1.4 t/ha) of four non-black Type I varieties (P392, P637, P692, P755) all had $\hat{b}$ values less than 1.0, indicating low mean performance across environments. A central group of 11 Type I, II, and III materials with mean yields of 1.4-1.6 t/ha showed wide variation in $\hat{b}$ values.

Figure 1 also shows materials clearly grouped according to subtype: the "Jamapa" group (P459, P302) are in a similar area of the graph, as well as the "Porrillo" group (P566, P757) and the Puebla 152 group (P498, P758).

Table 47 compares the yields of the variety means by type in 10 temperate and 31 tropical locations. Northern hemisphere breeders concentrate on Type I material for dry bean production but Type II material outperformed Type I at temperate locations. In addition, black-seeded selec-

Table 47. **Average yield in kg/ha of the 20 1976 IBYAN varieties grouped according to growth habit which were tested in 41 sites.**

Zone	No. of Experiments	Growth Habit I	II	III
Tropical	31	1701	1871	1492
Temperate	10	2428	2673	2276
Difference		-727	-802	-784

Table 48. **Average yield (kg/ha) of the 20 1976 IBYAN varieties grouped according to grain color, tested in 41 sites.**

Zone	No. of Experiments	Grain Color			
		Black	Red	White	Brown
Tropical	31	1877	1584	1411	1609
Temperate	10	2619	2137	2352	2500
Difference		-742	-553	-941	-891

tions were the highest yielding at temperate locations (Table 48). The tables also show *the superior performance of Type II* materials for 31 locations in the tropics. For tropical locations, black-seeded varieties were generally superior to non-black materials.

The 1977 IBYAN was divided into black-seeded and non-black-seeded sets of 20 varieties since the collaborators expressed seed color preferences. At all locations the best five local materials selected by the collaborators were included in a 5 x 5 lattice with three or four replications. Some 34 countries collaborated and 108 sets have been forwarded.

BEAN/MAIZE ASSOCIATION TESTING

Density Response in Climbing Beans

Two trials at CIAT evaluated optimum plant density for P589 in monoculture and in association with four population densities of maize over a range of conditions. Figure 39 shows that the optimum bean plant population was uniform at 120,000 plants/ha. However, as bean density increased maize yields decreased.

It was determined that economic optimum density is obtained when the value of the marginal increase in yield equals the price of the seed for planting an increased density and a seed/bean price ratio of 2:1 was assumed.

From eight trials with P259, the average optimum density for monoculture was

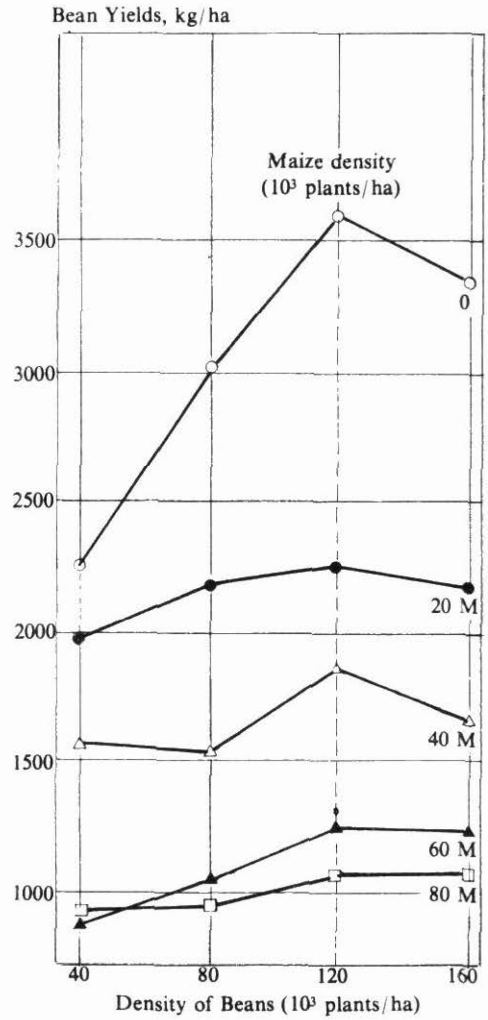


Figure 39. **Yield of climbing bean, P589, as affected by maize (H-210) and bean density.**

100,000 plants/ha but there was a wide range of optimum densities for this cultivar depending on environmental conditions. Low densities for climbing beans in monoculture were recommended since they can branch when light is not a limiting factor. There is no evidence that the farmer will achieve much yield response over 100,000 plants/ha of beans regardless of environmental conditions.

Competition between Beans and Maize

It was found that for all four *Phaseolus* bean types the bean yield was sharply reduced by simultaneous planting compared with planting 10 days before maize (Figure 40). However, the effect of planting Types I and II bush beans 10 days after maize was not significant whereas the yields of Types III and IV (semi-climbing and climbing, respectively) were severely reduced. Apparently, climbing types could not cope with strong maize competition from ICA H-207. Figure 41 shows the maize yields with four types of beans demonstrating that the climbing beans reduce maize yields more than the other types, especially when the two crops are planted simultaneously. At CIAT, simultaneous planting produced optimum yield of both crops in association but preliminary observations at Popayán indicate that this is temperature dependent and relative to the early crop vigor of the two species.

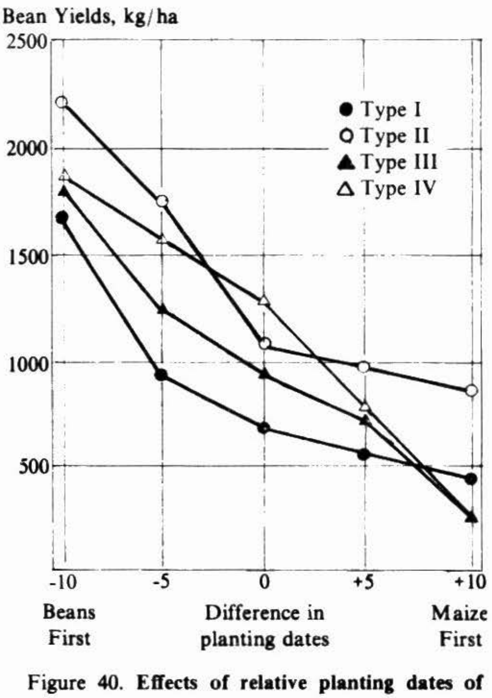


Figure 40. **Effects of relative planting dates of bean/maize association on bean yields.**

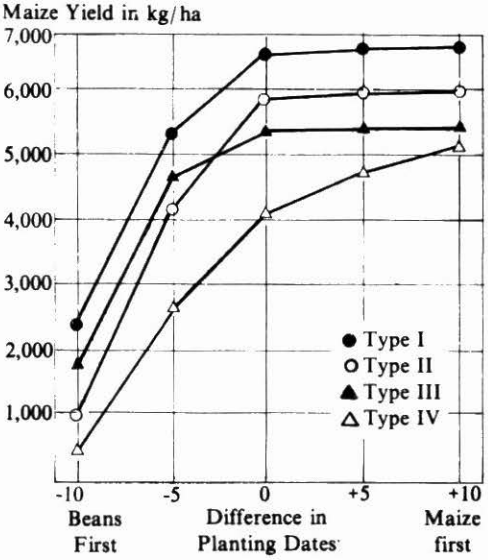


Figure 41. **Effects of relative planting dates on yields of maize (H-207) with 4 types of beans.**

The relative competitive ability of 20 different maize genotypes in association with beans was also investigated. Figure 42 compares the yield of the 10 best yielding maize varieties both in monoculture and associated with Type II and IV beans. Maize yields were more severely reduced by Type IV than by the Type II. However, there was also evidence for differences in competitive ability among the maize genotypes. There was less reduction in the yield of tall maize genotypes, especially those with a tendency to lodge. Root lodging of the maize was sharply reduced in association with beans. In many trials with tall maize genotypes this factor has

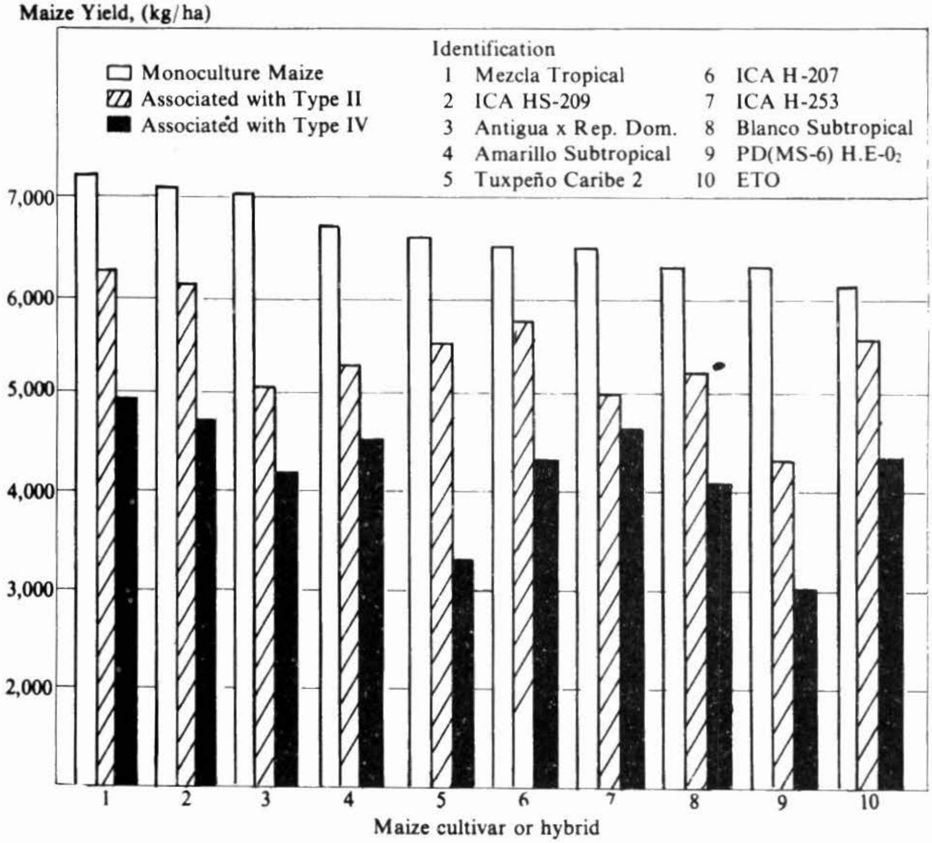


Figure 42. **Yield comparison of 10 maize varieties in monoculture and associated with two bean cultivars of contrasting growth habit.**

resulted in insignificant yield differences between associated and monocrop maize yields.

The yield of Type II beans was dependent on the yields of the maize genotypes (r = -0.89***) whereas there was no relationship with the yield of climbing beans. Low yielding maize genotypes gave insufficient support to the climbing beans to allow a high yield, whereas high yielding maizes were more competitive.

Genotype x System Interactions

Since varieties which perform well in monoculture may not be the best for associated cropping, 20 bush bean varieties were tested in monoculture and in association with maize during three consecutive seasons. Results for one season are shown in Figure 43. Average monocrop yields were reduced 58 percent in association with maize. Significant varietal differences were observed in each system and between the two systems. In the three seasons, the correlations between yields in the two systems were: 0.51, 0.88 (both in 18 d.f.) and 0.91 (7 d.f.), while rank correlation coefficients were 0.54, 0.58, and 0.93. Yield reduction and varietal ranking both were influenced by seasons.

Climbing beans were also tested for three seasons in monoculture and in association with maize and the results of

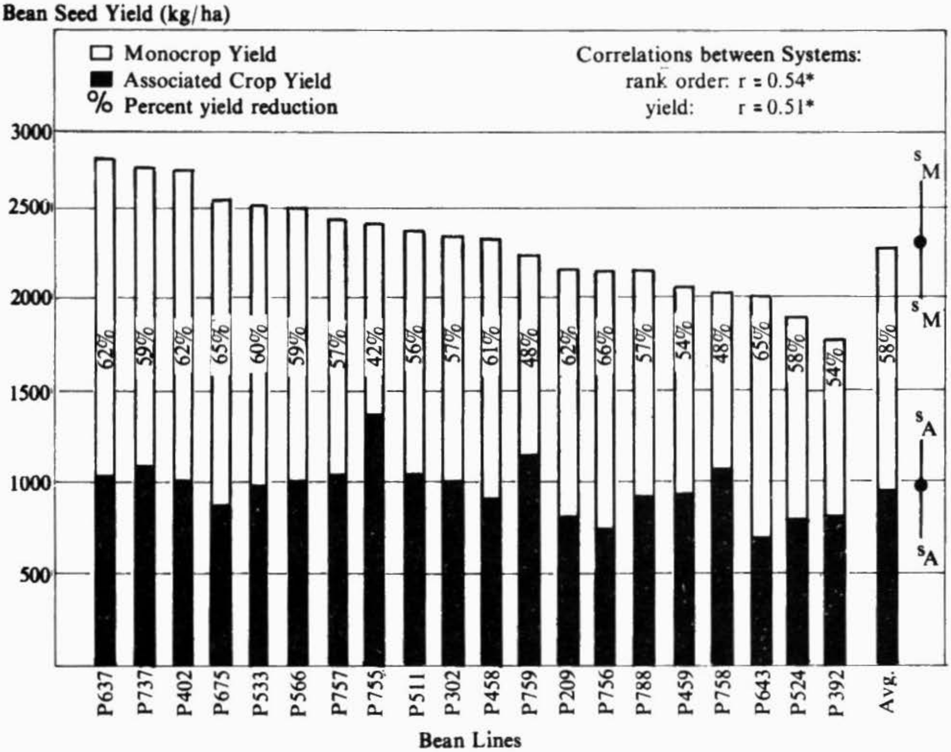


Figure 43. **Bush bean yields obtained from two cropping systems (Trial 7625).**

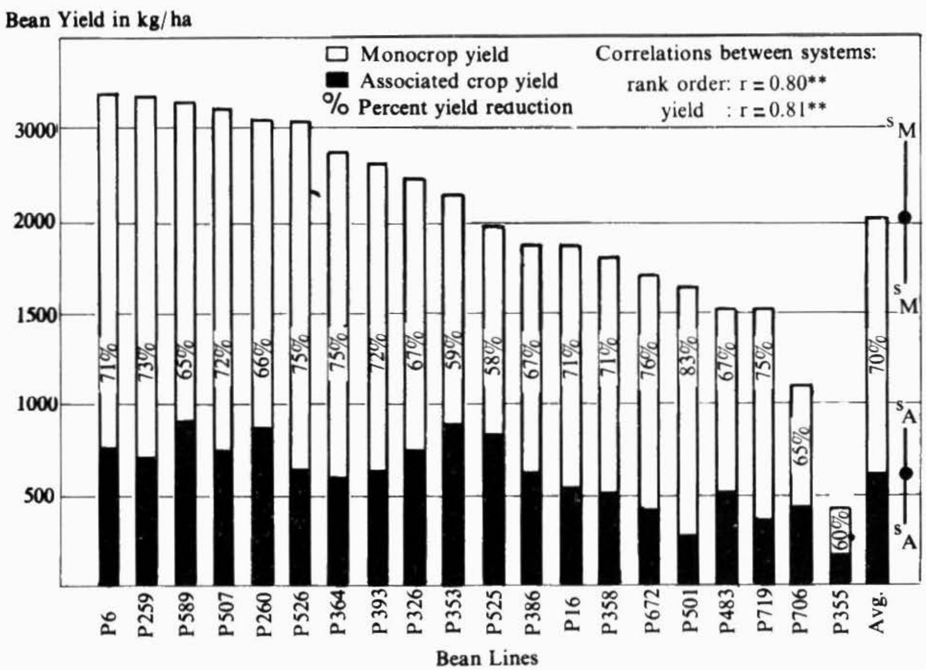


Figure 44. **Climbing bean yields obtained from two cropping systems (Trial 7605).**

one of these trials is shown in Figure 44. Correlations between yields for the two systems were: 0.41, 0.81 (both with 18 d.f.) and 0.90 (7 d.f.) and rank correlations were 0.09, 0.80, and 0.88 for the three seasons, respectively. Yields and varietal ranking also varied among seasons. In each trial, there were significant varietal differences among yields and percentages of yield reduction.

The disadvantages of using an associated cropping system to test breeding materials include poor separation of variety yields, limited seed production in each cycle and complexity of the system for observing individual lines. The improved separation of yields in monoculture, shown in Table 49, was due to greater absolute differences between the means combined with a reduced coefficient of variation for error in monoculture.

Table 49. **Climbing bean results from Trial 7624[1].**

	Bean Seed Yield in kg/ha		% Yield	Yield Rank No.	
Variety	Mono	Assoc.	Assoc./Mono	Mono	Assoc.
P501	2782d-g	971ab	35	13	15
P364	3453a	1245a	36	1	1
P6	3030a-e	1075ab	35	8	11
P449	3225a-c	951ab	29	4	16
P589	2950c-f	1242a	42	11	2
P483	2771d-g	1048ab	38	14	12
P393	3113a-d	934b	30	6	17
P706	3355a-c	1084ab	32	3	9
P353	2969b-f	1183ab	40	10	3
P260	2745d-g	1089ab	40	15	8
P259	3400a-c	1010ab	30	2	14
P326	3041a-e	1142ab	38	7	5
P504	3187a-d	926b	29	5	19
P355	2947c-f	1079ab	37	12	10
P16	2975b-f	1091ab	37	9	7
P719	2149i	472c	22	20	20
P507	2443g-i	932b	38	18	18
P525	2557f-i	1098ab	43	17	6
P672	2607e-h	1045ab	40	16	13
P526	2239hi	1143ab	51	19	4
Mean	2897	1038	36	-	-
C.V. (%)	9.8	19.0	-	-	-

1 Data in each column followed by same letter do not differ significantly (5%); absence of letters in a column indicate no significant differences among treatments.

Climbing Bean Variety Trials

Some 300 Type IV varieties selected for yield potential and grain color were sown with maize ICA H-207 in preliminary yield trials at CIAT. They were also planted at Popayán using old maize stems for support. In Table 50, the mean yields of the best 20 varieties at CIAT are compared with the best of eight standard control varieties representing the best varieties currently identified. A number of new (colored-seeded) materials including black showed good yield potential.

The yields of the best 20 varieties in Popayán are presented in Table 51. All but one of the varieties originated from Mexico. P364 was the highest-yielding control variety at both Popayán and at CIAT, but none of the 20 high-yielding varieties at either site yielded well in both locations. Six of the varieties were significantly higher yielding ($P < 1\%$) than

Table 50. **Yields of the best 20 varieties of climbing beans associated with maize (H-207) at CIAT.**

Identification	CIAT No.	Origin	Color	Yield Kg/ha
PI 201-348	G844	Mexico	Cream	1967
PI 311-861	G2227	Guatemala	Yellow	1907
Boyacá 21	G4590	Colombia	Cream	1790
P 114	G417	Turkey	White	1740
PI 310-767	G2026	Guatemala	Black	1737
Antioquia 130	G4567	Colombia	Cream	1720
Chiapas 163	G14762	Mexico	Cream	1718
PI 224-738	G983	Mexico	Brown	1696
PI 200-978	G1253	Guatemala	Brown	1692
Chiapas 163 (N)	G4762	Mexico	Black	1674
PI 310-680	G1962	Guatemala	Black	1639
PI 311-191	G2161	Guatemala	Black	1639
PI 282-024	G1079	Chile	Brown	1634
PI 310-767	G2026	Guatemala	Brown	1585
PI 204-721	G891	Turkey	White	1579
PI 209-801	G1365	Kenya	Coffee	1575
PI 311-904	G2258	Mexico	Purple	1571
Boyacá 21	G4590	Colombia	Black	1569
PI 310-783	G2033	Guatemala	Black	1569
PI 189-012	G731	Guatemala	Brown	1565
Best Control P364				1416
Mean of controls (n=8)				1099
Overall mean				1319
L.S.D. at .01 level = 392				

Table 51. **Yields of the best 20 varieties of climbing beans at Popayán.**

Identification	CIAT No.	Origin	Color	Yield Kg/ha
[illegible]	G3352	Mexico	Yellow	4502
P468	G3469	Mexico	Brown	4443
Guanajuato 22	G3445	Mexico	Yellow	4353
Black bean	G3208	Guatemala	Black	4348
Guanajuato 116-A	G3451	Mexico	Purple	4338
PI 313-724	G2597	Mexico	Yellow	4305
Puebla 422	G3391	Mexico	Yellow	4121
PI 313 730	G2602	Mexico	Grey (m)[1]	4076
PI 203 930	G875	Mexico	Yellow	4025
PI 313 758	G2620	Mexico	Yellow	4024
PI 313-730	G2602	Mexico	Grey	3998
PI 311-908	G2262	Mexico	Cream	3994
PI 319 631	G2829	Mexico	Brown	3963
PI 311-917	G2270	Mexico	Cream	3947
PI 201-317	G838	Mexico	Cream	3944
PI 313-776	G2634	Mexico	Brown	3919
PI 309-797	G1814	Mexico	Yellow	3891
Guanajuato 22(R)	G3445	Mexico	Red	3876
PI 313-514	G2497	Mexico	Black	3849
PI 313-755	G2618	Mexico	Brown	3833
Best control P364			White	3487
Mean of controls (n = 8)				2277
Overall mean				2505
L.S.D. at .01 level				778

[1] m = mottled

the best control variety, and the yields in Popayán were remarkably high considering the relatively simple and inexpensive support system used.

Economics

The principal economic research objective is to estimate the profitability of new technology and to identify the constraints to its introduction in Colombia and other countries. Results of experiments in Honduras and Restrepo, Colombia are included in this section. A secondary objective is to collaborate with other program scientists in the economic evaluation of their data. The economic aspects of some of the work with Agronomy are presented.

ON-FARM TECHNOLOGY TESTING

Honduras

For over a year CIAT has been collaborating with a Honduran program, Programa de Maíz y Fríjol (PROMYF) to increase the income of small and medium farmers through productivity increases in beans and corn. New bean varieties, fertilizers, insecticides and herbicides were tested on farmers' fields in seven locations during the "Postrera", the second Honduran planting season, which is characterized by more irregular and reduced rainfall than the first season. Most of the beans are produced during the Postrera following the corn of the first season. In most years water stress can be expected,hence varieties must be developed for these conditions.

Varietal Testing. In six of seven yield trials different CIAT selections (black-seeded varieties) gave significantly higher yields than the local reds. However, there is a local market price discount for black varieties due to consumer preferences for reds, and export markets for blacks have been unstable. When profitability of the red and black-seeded varieties was compared rather than yields, the red varieties gave significantly higher returns in four of seven trials. These results emphasize the importance of considering consumer preferences as well as yields. Farmer profits and the feasibility of a new technology fitting into a production system are the appropriate measures of the success of a new technology while comparative yields are often poor indicators.

Fertilizers. Using incremental budgeting, almost all fertilizer treatments in all regions resulted in an income loss as compared with zero fertilizer. Although an earlier planting date might have reduced the losses, these results indicate that fertilizer is a risky input under irregular rainfall conditions and without control of other yield-reducing factors. Risk as well as the expected return for all possible agroclimatic conditions must be considered when evaluating introduction of new technology.

Insecticides. *Empoasca kraemeri* and *Apion* are considered to be two of the principal constraints to increased bean yields in Central America. However, in these trials low incidence or poor application made "preventive" insecticide treatments consistently unprofitable at all locations. The cost of insecticide could be reduced by initiating control when populations reach economically damaging levels. The effectiveness of field identification of pests before "curative" insecticide spraying is being tested.

Herbicides. It was found that herbicides have several types of effects — on yields, on labor costs of weed control, and on the area cultivated when seasonal labor availability for weeding is a critical constraint. When the first two effects were evaluated, one traditional herbicide consistently lost money and reduced yields in fifty percent of the trials. Another herbicide, methobromuron, was profitable in six of the seven sites even when zero opportunity cost for family labor was assumed. During this season the use of the **appropriate** herbicide had an effect on yield, perhaps resulting from the increased water availability to the beans.

Simple economic analysis indicated the importance of seed color in evaluating varieties and the riskiness of high inputs for the Postrera season given the high probability of water stress. The development of an improved early red variety to fit better into the Postrera season is believed to be the most important component of a new technology package for the PROMYF program.

Restrepo, Colombia

Agronomic experiments to identify an improved technology for small farmers

Table 52. **Input use and returns data per hectare for best farmer practices, and new bean technologies in Restrepo.**

		New Bean Technology			
		On-farm Trials		Synthetic Data	
		Improved Practices and			
	Best Farmer Practices in Bean Production	Calima (Bush)- No Herbicide	New variety (Climbing)- No herbicide	Calima with Herbicide	New Climbing variety with Herbicide
Yields (kg/ha)	957[3]	1256	1419	1256	1419
Price of beans (pesos/kg)[1]	21.5	21.5	17.6	21.5	17.6
Variety	Several varieties including Calima	Calima	(P103, S220, P364)	Calima	(P103, S220, P364)
Labor requirements (man-day per ha)	97.3	122.5	132.5	111.5	121.5
Density (plants/ha)	110,000[4]	250,000	120,000	250,000	120,000
Fertilization	1.8 tons chicken manure	—50 kg P_2O_5/ha plus one ton of chicken manure—			
Pest control	None	— 4 sprayings of fungicide-insecticide—			
Weed control	— Manual labor (14 man-days)—			—Herbicide-cost of $819/ha plus 3 man-days for application.	
Gross income	20,575	27,004	24,974	27,004	24,974
Cost of purchased inputs	-5,752	-6,920	-3,930	-7,739	-4,749
Labor cost[2]	-6,587	-8,609	-9,312	-7,836	-8,539
Net Income	8,238	11,475	11,732	11,429	11,686

1 The Calima price was the average price received in the region for this variety. The new variety prices were for red beans except for P364, a white bean, and were discounted. However, this is a very conservative adjustment because among the red beans Calima has a substantial discount compared to Cargamanto, Radical or other large-seeded varieties.

2 Family labor was priced at the going wage rate. In the programming family labor was treated in the standard method as a fixed cost.

3 The average yields were based upon a survey of 22 farms.

4 This was the average density for single cropping in the region. When beans were intercropped with coffee, the density was 40,000 plants/ha.

were conducted the past two years in this region (see Hudgins). Experiments with improved climbing selections and Calima continued with a minimum input package since the costs of inputs in previous trials were still considered too high for the small farmer. Profitability estimates were made for two new bean technologies in on-farm trials. The technologies included improved climbing selections, phosphorus, increased organic fertilizer, and insect and disease control (Table 52). Results showed that new technology for climbing beans reduced the cost of purchased inputs. The higher population density of Calima and associated inputs increased the costs of the new bush bean technology. Nevertheless, new bean technologies increased farmer income by approximately 40 percent.

Labor availability *vs.* Herbicides. The principal constraint on new technology adoption in a coffee zone such as Restrepo may be seasonal labor availability. Labor requirements increased 26 to 36 percent with the new technologies. Synthetic data were derived for two labor saving technologies with herbicides[1] (Table 52). Herbicides slightly reduced net income as the cost was greater than that of the released labor; however, they would still be utilized if seasonal labor availability were a pressing constraint.

To evaluate the feasibility of introducing these four new bean technologies into the Restrepo farming system, profit-maximizing plans for farms of different sizes were computer programmed, considering available land, labor, capital, and alternative activities in the region. Results indicate that if the yields of Table 1 can be obtained on farmers' fields, then the new bean technology package will be profitable over a wide range of farm sizes (Table 53). Profit maximization estimates were made on the effects of the new technology on farm level profits and labor use for a typical Restrepo farm (7.8 ha) before and after the new technology introduction (Table 54). Results show that the new technology increases farm income, farm employment and bean area. Farm level profits should be further increased with improved red climbing and bush type germplasm incorporating resistance to some diseases for which spraying is now necessary.

Storage in Restrepo. Previous field research in Huila and Nariño indicated that small farmers sold 94 percent of their beans soon after the harvest. Therefore, beans had little effect on farm family nutrition and farmers suffered from the post-harvest price collapse. An analysis of bean samples from 18 Restrepo farms showed that all had serious problems with storage insects, principally. *Zabrotes subfasciatus*. Eight farmers sold their beans rather than keep them for home consumption; none stored beans for more than two or three months; and four treated the beans with aldrin or dried them in the sun.

The risk of storage and the necessity for immediate post-harvest sale at lower prices may be important factors in the lack of farmer interest in increasing bean productivity. CIAT Bean Entomology has found that vegetable oils effectively control *Z. subfasciatus* in stored beans (see Entomology) and is presently testing this practice in farm level trials.

ECONOMICS OF THE BEAN/MAIZE ASSOCIATION

Economic analysis of twenty agronomic trials at CIAT provided information on yields over seasons for monoculture climbing beans, monoculture maize, and bean/maize associations (simultaneous planting). Sensitivity of net income to change in production costs, yields of each crop, and relative prices of beans and maize were evaluated for a series of conditions relevant to Latin America. While there is a range in bean/maize price ratios in Latin America — 2:1 in Mexico and up to 7:1 last year in Brazil — the ratio in Colombia is relatively stable at 3.5 to 4:1. (See Francis and Sanders).

---

[1] The farm level testing in Restrepo did not include herbicides. It was assumed that herbicides would have no effect on yields. Costs and labor requirement of the technologies with herbicides were obtained from Colombian market data and other studies, respectively.

Table 53 **Profit maximizing farm plans for three different farm sizes in the coffee zone of Restrepo, Colombia.**

Activity	Unit	Farm Size 2.5 Ha	7.8 Ha	22.7 Ha
		Activity Level		
Gross Margin[1]	Colombian Pesos	102,042	276,410	667,875
Old coffee area[2]	Ha	1.5	1.5	1.5
New coffee area	Ha	.5	2.3	9.3
Cassava	Ha	-	0.2	4.1
Bean Technology IV (1st. semester)	Ha	.5	3.9	7.8
Labor selling : Jan.-Mar.	Man-days	1	-	-
Labor selling : Apr.-June	Man-days	23	-	-
Labor hiring : Jan.-Mar.	Man-days	-	280	956
Labor hiring : Apr.-June	Man-days	-	123	456
Family labor : Jan.-Mar.	Man-days	84	84	84
Family labor : Apr.-June	Man-days	84	84	84
Bean Technology II (2nd. semester)	Ha	.5	3.9	-
Bean Technology IV (2nd. semester)	Ha	-	-	1.8
Labor selling : July-Sept.	Man-days	18	-	-
Labor selling : Oct.-Dec.	Man-days	11	-	-
Labor hiring : July-Sept.	Man-days	-	192	399
Labor hiring : Oct.-Dec.	Man-days	-	191	449
Family labor : Jul.-Sept.	Man-days	100	100	100
Family labor : Oct.-Dec.	Man-days	100	100	100

[1] This is a programming concept equal to gross returns minus variable costs. When fixed costs are amortized between years and deducted, net profit is obtained.

[2] The old coffee plantation was considered to be fixed on all farms due to the high investment cost of replacing it.

Table 54. **Profit maximizing farm plans for the typical Restrepo farm (7.8 Ha) before and after the introduction of new technology in bean production.**

Activity	Unit	New Bean Technology Before	After
		Activity Level	
Gross Margin[1]	Colombian Pesos	225,190	276,410
Old coffee area	Ha	1.5	1.5
New coffee area	Ha	2.3	2.3
Cassava	Ha	1.1	0.2
Best Farmer Bean Technology (1st. semester)	Ha	2.8	-
New Bean Technology IV (1st. semester)	Ha		3.9
Labor hiring : Jan.-Mar.	Man-days	168	280
Labor hiring : Apr.-June	Man-days	148	123
Family labor : Jan.-Mar.	Man-days	84	84
Family labor : Apr.-June	Man-days	84	84

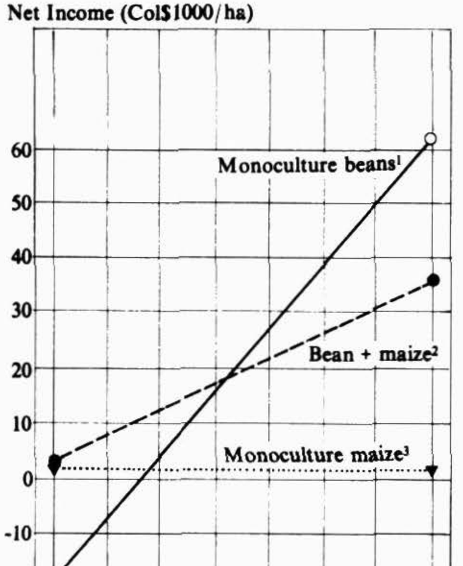
See footnote 1 of Table 53.

Table 54. (continued)

Activity	Unit	New Bean Technology Before	New Bean Technology After
		Activity Level	
Gross Margin[1]	Colombian Pesos	225,190	276,410
Best Farmer Bean Technology II (2nd. semester)	Ha	3.0	
New Bean Technology II (2nd. semester)	Ha	-	3.9
Labor hiring : July-Sept.	Man-days	124	192
Labor hiring : Oct.-Dec.	Man-days	184	191
Family labor : July-Sept.	Man-days	100	100
Family labor : Oct.-Dec.	Man-days	100	100

[1] See footnote 1 of Table 53.

Figure 45 shows that monoculture maize is the least profitable of the three alternatives. Monoculture climbing beans are more profitable above a 4:1 price ratio, and the bean/maize association more profitable below this ratio. The equal profitability of the two bean systems at the 4:1 ratio prevailing in Colombia is consistent with farm data collected in Huila where both systems gave almost identical returns, and the choice of the system appeared to be a function of farm size and labor availability.



[1] Monoculture bean yields 3000 kg/ha with production costs of Col$31,000/ha.

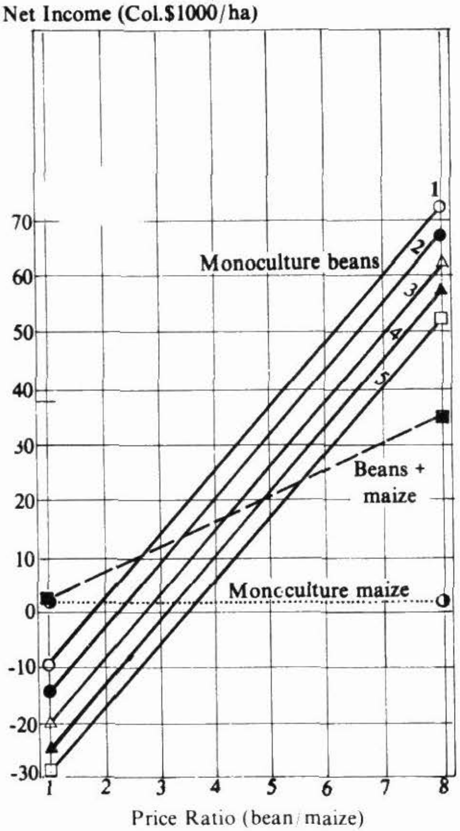
[2] Bean yields of 1200 kg/ha and maize yields of 5000 kg/ha with production costs of Col$22,000/ha.

[3] Monoculture maize yields of 5000 kg/ha with costs of Col$18,000/ha.

Figure 45. Net income from 3 cropping systems at several bean/maize price ratios.

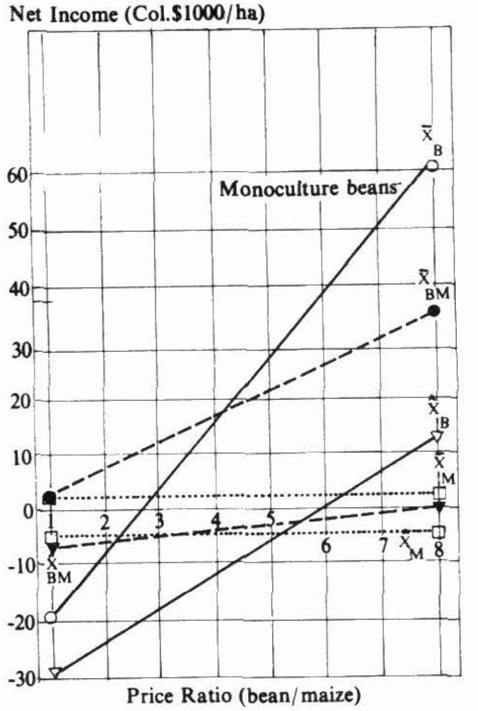
The advantage of monoculture climbing beans depends critically upon the labor and support costs. In a small farm system with surplus family labor and local materials available on the farm for artificial support, monoculture beans could be profitable at substantially lower price ratios, between 2 and 3:1 (Figure 46).

This analysis has only considered expected income. However, small farmers are also concerned with income variation (risk). Using the "guaranteed income" concept, risk is calculated as the minimum income produced by each activity with a given level of probability. Guaranteed income can be calculated as $\widehat{X} = \overline{X} - t_g s$, where $\widehat{X}$ is the minimum income goal, $\overline{X}$ is mean income, t_g is the "t" level at "g" probability and "s" is the standard deviation. This minimum income assures the farmer that in almost all cases his maximum loss or minimum gain under most agroclimatic conditions will be above the given $\widehat{X}$. In Figure 47, it is clear that beans



1 Stakes = 0, labor = 0, total Col$21,000
2 Stakes = Col.$5000, labor = 0, total 26,000
3 Stakes = Col.$5000, labor = Col.$5000, total 31,000
4 Trellis = Col.$15000, labor = 0, total 36,000
5 Trellis = Col.$15000, labor = Col.$5000, total 41,000

Figure 46. Net income from three cropping systems at several bean/maize price ratios, with variable monoculture bean costs.



1 Lower line ($\hat{X}_i$) for each system represents level above which income will occur with 90% probability($\hat{X} = \bar{X} - t_{.10}s$ where $t_{.10} = 1.6448$)

Figure 47. Guaranteed net income from three cropping systems at several bean/maize price ratios.[1]

alone are riskier than the bean/corn association until the price ratio is over 5.5:1 (90% probability). Small farmers who avoid high risks may prefer associated cropping even when the monoculture beans are more profitable. Most farmers, who have the necessary labor to use these associated cropping systems, must be concerned with the risks of crop loss. Therefore, they may be expected to choose associated cropping to reduce production costs and to achieve greater income stability.

Appendices

Appendix A. **List of Promising Lines of *Phaseolus* referred to in the 1977 Bean Program Annual Report.**

Program Promising No.	CIAT Accession No.	Identification or Registration	Source
P004	G0 2115	PI 310-878	USA
P005	1741	PI 307-824	USA
P006	2005	PI 310-739	USA
P008	2056	PI 310-814	USA
P009	2959	Pecho Amarillo	GUA
P011	3729	Argentina 2	VEZ
P012	5474	BRZ 1289 (69-6584-3)	BRZ
P014	2146	PI 310-909	USA
P016	3873	Trujillo 4	VEZ
P017	3719	Mexico 12-1	VEZ
P060	0143	PI 164-746 (SEM)	USA
P089	0302	PI 169-844	USA
P114	0417	PI 173-022	USA
P138	0556	PI 176-694 (Oturak)	USA
P141	0569	PI 176-713	USA
P153	0645	PI 179-715 (Rong)	USA
P155	0651	PI 180-729	USA
P167	0685	PI 182-007	USA
P168	0686	PI 182-011	USA
P169	0687	PI 182-026 (Windsor long pod)	USA
P174	0716	PI 186-492	USA
P178	0728	PI 186-505	USA
P179	0684	PI 181-996	USA
P182	0756	PI 193-569	USA
P189	0780	PI 194-578	USA
P194	0797	PI 195-391	USA
P199	1220	PI 196-927 (F. Criollo)	USA
P203	0818	PI 197-970 (Bayo Berendo)	USA
P204	0819	PI 197-971 (Berendo)	USA
P209	1259	PI 201-333	USA
P211	1264	PI 201-489	USA

Program Promising No.	CIAT accession No.	Identification or registration	Source
P226	1308	PI 207-198 (C.C.G.B-44)	USA
P239	1423	PI 226-895	USA
P243	1434	PI 226-938 (wachs hundert fur eine)	USA
P246	1050	PI 269-634	USA
P256	1524	PI 282-052	USA
P259	1093	PI 282-063	USA
P260	1098	PI 282-074 (Ocanero)	USA
P280	1682	PI 306-159	USA
P289	1694	PI 307-752 (S-137-N)	USA
P302	1820	PI 309-804	USA
P306	1833	PI 309-853	USA
P318	1962	PI 310-680	USA
P326	2006	PI 310-740	USA
P332	2026	PI 310-767	USA
P334	2034	PI 310-784	USA
P349	2281	PI 311-930	USA
P353	2327	PI 311-992	USA
P355	2337	PI 312-004	USA
P358	2382	PI 312-064	USA
P364	2540	PI 313-653	USA
P365	2549	PI 313-662	USA
P386	3269	Aguascalientes 70	MEX
P392	4498	Sanilac	USA
P393	3736	Alabama 1(I-1012)	VEZ
P401	3065	Blanco (GUA-0137)	GUA
P402	3807	Brasil 2 (Bico de Ouro)	VEZ
P420	3607	C.C.G.B.-44 (I-462)	VEZ
P422	3724	Compuesto negro (I-996)	VEZ
P432	3153	F. de parra (GUA-0350)	GUA
P437	3128	F. negro (GUA-0321)	GUA
P438	3131	F. negro (GUA-0325)	GUA
P439	3205	F. negro (GUA-0426)	GUA
P449	3451	Guanajuato 116A	MEX
P455	2960	Hailillo (GUA-0016)	GUA
P458	14454	ICA Tui	CLB
P459	3645	Jamapa (I-810)	VEZ
P461	3974	Jin 10B (C-90)	CRI
P468	3469	Michoacan 70	MEX
P478	4177	12-B-P-3 (N-159)	CRI
P483	3565	Oaxaca 39	MEX
P488	4142	Porrillo 70 (N-579)	CRI
P495	3352	Puebla 151B	MEX
P498	3353	Puebla 152	MEX

Program Promising No.	CIAT accession No.	Identification or Registration	Source
P500	3360	Puebla 173	MEX
P501	3363	Puebla 199	MEX
P504	3374	Puebla 304	MEX
P507	5693	California small white 643	USA
P509	4487	San pedro pinula 72	GUA
P511	3627	S-182-N (I-714)	VEZ
P512	4122	S-166-A-N (N-555)	CRI
P524	4421	S-630-B (C-63)	CRI
P525	3871	Trujillo 2	VEZ
P526	3872	Trujillo 3	VEZ
P533	3526	Veracruz 56	MEZ
P536	3531	Veracruz 157	MEZ
P539	3776	Venezuela 2 (I-1062)	VEZ
P540	3784	Venezuela 29 (I-1071)	VEZ
P545	3786	Venezuela 36 (I-1073	VEZ
P560	3834	51051 (I-1138)	VEZ
P561	4152	50609 (N-283)	CRI
P566	4495	Porrillo Sintético	HON
P567	5478	Tara	PRI
P568	5479	PR-70-15R87 (PR-5)	PRI
P569	5481	Cacahuate 72	MEX
P588	4455	ICA huasaño	CLB
P589	2525	PI 313-624	USA
P590	5702	Cargamanto	CLB
P597	1222	PI 196-932	USA
P622	5697	2114-12	USA
P623	4458	27R	CRI
P631	5696	Cornell 046-C	USA
P634	5683	ICA dura	CLB
P635	4452	ICA guali	CLB
P637	4523	Línea 17	CLB
P639	3467	Michoacan 31	MEX
P643	4459	NEP - 2	CRI
P645	3597	Diacol nima (I-204)	VEZ
P646	0881	PI 203-958 (N-203)	USA
P649	4312	Puebla 439	MEX
P670	3059	Mateado sesentano	GUA
P672	4164	G1-1-5-1 (N-315)	CRI
P675	4525	Línea 32 (ICA pijao)	CLB
P678	3058	De vara (GUA-0129)	GUA
P681	5054	H1 Mulatinho (BRZ-343)	BRZ
P682	5208	BRZ - 1087 (I-162)	BRZ
P684	1320	PI 207-262 (tlalnepantla 64)	USA

Program Promising No.	CIAT accession No.	Identification or registration	Source
P685	5694	Cornell 49-242	USA
P691	4489	Cuilapa 72	GUA
P692	4494	Diacol calima	CLB
P693	5653	Ecuador 299	ELS
P696	4791	Honduras 46	NIC
P698	5476	Jules	USA
P699	5652	Mexico 309	ELS
P704	4795	Porrillo 1	ELS
P706	5701	Rojo 70	ELS
P708	4473	Titan	CHL
P709	4485	Turrialba 1	GUA
P712	4792	51052	NIC
P714	4505	Top crop	USA
P718	4789	Cubagua	VEZ
P719	5710	G.N.UI.31	USA
P720	0832	PI 200-974	USA
P721	1401	PI 224-743	USA
P729	1951	PI 310-668	USA
P737	4456	Jamapa	CRI
P739	4509	Masterpiece	UTK
P743	4829	Paraná (lote 3)	BRZ
P746	4830	Rio tibagí (lote 10)	BRZ
P755	4460	Pompadour 2	CRI
P756	4445	Ex-rico 23	CLB
P757	4461	Porrillo 1	CRI
P758	4446	Ex-puebla 152 (Brown seeded)	MEX
P759	0076	Red kloud	USA
P763	3329	Puebla 38-1	MEX
P766	5719	Aurora	USA
P775	4197	Black turtle soup B.	CRI
P776	4472	Tortolas	CHL
P778	4637	Cundinamarca 115C (arbolito)	CLB
P779	4638	Cundinamarca 116 (arbolito)	CLB
P780	2997	Rabia el gato	GUA
P782	6380	Kaboon	NET
P788	1540	PI 284-703	USA
P793	5712	Comp. chimaltenango 3	GUA

Appendix B. List of CIAT accessions (not classified as Promising Lines) of *Phaseolus* referred to in the 1977 Bean Program Annual Report.

CIAT accession No.	Identification or registration	Source
GO0729	PI 186-506	USA
0731	PI 189-012 Tsib. Tsinap'ul	USA
0738	PI 189-406 Piligue	USA
0805	PI 197-034	USA
0838	PI 201-317	USA
0843	PI 201-345	USA
0844	PI 201-348	USA
0875	PI 203-930	USA
0891	PI 204-721	USA
0951	PI 209-479	USA
0983	PI 224-738	USA
1018	PI 244-715	USA
1069	PI 281-979	USA
1079	PI 282-024	USA
1080	PI 282-025	USA
1157	PI 299-388 *Phaseolus lunatus*	USA
1212	PI 196-299	USA
1224	PI 196-936	USA
1253	PI 200-978	USA
1257	PI 201-300	USA
1365	PI 209-801 Kapumbu	USA
1814	PI 209-797 F. azufrado amarillo	USA
2033	PI 310-783	USA
2161	PI 311-191	USA
2227	PI 311-861	USA
2258	PI 311-904	USA
2262	PI 311-908	USA
2270	PI 311-917	USA
2497	PI 313-514 Negro	USA
2597	PI 313-724	USA
GO2602*	PI 313-730	USA
2618	PI 313-755	USA
2620	PI 313-758	USA
2634	PI 313-776	USA
2829	PI 319-631 Fríjol apetito	USA
3208	Fríjol Negro (GUA-431)	Guatemala
3391	Puebla 422	Mexico
3407	Puebla 441	Mexico
3445*	Guanajuato 22	Mexico

CIAT accession No.	Identification or registration	Source
4016	Stringless Green refugee (P-120)	Costa Rica
4231	Mexico 21N (N-22)	Costa Rica
4503	Widusa	Francia
4567	Antioquia 130	Colombia
4590*	Boyaca 21 Sangileno	Colombia
4762*	Chiapas 163	Mexico
4826	Pintado	Brazil
5487	Great Northern U.I. 123 (V-1217)	United Kingdom
5714	Seafarer	USA
5732	Mexico 235	Salvador
5772	Diacol Andino	Colombia
5942	PR-70-15R-55 (PR3)	Puerto Rico
6014	Guatemala 388 (HON-0491)	Honduras
6374	Bountiful	USA
6391	Linea 20667	Colombia
6719	Jubila	Holanda
6732	Stringless Green Pod	USA
6734	Improved Tender Green 40031	USA
7121	Goiano Precoce (HON-2633)	Honduras
	TMD-1	Brasil*
	Zamorano	Honduras*

Appendix C. **Description of growth habits of *Phaseolus vulgaris* L. used by the CIAT Bean Program.**

Following are the definitions of the growth habits for *Phaseolus vulgaris* L., as used by the CIAT Bean Program.

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 III: 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 prostrate branches borne on the lower nodes; prostrate plant with spreading habit; guide development extremely variable with some tendency to climb in some materials under certain conditions but generally showing only weak climbing ability.

TYPE IV: Indeterminate growth habit; vegetative terminals on the main stem; heavy node production on the main stem after flowering commences; branches not well developed compared to main stem development; types which show moderate to strong climbing tendencies on supports.

Notes: The most important distinguishing features of the four growth habits are as follows: terminal raceme on main stem for Type I; indeterminate with erect branches for Type II; indeterminate with prostrate habit and branches for Type III; and indeterminate with well developed climbing ability in Type IV. Intermediate types occur between Types II and III and between III and IV. Growth habit is not a stable characteristic of many genotypes since drastic changes in growth habit occur from one location to another. Relative guide development is not a good indication of growth habit due to extreme instability in this character.

Appendix D. **Description of bean ideotypes according to their characteristics under development in the CIAT Bean Program.**

Following are summaries of the main characteristics of four ideotypes which have been defined as goals for selection in the breeding program at CIAT.

IDEOTYPE A: Indeterminate growth habit (Type II) with a short growing season (less than 70 days to physiological maturity); erect plant type with erect branches; limited node production on the main stem after flowering; pods borne as high as possible to avoid pod contact with the soil; lodging resistant. Defined for cropping systems (monoculture, association or relay) which require bush beans of early maturity and where plant densities can be maintained at approximately 250 x 10^3 plants/ha.

IDEOTYPE B: Indeterminate growth habit (Type II) with a long growing season of more than 90 days to physiological maturity with a long preflowering period of more than 50 days; erect main stem with few branches borne erectly; moderate node production on the main stem after flowering but with limited guide development; highly lodging resistant; pods borne out of contact with the soil.

Defined for monoculture cropping systems requiring a late high yielding variety which can be mechanically cultivated or associated and relay systems where plant densities can be maintained at approximatelly 250 x 10^3/ha.

IDEOTYPE C: Indeterminate growth habit (Type III) with a range of maturity types; prostrate plant type with well developed branches which show ability to compensate for low plant densities and irregular distribution; long flowering period (compared to ideotypes A and B) but with relatively even pod maturity; some ability to climb weakly could be an advantage.

Defined for cropping systems requiring bush beans with stable yields under suboptimal growing conditions; monoculture associated or relay systems where plant densities are usually below 200 x 10^3/ha and where the level of agronomic inputs in restricted.

IDEOTYPE D: Indeterminate growth habit (Type IV) with a range of maturity types; climbing beans with vigorous climbing ability on associated or relay crops or in monoculture on artificial support; limited branch development and with stable growth habit.

Defined for cropping systems requiring climbing ability to exploit the yield advantage of climbers and where a relatively high level of manual labor input is possible; cropping systems with maize in direct association or in relay or in systems where artificial support systems are possible under monoculture conditions.

NOTE: A determinate (Type I) ideotype is not included in these recommendations. However for areas where extreme earliness in required the only alternative may lie in the use of determinate materials. Type I materials have shown poor adaptation and strong instability of yield in many CIAT experiments and the 1976 IBYAN.

Publications

Altieri, M.A., C.A. Francis, A. van Schoonhoven, and J.D. Doll. 1977. A review of insect prevalence in maize (*Zea mays* L.) and bean (*Phaseolus vulgaris* L.) polycultural systems. Field Crops Research. (in press).

Francis, C.A., M. Prager, D.R. Laing, and C.A. Flor. 1977. Genotype by environment interactions in bush bean cultivars in monoculture and associated with maize. Crop Science. (in press).

Francis, C.A. and J.H. Sanders. 1977. Economic analysis of bean and maize systems: monoculture versus associated cropping. Field Crops Research. (in press).

Francis, C.A., S.R. Temple, C.A. Flor, and C.O. Grogan. 1977. Effects of competition on yield and dry matter distribution in maize. Field Crops Research. (in press).

Graham, P H. and Halliday, J. 1977. Inoculation and nitrogen fixation in the genus *Phaseolus*. In "Exploiting the legume-*Rhizobium* symbiosis in tropical agriculture. J.M. Vincent Editor. University of Hawaii, College of Tropical Agriculture, Miscellaneous publication 145, pp.237-252.

Graham, P.H. and Rosas, J. 1977. Growth and development of indeterminate bush and climbing cultivars of *Phaseolus vulgaris* L. inoculated with *Rhizobium*. J. Agric. Sci. (Camb) 88, 503-508.

Hudgins, R.E. 1977. Adapting agronomic technology for small farm bean production in highland Colombia. Unpublished PhD. Thesis. University of Florida, Gainesville, Fla.