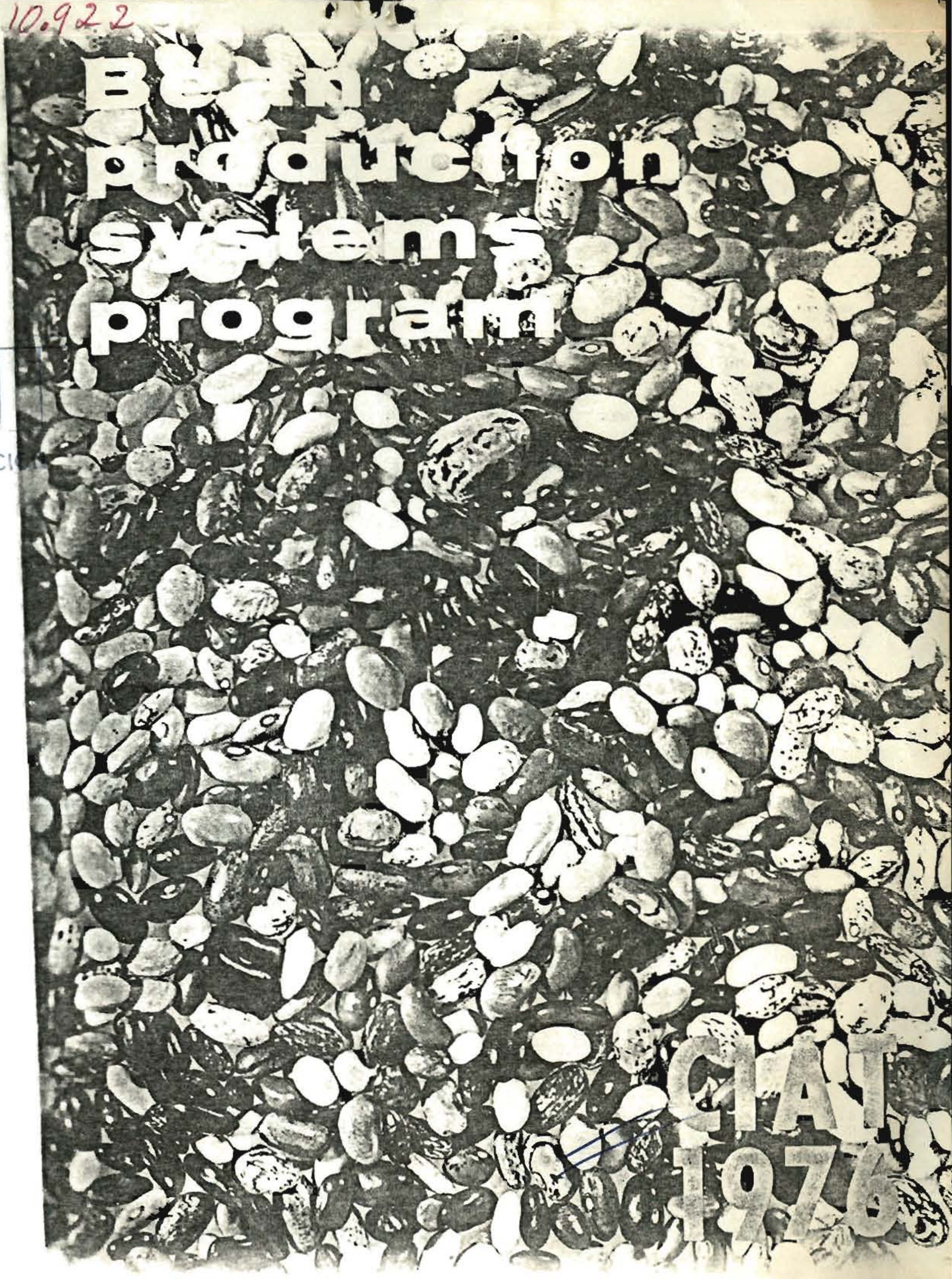
Bean production systems program



CIAT 1976

Bean production systems program

HIGHLIGHTS IN 1976

National bean programs in Latin America vary. While some are limited to a few scientists undertaking activities which must span several disciplines, others have multidisciplinary research teams with numerous highly qualified scientists. The CIAT bean program, which was asked by the Technical Advisory Committee of the Consultative Group for International Agricultural Research to establish a collaborative bean research network in Latin America, must, therefore, be attentive to markedly different needs. While the program's chief product is germplasm, this may be supplied to national programs as a promising source of disease or insect resistance; as hybrid material with nationally-important varieties already crossed to the resistance source; as late generation "elite" materials previously screened at CIAT; or as formed varieties from CIAT or other national programs. Even so-called "technology packages" will differ according to the needs and capabilities of each country and its predominant agricultural forms.

The major highlights of the program's work in 1976 illustrate the breadth of activities and their integration with the needs of national bean programs.

In 1976, and after consultation with national programs on methodology, CIAT established the first International Bean Yield and Adaptation Nursery (IBYAN). To date 128 requests for the trial have been received. These derive from 20 countries in the Americas as well as from England, India, Israel, Japan, Kenya, Malawi, Portugal, Tanzania and Thailand. Seventy-six trials have already been shipped. While most plantings were scheduled for the second semester of 1976, results have already been received from 12 trials.

The second International Bean Rust Nursery (IBRN) is being tested in 14 locations in 1976. Results from the first IBRN showed three accessions resistant to rust attack at all six testing locations. Two of these accessions, P699 and P717, are being used as rust resistance sources by the breeding program.

This year CIAT was named as the world center for *Phaseolus* germplasm resources. The first meeting of the *Phaseolus* Germplasm Advisory Committee, in September, reviewed and approved program plans for the storage, identification, characterization and data retrieval associated with germplasm activities. A detailed catalogue of more than 700 promising cultivars has been published.

Rates of nitrogen fixation as high as 40 kg/ha/growing season were obtained. High fixation was most common in climbing cultivars and was strongly correlated with high soluble carbohydrate levels in the plant.

Evaluation of cultural practices and cultivars for associated cropping of maize and beans continued with the maximum bean yield of 2,070 kg/ha achieved in association with a yield of 4.93 tons of maize.

One hundred seventy-eight cultivars were used in bean hybridizations during 1976 with approximately 3,000 different parental combinations effected. Detailed plans were developed to sequentially evaluate these hybrids for disease resistance and yield, and to pass promising material as rapidly as possible to interested national programs.

In 1976 the program received 38 trainees including four postdoctoral scientists. Continued contact with former trainees has permitted a wide range of screening activities for diseases, insects and stress conditions not found at CIAT. These include resistance studies on *Apion*, *Epinotia*, golden mosaic virus and on drought tolerance screening.

GERMPLASM

In 1976 CIAT accepted primary responsibility under the International Board for Plant Genetic Resources (IBPGR) for the maintenance and characterization of *Phaseolus* germplasm.

Germplasm Evaluation

Of the 12,000 seed samples already received at CIAT, some 7,000 have been multiplied and characterized morphologically. Another 3,000 accessions are currently being multiplied to provide 10,000 evaluated materials by the end of 1976. These accessions include a number of active or obsolete land cultivars of *Phaseolus vulgaris*, improved commercial varieties, wild and indigenous types, and natural and artificial crosses of *P. vulgaris* by *coccineus*, *P. acutifolius*, *P. lunatus*, and wild species such as *P. ritensis*, *P. dumosus*, *P. polystachus*, and *P. adenanthus*.

Some 2,200 new accessions were received in 1976, including 1,200 samples from the Norvell explorations of Mexico and Guatemala and interesting new materials from Germany, Holland and France. After meeting at CIAT in September to review the current status of *Phaseolus* spp. germplasm, the *Phaseolus* Germplasm Advisory Committee (PGAC) recommended additional collecting in Africa and Central America during 1977. Additional information will also be sought from major existing collections not already included in the CIAT bank.

Field evaluation and characterization of accessions for 52 plant morphological features continued in 1976. The PGAC has identified 20 of these as essential descriptors for *Phaseolus* collections. Results from an evaluation of 781 materials identified by CIAT scientists as "promising" were published in the form of a descriptive listing (Fig. 1)[1]. A second listing with information for 2,400 additional accessions will be prepared in 1977.

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1 Many of these promising accessions are referred to in this report. A list on page A-80, further identifies these accessions (referred to as P000) by their varietal name or other title, the CIAT germplasm bank number (as G 00000) and the source country (but not necessarily its origin) for the accession. Germplasm bank accessions mentioned in this report are listed following the promising accessions.

Figure 1. A catalogue characterizing 780 promising accessions of *Phaseolus vulgaris* was completed and published in 1976.

Germplasm Storage

CIAT bean germplasm is currently maintained in cold rooms without humidity control, necessitating frequent germination tests and seed regeneration at four-year intervals. In 1976 plans were completed for a new germplasm facility to become available early in 1977. The structure will accomodate up to 60,000 accessions at +15ºC conditions, and an equal number, in small quantities, at -15ºC. All seed will be packaged under low humidity, ensuring viability for 6-10 years in the +15ºC section and for up to 100 years in the -15ºC section.

Seed Shipments

More than 3,000 seed samples were shipped in 1976. Table 1 shows the distribution of those materials by major region.

Table 1. Distribution of seed samples in 1976 from the CIAT *Phaseolus* Germplasm Bank.

Region	Samples sent
South America	923
Africa	869
Central America, Caribbean	714
Europe	343
North America	100
Australia	454
Total	3,403

Common Bacterial Blight

Pathogenic variation

CIAT screening for bacterial blight from 1972 through 1975A used the Colombian isolate C6, originally obtained in 1969 by Schuster and Coyne from *Phaseolus vulgaris* var. Diacol Calima.

Additional studies were undertaken in 1976 to obtain new isolates and compare them with the C6 isolate. Isolations of the blight pathogen *Xanthomonas phaseoli* were made from blight-infected leaves and seed obtained in Colombia. Isolates were identified by colony morphology and pathogenicity tests, then compared in pathogenicity with isolates C6 and C7, the latter also isolated by Schuster and Coyne from Colombian seed material. Isolate 611 from the Cauca Valley of Colombia was most virulent, causing complete wilting of a susceptible host two weeks after inoculation (Fig. 2). In contrast, isolate C6 was only weakly virulent, causing flagging of the primary leaves. Isolate C7 was not pathogenic by this test, suggesting that the bacteria may decline in pathogenicity after repeated subculturing. Studies are in progress to determine how best to use such differential pathogenicity in screening for bacterial blight tolerance under controlled conditions.

Field screening

Field experiments were conducted at CIAT in 1975 and 1976 and also in 1976 at Nataima, a site in the Tolima region of Colombia where temperature and moisture conditions are excellent for blight development. These tests compared disease reactions of 4,000 accessions from CIAT's germplasm bank. Materials from the University of Nebraska (U.S.A), Michigan State University (U.S.A.) and Puerto Rico were included, as were two lines of *P. acutifolius*, as tolerant checks.

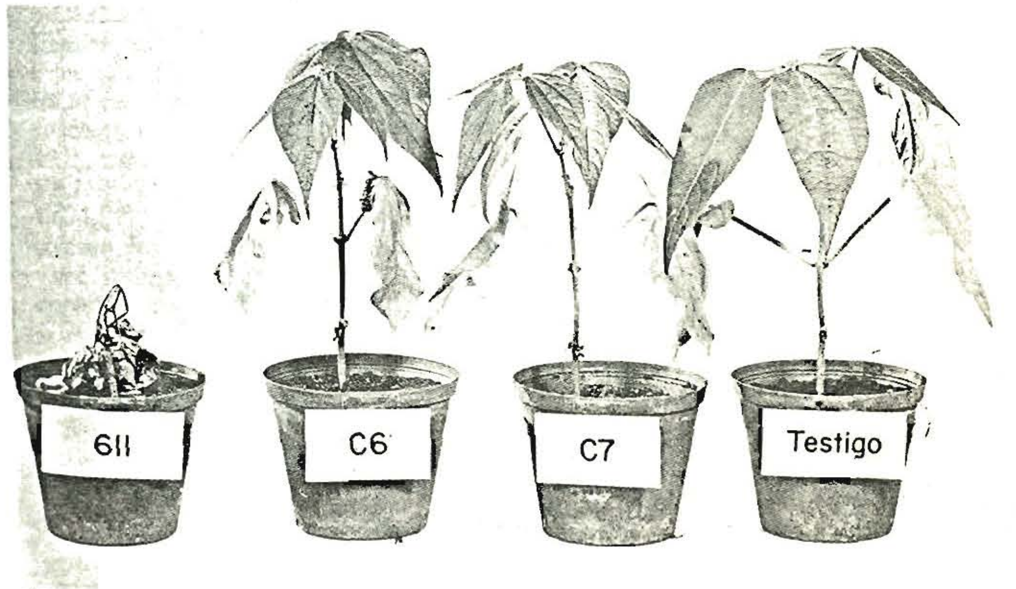


Figure 2. Pathogenic variation among Colombian isolates of *Xanthomonas phaseoli* on *Phaseolus vulgaris*. Seedlings of the cultivar Manitou, a light red kidney bean, were inoculated in the cotyledonary node at the crook-neck stage with isolates 611, C6, C7 and a water control (check). The picture was taken two weeks after inoculation.

Entries were evaluated first at CIAT in an unreplicated planting. Tolerant materials were reevaluated in replicated tests at CIAT and Nataima. The plot design for disease screening at CIAT (Fig. 3) was similar to methods previously described (CIAT Annual Report, 1974), while at Nataima rows were spaced 60 centimeters apart without ridges. Infected seed of the susceptible cultivar Porrillo Sintético was planted as borders 2-3 weeks before the general planting date.

Plants at CIAT were directly inoculated five weeks after planting using *X. phaseoli* isolate 611 as a suspension containing 5 x 10^7 cells/ml. Inoculum was applied at sunset as a spray at about 100 psi to produce leaf water-soaking (Fig. 4), and bean rows were furrow irrigated the day before and the day after inoculation to create a favorable microclimate for disease development. Plants were then sprayed with water and irrigated each week thereafter to enhance spreading of artificial as well as natural infections. At CIAT, reactions were recorded three weeks after inoculation using a 1-5 scale for foliar and a 1-3 scale for pod reactions.

At Nataima, severe infection occurred naturally and no inoculation was needed. Disease reaction was recorded 7-8 weeks after planting.

Two lines of *P. acutifolius* (P597 and Tepary 10) had the highest tolerance, showing no symptoms on either foliage or pods (Table 2). No *P. vulgaris* entries were free of leaf symptoms. Two *P. vulgaris* lines (P662 and P261) were tolerant in foliar reaction, but the latter showed pod susceptibility. P464 and P252, tolerant in 1975, were susceptible in subsequent tests. PI 169 727, P684, PI 197 687, Guali and P694, reported in other studies to be tolerant to U.S. isolates of *X. phaseoli,* were susceptible in these tests. Tolerant commercial U.S. cultivars P698, P567 and G.N. Valley were susceptible as they neared maturity.

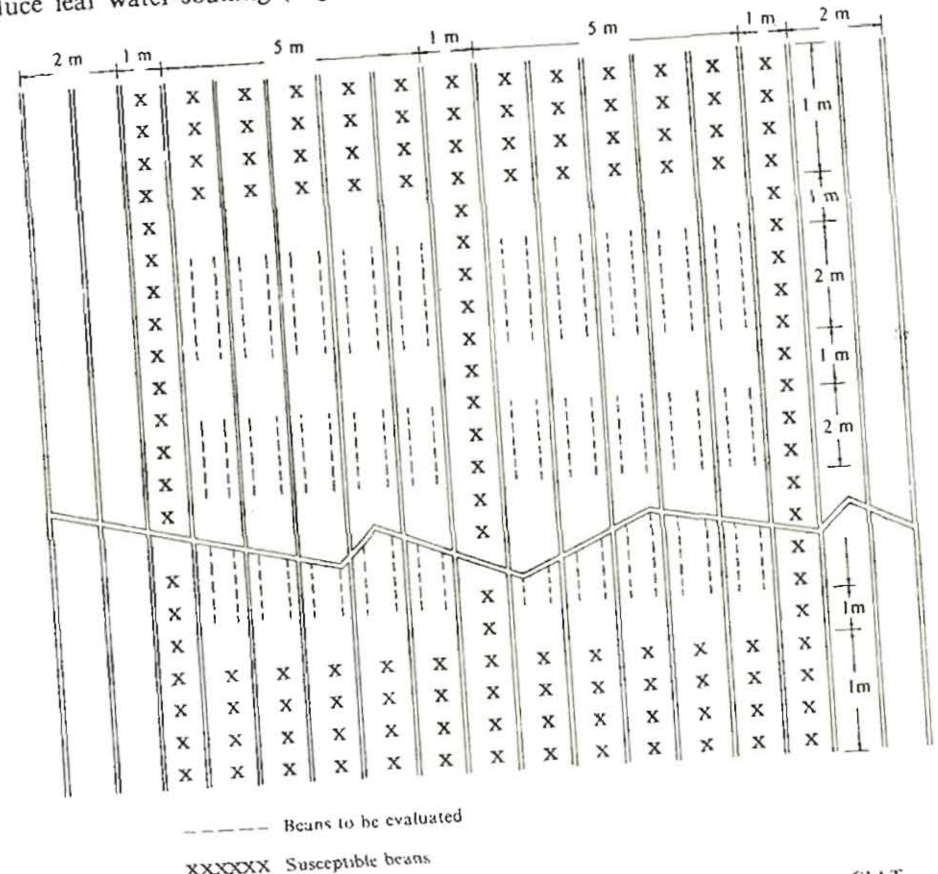


Figure 3 Planting pattern for evaluating bean tolerance to common blight, at CIAT.

Figure 4. Bean plants are inoculated with the bacterial suspension in the field at CIAT using a pressure sprayer.

Fungal Diseases

Rust (*Uromyces phaseoli*)

In 1976, 1,700 collections from the germplasm bank were evaluated for rust resistance at CIAT and Popayán; 189 were resistant at both locations. These collections will be further tested and incorporated into future International Bean Rust Nurseries (IBRN) for testing against races of the fungus not present in Colombia.

Twenty-six IBRN sets, each containing 123 cultivars, reported as resistant to different races of the pathogen, or of promise in donor countries, were sent to 14 cooperators during the year. Results from 12 of 14 sets sent in 1975, and four of the 26 sent in 1976 have been received. These were analyzed by computer using a resistance index generated from pustule size (1-5) and percentage of infection intensity, from observations at 30 and 45 days after planting (Fig. 5). Summarized results have been distributed to IBRN collaborators and other interested scientists.

The accessions P693, P699 and P717 were consistently resistant to rust in two years of IBRN testing. P699 and P717 have

Table 2. Reaction of pods and foliage of several field-grown bean cultivars and lines to Colombian isolates of *Xanthomonas phaseoli*.

Accession no. or other identification	Foliage reaction [1]			Pod reaction [2]		
	CIAT		Nataima	CIAT		Nataima
	1975B	1976A	1976A	1975B	1976A	1976A
Phaseolus acutifolius						
P597	1	1	1	1	1	1
Tepary Nebr. Acc. 10	3	1	1	—[3]	1	1
Phaseolus vulgaris						
P662	2	2	2	2	1	1
P261	2	2	2	3	3	3
P464	2	2	3	2	1	1
P252	2	3	3	2	3	2
P.I. 169 727	—	4	—	—	3	—
P.I. 197 687	—	3	—	—	1	—
ICA-Guali	3	4	3	3	3	2
G.N. Valley	—	3	3	—	1	2
P684	3	3	3	2	1	1
P698	3	3	3	3	1	2
P498	3	3	3	2	1	1
P567	3	3	4	2	1	2
P694	3	3	3	2	2	2
P092	3	3	3	3	2	3
P760	—	4	4	—	2	2
P566	3	4	4	2	2	2

1 Foliage reactions: 1 *Highly tolerant* — no visible symptoms; 2 *Tolerant* — slight, small lesions on 1-5% of leaves; 3 *Moderately susceptible* - moderate lesions of various sizes, some leaves chlorotic, 4 *susceptible* - severe with many large lesions on most leaves, pronounced chlorosis and necrosis; and 5 *Highly susceptible* — very severe, plants chlorotic and largely defoliated.

2 Pod reactions: 1 *Tolerant* — no lesions; 2 *Intermediate* — a few small lesions; and, 3 *Susceptible* — numerous large lesions.

3 Blanks mean not tested at this site or season.

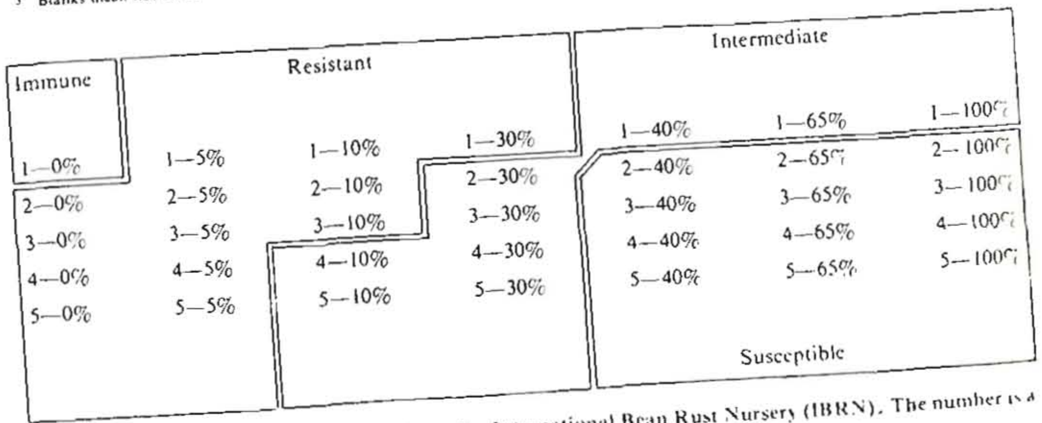


Figure 5. Resistance index used to evaluate the International Bean Rust Nursery (IBRN). The number is a rating of the pustule size on a scale of 1-5 with the infection intensity given as a percentage.

been widely used in CIAT crossing programs for rust resistance.

Anthracnose *(Colletotrichum lindemuthianum)*

Screening for resistance. A total of 524 promising accessions were screened for anthracnose in Popayán (1,600 m) and Bogotá (2,600 m). More than 100 were resistant at both sites and additional accessions were resistant in one location and susceptible in the other. The β race of *Colletotrichum lindemuthianum* was present in Popayán. Accessions P685, Widusa, P302, P347, P432, and P540 have been consistently resistant in two years of testing. P685, P782, Cordonco and Vernandon are being used as resistance sources in the breeding program.

Powdery mildew *(Erysiphe polygoni)*

Screening for resistance. An epiphytotic of powdery mildew *(Erysiphe polygoni)* occurred in the anthracnose nursery in both Bogotá and Popayán. Accession P278 was observed to be highly resistant.

Web blight *(Thanatephorus cucumeris)*

Screening for resistance. Environmental conditions during 1976 were not favorable for the development of *Thanatephorus cucumeris*. Nevertheless, from 3,505 collections planted at Turipaná, only 310 were rated tolerant. These collections will be further tested under more controlled conditions. The most tolerant materials were P017, P358, P401, and P716. They have also been tolerant in previous screenings.

Root rots

Endemic infestation of *Rhizoctonia solani* permitted evaluation of 524 promising materials under natural conditions in Popayán. The most outstanding collections for resistance were P235, P334, P352, P502, P503, P646, and P693.

Viral Diseases

Common bean mosaic virus

Seed contamination. The study of recontamination of seed under field conditions resembling those of small farmers (1975 Annual Report) was continued. When seed free of internally seed-borne pathogens (clean seed) was increased far from commercial beans, harvested seed remained virus-free. Plots close to contaminated fields, planted with clean seed developed 15 and 12 percent infections for the susceptible varieties ICA-Guali and ICA-Duva, respectively, and 6 and 5 percent infections for the tolerant varieties ICA-Tuí and P459, respectively. No control of the vectors was programmed.

In the case of tolerant varieties such as ICA-Tuí, the symptoms are not clearly expressed and this may lead to a constant use of infected seed. Nevertheless, clean-seed plots of ICA-Tuí yielded much more than plots planted with infected seed (2,720 kg/ha vs. 1,691 kg/ha).

Screening for resistance. CBMV consists of more than seven strain classes. Several are present in tropical zones and also perhaps, new ones as yet unidentified. Using a mild strain isolated at CIAT from the Calima cultivar, 151 promising accessions were evaluated in the greenhouse. Eighty-eight were resistant, and 63 were susceptible. Neither necrosis nor black-root symptoms were observed in accessions known to have the hypersensitive gene in this test.

Among 436 climbing accessions evaluated in the field, 345 were susceptible. The others either showed mild symptoms or were disease-free. These will be reevaluated under controlled conditions. From 3,610 entries from the germplasm bank, 2,955 were susceptible in the field.

F_1 seed of 76 single crosses (families), that included three sources for the dominant source of tolerance to CBMV were tested in the screenhouse by mechanical inoculation; 72 were tolerant and four susceptible.

Bean golden mosaic virus

Screening for resistance. A total of 2,150 entries were evaluated under natural conditions in Guatemala, El Salvador and Brazil with no accession being resistant to the virus. With this evaluation 5,850 accessions have now been tested, but few materials tolerant to BGMV have been identified

International Bean Golden Mosaic Virus Nursery. An International BGMV Nursery consisting of 80 collections was established. Sets were sent to Guatemala, El Salvador, Brazil and Tanzania for evaluation. The results indicated that some promising materials (including P466, P709, P757, P488, P566, Puebla 441, Venezuela 68, PI 313 878, and PI 313 882) were tolerant to the virus present in both Central America and Brazil.

The 1977 IBGMVN will contain 190 collections and will be planted in more sites in the Americas and Africa.

BGMV antiserum. The purification of the BGMV (1975 Annual Report) made possible preparation of a specific antiserum. Antiserum tests have established that the disease present in Guatemala, El Salvador, Colombia and Puerto Rico is caused by the same virus. These serological tests will be further expanded to several Latin American, Caribbean and African countries to better identify a "yellow mosaic" reported in all these countries (Fig. 6).

Seed Pathology

Production of pathogen-free seed

Cleaning seed of seed-borne pathogens continued as a priority project. In the screenhouse, 442 collections were cleaned. Promising materials, as well as entries from the Netherlands, Belgium, New Zealand, Perú, Honduras, Haiti, and the international nursery sets were included. A total of 875 materials were increased in field plantings.

Large-scale production of clean seed for experimental and national program purposes was done by the bean agronomy group. Three tons of seed of 20 varieties was produced at Loboguerrero, a relatively dry site outside the bean producing area of the Cauca Valley where CIAT is located.

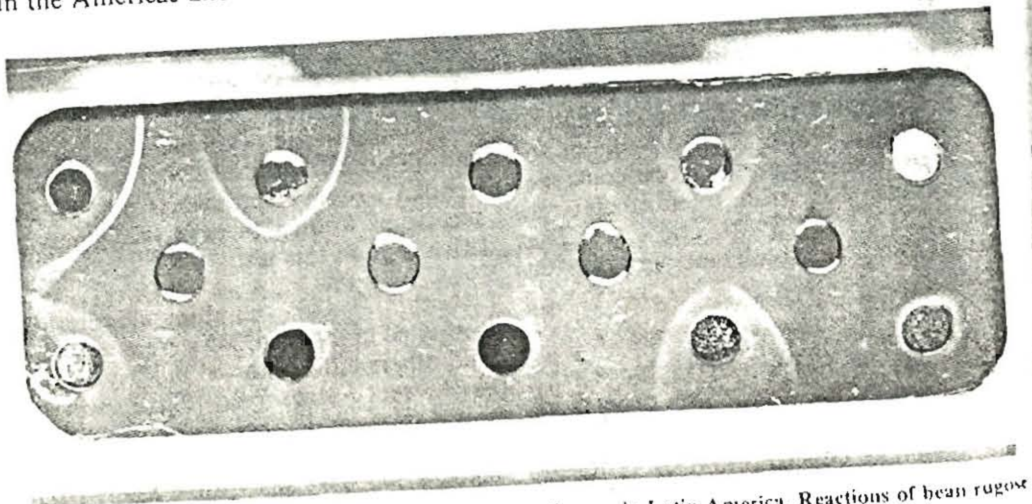


Figure 6. Serological tests help in identifying virus diseases in Latin America. Reactions of bean rugose mosaic, swelling mosaic and golden mosaic to their homologous antisera are shown.

Production of anthracnose-free seeds using fungicides

Seeds of the susceptible variety Nima were planted at Popayán where anthracnose is severe and endemic. Applications of benomyl (a systemic fungicide) and captafol (a protectant fungicide), were made singly or in combination beginning 30 days after planting. Due to disease severity, treatments were made five times, at nine-day intervals.

Plants sprayed with benomyl at 1 kg/ha remained free of anthracnose, and at .5 kg/ha good control was attained. Poor disease control was attained on plants sprayed with benomyl at .25 kg/ha plus captafol at 1.5 kg/ha. Captafol at 3 kg/ha did not control the disease because of heavy rains. All nonsprayed (control) plants were killed by anthracnose within 50 days after planting. No significant yield differences were measured between plants sprayed with benomyl at .5 and 1 kg/ha. Plants in both treatments yielded significantly higher than plants sprayed with benomyl (.25 kg/ha) plus captafol or captafol alone, though benomyl- plus captafol-sprayed plants yielded significantly higher than plants sprayed with captafol alone. Bioassays for internally seed-borne fungi showed seed from plants sprayed repeatedly with benomyl at 1 kg/ha to be free of *C. lindemuthianum*. All plants sprayed with benomyl produced seed with significantly less total internally seed-borne fungi as *C. lindemuthianum* and *Fusarium* spp. than plants sprayed with captafol alone.

Under normal environmental conditions four applications of benomyl are needed to control anthracnose. The price of the bean seed in Colombia makes the use of this systemic fungicide economically feasible, even when five applications are necessary to ensure the production of good quality seed.

Effect of late harvest and of foliar applications of systemic fungicides on seed quality

To evaluate the effect of late harvest on seed quality, seeds of the variety Tuí were harvested at maturity or harvesting was delayed up to a maximum of four weeks. Fungicides were applied at maturity or post-maturity in some cases. Results are in Table 3.

With seed harvest at plant maturity, all treatments including the control had good seed quality, having a percentage germination *in vitro* and field emergence of at least 85 percent. As harvest was delayed, germination and emergence percentages decreased while seed infection increased, in treated and nontreated groups alike.

Fungi of 13 genera were recovered from seed in this study. The majority of seed infection in the control treatment was due to *Fusarium* spp. while most infections in both treatments which included benomyl were caused by *Alternaria* spp.

The results indicate that time of harvest appears to be extremely important in producing high quality seed. Delaying harvest can result in reduced germination in vitro and field emergence, as well as increased seed infection by fungi. Increases in the percentage of seeds infected by fungi appears to be accompanied by decreases in seed germination. Moreover, delayed harvest can result in physical damage to seeds, due to alternating wet and dry field conditions.

Effect of pod contact with soil on fungal infection of seeds

As revealed in the bean economic survey discussed in the 1975 Annual Report, many Colombian farmers save seed from a

Table 3. Percentage germination *in vitro*, field emergence, internally seed-borne fungi and 1,000-seed weights of seeds from *Phaseolus vulgaris* cv. Tui plants not treated or treated with two systemic fungicides and harvested at maturity or at weekly intervals thereafter.

Treatment	Time of harvest	Mean %[1] Germination	Mean %[1] Emergence at 15 days	Mean %[1] Seed with fungi	1,000-seed wt (g)
benomyl	Maturity	95	87	4	201
	1 week after	92	84	15	205
	2 weeks after	92	87	26	201
	3 weeks after	93	82	38	205
	4 weeks after	76	71	96	206
oxycarboxin	Maturity	98	86	4	194
	1	97	86	13	207
	2	91	84	26	204
	3	82	82	56	198
	4	75	67	99	197
benomyl + oxycarboxin	Maturity	94	85	5	201
	1	95	84	17	208
	2	92	86	27	203
	3	86	84	54	203
	4	74	72	98	205
Nontreated	Maturity	87	86	13	152
	1	79	75	48	149
	2	63	69	86	147
	3	64	67	100	150
	4	60	61	100	154
	L.S.D. at .05	3.71	3.43	8.87	13.86
	L.S.D. at .01	4.94	4.57	11.82	15.15

1 Three replications of 100 seeds each for each treatment and harvest date

crop for later plantings. While they select
from seeds available for those with
reasonable grain features, they do not
select the seed they harvest. Since pod
contact with soil both decreases seed
germination and promotes internal seed-
borne fungi, studies were done to evaluate
selective seed harvest as a means of
improving crop stands on small farms.
Results of the experiment are in Table 4.

While many seeds from pods in contact
with soil were discolored, wrinkled or
lesioned, most appeared physiologically
normal. All seeds from pods not in contact
with soil appeared normal. Similarly, while
the percentage recovery of internally-
borne fungi varied with cultivar, the levels
were always greater in seed from pods in
contact with soil. *Phomopsis* spp. and
Macrophomina phaseolina were never

Table 4. Percentage germination, seed with internally seed-borne fungi, viability, and field emergence of seeds from pods of five *Phaseolus vulgaris* cultivars in contact or not in contact with soil in the field at CIAT.

Treatment[1]		Cultivar Calima	Cultivar Guali	Cultivar Huasanó	Cultivar Porrillo Sintético	Cultivar Tui
Germination						
Soil contact		57	46	50	47	59
No contact		100	92	95	97	99
	L.S.D. at .05	17.9	9.3	16.9	10.5	11.6
	L.S.D. at .01	41.2	2.4	38.6	24.2	26.9
Seed with fungi						
Soil contact		64	90	88	92	78
No contact		3	30	26	19	14
	L.S.D. at .05	22.2	21.1	13.6	6.1	6.9
	L.S.D. at .01	34.0	44.4	31.3	13.9	15.9
Seed viability						
Soil contact		75	68	65	65	78
No contact		95	91	91	100	95
Field emergence						
Soil contact		63	47	58	51	69
No contact		92	86	84	83	95
Soil contact, treated with thiram		82	75	69	68	85
No contact, treated with thiram		95	90	86	86	94
	L.S.D. at .05	18.7	13.4	13.0	12.4	14.8
	L.S.D. at .01	28.9	20.7	19.7	19.0	22.3

1 Three replications of 100 seeds each, except for viability test which was 100 seeds. Viability measured by the tetrazolium test. Thiram treatment was 2 g/1,000 g of seed.

recovered from pods not in contact with soil while *Rhizoctonia solani* was not recovered from seeds of Calima, Huasano or Porrillo Sintético pods not in contact with soil. The mean percentage germination *in vitro* and viability (by the tetrazolium test) of seeds from pods not in contact with soil was over 90 percent and significantly higher than for seeds from pods in contact with the soil. Similarly emergence was greater for seeds from pods not contacting soil.

The following fungal species were recovered from surface-sterilized seeds out of pods touching the soil: *Alternaria* spp., *Aspergillus* spp., *Cladosporium* spp., *Fusarium* spp., *Isariopsis griseola*, *M. phaseolina*, *Monilia* spp., *Nigrospora* spp., *Penicillium* spp., *Pestalotia* spp., *Phoma* spp., *Phomopsis* spp., *Rhizopus* spp. and *R. solani*. *Fusarium* spp., *R. solani*, *M. phaseolina*, *Phomopsis* spp. and *Alternaria* spp. were most commonly encountered.

"Problem X"

A disease of unknown cause, reported in the Cauca Valley of Colombia as early as 1953, has become significant at CIAT in the last two years.

The symptoms are most striking in the varieties P011 and P459 (Fig. 7). Symptoms appear in the first trifoliate, becoming systemic and more severe in the new leaves. Vein clearing is observed on the leaves which become malformed resembling damage by hormonal herbicides. Witches' brooms form and the vegetative period is extended. Pods hardly ever form. When a few seeds are produced, they are deformed and wrinkled, although some plants subsequently undergo a secondary flowering and produce apparently normal seed. The disease is soil-borne, and the symptoms might be due to soil conditions, physiological disorders or genetic abnormalities, pathological conditions or a combination of these. The spreading of the problem in the field is not, however, typical of a pathogenic, soil-borne disease, as whole blocks of plants show symptoms almost overnight.

Figure 7. Plants of *Phaseolus vulgaris* accession P459 affected by Problem X.

Because this condition interferes with experiments and limits evaluation of breeding materials through changes in growth habit or yields, considerable attention has been paid to it in 1976.

Soil-transmission. When seeds of the varieties P011, P459, P566 and P634 were planted in the greenhouse in soil from infested areas, Problem X symptoms were reproduced. Symptoms were not observed when seeds were sown in soil sterilized with methyl bromide, nor in soil from a commercial nursery. Accessions P011 and P459 were more affected than P566 and P634 (68, 90, 47 and 11 percent, respectively) and P634 and P635 did not show any symptoms in some experiments.

Soil mixtures and filtrates. When infected soil was mixed 1:1 with disinfected soil, susceptible varieties did not develop symptoms. Likewise, disease symptoms were not observed when disinfected soil was irrigated with filtrates from infected soil.

When plants, grown either in disinfected soil or in Petri dishes on filter paper, were irrigated during two days with root soakings, no symptoms of the disease were reproduced.

Mechanical inoculation. Using common mechanical transmission methods for viral diseases, attempts were made to transfer the possible causal agent from diseased to healthy plants. Extracts were obtained in different buffers (phosphate, citrate, borate, EDTA, tris) with different molarities and pH's, and with reducing and chelating agents added to stabilize the possible causal agent. Over 1,000 bean seedlings of susceptible varieties have been inoculated without any success.

Grafting. Healthy P459 plants have been grafted onto diseased P459 plants, and vice versa. No symptoms were subsequently observed in healthy plants in which grafting was successful.

Seed transmission. Over 5,000 seeds from plants showing Problem X symptoms have been grown out in sterilized soil from infected fields to determine seed transmission. No plant showed symptoms during 45 days of observation. Differences in the severity of the symptoms of P459 were observed according to the origin of the seed when plants were grown in infected soil. This may suggest that the cause is associated with some factor involved with the seed coat.

The treatment of seed with fungicides or silver chloride or sodium hypochlorite did not improve control of the disease. While methyl bromide fumigation reduced the incidence of the disease in the field SMDC or PCNB had no effect.

Nematode extraction. Infected soil was submitted to nematode extraction by screening, centrifugation on sugar, and soil suspensions on distilled water. The population of nematodes was almost nil.

Electron microscopy. Preliminary observations of fixed tissue, and of partially clean extracts have not revealed any suspicious virus- or mycoplasma-like bodies.

Host-range. Soybeans (vars. Amsoy and Pelican), lima beans, cowpea, pumpkin, squash, cucumber, tomato, lettuce, broad beans, tobacco, *P. lathyroides, Rhin[illegible]osia minima, Gomphrena globosa, Datura stramonium, Nictiana glutinosa, Chenopidium album, Chenopodium quinoa,* and *P. vulgaris* were planted in infected soil. Only *P. vulgaris* showed symptoms of the disease as follows: P011 (92%), P459 (95%), P566 (90%), P714 (80%), P634 (0%), and P635 (0%). A variety of winged bean *(Psophocarpus tetragonolobus)* planted in an infected field also suffered severely from the condition.

The same hosts (at least 30 plants/host) were inoculated mechanically with extracts from diseased plants. None showed any sort of symptoms resembling those produced by Problem X.

Soil nutritional evaluations. Because of the alkaline soil conditions on the CIAT farm, a number of field and glasshouse studies have been undertaken to determine whether Problem X might result from a soil nutritional imbalance. Microelements such as zinc, iron, manganese or boron, applied either to the soil or foliarly and singly or in combination, have not decreased the severity of the condition in infected plots. Sulfur (2 t/ha) and bagasse (2 t/ha) incorporated into soil have both reduced the severity of the condition but have not eliminated it. Several explanations could be advanced for such results.

Since the cause of the problem remains to be identified, pathological and agronomic studies will continue in 1977. Experiments to evaluate the control of the problem by better rotational systems are also being planned.

ENTOMOLOGY

Emphasis in 1976 was again on screening germplasm and segregating populations for resistance to *Empoasca kraemeri*, the leafhopper. Cooperative screening of germplasm for resistance to insects of major importance in other countries but not present at Colombian testing sites was also intensified. Studies on using insecticidal sprays more efficiently by proper timing or to reduce pest levels by cultural methods were continued.

Empoasca kraemeri

Resistance studies

Initial screening of the germplasm bank for resistance to *E. kraemeri* revealed only moderate tolerance levels to this important insect. Seventy-six promising cultivars will be retested to determine levels and types of resistance present. Some lines were tolerant though carrying high nymphal populations. In others tolerance was associated with low nymphal counts (Table 5). Levels of tolerance were recovered in first screenings of segregating populations involving resistant parents.

As no oustanding resistance was found within *P. vulgaris*, resistance was sought in species such as *P. coccineus* or related wild types which hybridize with this species. Among 54 accessions tested, two *P. coccineus* accessions (G 04834 and G 04835) showed good resistance levels (Table 6). Ancestral types and interspecific *P. coccineus* x *P. vulgaris* hybrids tested were all susceptible. This experiment again showed that there was no relationship between damage grade and nymphal count. The susceptible variety Diacol Calima was so heavily damaged by leafhoppers that it supported only low levels of nymphs while adults moved to Tui variety, which was damaged less and therefore provided better oviposition sites.

Table 5. *Phaseolus vulgaris* accessions showing high tolerance to *Empoasca kraemeri* attack at two levels of nymphal populations.

Accession	Avg. damage score (0-5) 1975	Avg. damage score (0-5) 1976	Nymphs/leaf[1] 1975	Nymphs/leaf[1] 1976
High nymphal populations				
P466	1.8	1.6	12.1	16.6
G 04165	1.3	1.3	10.0	13.9
G 02704	2.4	2.0	7.7	13.2
Low nymphal populations				
P414	2.3	2.6	3.7	6.9
G 05086	2.4	1.8	4.4	7.8
P 325	2.3	1.5	5.1	8.0

Table 6. Resistance to *Empoasca kraemeri* in two *Phaseolus coccineus* accessions compared with susceptible and resistant *Phaseolus vulgaris* varieties.

Species and identification	Nymphs/leaf[1]	Avg. damage score (0-5)[1]
Phaseolus coccineus		
G 04834	1.5	1.2
G 04835	1.5	1.6
Phaseolus vulgaris		
Diacol-Calima (susceptible)	3.2	5.0
ICA-Tuí (resistant)	8.7	2.0

[1] Four observations of 20 leaves/plant

Since most resistance sources located thus far show only field tolerance, it is difficult to distinguish tolerance levels among accessions or between plants in segregating populations involving resistant parents. A study is in progress using 10 varieties, planted in dry and wet seasons and under four insect control regimes to identify optimum screening conditions and to select those plant parameters most likely to reflect differences in tolerance levels. Yield data for the two seasons are in Table 7. In each treatment and variety several characteristics, including leaf number and size, petiole length, plant height and flowering dates, are measured and correlated with treatment effects. An analysis of data from wet season plantings showed adult and nymphal populations, plant height and weight and leaf area, correlated with increased yield due to pesticide protection. The dry season data are being analyzed.

Table 7. Average yields of 10 *Phaseolus vulgaris* varieties with differing levels of resistance to *Empoasca kraemeri* in wet and dry seasons and under four levels of insect control.

Insect control level	Yield (kg/ha) Wet season	Yield (kg/ha) Dry season
Control throughout season	2,500 a	1,911 a
Control before flowering	2,355 a	1,524 b
Control after flowering	2,399 a	1,571 b
No control	2,138 b	1,007 c

[1] Means within columns and followed by the same letter are not significantly different at .05 by the L.S.D. method.

Cultural control

In previous experiments beans grown with maize were less infested with *E. kraemeri* than beans grown alone. To study this effect further, beans (var. Diacol Calima) were grown untreated, under shading (50% light interception), and with a mulch of rice straw. Shading was chosen to simulate the microclimatic effect of maize on bean insect populations. In early stages of plant growth, shading, and more so mulching, greatly reduced leafhopper infestations. Later, the mulched plots were so much less damaged that the leafhoppers migrated to them causing highest infestations on these plots late in the growing season (Fig. 8). Despite this, yields in the mulched plots were twice those of non-treated plots.

Maximum reduction of leafhopper populations on beans planted with maize occurred when the maize was planted 20-30 days before the beans (Table 8). Similarly, maximum suppression of *Spodoptera frugiperda* on maize-bean associations occurs when beans are planted up to 20 days before maize.

Beans in pots placed in weedy plots remained less damaged by insects than beans potted in clean fields. To test this effect further, beans were planted in the wet season with varying percentages of weed soil cover. As shown in Table 9, the increasing weed cover reduced leafhopper populations significantly, while yields remained equal. It is probable that in terms of yield the reduced leafhopper population was counterbalanced by increased weed competition. The reduction of leafhopper populations in weedy habitats was not due to increased activity of *Empoasca* predators and parasites, as *Anagrus* parasitism and populations of Nabidae, Reduviidae and Dolichopodidae were equal in all treatments.

Chemical control

To better rationalize the use of insecticides in controlling *Empoasca*, studies were done in which the susceptible variety Calima was treated with the systemic insecticide monocrotophos when leafhopper populations reached varying levels per leaf. Non-treated plots and plots with complete insect control were included. In two experiments linear regressions of yields on leafhopper nymphal population were obtained, with each additional nymph reducing yield about 6.4 percent (Fig. 9). A later study yielded a regression best fit by a quadratic curve, indicating that the first nymphs permitted per leaf before chemical control was made, reduced yields more than did additional nymphs (Fig. 10). This is unfavorable for integrated control methods where one tries to permit the highest possible population without reducing yields. In the latter trial, when 3-7 nymphs were allowed per leaf, the yield was again reduced 6 percent per additional nymph permitted per leaf. In yet another study, plants of the variety Diacol Calima were chemically protected in the dry season with low dosages of monocrotophos. In this study, where the leafhopper attack began relatively late in the bean growing cycle, it appeared that chemical control was not needed until 44 days after planting (Fig. 11). Furthermore, plots receiving

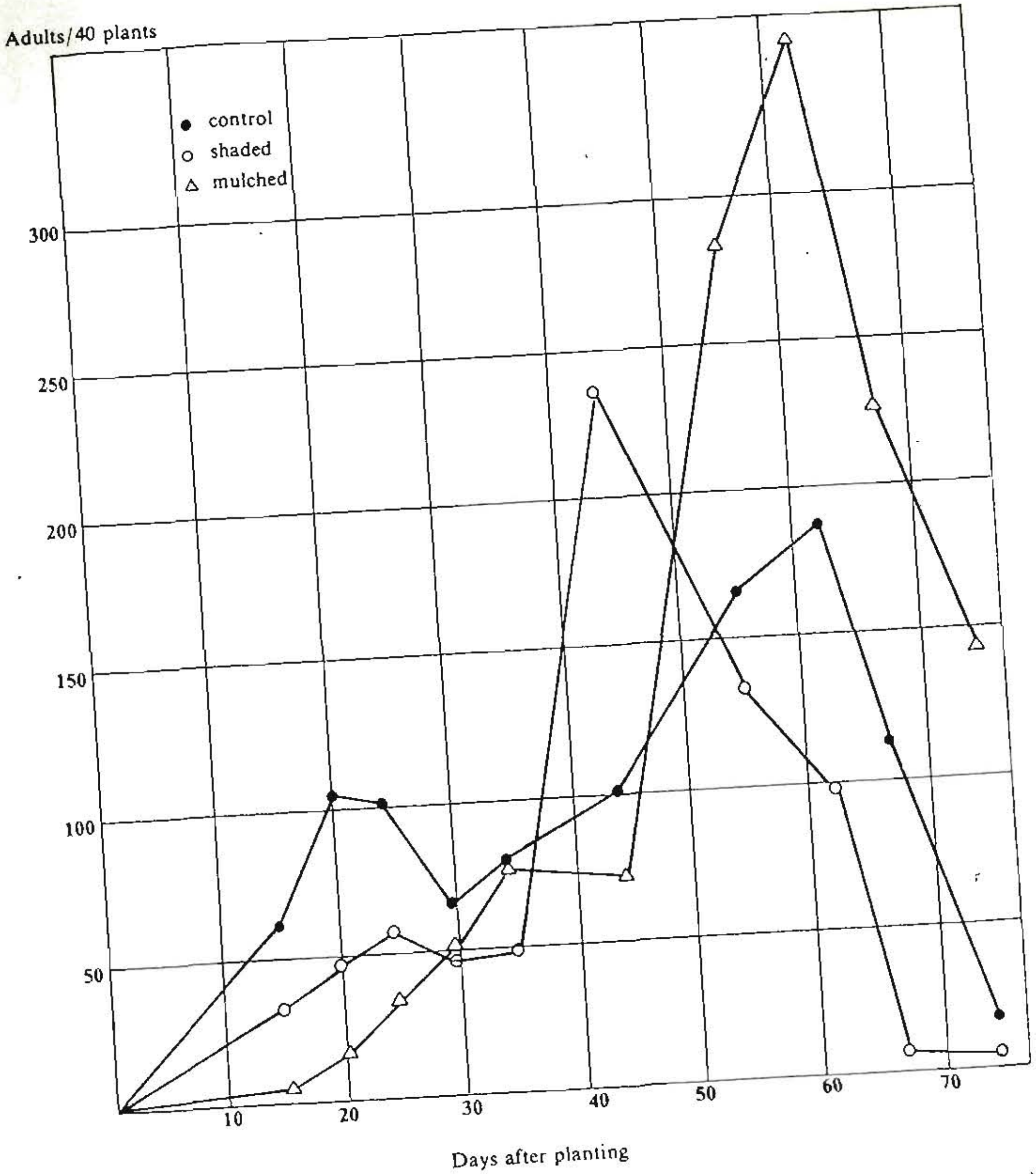


Figure 8. *Empoasca kraemeri* adults on control, shaded and mulched beans. (Avg. of 3 replications each date.)

only two applications of insecticide yielded the same as those receiving five applications. A curious note was the high incidence of attack by *Heliothis* sp. in the chemically-protected plots (41% incidence) compared to an average of 19 percent in non-treated plots.

Systemic, soil-applied insecticides have strong ecological advantages and can

Table 8. *Empoasca kraemeri* adults on *Phaseolus vulgaris* associated with maize and planted at different times in relation to the maize.

No. of days maize was planted before beans	Adults/80 bean plants[1]
30	25.7 a [2]
20	72.3 b
10	138.2 bc
0	133.1 bc
-10	152.9 c
-20	149.5 bc

[1] Average of three replications on each of five sampling dates.

[2] Means within columns and followed by the same letter are not significantly different at .05 by the L.S.D. method

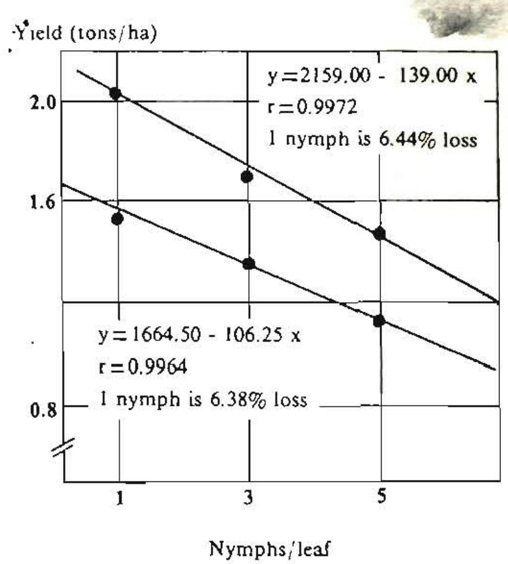


Figure 9. Dry bean yields at increasing *Empoasca kraemeri* populations in 2 experiments. Fields were sprayed when populations were 1, 3 or 5 nymphs/leaf. (Avg. of 4 replications each treatment.)

provide long-lasting protection, as seen in Figure 12 for carbofuran. Higher nymphal populations developed on carbofuran-protected plots after the residual effect of the pesticide had worn off.

Polyphagotarsonemus latus (Banks)

Resistance screening

Screening continued for resistance to the *P. latus* mite, with about 2,000 accessions being tested. Differences in resistance were observed, but infestations were not high enough to draw proper conclusions. The mite was effectively controlled chemically with a wettable sulfur powder formulation.

Table 9. *Empoasca kraemeri* adults and nymphs on *Phaseolus vulgaris* and yields under five densities of weeds.

% Soil cover with weeds	Adults/ 80 plants[1]	Nymphs/ 15 leaves[1]	Bean yield (t/ha)[1]
0	52.8 a[2]	22.4 a	1.70
25	37.7 b	13.8 b	1.78
50	29.7 c	10.5 b	1.75
75	28.4 c	11.8 b	1.79
100	30.1 c	6.7 c	1.85

[1] Average of three replications on each of six sampling dates.

[2] Means within columns and followed by the same letter are not significantly different at .05 by the L.S.D method.

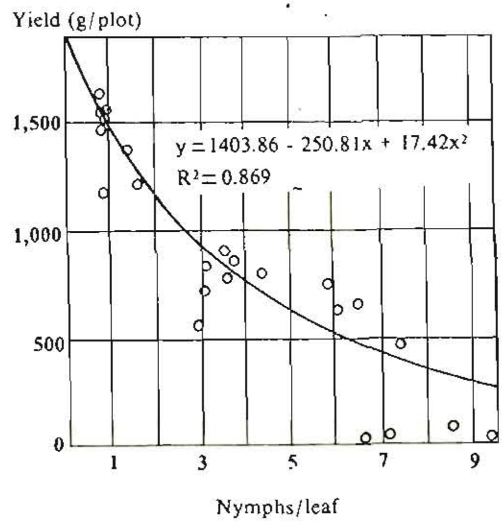


Figure 10. Dry bean yields at increasing populations of *Empoasca kraemeri*. Fields were sprayed when populations were 1, 3, 5, 7 or 9 nymphs/leaf.

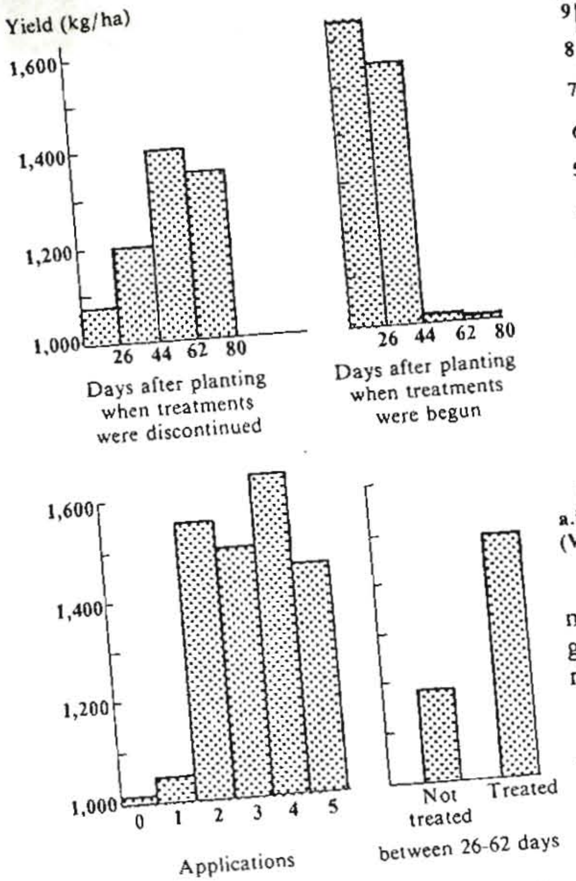


Figure 11. Yields of Diacol Calima beans under different treatments for insect control with monocrotophos.

Zabrotes subfasciatus

Among 781 promising accessions currently selected, 112 have shown initial resistance to *Z. subfasciatus*. These materials were selected because, when infested with adult *Zabrotes* at the rate of five pairs/50 seeds, few eggs were laid, few adults emerged or their emergence was retarded. Several seed samples were contaminated with pesticides and are being retested. Some materials, which appeared resistant in the first test were susceptible [illegible]ive testing with newly [illegible]

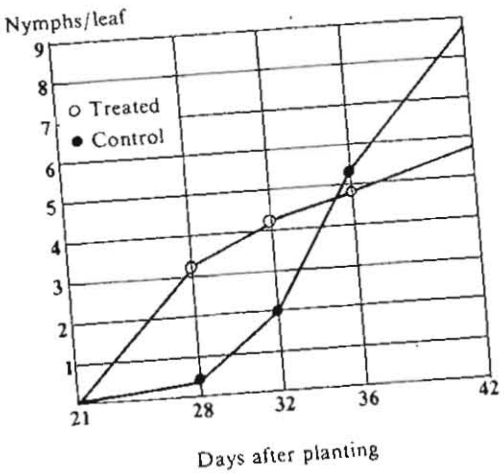


Figure 12. Residual effect of carbofuran (0.9 kg/ha a.i., granular soil-applied) on *Empoasca kraemeri*. (Variety Diacol Calima, 30 leaves/sample).

materials have to be retested for three generations prior to being classed as resistant.

Nonchemical control of *Z. subfasciatus* was further studied. Harvest plant debris provided only a low degree of control in stored beans to this bruchid attack (Table 10). It appears that the control is mechanical as beans in the bottom part of the jars are best protected.

Vegetable oils were tested for their action against *Z. subfasciatus*, a custom

Table 10. Percentage seed damaged by *Zabrotes subfasciatus* when various percentages of harvest debris were added to stored seed.[1]

Section of jar	% debris 0	10	20
Top	100.0	99.0	99.3
Middle	99.8	97.2	95.7
Bottom	99.6	76.3	61.8

[1] Diacol Calima variety with ten pairs of adults per 100 g seed in six [illegible] for 90 days.

Table 11. Effects of vegetable oils mixed with stored *Phaseolus vulgaris* on emergence of *Zabrotes subfasciatus* adults.[1]

Treatment	Emerged adults: 1 ml oil/kg	5 ml oil/kg
Coconut oil	13.8	0.2
Soybean oil	28.0	2.4
Oil palm oil	4.2	0.0
Cottonseed oil	5.2	0.0
Control	264.8	

[1] Diacol Calima variety with seven pairs of adults on 100 g of seeds.

for pulses in India and tested with cowpeas at International Institute for Tropical Agriculture (IITA), and appeared to be effective (Table 11). The oils were applied on the seeds and mixed in a tumbler. In time, oils were increasingly absorbed into the seed, leaving the physical appearance of the bean unaffected.

Chemical control of *Z. subfasciatus* is readily obtained with a variety of products, of which the pyrethrins and pyrethroids may be among the safest. Some of these compounds gave long residual control, when tested under laboratory conditions in continued darkness (Table 12). The products on bases of marc (ground flower) adherred less to the seed, but made them more acceptable in appearance after treatment as compared with products on talc bases.

Table 12. Effects of pyrethrins and pyrethroids on *Zabrotes subfaciatus* adults in stored *Phaseolus vulgaris*.[1]

Treatment	Dosage (ppm)	Adhesion to seed (%)	% Adult mortality 2 days after reinfestation at 0 days after treatment	120	360	Emerged adults/rep.
pyrethrins + piperonyl butoxide (on marc base)	1.5	77.3	100.0	93.4	80.9	0.4
	2.5	57.0	100.0	90.7	83.1	0.0
	4.0	32.5	100.0	97.5	91.6	0.1
pyrethrins + piperonyl butoxide (on talc base)	1.5	100.0	100.0	99.4	91.6	2.8
	2.5	100.0	100.0	100.0	96.9	0.0
	4.0	100.0	100.0	100.0	99.1	0.4
bioresmethrine + pyrethrins (on bean residues)	1.5	57.0	100.0	74.4	54.7	29.1
	2.5	43.0	100.0	80.3	48.1	31.4
	4.0	31.5	100.0	82.5	61.6	8.0
bioresmethrine + pyrethrins (on talc base)	1.5	100.0	100.0	65.9	46.3	36.5
	2.5	100.0	100.0	98.8	75.6	3.1
	4.0	100.0	100.0	100.0	91.9	0.5
Control			0	1.1	0	398.2

[1] Average of eight replications; Diacol Calima variety with 100 g seed/rep. and infested with 20 pairs of adults at beginning.

Economic Importance of Stored Grain Insect

In a survey with the bean economics group, the relative importance of stored grain insects was studied on the farm and in 30 warehouses in bean producing areas of Colombia. Average losses were estimated at 7.4 percent (Table 13). Losses are probably low because of the short storage period for beans (an average of eight and 44 days on farms and in stores, respectively).

Table 13. **Losses from Bruchid attack in 30 bean warehouses in Colombia.**

Percentage of stores with infested beans	20.0
Percentage of bags infested	2.3
Percentage of bags refused due to Bruchids	5.1
Estimated loss from Bruchids 2.3% + 5.1% = 7.4%	

MICROBIOLOGY

Nitrogen Fixation

Studies in 1976 employed acetylene reduction techniques for weekly or biweekly testing of nitrogen fixation in *P. vulgaris*. First, an understanding of parameters of fixation in a number of phenologically distinct bean cultivars was sought, then, explanations of observed differences were developed. Breeding for improved nitrogen fixation in beans was initiated as was a reevaluation of a number of inoculant strains.

Parameters of nitrogen (C_2H_4) fixation in beans

During the year nitrogen fixation rates (measured by ethylene produced from the reduction of acetylene) up to 38μ mol/plant/hr were obtained in replicated conditions at Popayán. Fixation rates commonly surpassed the highest levels achieved in 1975. Specific nodule activities ranged from 130-250μmol C_2H_4/g nodule dry wt/hr with maximum nodule mass more than 600 mg dry wt/plant. As Table 14 shows, these figures are amongst the highest reported so far for grain legumes. Varietal differences in fixation over the growing season were very marked (Fig. 13). Based on the data in this figure the cultivar P590 achieved fixation levels equivalent to a nitrogen gain of 41 kg/ha/growing season. The average for 14 cultivars studied was over 20 kg N/ha/growing season. Figure 14 shows early nodulation in one of the promising

Table 14. **Parameters of nitrogen fixation in some grain legumes (data from various sources).**

Species	Nodule dry weight (mg/plant)	Specific nodule activity (μ mol/g nod wt/h)	Acetylene reduction (μ mol/plant/h)	Nitrogen fixed (kg/ha/yr)
Phaseolus vulgaris (P590)	167-300	228	20-30	82
P. vulgaris, 20 cultivars	259-665	124-270	18.5-38.8	50-60
Glycine max	133	35-176	4-29	57-94
Arachis hypogea	80	135	27	35
Vigna unguiculata	210-413	80-288	42	95
Pisum sativum	2-150	60-228	4-16	25

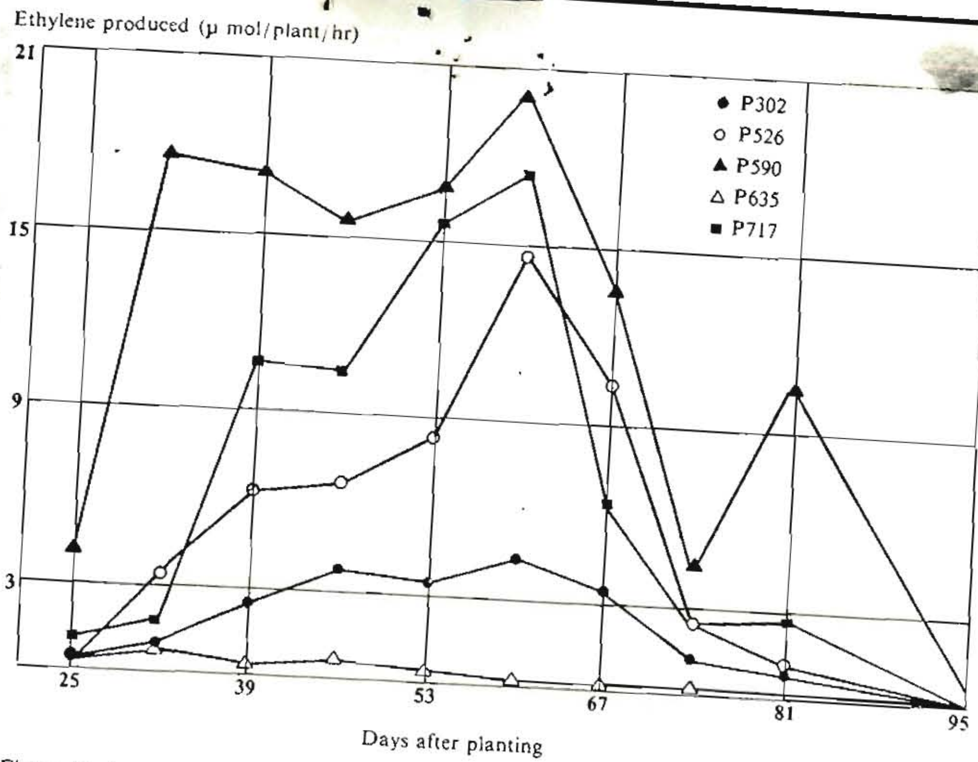


Figure 13. Acetylene reduction profiles for 5 accessions of *Phaseolus vulgaris* at Popayán, 1976A.

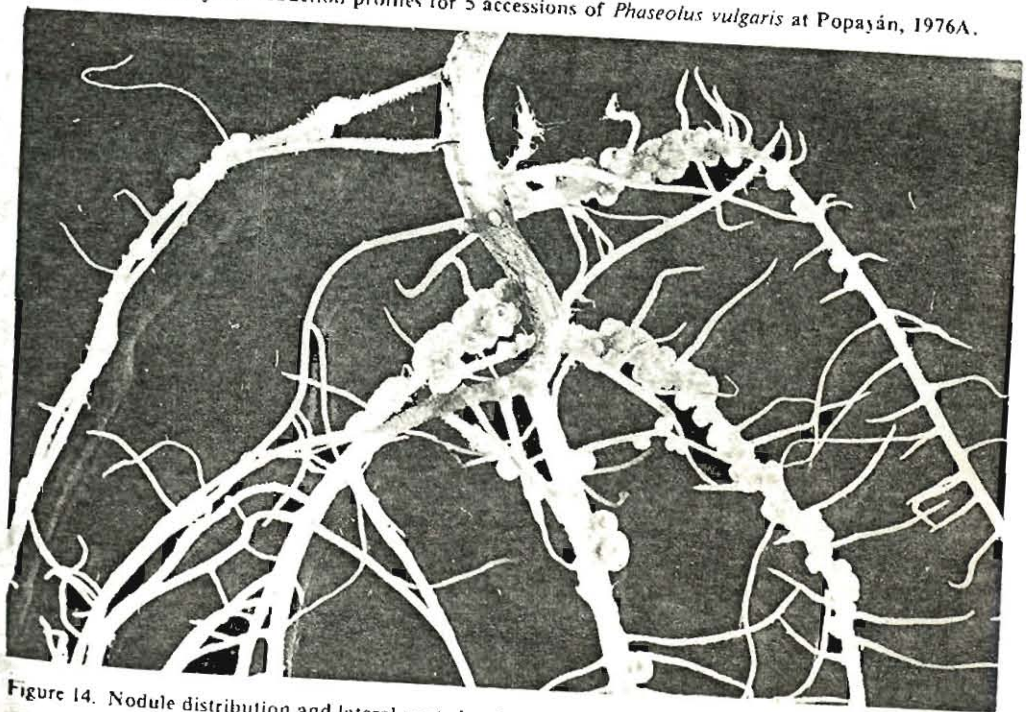


Figure 14. Nodule distribution and lateral root development in *Phaseolus vulgaris* 18 days after planting.

cultivars with nodules mainly found on secondary roots.

In a second study in which 10 cultivars from each group were compared, bush beans proved weaker in fixation than the more primitive climbing cultivars (Fig. 15). Cultivar P590 again proved outstanding in nitrogen fixation in this study. In contrast, a soybean cultivar (Pelikan) included as a control proved disappointing.

Figure 16 shows that bush cultivars assimilated more soil nitrogen in the prefixation period than did climbers. Breeders. have tended to select for yield in this plant type using N-fertilized conditions, perhaps inadvertently also selecting for plants with early rooting vigor. In such plant types, nodules would face strong competition for energy and could even be repressed by rapid nitrogen uptake. The effect is being further investigated.

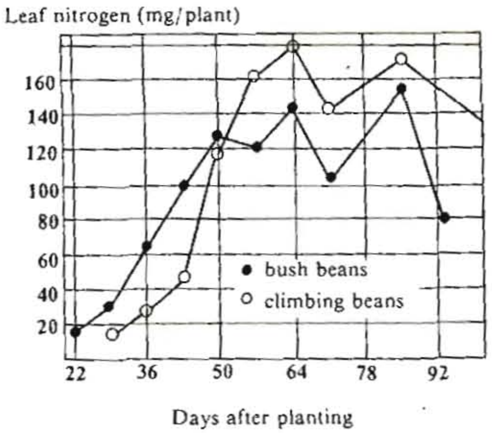


Figure 16. Nitrogen content of leaves of bush and climbing cultivars of *Phaseolus vulgaris* at different stages in the growing season. Each point averages results for 10 cultivars in 4 replications.

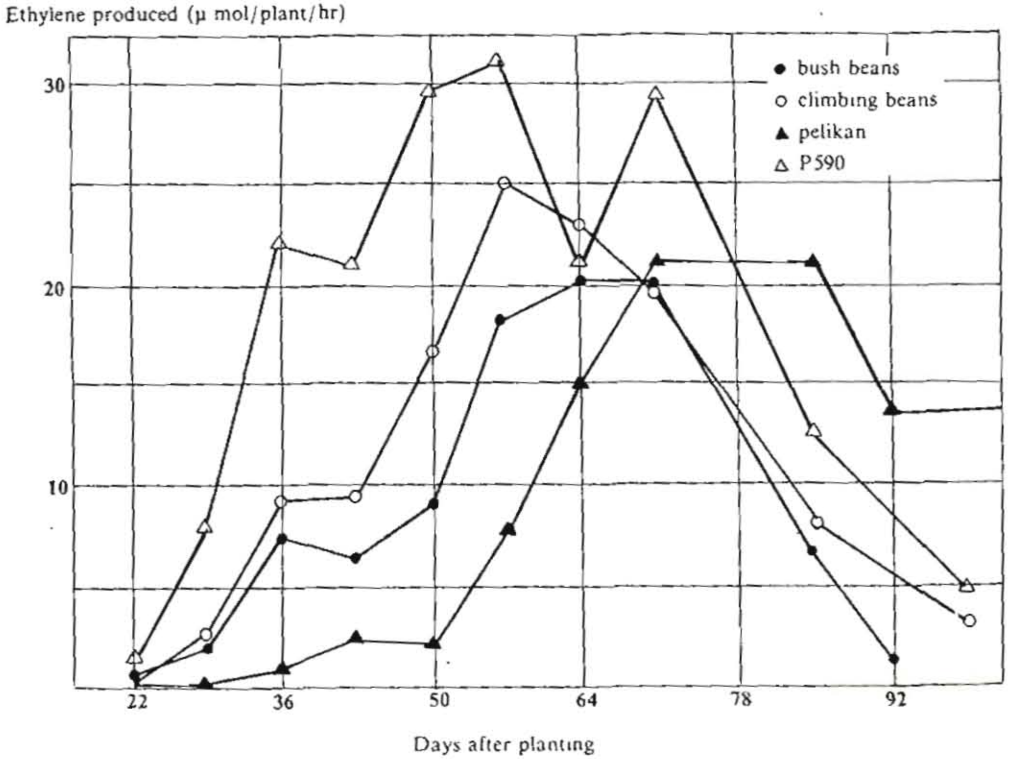


Figure 15. Acetylene reduction profiles for bush and climbing cultivars of *Phaseolus vulgaris*. Each point averages results for 10 cultivars. Accession P590 and the soybean variety Pelican were checks.

As is evident in Figures 13 and 15, the fixation period for most bean cultivars was short. At 18-20ºC few cultivars initiated fixation prior to 28 days after planting, and in most, activity began to decline at about 10 weeks. This period compares unfavorably with the 90-105 day fixation period reported for soybean and *Vicia*.

Carbohydrate supply and nitrogen fixation

Following up work begun last year (CIAT Annual Report, 1975) a number of experiments were undertaken to measure carbohydrate form and availability in different cultivars and to relate this information to nitrogen fixation.

In one experiment, 14 cultivars inoculated with the CIAT *Rhizobium* strain 57 were sampled at 39 (initiation of active fixation) and 61 (beginning of decline of fixation rates) days after planting. All plant parts were sampled and analyzed for ethanol soluble and insoluble carbohydrate. The acetylene reduction data of Figure 13 formed part of this study.

Again marked varietal differences were found. Tables 15 and 16 compare carbohydrate patterns in the cultivars P590 and P635, the former being highly active in fixation, the latter inactive despite copious nodulation (Fig. 13). P590 not only has a higher percentage soluble carbohydrate in

Table 15. Distribution of carbohydrate[1] in two accessions of *Phaseolus vulgaris* at two plant development stages.

Plant part	Total carbohydrate (mg/plant)			
	39 days after planting		61 days after planting	
	P590	P635	P590	P635
Nodules	35.35	10.94	100.62	0.92
Roots	55.29	90.84	175.39	247 04
Stem				
nodes 1 + 2	124.58	395.13	110.07	678.68
nodes 3 + 4	118.68	118.67	414.51	71.97
nodes 5 + 6	52.23	—	111.06	174.23
nodes 7 + 8	—	—	157.44	—
8	—	—	70.40	—
Leaf				
nodes 1 + 2	270.02	336.44	191.50	88.03
node 3 + 4	114.48	171.38	404.65	60.29
nodes 5 + 6	66.40	—	146.60	99.06
nodes 7 + 8	—	—	227.43	—
8	—	—	51.50	—
Pods	—	—	—	132.76
Total	837.03	1,123.40	2,121.17	1,552.98

[1] Both ethanol soluble and insoluble carbohydrate.

Table 16. Ethanol soluble and insoluble carbohydrates in selected varieties or accessions of *Phaseolus vulgaris* at two plant development stages.

Plant part	Carbohydrate source	% of total carbohydrate: Avg. 14 varieties, 39 days after planting	Avg. 14 varieties, 61 days after planting	P590, 39 days after planting	P590, 61 days after planting	P635, 39 days after planting	P635, 61 days after planting
Nodules	Soluble	0.68	0.34	1.34	1.84	0.61	0.02
	Insoluble	1.40	0.69	2.87	2.81	0.29	0.04
	Total	2.08	1.03	4.21	4.65	0.90	0.06
Root	Soluble	3.82	2.95	4.02	3.71	5.08	4.09
	Insoluble	2.46	5.40	2.58	4.41	3.00	11.82
	Total	6.28	8.35	6.60	8.12	8.08	15.91
Stem	Soluble	10.92	16.52	15.90	28.46	15.76	5.29
	Insoluble	17.66	25.22	19.39	11.49	29.98	54.26
	Total	28.58	41.74	35.29	39.95	45.74	59.55
Leaves	Soluble	20.36	21.62	29.30	31.53	15.43	4.33
	Insoluble	43.33	25.98	24.56	15.75	29.78	11.60
	Total	63.69	47.60	53.86	47.28	45.21	15.93
Pods	Soluble	-	0.90	-	-	-	5.17
	Insoluble	-	0.78	-	-	-	3.38
	Total	0	1.68	0	0	0	8.55
Total	Soluble	35.25	42.33	50.59	65.56	36.50	18.90
	Insoluble	64.78	58.07	49.41	34.44	63.50	81.10

all organs but partitions more of its total carbohydrate to the nodule.

Starch accumulation in the stem of determinant (bush-type) cultivars of *P. vulgaris* (as is P635) was reported last year (CIAT Annual Report, 1975) and is currently being investigated for its influence on flower and pod abortion and on yield (see p. A-56). In this study, the best five cultivars in nitrogen fixation tended to maintain more carbohydrate in a soluble form (Fig. 17) and had lower starch

A strong correlation existed between carbohydrate supply and nitrogen fixation. Figure 18 relates total soluble carbohydrate in the nodule to levels of acetylene reduction, with the suggestion—not previously reported—that the nodular system can be oversupplied with energy and not fully utilize it. Figure 19 shows starch accumulation in stem cells and in uninvaded cells of the nodule complex. Invaded cells showed little starch.

A comparative study of seasonal and diurnal changes in nitrogen fixation by a

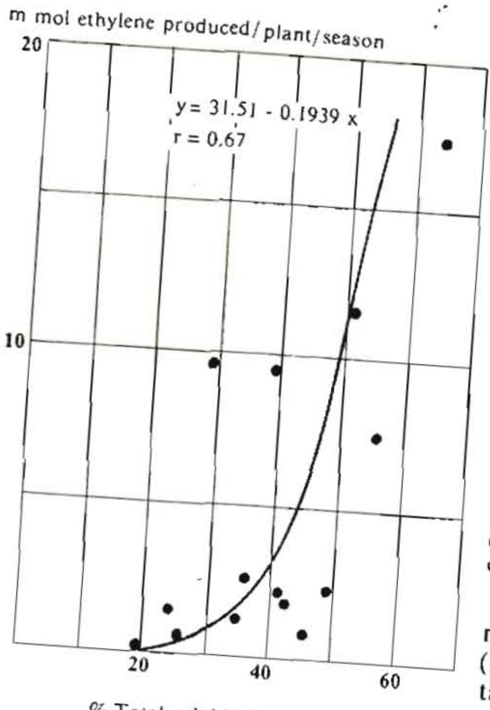


Figure 17. Relationship between seasonal levels of nitrogen fixation and percentage nonstructural carbohydrate maintained in soluble form.

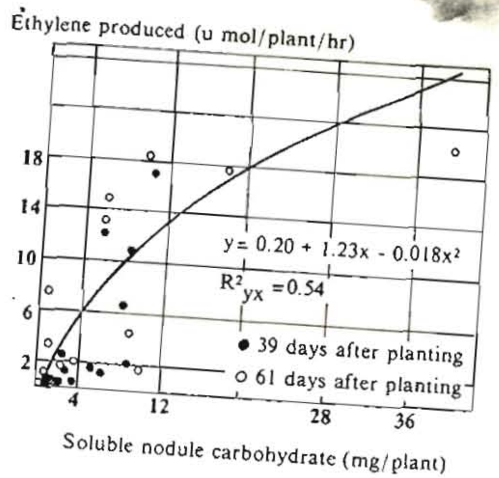


Figure 18. Relation between soluble nodule carbohydrate and acetylene reduction levels in 14 cultivars of *Phaseolus vulgaris*.

representative bush (P302) and climbing (P590) cultivar reconfirmed the importance of the form and location of compartmented carbohydrate. The bush cultivar, while poorer in nitrogen fixation and with considerable stem starch, still accumulated starch in its nodules at a time when energy requirement for nitrogen

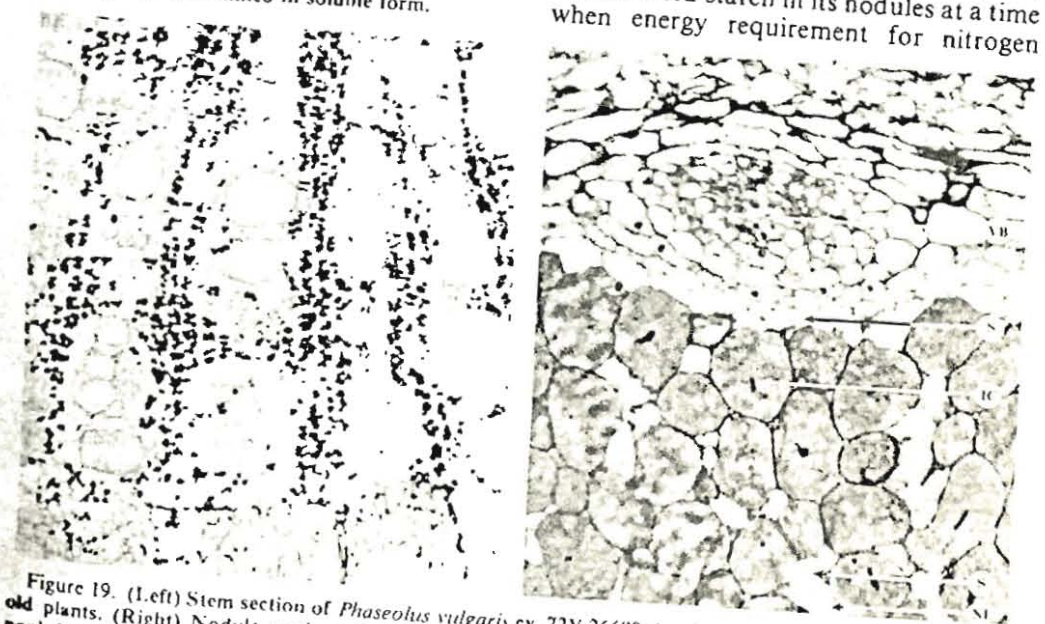


Figure 19. (Left) Stem section of *Phaseolus vulgaris* cv. 72V 26689 showing starch accumulation in 60-day-old plants. (Right) Nodule section of same plants showing vascular bundle (VB), starch granules (S) in noninfected (NI) cells and cells infected with *Rhizobium* (IC). (Photos R. Martinez)

fixation would have been greatest (Fig. 20). Specific acetylene reducing activities in nodules of each cultivar were similar in mid-vegetative growth and declined only slightly at night (Fig. 21). The soluble carbohydrate pools of the leaves became depleted in the late afternoon (Fig. 22a) and continued carbohydrate support to sinks was maintained by release of leaf starch at night (Fig. 22b). The bush cultivar released 33 percent of its leaf starch but it appears that the roots benefited more from the translocated carbohydrate than nodules since the former were able to accumulate starch (Fig. 22c) whereas the latter consumed some of their storage reserves (Fig. 22d). The climber released much more (75%) of its leaf starch (Fig. 22b) and the nodules were able to acquire sufficient of the translocates not only to maintain nitrogenase activity but also to synthesize starch (Fig. 22d).

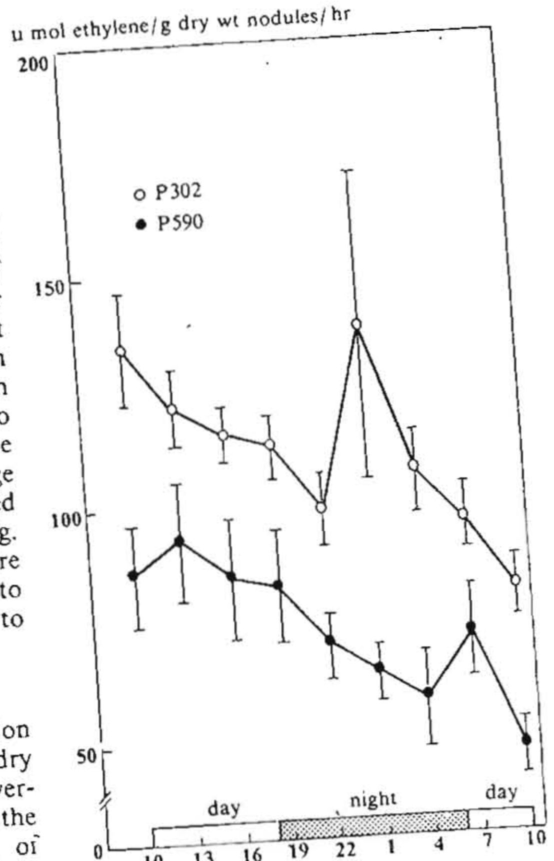


Figure 21. Specific nodule acetylene reducing activity in two *Phaseolus vulgaris* accessions over a 24-hour period.

In 1975, in the laboratory, correlation was shown between maximum nodule dry weight achieved and days taken to flowering. This study was continued in 1976 in the field. Fourteen cultivars were used of which eight flowered in 63 and six in 43 days. Leaf, stem and root development for each group is shown in Figure 23 with cultivars used as replicates. The earlier increase in leaf and stem weight/plant of the more precocious cultivars is apparent, as is the rapid decline in leaf weight in this group after flowering. Plants flowering in 63 days showed a longer period of leaf weight increase with limited decline in leaf weight by the time the experiment was terminated. Despite this, seasonal curves for nodule dry weight development and nitrogen fixation were remarkably similar (Fig. 24) with significant differences only at the last sampling date. This experiment is being repeated to determine the effect of shorter leaf life on nitrogen fixation.

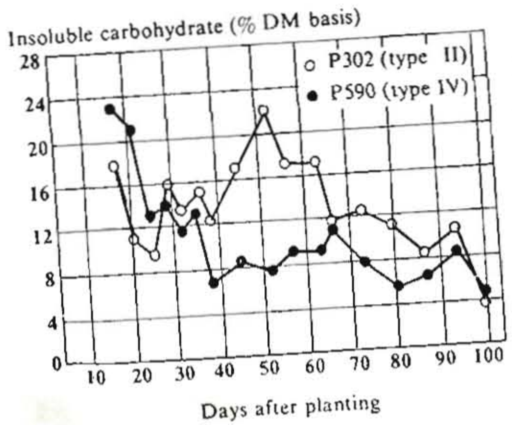


Figure 20. Seasonal variation in nodule starch ... accessions.

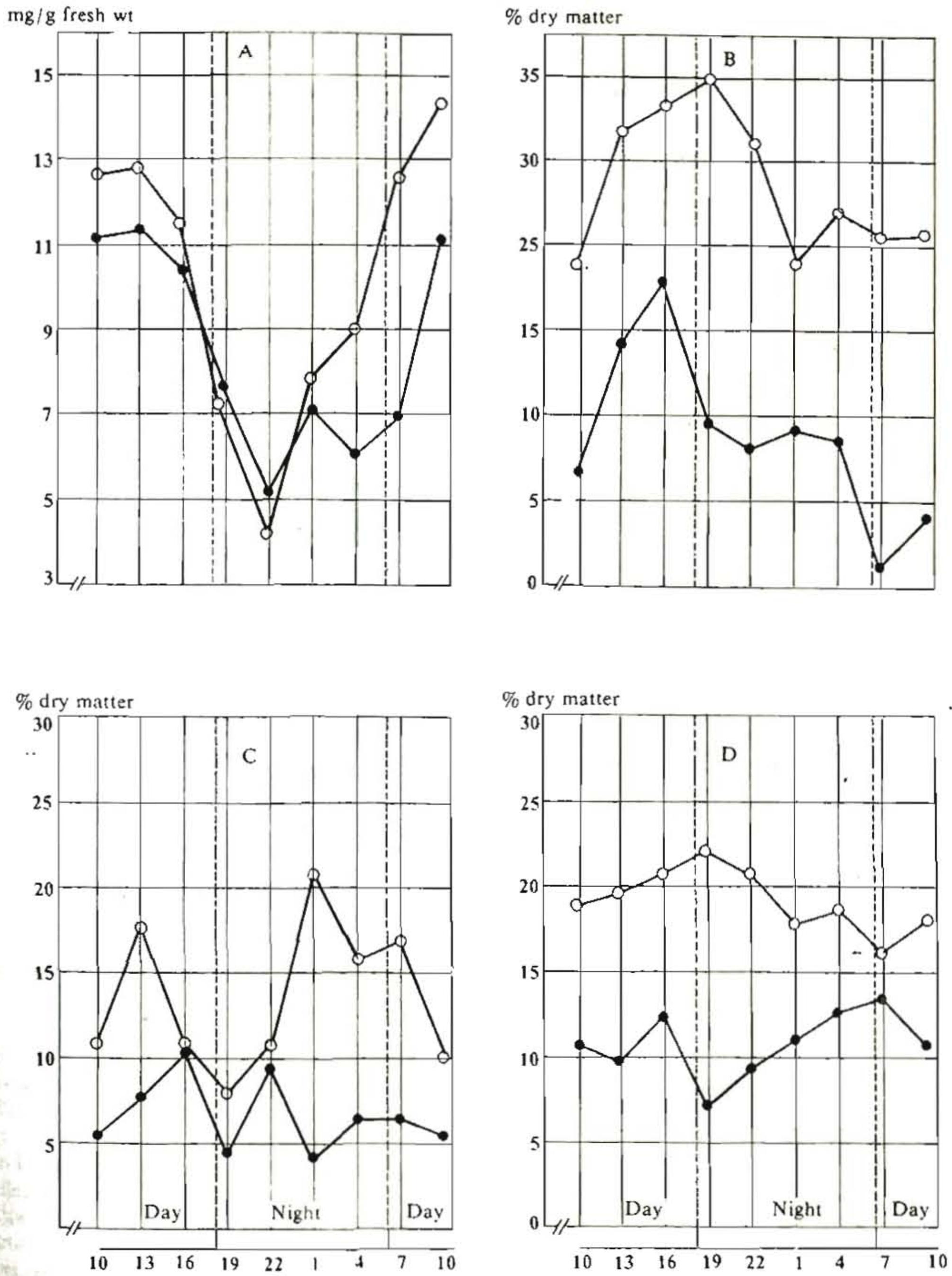


Figure 22. Diurnal changes in soluble carbohydrate concentrations in leaves (A) and insoluble carbohydrate concentrations in leaves (B), roots (C) and nodules (D), in two *Phaseolus vulgaris* accessions. (o P302, and • P590).

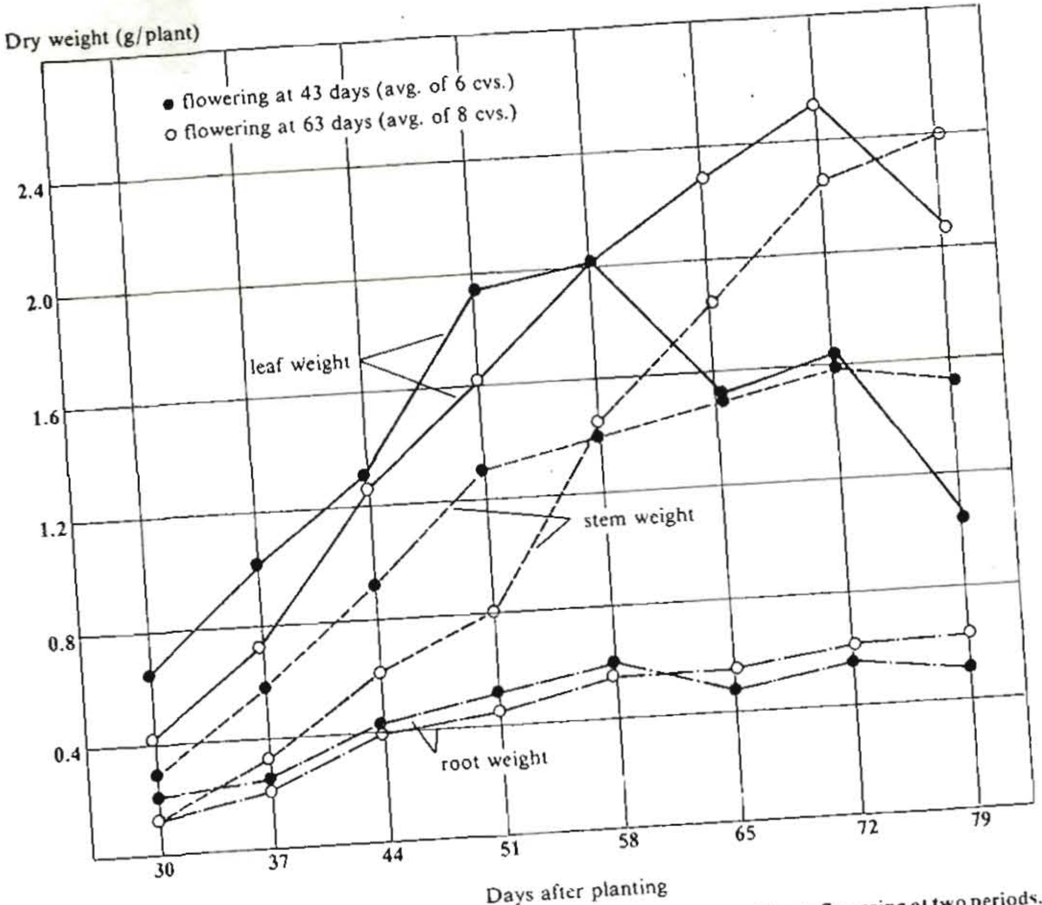


Figure 23. Changes in leaf, stem and root dry weight for *Phaseolus vulgaris* cultivars flowering at two periods.

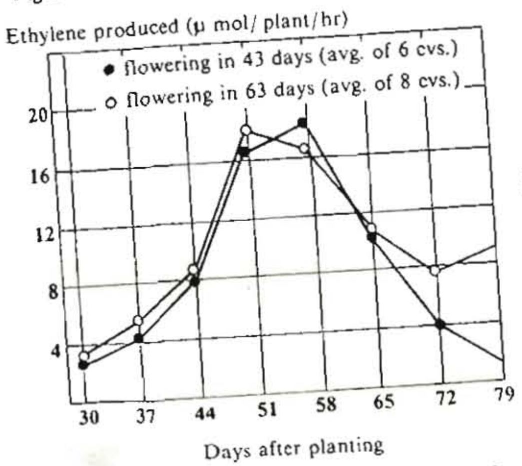


Figure 24. Seasonal profiles in nitrogen fixation for … flowering at two periods

Nitrogen fixation in maize-bean associations

Because beans are grown with maize in many areas, and could have to compete for light, experiments were begun to determine nitrogen fixation levels under monocrop and associated cropping conditions. The cultivar P590 was grown on trellises (200,000 plants/ha) or in association with the maize hybrid H 207 (40,000 maize and 200,000 bean plants/ha). Although the maize was planted one month before the beans, it failed to compete with the bean or to provide adequate support for bean development. It is of interest, however, that in the early period of development nitrogen fixation levels in the associated cropping were greater than in the monocrop (Fig. 25). This can probably be attributed to improved soil aeration or temperature control; additional experiments in 1977 will further evaluate this finding. Later in the plant cycle the beans on trellises fixed more nitrogen than did the plants grown with maize. This undoubtedly reflected the poor canopy presentation of associated beans in the absence of satisfactory support. At no stage was nitrogen fixation detected in any of the maize plants sampled.

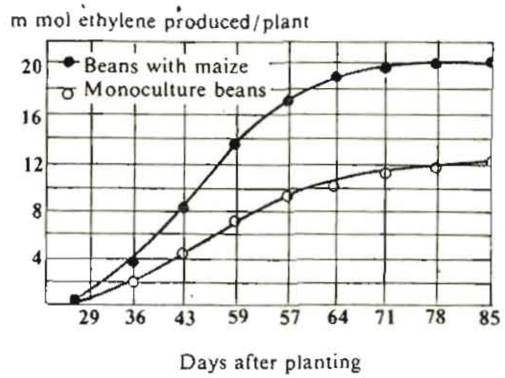


Figure 25. Effect of cropping system on the total nitrogen (C_2H_4) fixed by the cultivar P590. Correction has been made for diurnal variation in fixation.

Strain testing of *Rhizobium phaseoli*

Sixty-one strains of *Rhizobium phaseoli* were tested in the field for inoculation response in the cultivars Porrillo Sintetico and 72 vul 20972. Response to inoculation was striking, with uninoculated plants showing clear symptoms of nitrogen deficiency. With Porrillo Sintetico only seven strains produced nodule dry weight and acetylene reduction responses similar to, or better than, the CIAT strain 57 commonly used in field experiments (Table 17). Only three strains (CIAT 75, 135 and

Table 17. Response of *Phaseolus vulgaris* var. Porrillo Sintetico to inoculation with different *Rhizobium* strains.[1]

Treatment	Nodule dry wt (mg) 45 days after planting	Nodule dry wt (mg) 60 days after planting	Nitrogen fixation at 60 days (µ mol ethylene/ plant/hr)	Plant dry wt at 60 days (g/10 plants)
Not inoculated, no added nitrogen	209.5	66.2	0.98	35 34
Not inoculated, with added nitrogen	100.3	137.2	0.16	53.41
Inoculated:				
Strain 57	996.0	1,083.0	15.09	62.23
Strain 147	503.2	1,770.0	47.62	72.68
Strain 686	1,369.1	1,335.0	39.53	66.96
Strain 404	1,107.9	738.5	26.40	70.98
Strain 73	-[2]	2,034.5	21.90	69.91
Strain 160	1,115.4	888.7	37.79	81.51
Strain 78	1,022.2	1,233.8	26.74	78.00
Strain 255	1,455.9	1,800.0	39.48	68 60

[1] Un replicated 10-plant sample for each strain, control: repeated every 10 strains.
[2] Sample destroyed accidently.

255) equaled CIAT 57 when 72 vul 20972 was used as host. These strains will be compared again in future experiments.

Hybridization for improved nitrogen fixation

In collaboration with breeders in the program a number of crosses have been made to study the inheritance of nitrogen fixation in beans. These crosses stressed P590 as a parent combining both high fixation capacity and high levels of soluble carbohydrate, and used P635, P589 and P569 as cultivars weak in nitrogen fixation and/or soluble carbohydrate levels. P302 was also crossed with P590. F_2 seed will be grown at Popayán in the next season. Techniques for evaluating fixation in hybrids are being developed.

Inoculant supply

As in previous years the soil microbiology group continued to supply inoculants to requestors in Latin American countries.

AGRONOMY

Varietal Testing

Experiments to identify high-yielding materials among both bush and climbing cultivars of *P. vulgaris* intensified in 1976.

Bush cultivars

During the year, 146 new bush cultivars were evaluated in four Preliminary Yield Trials at CIAT (methodologies of different trials are described in CIAT's 1975 Annual Report).

Seed yields in the first trial ranged from 1,233 to 2,996 kg/ha and for the second trial from 1,010 to 3,659 kg/ha. Thirty black varieties equalled or exceeded the yield of the black check varieties, but in the non-black seeded group only 14 of the cultivars tested performed as well as the standard varieties included.

Promising varieties selected from Preliminary Yield Trials of the previous season were entered in Uniform Yield Trials, with seven such trials conducted as of September 1976. In the first group of trials, at two locations in Colombia and one in Ecuador, materials of all colors were included. Results of the 15 best entries are presented in Table 18; eight of the best nine materials were black-seeded. The exception, P758, a brown-seeded, type III plant, outyielded all cultivars in the CIAT trial. Because of this marked difference, cultivars were separated according to color in the two subsequent trials with each group tested at CIAT and Popayán. Results of these four trials are shown in Tables 19 and 20.

Climbing cultivars

Because studies were initiated later and required considerable seed multiplication, yield trials with climbing beans are not as advanced as with bush beans. More than 1,500 collections of type IV and tall type III beans have been screened for yield under trellis (monoculture) conditions, and 700 of these are currently being evaluated in association with maize. Several type IV promising cultivars have been planted in replicated yield trials both monocropped and associated with maize. Yields of five of these are shown in Table 21 and a typical cultivar, in Figure 26.

Uniform Yield Trials with climbing beans are planted in five locations in Colombia and Ecuador, and compare 20 high-yielding cultivars associated with maize. In these trials, and as a result of findings by the microbiology group, *Rhizobium* inoculation is being used. Bush bean trials depend to the moment on fertilizer nitrogen.

Table 18. Highest yielding bean cultivars and check varieties in Uniform Yield Trials in Colombia (CIAT and Dagua) and Ecuador (Boliche).

Identification	Seed color	Growth habit	Yield (kg/ha)			
			CIAT	Dagua	Boliche	Mean
Test materials						
P302	Black	II	2,009	2,618	3,396	2,674
P737	Black	II	2,011	2,585	3,145	2,580
P712	Black	II	1,895	3,060	-	2,477
P758	Brown	III	2,144	2,313	2,841	2,433
P675	Black	II	1,461	2,628	3,187	2,425
P459	Black	II	2,008	2,496	2,725	2,410
P560	Black	I	1,513	2,718	2,936	2,395
P511	Black	II	1,671	2,405	3,037	2,371
P512	Black	III	1,847	2,606	2,488	2,314
P692	Red Mottled	I	1,926	2,378	2,076	2,127
P566	Black	II	1,640	2,329	2,406	2,125
P498	Black	III	2,061	1,835	2,470	2,122
P637	Red Mottled	I	1,530	2,634	2,183	2,116
P757	Black	II	1,687	1,789	2,694	2,057
P756	White	I	1,793	1,487	2,610	2,030
Check materials						
Procaraota	Black	II	1,652	2,594	-	-
P458	Black	II	1,688	2,452	-	-
P635	Red Mottled	I	1,128	2,232	-	-
P402	Beige	I	-	-	3,108	-
Amarillo	Yellow	III	-	-	1,444	-
Blanco	White	II	-	-	1,067	-
Trial means and ranges						
Yield mean (kg/ha)			1,614	2,222	2,380	
Lowest yield (kg/ha)			772	1,487	556	
Highest yield (kg/ha)			2,144	3,060	3,396	
L.S.D. at .05			396	371	609	
C.V. (%)			15.3	10.4	16.0	

International Bean Yield and Adaptation Nurseries (IBYAN)

Proposed methodologies for a series of international yield and adaptation nurseries were presented in the 1975 Annual Report. Objectives are to evaluate the yield and adaptation of cultivars over a wide range of experimental conditions and to allow national programs to compare a

Table 19. Yield of non-black bean varieties of the Uniform Yield Trial at two locations in Colombia.

Identification	Seed color	Growth habit	Yield (kg/ha)		
			Popayan	CIAT	Mean
Test materials					
G01212	Red	III	2,641	2,106	2,374
P524	Beige	II	2,540	2,185	2,362
P17	Brown	II	2,572	1,949	2,260
G01540	Yellow	I	2,050	2,396	2,223
G01224	Brown	II	2,329	2,106	2,218
P381	White	I	2,189	2,206	2,198
G01213	Grey	III	2,186	2,107	2,146
Lamanier	Purple	II	2,070	2,198	2,134
Linea 20667	Beige	I	2,426	1,832	2,129
G00805	Red	III	2,082	1,681	1,882
Pintado	Beige	II	1,585	2,059	1,822
Linea 00738	Purple	I	1,382	1,796	1,589
Mean			2,171	2,052	
Check materials					
P756	White	II	2,792	1,944	2,368
P459	Black	II	2,700	1,774	2,237
P692	Red	I	1,998	1,661	1,830
P392	White	I	1,383	1,414	1,398
Mean			2,218	1,711	
L.S.D. at .05			532	422	
C.V. (%)			17.3	15.6	

range of promising materials. This testing was activated in 1976 with strong support. Through late 1976, 128 requests for the first IBYAN have been received, covering 90 sites in 35 countries. As shown in Table 22, seed has already been dispatched to 76 collaborators, with the remainder to be shipped shortly. Figure 27 shows an IBYAN set being prepared for shipment. Plans are being developed for a limited [illegible] yield and adaptation

Bean-Maize Associations

Plant densities

Under monocrop conditions at CIAT, optimum planting density for highest production in climbing beans is 120,000 plants/ha and for maize, 80,000 plants/ha. In association with maize at a constant density of 40,000 plants/ha, optimum bean density remains about 120,000 plants/ha ([illegible] 28). The apparent lack of interaction

Table 20. Yield of black bean varieties of the Uniform Yield Trial at two locations in Colombia.

Identification	Growth habit	Yield (kg/ha)		
		CIAT	Popayan	Mean
Test materials				
P209	II	2,930	3,174	3,052
P668	II	2,822	2,788	2,805
P700	II	2,741	2,840	2,790
P481	II	2,538	3,009	2,774
P579	II	2,838	2,653	2,746
P437	II	2,602	2,814	2,708
P509	II	2,763	2,544	2,654
P225	II	2,475	2,708	2,642
P9	II	2,588	2,687	2,638
P443	II	2,667	2,587	2,627
P667	II	2,548	2,694	2,621
P226	II	2,454	2,772	2,613
P14	II	2,448	2,658	2,553
P527	III	2,689	2,161	2,515
P199	II	2,320	2,675	2,498
P322	III	2,292	2,690	2,491
P320	II	2,259	2,715	2,487
P337	II	2,141	2,713	2,427
P349	II	2,479	2,224	2,352
P491	III	2,413	2,159	2,286
P422	II	2,169	1,577	1,873
Mean		2,523	2,612	-
Check material				
P459C	II	2,693	2,831	2,762
P459B	II	2,826	2,671	2,748
P675	II	2,804	2,396	2,600
P566	II	2,318	2,252	2,285
Mean		2,660	2,538	
L.S.D. at .05		277	382	
C.V. (%)		9.6	10.6	

Table 21. Yields of five promising accessions of climbing beans in replicated trials in CIAT.

Accession	Color	Country of origin	No. of trials	Yield (kg/ha) Monocrop Min.	Monocrop Max.	Associated Min.	Associated Max
P589	Cream	Colombia	6	2.0	4.3	.6	2.1
P526	Black	Venezuela	5	1.4	4.3	.4	1.7
P525	Black	Venezuela	5	1.4	2.3	.5	1.5
P259	Brown	Chile	14	1.5	3.6	.2	1.5
P006	Black	Guatemala	4	1.8	2.7	.3	1.7

of bean density by planting system simplifies both experimental procedures and eventual recommendations to national programs.

Figure 26. A promising type IV bean grown in association with maize can yield over 2 t/ha without

Table 22. Countries collaborating in the first International Bean Yield and Adaptation Nursery (IBYAN).

	Requests	Dispatched through October 1976
Latin America and the Caribbean		
Belize	2	1
Bolivia	3	1
Brazil	21	9
Colombia	8	7
Costa Rica	1	1
Chile	4	4
Ecuador	10	4
El Salvador	6	5
Guadalupe	2	-
Guatemala	4	3
Haiti	5	-
Honduras	4	3
México	4	4
Nicaragua	3	3
Panamá	1	1
Perú	5	5
Dominican Republic	4	4
Surinam	1	-
Trinidad	1	-
Venezuela	4	2
	93	57

Cont

Table 22. Continuation.

	Requests	Dispatched Through October 1976
North America and Europe		
Canada	1	1
Portugal	1	-
United Kingdom	2	2
United States	2	2
	6	5
Africa - Asia Oceania		
Afghanistan	1	-
Iran	1	-
Israel	1	1
Japan	2	2
Kenya	5	5[1]
New Caledonia	1	-
Malawi	3	-
Pakistan	1	-
Philippines	3	1
Tanzania	5	4
Thailand	6	-
	20	14
Total	128	76

[1] Due to quarantine restrictions, seed samples were sent to be increased locally

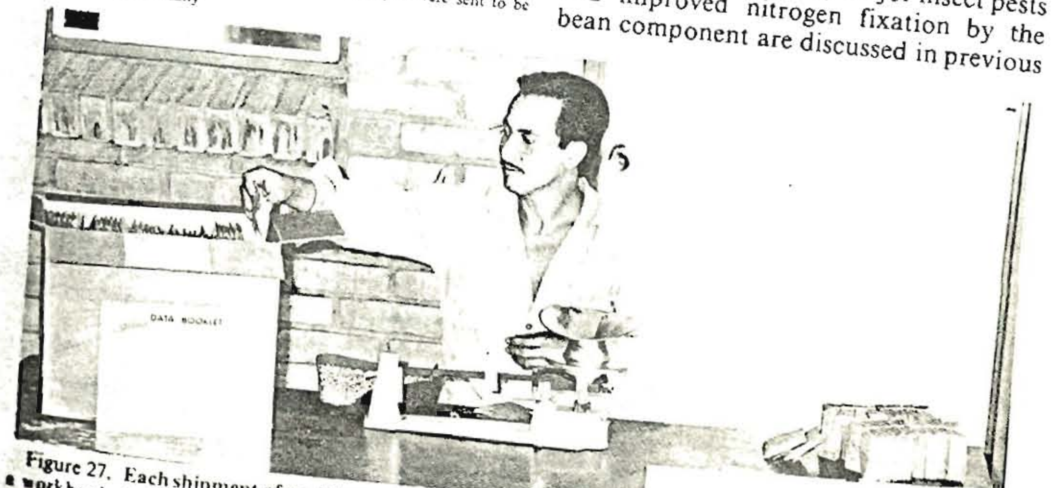


Figure 27. Each shipment of seed for an International Bean Yield and Adaptation Nursery is accompanied by a workbook detailing essential and suggested measurements to be taken and the methodolo... Workbook data can pass directly to biometric analysis.

Bean and maize yields

Reduction in bean yields due to association with maize depends on relative planting date, maize and bean density, plant type and location. At CIAT near optimum production of both maize and beans is obtained by simultaneous plantings, though yields of bush types are increased somewhat when they are planted one week before the maize (Fig. 29). Over a large number of trials, bean yields in association with maize were reduced about 30 percent in types II and III (non-climbing), and about 50 percent in type IV (climbing) beans. In current trials lower maize densities are being tested to develop response surface comparisons of various maize/bean density combinations. The optimum system for greatest economic return depends also on relative prices of maize and beans. The maize:bean price ratio varies in Latin America from 1:2 up to 1:6 in some countries for special colors and seed sizes of beans. Many factors appear to contribute to the well-being of the maize and bean system when the two species are intercropped, and to compensate for light and nutrient competition. Differences in attack by major insect pests and improved nitrogen fixation by the bean component are discussed in previous

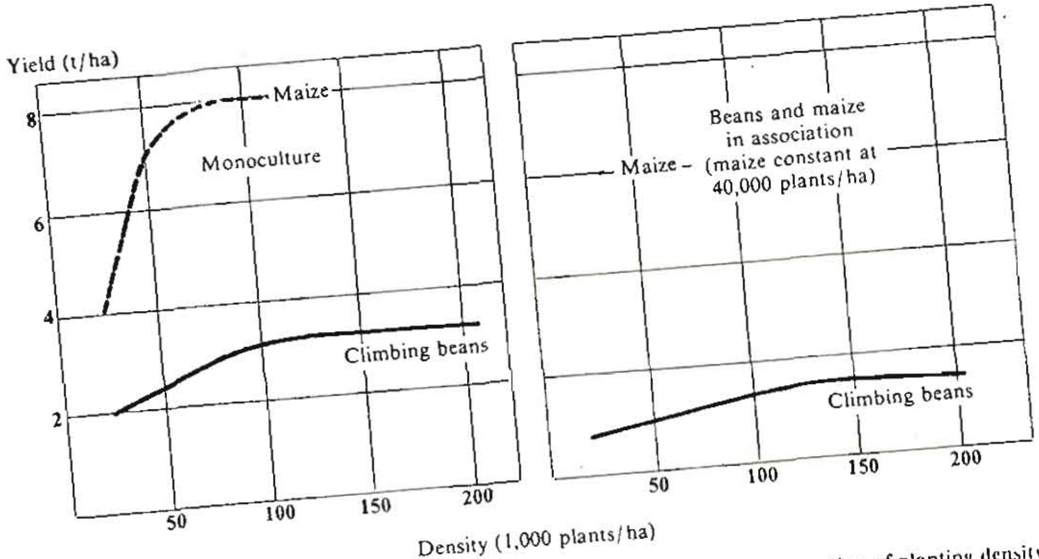
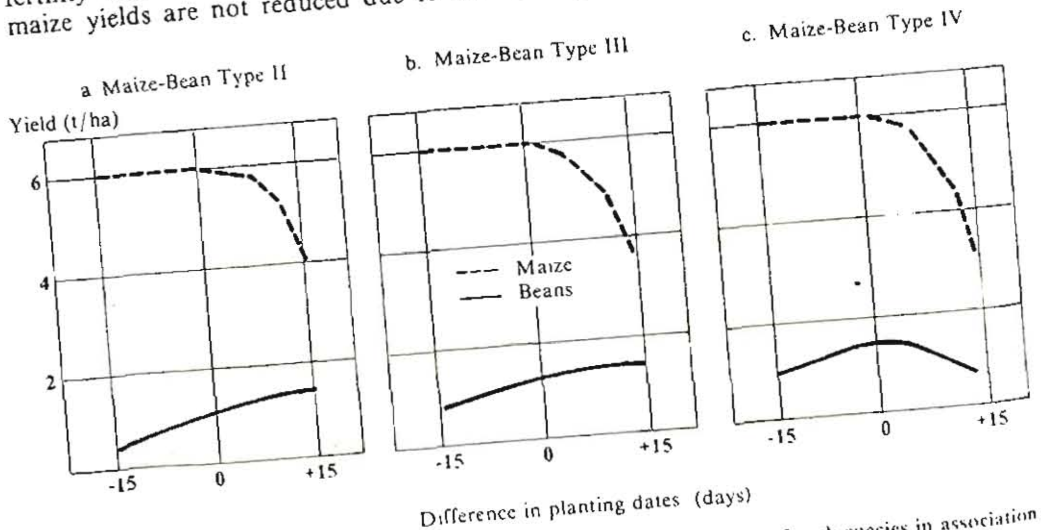


Figure 28. Yields of maize and beans in monoculture and in association as a function of planting density.

sections. Table 23 shows the reduced lodging in maize grown associated with beans.

Trials in CIAT with both bush bean/maize associations and climbing bean/maize associations show that when fertility and moisture are not limiting, maize yields are not reduced due to the association. In paired comparisons of plots with densities from 30,000 up to 90,000 plants/ha of maize, this relation was maintained. There also were no differences in maize plant height, harvest index, biological yield, prolificacy, length and diameter of ear and cob, row number, and moisture content of grain and stover in the two systems.



... dates of maize and beans on yields of each species in association

Table 23. Percentage maize lodging in six trials in monoculture and in association with bush and climbing beans at CIAT.

Maize hybrid	Bean cultivar	Root lodging mono	Root lodging assoc.	Stalk lodging mono	Stalk lodging assoc	Total lodging mono	Total lodging assoc
H-210	P259 (climbing)	1.6[1]	.3	9.6	3.8	11.2	4.2
H-207	Pijao (bush)	29.4	9.6	6.4	5.2	35.8	14.8
H-207	P259 (climbing)	53.2	17.0	6.2	6.5	59.4	23.5
H-207	Jamapa (bush)	64.3	14.0	1.0	3.3	65.3	17.3
H-207	P259 (climbing)	46.5	2.2	15.8	3.0	62.3	5.2
H-207	Pijao (bush)	14.0	26.0	9.0	0	23.0	26.0
Average lodging in 13 trials						33.8	16.1

1 Underscored data in adjacent columns are not significantly different at .05 by the L.S.D. method

Planting systems for associated cropping

Manipulating the spatial arrangement of two species in association to achieve the best possible light environment for each space should result in higher total system yields. Growing maize in paired rows did not affect bush bean yields compared to uniformly spaced rows (Fig. 30). In association with climbers grown in paired rows, maize yields were decreased relative to those achieved with normally-spaced rows. In this trial, maximum bean yields of 2.07 t/ha were obtained with a 4.93 t/ha maize yield. Monocrop bean yields of 4.3 t/ha were produced with P589, a cream-colored, late-flowering cultivar.

Genotype x system interaction

It is crucial to the breeding program to determine whether the best bean varieties selected under monoculture conditions are also the best when associated with maize. Preliminary results on this system x genotype interaction suggest that there is a strong correspondence between results from the two systems, both in rank order and yields. In nine varieties of bush beans, the correlation between ranks in the two systems was highly significant (r = 0.93**), as was the correlation for yields (r = 0.91**). In nine varieties of climbing beans, results were similar — ranks (r = 0.88**) and yields (r = 0.90**). When 15 varieties of maize were tested in three systems (monoculture, and associated with bush beans or climbing beans), results were less consistent. Correlations between pairs of systems for yield and rank order, respectively, were the following: monoculture vs. association with bush beans (r = 0.23, r = 0.45), monoculture vs. association with climbing beans (r = 0.46, r = 0.56*), association with bush vs. association with climbing beans (r = 0.66**, r = 0.72**). These data will be confirmed in other locations and seasons but suggest that selection and testing of bean varieties, as well as progeny evaluation, may be carried out in the most convenient or lowest cost system available.

Technology Packages

To determine the relative importance of certain agronomic practices, the possible components of a "technological package" for beans, experiments were planted in CIAT, Popayán and Montería. In each trial the complete package was compared

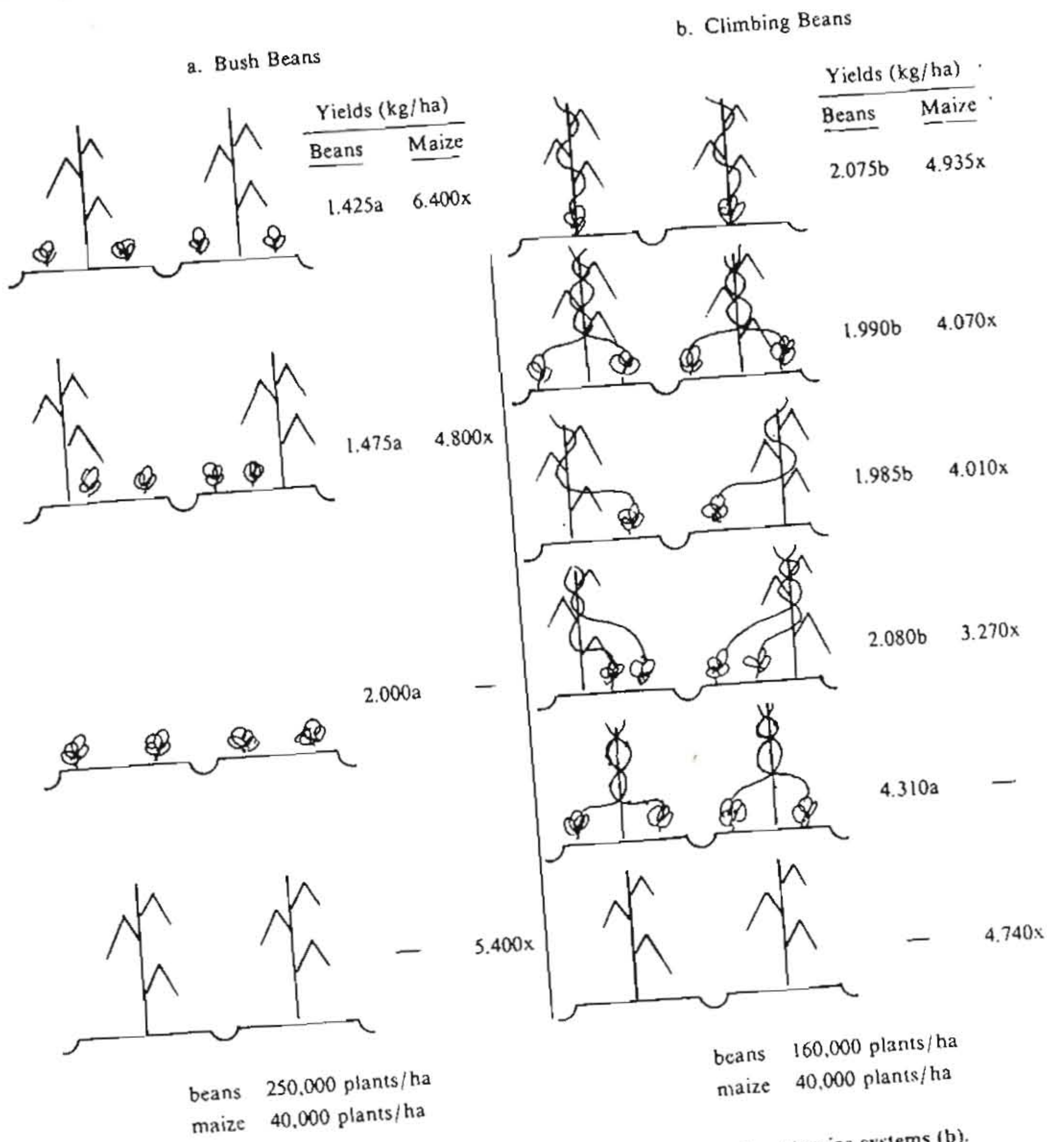


Figure 30. Comparisons of several bush bean/maize (a) and climbing bean/maize systems (b).

with various treatments in which, in turn, each component was left out; an absolute check without any cultural practices was included.

Figure 31 shows the effect of using seed free of internally-borne pathogens (clean), the use of beds, disease, insect and weed control, irrigation, liming and fertilization on bean yields. In each trial cleaned seed of a different black-seeded variety was used, except for the "minus clean seed" treatment in which no special precautions were taken to ensure seed of highest quality. Yields in Montería were extremely low because of unfavorable climatic conditions and an infestation of nutsedge, which was not controlled by the herbicides used.

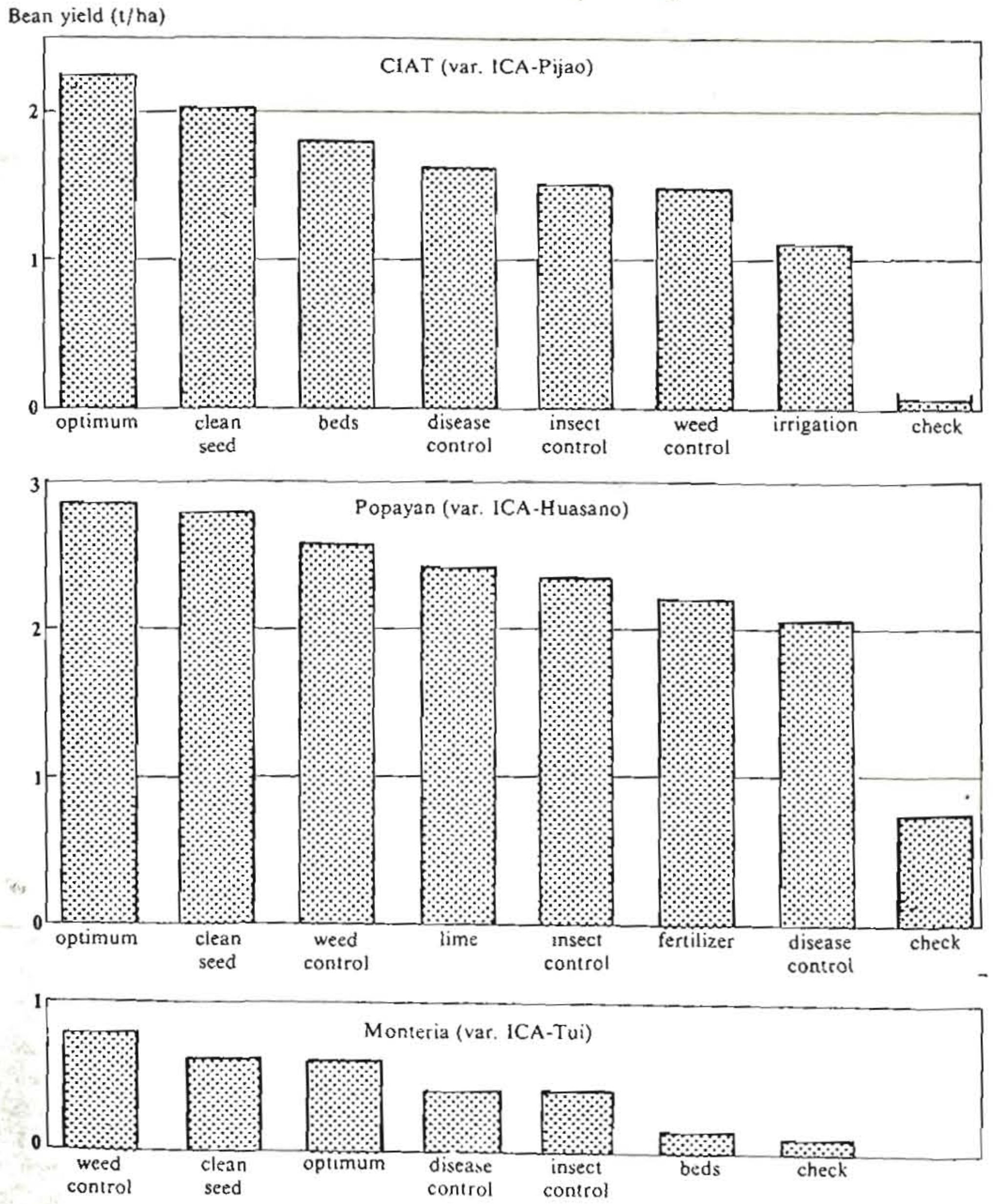


Figure 31. The effect of agronomic practices on the yield of three black bean varieties grown in CIAT, Popayán and Montería.

In all, the use of seed free from internal pathogens had the least effect on yield. This is contrary to other reports in which large yield increases were obtained with the use of "cleaned" as compared to "farmers" seed (see also p. A-7). In the present trials however, the seed used was of relatively good quality, with little more disease incidence than had the cleaned seed.

In CIAT, the lack of irrigation during the dry period between flowering and maturity affected yield most profoundly, with the lack of disease, insect and weed control reducing yields 27, 34 and 34 percent, respectively. The absolute check gave zero yield clearly demonstrating the need for proper cultural practices in bean cultivation.

In Popayán, the factors most influencing yields were disease control, fertilization and insect control, in the absence of which yields were reduced by 30, 28 and 19 percent, respectively. Residual fertilizers from the previous semester masked to some degree the effect of P-fertilization; virgin soil without P-fertilization normally yields only 20-30 percent of fertilized plots (see following section).

In addition to experiment station trials, several experiments were planted on small farms in collaboration with the Colombian Coffee Growers Federation in the Restrepo region (1,500 meters elevation, 1,300 millimeters rainfall). This thesis project focused on the introduction of new technology to farmers with limited resources. Results from the first season (Table 24) indicate a potential for high yields among small farmers using improved technology and plant materials. In bush varieties tested in four locations, yields of Calima variety currently used by farmers was significantly lower than yields of introduced varieties under both systems of production and both levels of technology. Four varieties in monoculture and one black-seeded variety in association with maize gave bean yields over 2 t/ha using improved technology (increased density, granular insecticide at planting and a low level of chemical fertilizer).

Table 24. On-farm yields (kg/ha) of bush and climbing beans at Restrepo, Colombia, with two systems and two levels of technology.

Bean identification	Color	Monoculture System: T (farmer technol.)	Monoculture System: T (impr. technol.)	Associated with Maize: T (farmer technol.)	Associated with Maize: T (impr. technol.)	Overall mean
Bush Beans (mean of two trials)						
P459	Black	1,807a[1]	2,291abc	707abc	2,073a	1,720a
P302	Black	1,589a	2,439a	750ab	1,663bc	1,610ab
ICA Tui	Black	1,711a	2,331ab	652abc	1,664bc	1,590ab
P524	Cream	1,698a	2,032 bcd	836a	1,476bcd	1,511 bc
P756	White	1,165bc	1,744 d	432 c	1,470bcd	1,203 d
P643	White	1,475ab	1,953 d	605abc	1,590bc	1,406 c
ICA Linea 17	Red	979cd	1,291 e	528 bc	1,200 d	1,000 e
P758	Brown	1,674 a	1,964 cd	582abc	1,798ab	1,505 bc
Calima	Red	780 d	1,086 e	452 c	576 c	724 f
Mean		1,431	1,903	616	1,501	1,363
C.V. (%)		20.7	14.3	36.9	17.5	-

Cont

Table 24. Continuation.

Bean identification	Color	Monoculture System: T (farmer technol.)	Monoculture System: T (impr. technol.)	Associated with Maize: T (farmer technol.)	Associated with Maize: T. (impr. technol.)	Overall mean
Climbing Beans						
P525	Black	1,176a	1,570a	624a	1,048a	1,105a
P259	Brown	678bcd	1,431a	351b	672ab	783bc
P364	White	1,021bcd	1,324ab	369b	832a	887 b
P449	Brown	455cd	917bc	263b	800a	609c
P589	Cream	858abc	1,243ab	424ab	673ab	800bc
Radical	Red	389d	682c	304b	227b	401d
Mean		763	1,195	389	709	764
C.V. (%)		28.9	21.8	35.9	46.6	

[1] Values not followed by the same letter are significantly different at the .05 level of significance by the L.S.D. method.

Introducing improved technology increased bush bean yields by 33 percent in monoculture and by 144 percent in association with maize. Climbing bean yields from two marginal locations showed the same tendencies, with a maximum yield of 1,570 kg/ha for cultivar P525 in monoculture in one trial. These results indicate that varieties and technology can be adapted to farm conditions, and give the small farmer significant production increases.

Time of seeding

The time of seeding trial in Popayán (1975 Annual Report) was repeated this year. Figure 32 shows the influence of seeding date on yield with and without insect and disease control. Because of the extended cropping sequence, disease and insect damages were more severe than in the previous year and yields were zero during eight months of the year. Without proper control even under protected conditions yields decreased from 2.7 t/ha in the June seeding to 61 kg/ha in the October seeding because of excessive rainfall during October and November.

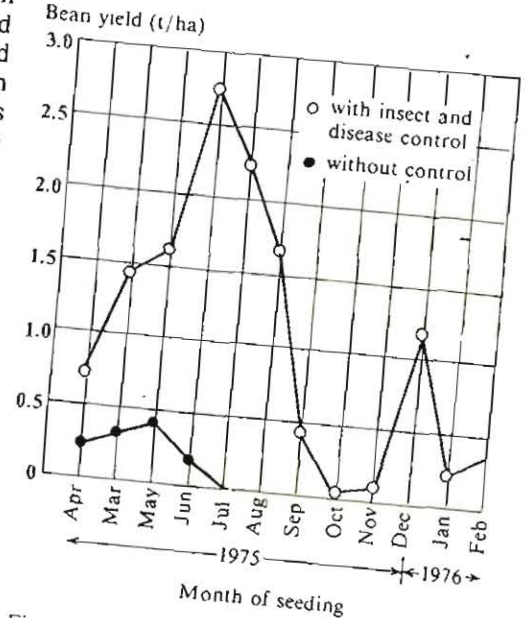


Figure 32. Effect of month of seeding in Popayan on the yield of Guali beans grown with and without control of insects and diseases.

SOIL FERTILITY

Tolerance to Low Phosphorus

A total of 176 promising bean accessions were screened in Popayán for tolerance to low levels of soil phosphorus. Beans were seeded in single rows in plots having phosphorus treatments of 0 and 300 kg P_2O_5/ha, applied as triple superphosphate (TSP) in bands. Figure 33 shows that plant growth without applied phosphorus was extremely poor compared with luxurious growth at the high phosphorus level. Maximum bean yield obtained without phosphorus was 0.97 t/ha while at the high phosphorus level, maximum yield was 3.96 t/ha. With no phosphorus added the most tolerant variety yielded 44 percent of that produced with high phosphorus, while on the average, percentages were as follows for the various bean colors: white, cream, yellow beans (16%); brown and gray beans (19%); red, pink, purple beans (20%); and, black beans (21%).

Further studies are in progress to confirm these differences using intermediate levels of phosphorus. Given the low availability of phosphate fertilizer in many countries and the limited credit available to many farmers, the results could be of major significance.

Levels and Sources of Phosphorus

This research was done in cooperation with the International Fertilizer Development Center (IFDC). Figure 34 shows the response of beans to various levels and sources of applied phosphorus in Popayán (see also CIAT Annual Report, 1975). A positive response to application rates as high as 400 kg P_2O_5/ha was obtained. Though TSP produced the best response, relatively soluble rock phosphates from Gafsa (Morocco), North Carolina (U.S.A.), Sechura (Perú), and Huila (Colombia) also gave good responses. Yields with more insoluble rock phosphates from Tennessee and Central Florida (U.S.A.) were lower but still significantly better than the control. The agronomic effectiveness of the sources followed closely their solubility in *N* ammonium citrate (Fig. 34), a commonly used measure of "available" phosphate. A critical phosphorus content in the leaves at flower initiation was determined to be 0.35-0.4 percent.

Figure 33. Screening of bean varieties for tolerance to low levels of phosphorus. Each row is one variety with beans in foreground grown without phosphorus while the same varieties in the background have received 300 kg P_2O_5/ha.

Lime x Phosphorus Interactions

Manganese toxicity symptoms have been observed in Popayán experiments in beans where previous heavy fertilization had produced a decrease in soil pH. Liming such soils is the most effective way to eliminate manganese toxicity but at the same time, can reduce the effectiveness of rock phosphates. The interaction of lime and phosphorus was studied using three levels (0, 200 and 400 kg P_2O_5/ha) and three phosphorus sources (TSP and Gafsa and Huila rock phosphates) at four levels of lime (0, .5, 2 and 6 t/ha).

Figure 35 shows the effect of phosphorus levels and liming on yield. Although the Gafsa rock was slightly better than TSP at 0 lime and slightly poorer at the high lime level, there were no significant differences among the phosphorus sources. At low liming rates response to phosphorus was significant, but at the high lime levels, there was no phosphorus response (some residual phosphorus remained from a previous crop). Above 0.5 t/ha of lime applied, beans responded mainly to the application of lime. The negative response to the lowest lime application was unexpected considering that lime consistently increased pH, decreased exchangeable aluminum (Fig. 36a) and slightly decreased manganese. However, both the exchangeable calcium in the soil and the calcium content of the leaves was lower at 0.5 ton lime than at 0 lime, while the phosphorus content (Bray I) of the soil reached a minimum at the 2 t/ha lime level, both for the residual phosphorus as well as the recently applied phosphorus treatments (Fig. 36b). Thus, liming was beneficial by increasing pH and calcium and decreasing toxicity of aluminum and manganese but at low levels was detrimen-

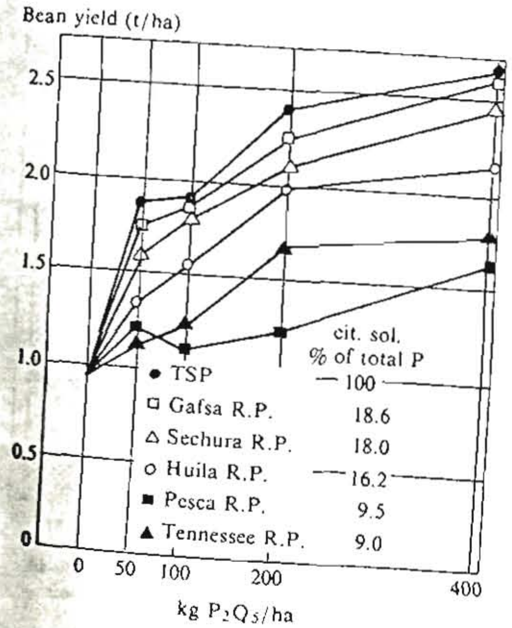


Figure 34. Response of beans to various levels of phosphorus applied as triple superphosphate (TSP) and various rock phosphates (R.P.) in Popayán.

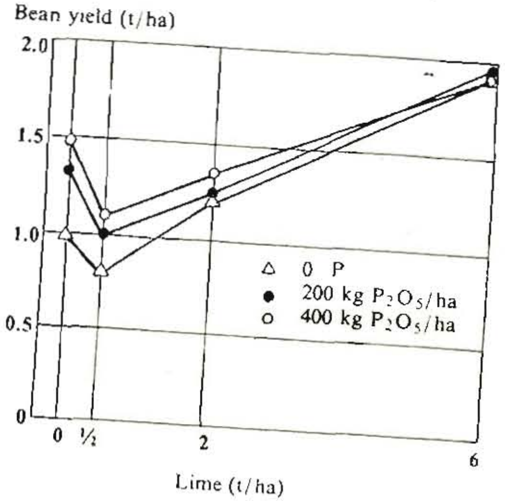


Figure 35. The effect of the application of lime and phosphorus on bean yields in Popayan. Curves are the average of three phosph...

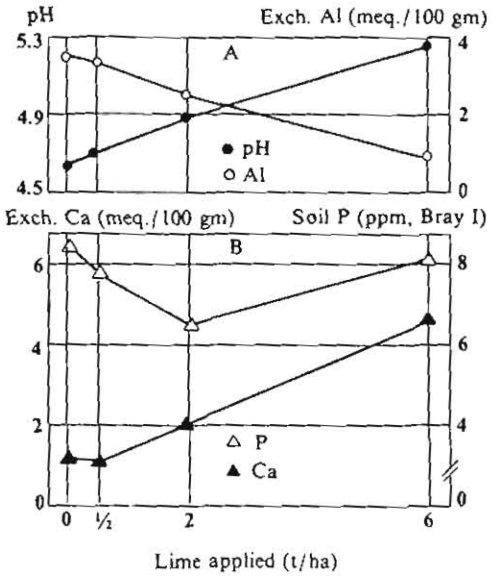


Figure 36. The effect of lime applications on soil pH, exchangeable Al, exchangeable Ca and available P in Popayan. Curves are the average of three levels and three sources of P.

tal because of decreased phosphorus availability as well as reduced phosphorus and calcium dissolution from the rock sources. Yields were best correlated with exchangeable calcium and aluminum in the soil, and were highest with more than 4.5 meq calcium and less than 1.5 meq aluminum/100 g soil. The critical calcium content of leaves was 1.44 percent.

Foliar Application of Phosphorus

In soils like those of Popayán with a very high phosphorus-fixing capacity, foliar applications of phosphorus could supply small quantities to the plant without fixation by the soil. However, foliar application must be combined with soil phosphorus application to ensure foliar development sufficient to spray and the right combination of soil and foliar applied phosphorus is difficult to determine.

Figure 37 shows the result of the foliar application of various phosphorus sources compared to the check and to soil applied phosphorus. All plots received 150 kg P_2O_5/ha as incorporated basic slag, resulting in a relatively high yield for the check. The best foliar treatment was that of three applications of 2.4 percent $NH_4H_2PO_4$ which increased yields 225 kg/ha while applying only 6 kg phosphorus/ha. Part of the beneficial

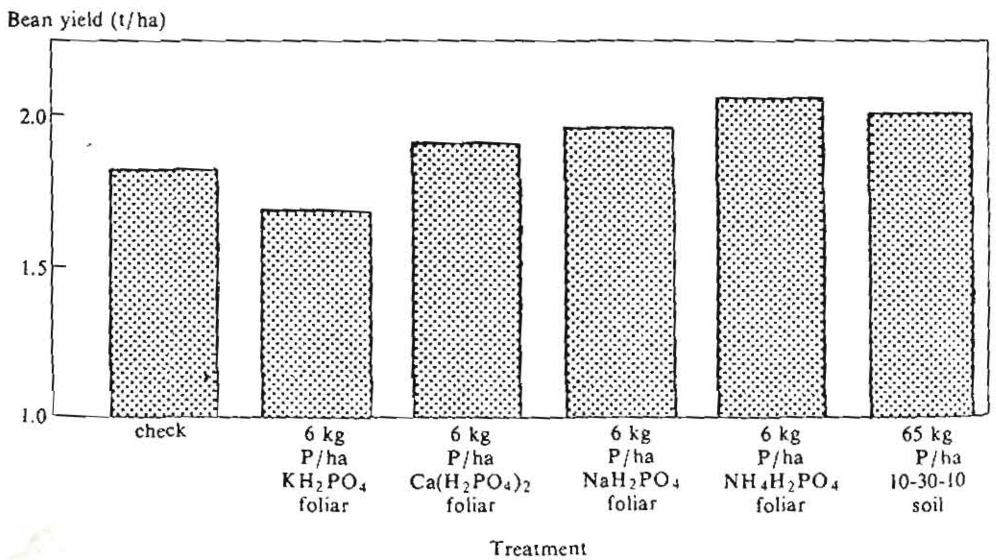


Figure 37. Effects of soil and foliar applications of various phosphorus sources on bean yields.

effect may be due to the nitrogen in the source. Other sources were not very effective, because of the high basal soil application. Studies using potassium polyphosphate and urea in foliar dressings are continuing.

PHYSIOLOGY

Physiological studies on yield limiting factors and adaptation characteristics continued during 1976, under irrigated, fertilized and protected conditions at CIAT.

Growth and Development

Bean growth and development studies concentrated on the cultivar P566, a material representative of several type II varieties showing high yield and relatively wide adaptation (see p. A-33). The results of two semesters (1975A and 1975B) of growth analysis with P566 are compared in Figures 38 and 39 and in Table 25. Leaf area development, node structure and pod number are very similar for the two semesters although total yields differed 19 percent. Climatic data for the two semesters were very similar with respect to temperature and solar radiation. The main

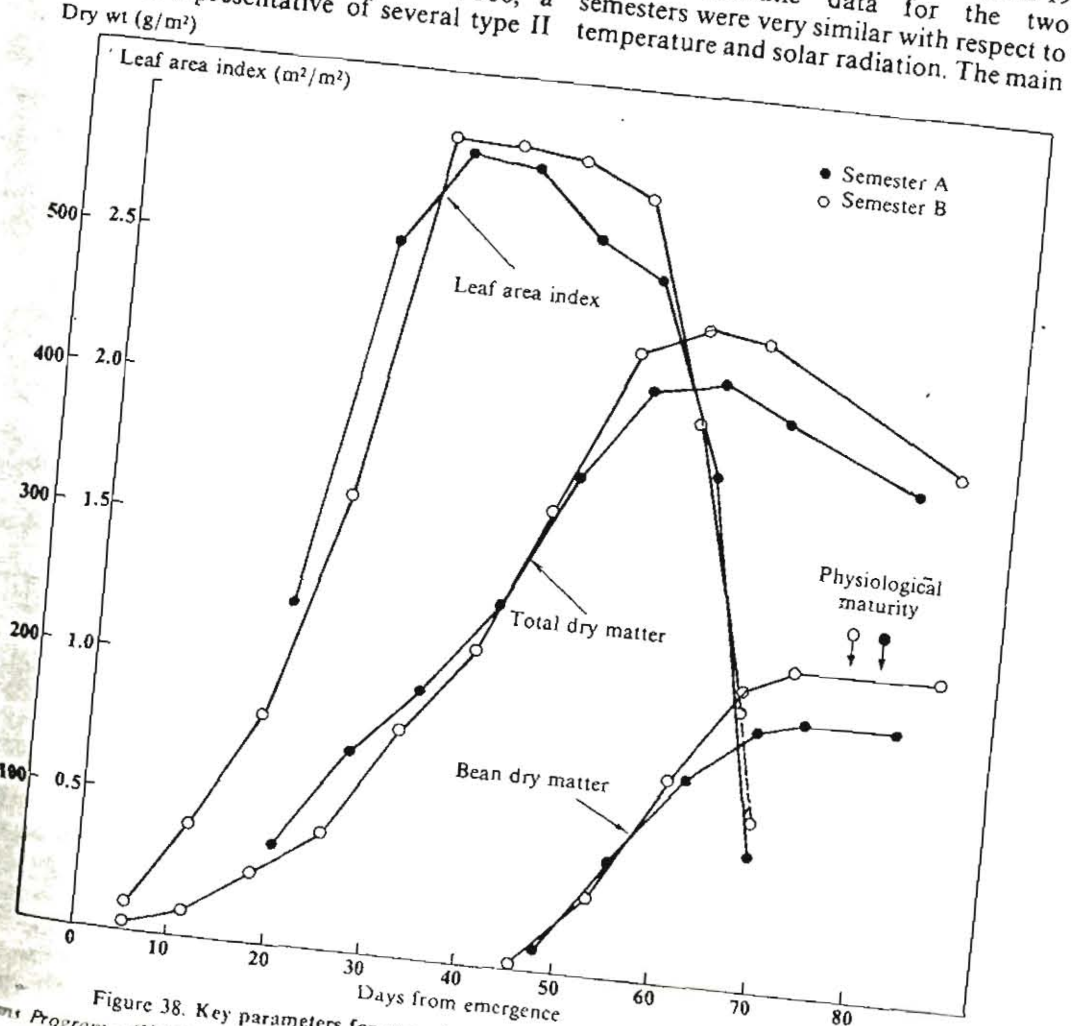


Figure 38. Key parameters for accession P566 in growth analy...

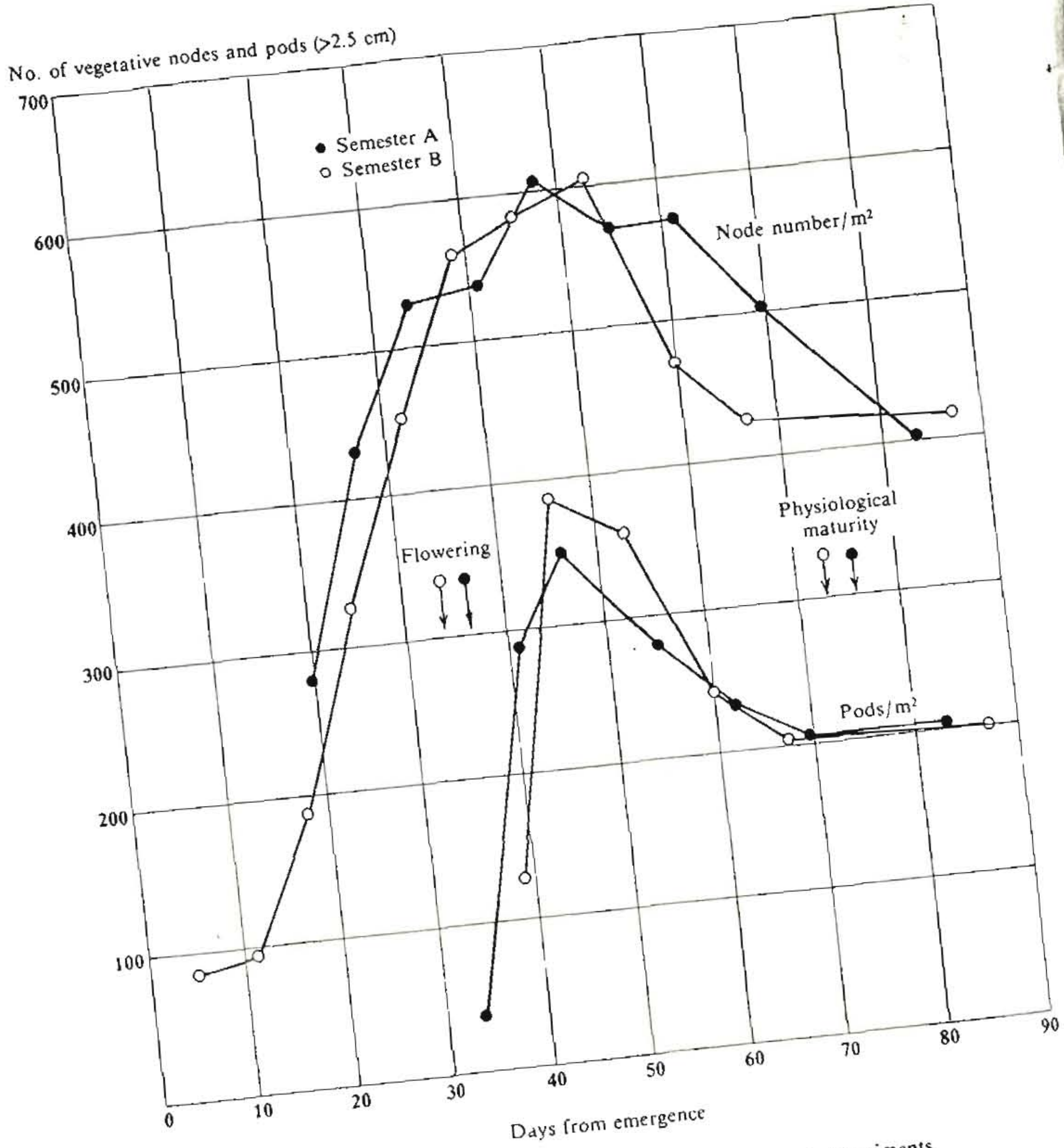


Figure 39. Key parameters for accession P566 in growth analysis experiments.

yield component associated with this yield difference was the number of mature beans per pod. The crop in the first semester lodged more extensively resulting in poor canopy structure after flowering and, possibly, lowering the efficiency of the ... higher proportion of yield borne on the branches in semester A also suggests that lodging may have stimulated greater pod set on branches.

The vertical distribution of yield components for semester B is shown in Figure 40. Yield variation is strongly associated

Table 25. Yield and associated final harvest parameters for accession P566 in growth analysis experiments in two semesters at CIAT

Parameter	Semester A	Semester B	(A/B x 100) %
Yield (t/ha, 14% moisture)	2.28	2.71	(119)
Yield (g/m², dry wt)	195.85	232.89	(119)
Bean size (mg/bean)	191	191	(100)
Harvest index (%)	0.57	0.62	(109)
Total dry matter (g/m²)[1]	342.6	376.7	(110)
Stem weight (g/m²)	81.70	82.20	(101)
Pod wall weight (g/m²)	65.08	61.50	(94)
Node number/m²	410.9	421.7	(103)
Raceme number/m²	111.8	118.3	(106)
Pod number/m²	210.4	205.5	(98)
Stem height (cm)	71.86	87.18	(121)
Root weight (g/m²)	17.95	16.66	(93)
Bean number/pod	4.87	5.93	(122)
Bean yield/pod (g)	0.93	1.13	(122)
Yield on branches (%)	22.6	12.0	

[1] Above ground dry matter at maturity not including petioles and leaves.

with pod set at each node and with the number of mature seeds per pod; both parameters peaked at node 7. Mean bean size did not vary greatly among those nodes contributing most to yield.

Close observations of flower and pod development in P566 showed effects similar to those reported previously (1975 Annual Report). Figure 41 shows pod set data by node position on the main stem and by position within each raceme. The within-raceme positions are numbered consecutively from position 1 nearest to the main stem. Usually two flowers are borne simultaneously at each position on either side of the raceme. The critical features of this data are: (a) the high proportion of flowers at position 1 which set mature pods, and, (b) that nodes flowering earlier in the sequence usually bear mature pods. Flowers opening later on the same raceme (in positions 2 and 3) usually abscise. At all nodes the day of flower opening for position 1 is usually three to four days earlier than position 2. The pod set ratio for position 1 on the respective racemes decreased from 100 percent at node 5 to 0 at node 14. The presence of earlier fertilized pods on the raceme appears to strongly influence the abscission of later formed flowers.

The yield profile in Figure 40 directly reflects this pod set pattern. Node 7, with the earliest flowers and high pod set, has the highest yield per node. The importance of time of flowering is further demonstrated in Figure 42 where the flower production/m²/day and the number of mature pods which were produced from those flowers are plotted. Almost all pods were produced from flowers opening in the first 10 days of the 20-day total flowering period. The peak of pod production occurred 3-4 days after the commencement of flowering. As was observed in 1975, pod set on branches in this variety is low. Flowering normally occurs later on the branches and they

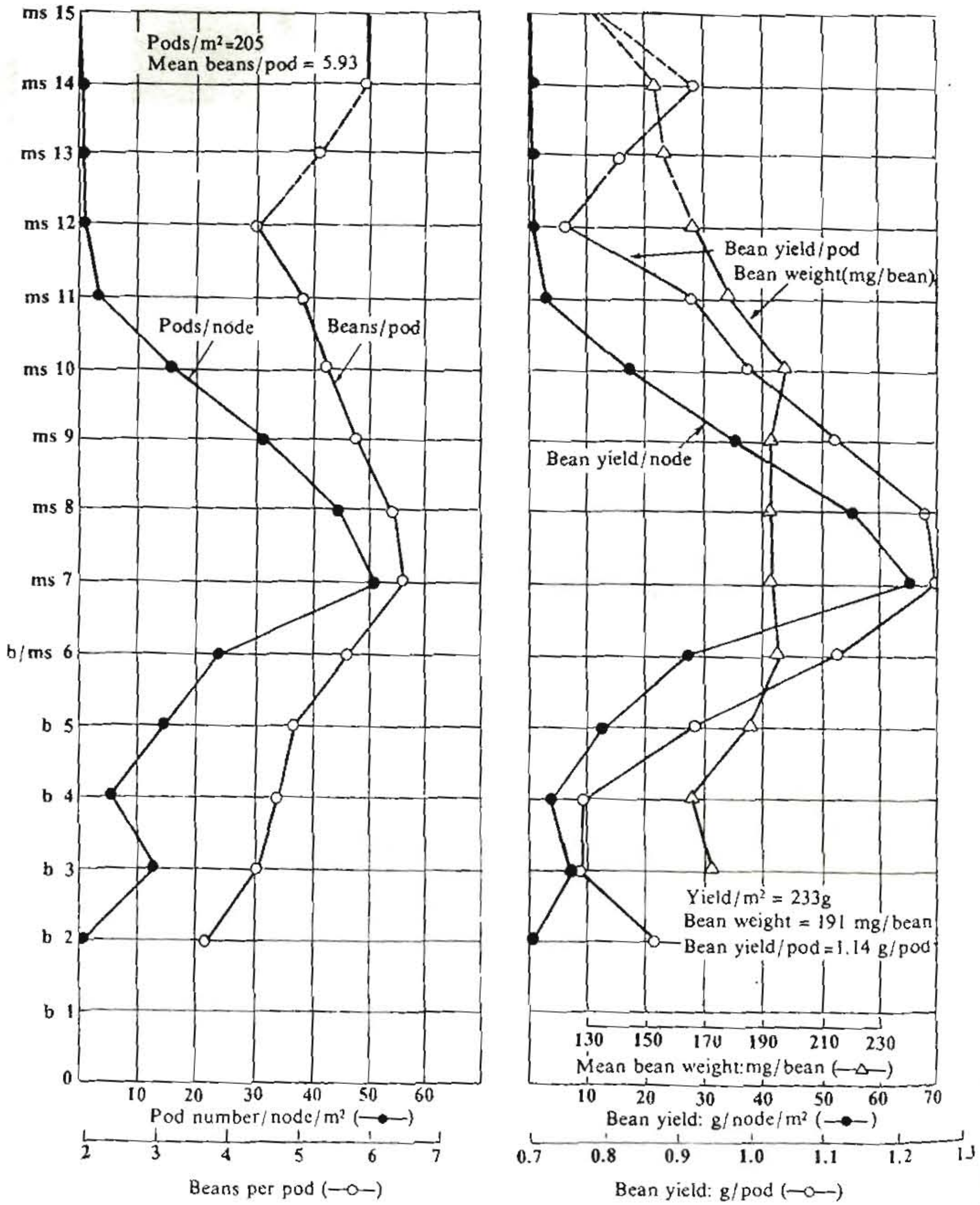


Figure 40. Distribution of yield components by leaf node position in the accession P566.

probably suffer greater competitive stress due to self-shading at the lower node positions and at the plant densities utilized in these experiments (30 established plants/m²).

Maximum leaf area in P566 usually occurs at about 12-15 days after flowering. Figure 43 shows the leaf area profiles at flowering and 15 days after flowering (maximum LAI). Green leaf area lost from

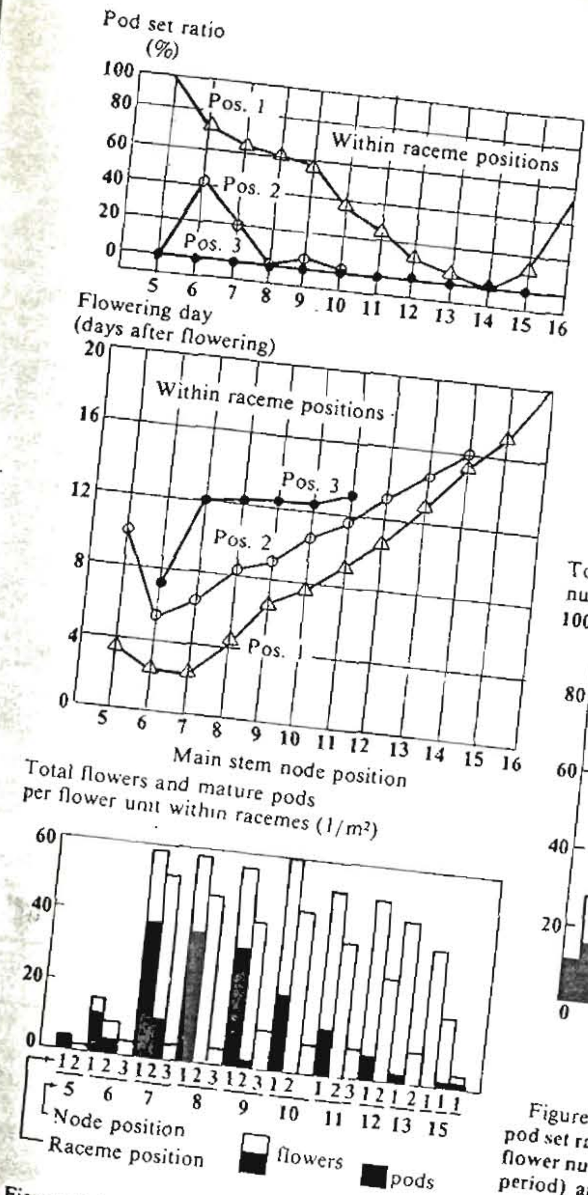


Figure 41. Relationship between flower unit within each raceme at each node position and flowering day of each flower unit and the pod set ratio for each flower unit on the racemes on the mainstem for Porrillo Sintético. Data of branches excluded due to high variability. Data obtained from eight plants observed daily; adjusted for the final plant density

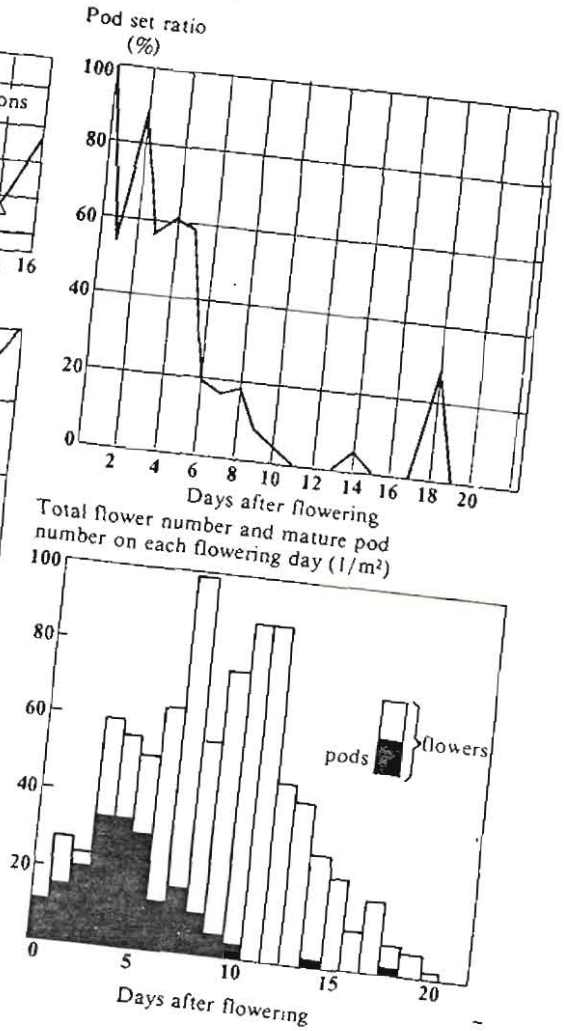


Figure 42. Relationship between flowering day and pod set ratio (the ratio of mature pod number to total flower number blooming on each day of the flowering period) and the actual number of flowers bloomed and pods produced per flowering day for Porrillo Sintetico. Data are the mean of eight plants observed daily and corrected for the actual plant stand at harvest.

the base of the canopy (nodes 3-7) is more than compensated for by new leaf area produced at nodes 8-15. Since the pod set on the upper nodes is very low, it is reasonable to assume that this new and active leaf area is contributing photosynthate during bean filling to the lower nodes where the majority of yield is borne. This loss of leaf area on the lower nodes has considerable relevance to post-

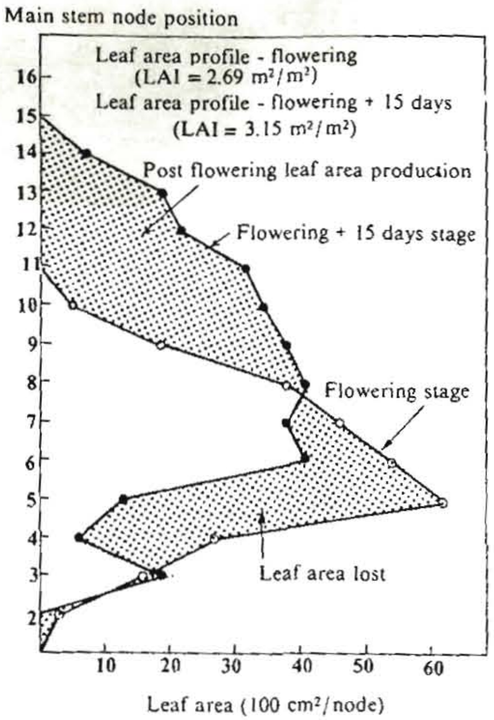


Figure 43. Leaf area profiles per main stem node position, including branches subtended at each node, for two growth stages in accession P566

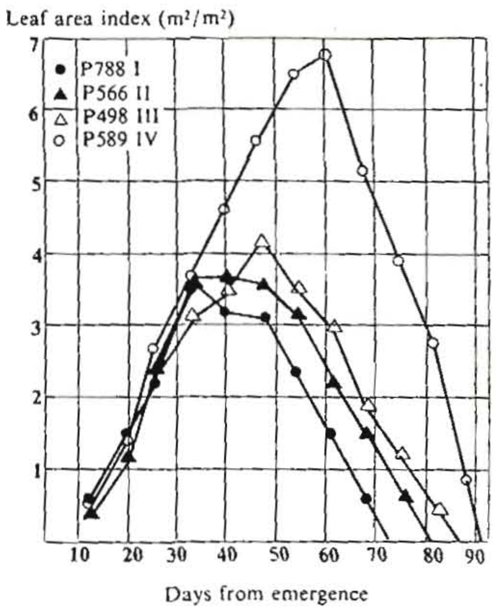


Figure 44. Leaf area index for four contrasting varieties in growth analysis experiment.

flowering decreases in nitrogen fixation (see page A-30).

Table 26. Comparison of attributes among four varieties of *Phaseolus vulgaris* used in growth analysis studies at CIAT.

Accession Growth habit	P788 I	P566 II	P498 III	P589 IV
Bean yield (g/m² 14%)[1]	2.85	2.65	3.05	4.54
Bean yield (g/m² dry wt)[2]	262	282	296	393
Pods/m²	311	255	294	315
Beans/pod	2.65	2.97	4.07	6.22
Bean weight (mg/bean)	317	186	247	200
Percent yield on branches (%)	76	16	80	5
Days to flowering[3]	31	39	40	47
Days to physiological maturity[3]	77	82	90	96
Bean yield per day (g/day)[4]	3.70	3.23	3.39	4.73
Total dry matter (g/m²)[5]	454	494	475	583
Harvest index (%)	57.8	57.5	62.5	67.4
Percentage abscission (pods 3cm)[6]	65	52	59	55
Percentage abscission (pods 3cm)[6]	10	17	17	18
Percentage abscission total [6]	75	69	76	73

1 Yield from 10m² yield sample area
2 Yield of subsample (1 m²) used for yield profile in Figure 10
3 Days from seeding
4 Seeding to physiological maturity
5 Minus leaves and petioles at maturity
6 Percentage of total flowers bloomed m²

A growth analysis of four accessions (P788, P566, P498 and P589) with contrasting growth habits (types I-IV) was carried out.

The climbing bean (P589) under supported monoculture conditions developed a maximum LAI (Fig. 44) of 6.8 at about 60 days while the three non-climbers attained maximum LAI's of 3.5-4.0. Types I and II differed mainly in time at which leaf area decline commenced while P498 (type III) showed a later and slightly higher peak with a similar rate of decline. Table 26 summarizes other key characteristics. The yield differences between the bush bean varieties (types I-III) were associated with maturity (bean yield/day values similar). The determinate variety P788 used in these trials showed excellent yield potential as across a wide range of varieties and environments, type II varieties normally outyield the more determinate types. The higher yield level of the climbing variety (P589) is also shown in Tables 21 and 22. The overall pod abscission pattern of the four varieties is quite similar with a slight tendency for the type I variety to abscise more small pods (flowers opened up to a pod size < 3 cm). No conclusions can be drawn at this stage with respect to the existence of major genetic differences in pod abscission rates.

The pattern of flower and pod formation during flowering is illustrated in Figure 45. The other varieties show trends similar to those discussed earlier for P566, especially with respect to the importance of the earlier formed flowers. The type III variety had the longest flowering period (28 days) and the determinate type I, the shortest period (13 days). P788 (I) and P566 (II) differed in pattern of flower set during the first five days of flowering with pod abscission during this period being much more severe in the tupe I plant. Cyclic flower production is also apparent, particularly in the indeterminate varieties.

Yield profiles for the four growth habits are presented in Figure 46 with the yield per node strongly correlated with pod number per node and mature beans per pod. Differences in branching pattern

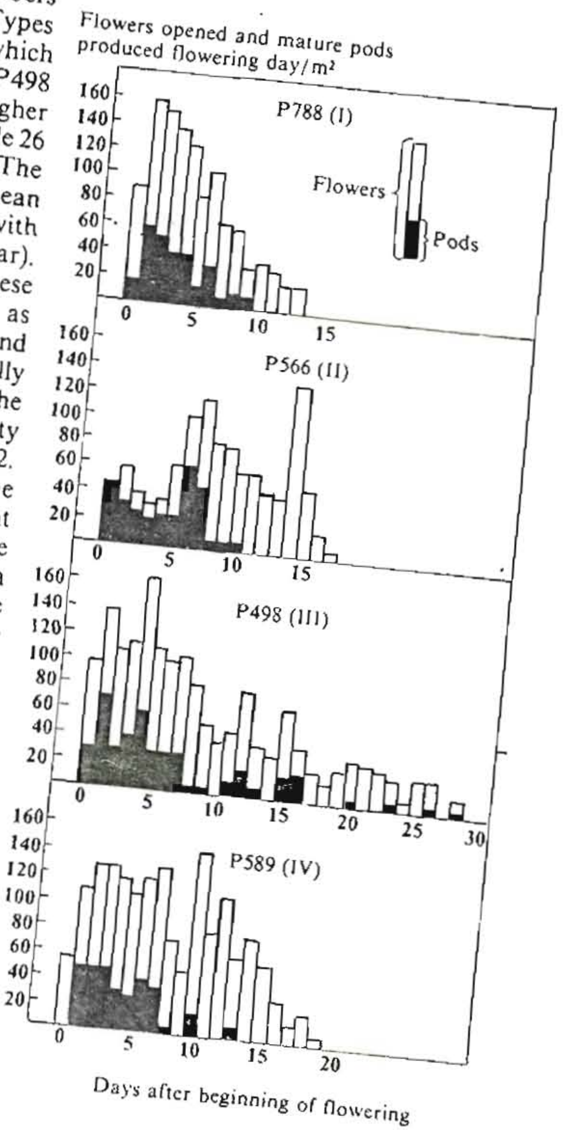


Figure 45. Flower and pod production/m² with respect to days from flowering commencement in four varieties in growth analysis experi...

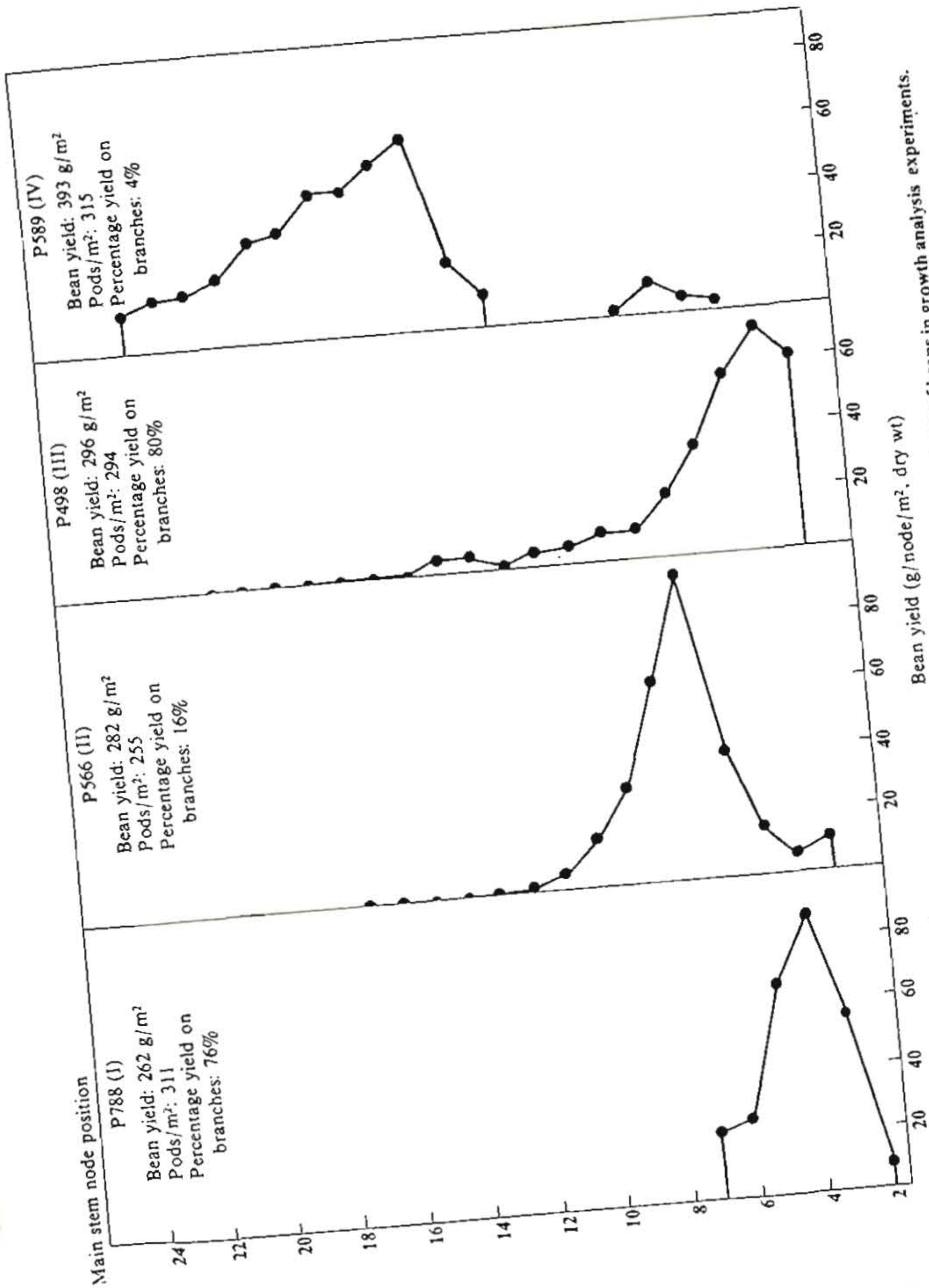


Figure 46. Yield profiles by node position (including branches) for four varieties of beans in growth analysis experiments.

between varieties are reflected in the yield profiles. Thus P498, a heavily branched, prostrate variety with good yield potential has a heavy yield concentration on lower nodes (3-7) where branches comprise 100 percent of the yield, while the relative lack of branches in P566 results in a yield peak at a higher node level. The low proportion of yield on branches in P589 is rather typical of the strong climbers at high density. While variation within growth habits exists for the proportion of yield borne on branches, the varieties used here appear typical of the majority of germplasm lines within each habit.

Contrasting growth habits differed in the proportion of nonreproductive dry matter production after flowering (Fig. 47). The determinate P788 produced 50

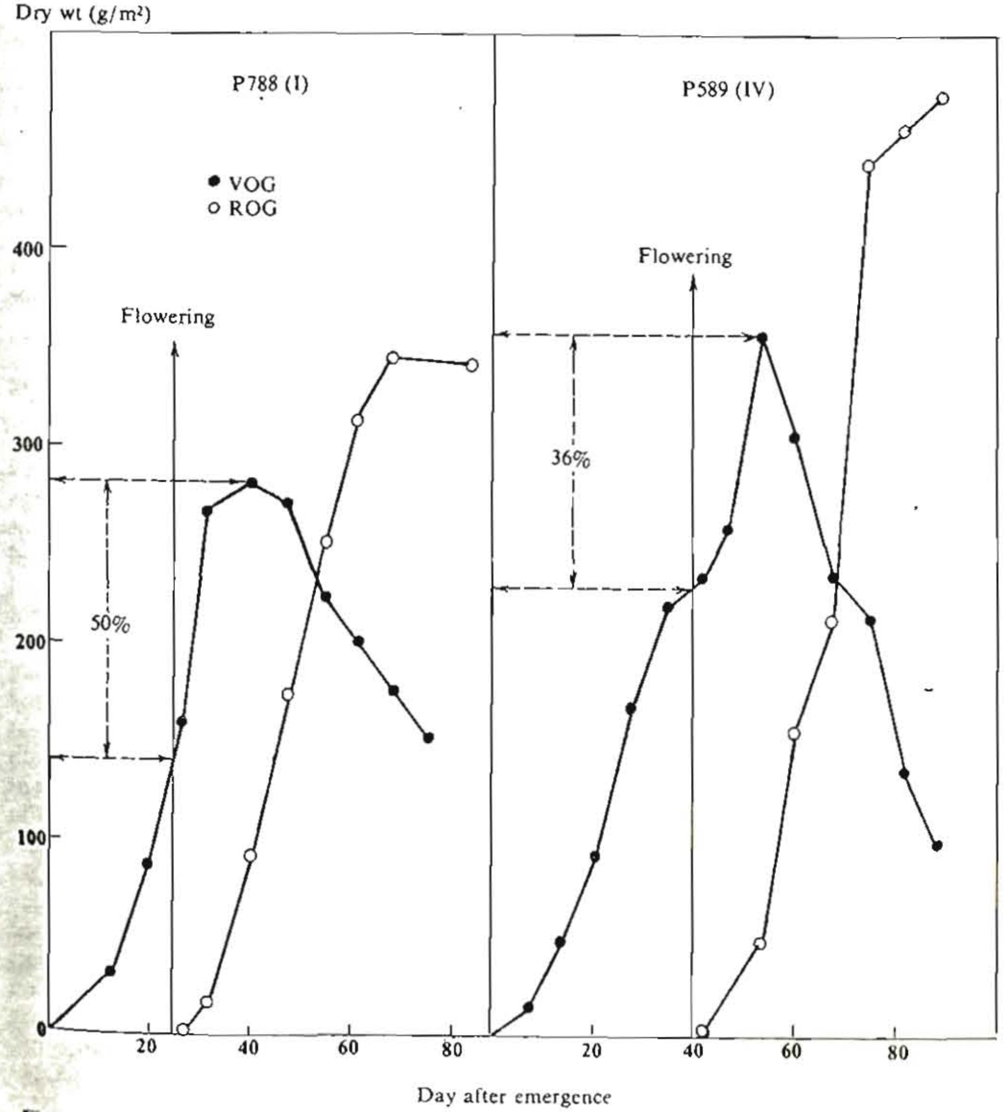


Figure 47 Vegetative (VOG) and reproductive organ growth (ROG) in two contrasting varieties in growth analysis experiments.

percent of the maximum dry weight of its vegetative organs after flowering whereas P589 (IV) produced only 36 percent. Post-flowering growth of branches in the determinate variety compensates for the increased dry matter production in main stem structures in the indeterminate variety.

Carbohydrate (sugars and starch) determinations were carried out on the main stem and branches. Results in 1975 suggested large differences in stem storage between varieties. Data for the 1976 experiment for three varieties is presented in Figure 48 for grams of stem carbohydrate/m². Maximum storage (about 10-12 days after flowering) occurs just prior to the commencement of rapid bean

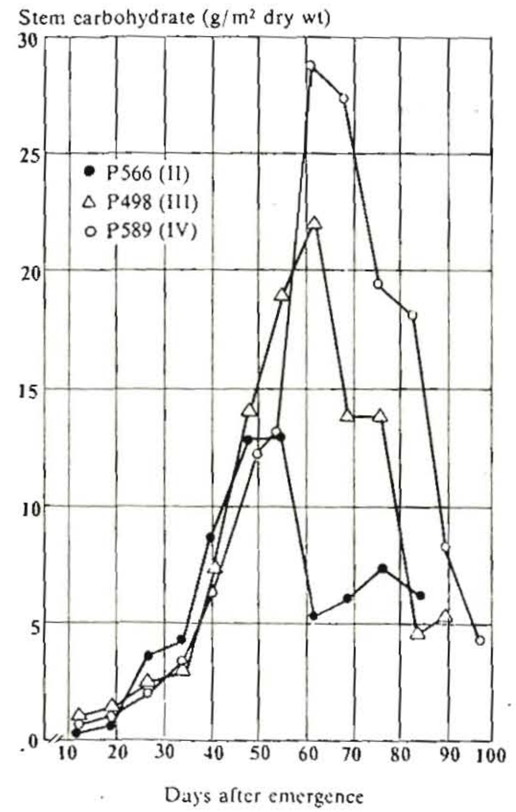


Figure 48. Total stem carbohydrate (sugar and starch) for three varieties of beans, in growth analysis experiments.

filling and subsequent pod filling reduces storage levels considerably in all varieties. The actual quantities transferred from the stem are relatively small in relation to final bean yield, i.e. from 2-5 percent. The relationship between the stored photosynthate and pod abscission has not yet been studied intensively. However, the varieties in this study with very similar levels of flower abscission (Table 26) had quite different levels of stem storage in the period immediately after flowering. The results for P589 (IV) very sharply contrast to results for Trujillo 3 (IV) (CIAT Annual Report, 1975).

Crop Manipulation

A series of experiments was carried out with P566 and other selected varieties to study the influence of alterations in crop structure and/or environmental conditions on yield potential.

Extension of crop cycle using photoperiod response

The photoperiod sensitive P566 (grade 2 on a 1-5 scale of increasing sensitivity) was grown in a 16 h 30 min photoperiod as described in 1973. Growth analysis and final yields were measured on a series of plots at various distances from the light source. By using a slightly higher intensity light (lamps at 2.5 m height), preflowering was extended 15 days. The yield response comparing control plots 19-20 m from light (effective daylength ≃ 12 h 20 min) with "treated" plots 1-2 m from the lights was from 2.77 t/ha to 4.12 t/ha. The data in Table 29 compares key parameters measured at four distances from the light source. The majority of the yield increase occurred on branches, with increased branching at nodes 7-14 in the upper part of the canopy where light conditions and leaf efficiency are better than at lower levels. An increase in pod number/m², partly influenced by reduced pod abscission and partly through an increase in total flowers bloomed/m², was the only yield

Table 27. Crop parameters for accession P566 measured at varying distances from a linear light source with a photoperiod of 16h 30 min.

Parameter	Distance from light source (m)			
	1-2	7-8	13-14	19-20
Bean yield (g/m²) (14%)[1]	412	347	298	277
Pods/m² (2)	314	255	214	208
Beans/pod	5.73	5.78	5.65	5.49
Bean weight, mg/bean	197	201	210	207
Nodes on mainstem/m² (3)	520	460	407	370
Nodes on branches/m² (3)	268	272	147	179
Total dry matter (g/m²)[4]	778	646	614	532
Harvest index (%)[5]	49	50	51	54
Maximum leaf area (m²/m²)	3.96	3.76	3.01	2.66
Days to flowering[6]	51	43	36	36
Days to physiological matur.[6]	95	84	71	69
Bean yield/day, (g/day)[7]	4.04	3.81	3.82	3.64
Percent yield on branches (%)	82	39	18	14
Percent total abscission[8]	59	-	-	68

1 Mean of four replications, plot area 8 m²/replication
2 All yield components derived from 1m subsample area
3 Nodes counted at maturity
4 Minus leaves and petioles at maturity, 1m² subsample
5 Determined on 1 m² subsample
6 Days from seeding
7 Seeding to physiological maturity
8 Percent of total flowers bloomed on eight plants per treatment

component changing significantly with treatment. The harvest index was lower near the lights suggesting excessive vegetative growth over the longer growth period available. The light treatment did not significantly alter crop growth rate, the differences in dry matter accumulation being due solely to the increased period of growth. While bean yield/day, increased slightly, most of the 49 percent yield increase was associated with increased length of growing season. LAI (Fig. 49) was ≃ 1.3 units higher near the lights compared to the control plots with a similar rate of decline of LAI after the maximum in all treatments.

The results of this experiment, as in 1975, demonstrate one direction for yield improvement, namely, an extension of the preflowering period, allowing greater node development and hence increased sink potential while at the same time increasing leaf area index (source) in order that the crop has sufficient capacity to fill the increased sink available. Though there was no lodging in this experiment, improved lodging resistance could be necessary to maintain post-flowering canopy integrity, given the increased vegetative development.

The results of a shading experiment with P566 are presented in Figure 50. The shade treatment (66% interception) was applied in each of nine growth stages of one week commencing 20 days before flowering. Significant yield reductions occurred during the first four weeks after flowering. In the first two weeks after flowering (periods 4 and 5) pod number was most reduced, in the third week (period 6) bean number per pod was reduced while in the

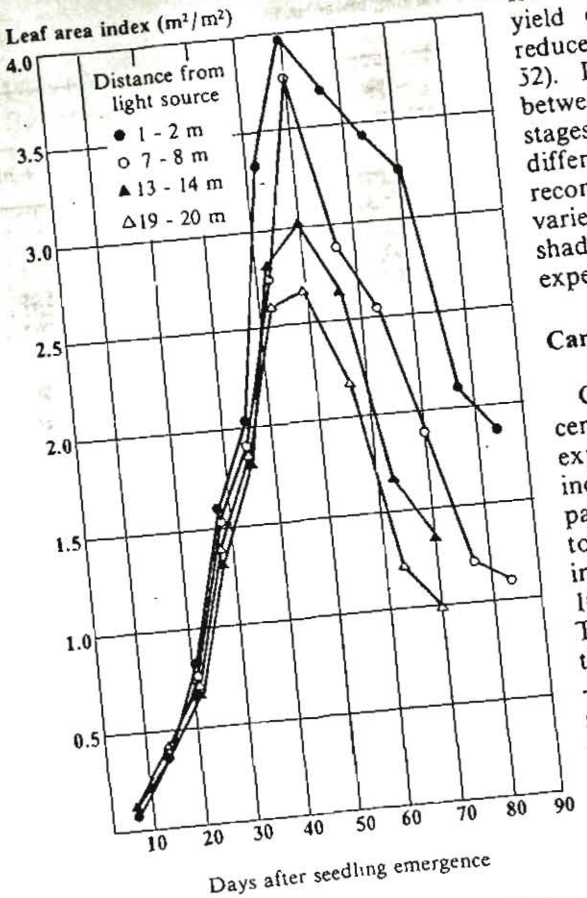


Figure 49. Leaf area index for accession P566 at four distances from the lights in photoperiod extension of growth cycle experiments.

weight was most affected by shading. Sequential determination of the yield components is clearly demonstrated in this experiment. Reduced photosynthate supply, particularly during the immediate post-flowering period, increased flower and small pod abscission.

In another experiment (Fig. 51) with a range of varieties and with two-week shading intervals the maximum yield reduction occurred at different growth stages according to variety. P459 and P302 showed the largest reduction at 14-28 days after flowering while the other varieties ... 0-14 days from flowering. In all cases however, the yield component most associated with reduced yield was pod number/m² (Fig. 52). Difference in source-sink balance between the varieties at different growth stages probably account for these differences. The variety P302 has been recommended to the Cassava Program as a variety showing less yield reduction due to shading for use in associated cassava-bean experiments.

Carbon Dioxide Fertilization

Carbon dioxide fertilization (CO_2 concentration 1,200 ppm) was used as an experimental tool to evaluate effects of increased photosynthate supply on yield, particularly on pod set. Transparent open-topped chambers, 1 m² in area, were placed in a crop of P566 at four growth stages of 10 days each. Results are summarized in Table 28. CO_2 significantly increased yield through higher pod set when applied from -2 to +8 days from flowering. The immediate post-flowering period is critical with respect to pod production from flowers which bloom in this period. The results suggest that increased photosynthate supply applied over a short period can increase pod set. The importance of total photosynthate supply during the pod set period is clearly demonstrated.

Canopy Support and Artificial Lodging

Three treatments involving degrees of canopy support in P566 were applied to evaluate the importance of canopy structure on yield. Control plots (S_1) were compared with two horizontal wire supports, 30 and 60 centimeters high on either side of the row (S_2) and a 2-meter trellis with a vertical array of strings (S_3). Lodging occurred at flowering in S_1 and to some extent in S_2. The variety showed a natural tendency to climb on the strings in S_3 reaching a final canopy height of 140 centimeters compared to a maximum prelodging height of 65 centimeters and 75 centimeters in S_1 and S_2, respectively (Fig.

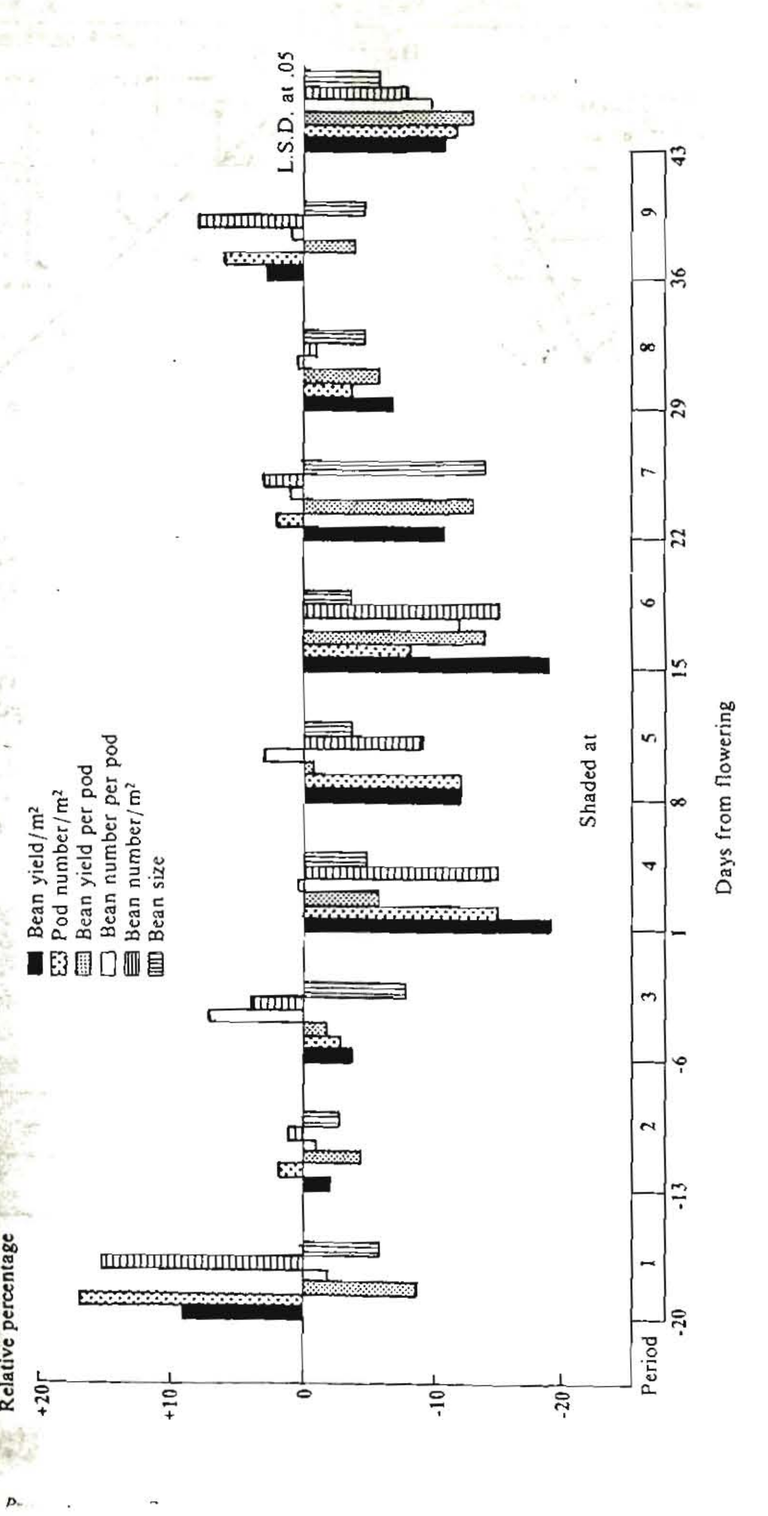


Figure 50. Effect of shading at different growth stages on bean yield and yield components for P566. Data are expressed as relative values (control plot: 100%)

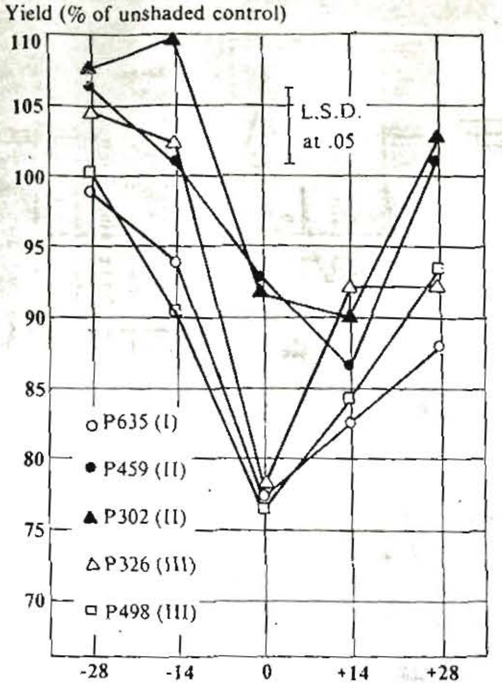


Figure 51. Effect of shading at five growth stages on five varieties of beans.

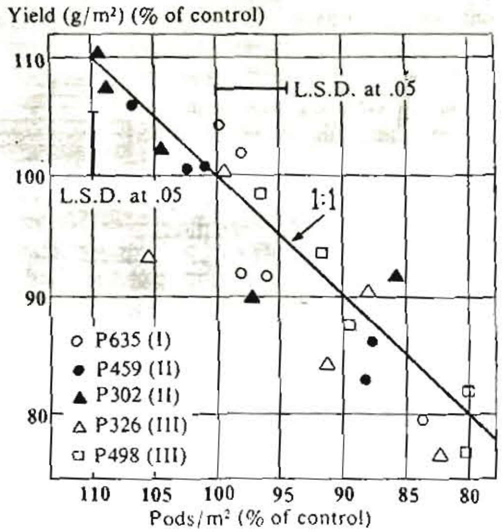


Figure 52. Relative reduction in yield and pods/m² for five bean varieties. Results are expressed as a percentage of unshaded control plots in each variety.

53). S_3 had a longer leaf area duration particularly on the upper nodes of the main stem although maximum LAI values were similar. Increased node production 20-40 days after flowering and increased pod set on these upper nodes in S_3 over the other treatments was also observed. The yield increase from 2.77 t/ha to 3.55 t/ha (28%) from S_1 to S_3 was mainly associated with increased pod set on the upper nodes of the main stem. S_3 reached physiological maturity 13 days after S_1 due to later flowering and pod set on the new nodes formed late in the growth cycle.

Determinations of total carbohydrate content in the main stem (Fig. 54) at various stages shows a higher level of stem storage in S_3 and a slower rate of decline

Table 28. Response[1] to carbon dioxide fertilization at four growth stages in accession P566.

Growth[3] stage	Yield (g/m²)		Pod number/m²	
	Control	CO_2	Control	CO_2
-2 - +8	330	363 (110)[2]	267	297 (111)[2]
+8 - +18	297	310 (104)[4]	268	282 (105)
+18 - +28	272	286 (105)	253	264 (104)
+28 - +38	288	298 (103)	265	271 (102)
L.S.D. at .05	31.4		23.3	

[1] Mean of five chambers in control and CO_2 treatments at each stage
[2] CO_2 as % of control treatment
[3] Days from flowering
[4] Mean of three replications only

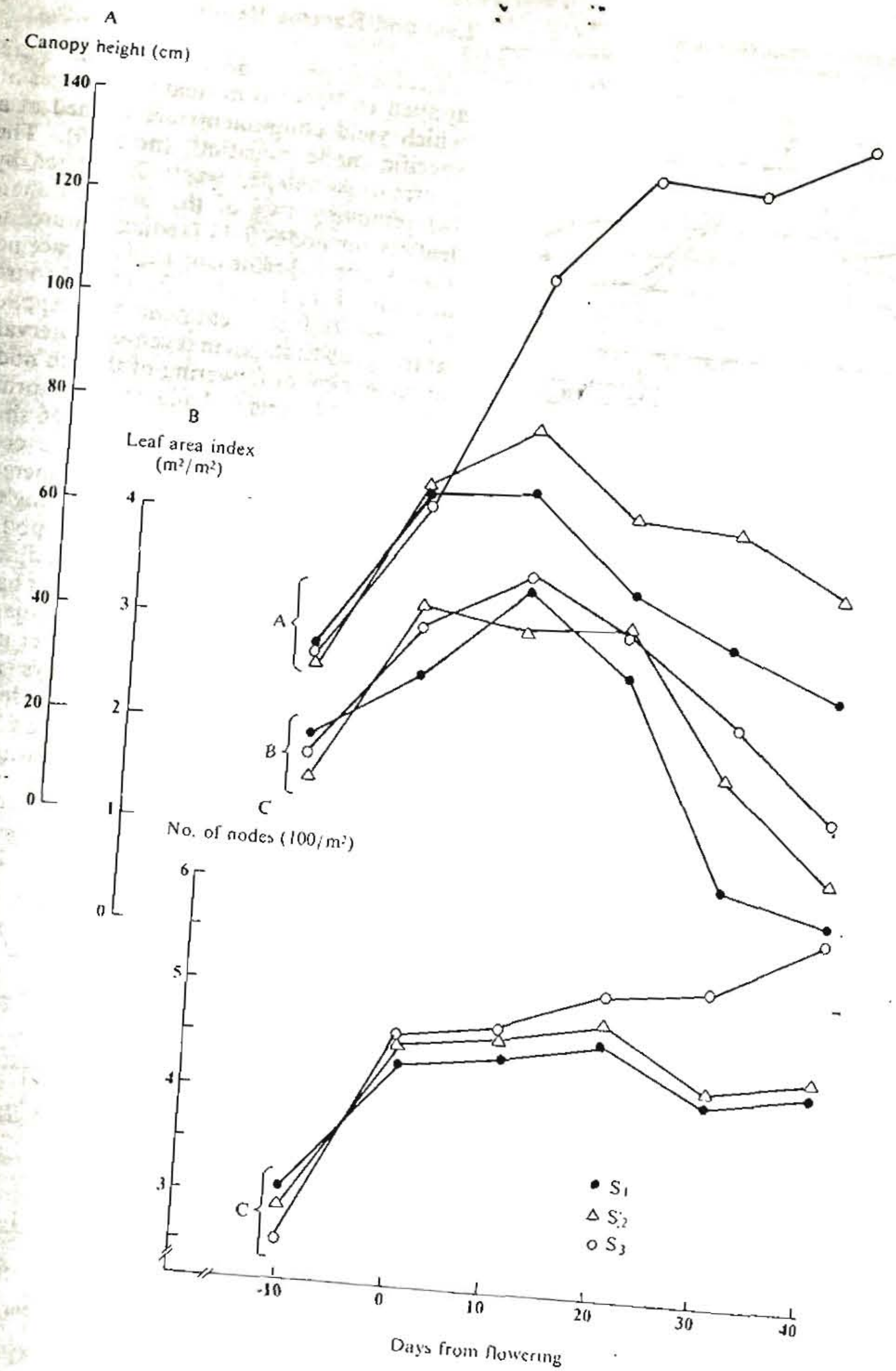


Figure 53. Canopy height, leaf area index and total node number of three support systems (S_1, S_2, S_3) at different growth stages in P566.

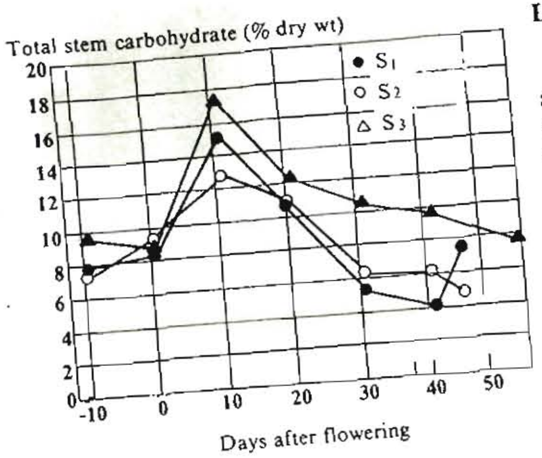


Figure 54. Total carbohydrate (sugar and starch) content in stems of three support systems (S_1, S_2 and S_3) at different growth stages in P566.

after the maximum (10 days after flowering). This evidence of excess photosynthate availability in the supported system during a period when increased pod set occurred may suggest that excess photosynthate was available above the requirements for pod set and pod filling.

Artificial lodging (Fig. 55) at seven growth stages (at one-week intervals) was applied to P566 by rolling the plots with a bamboo pole. Prior to the rolling treatment all artificially lodged plots were supported using system 2 described in the previous support experiment. Maximum yield reduction, compared to the fully supported control, occurred during the immediate post-flowering period with yield reduction associated both with decreased pod set and decreased bean number/pod. The results of various shading and lodging experiments at different growth stages show a striking similarity suggesting that lodging disturbs canopy light conditions and reduces photosynthate supply during the pod set and filling stage. Reasons for the yield differences in Table 25 are now more clearly identified and related to the effects of reduced photosynthate supply on the number of mature beans/pod.

Leaf and Raceme Removal

Leaf and pod removal treatments were applied to P566 to evaluate the stages at which yield components are formed at a specific node position (node 9). The source-sink balance was manipulated by (a) removing two of the three trifoliate leaflets on nodes 7-11 (reduced source to node 9), or, (b) removing adjacent racemes at nodes 7, 8, 10 and 11 (increased source for node 9). Both treatments were applied at five growth stages in seven-day intervals, commencing at flowering of the 9th node, to randomly selected plants in a normal crop stand. The results in Figure 56 show the relative value of the yield and components of yield at node 9. A large increase in yield at 0 and 7 days from flowering was directly associated with increased pod set when the competition from adjacent racemes were removed. On the other hand, two-thirds leaf removal from all adjacent nodes had a small depressing effect upon yield. Leaf removal at 14 days after flowering also had the additional effect of reducing beans per pod. Effects on bean size were non-significant in all treatments.

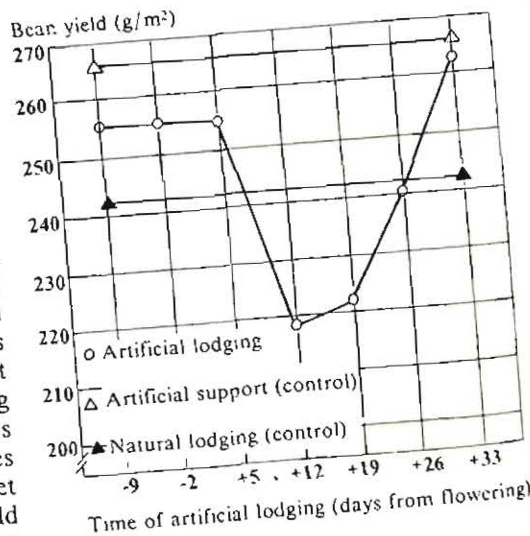


Figure 55. Effect of time of artificial lodging on yield of P566 in relation to natural lodging and artificially supported plots

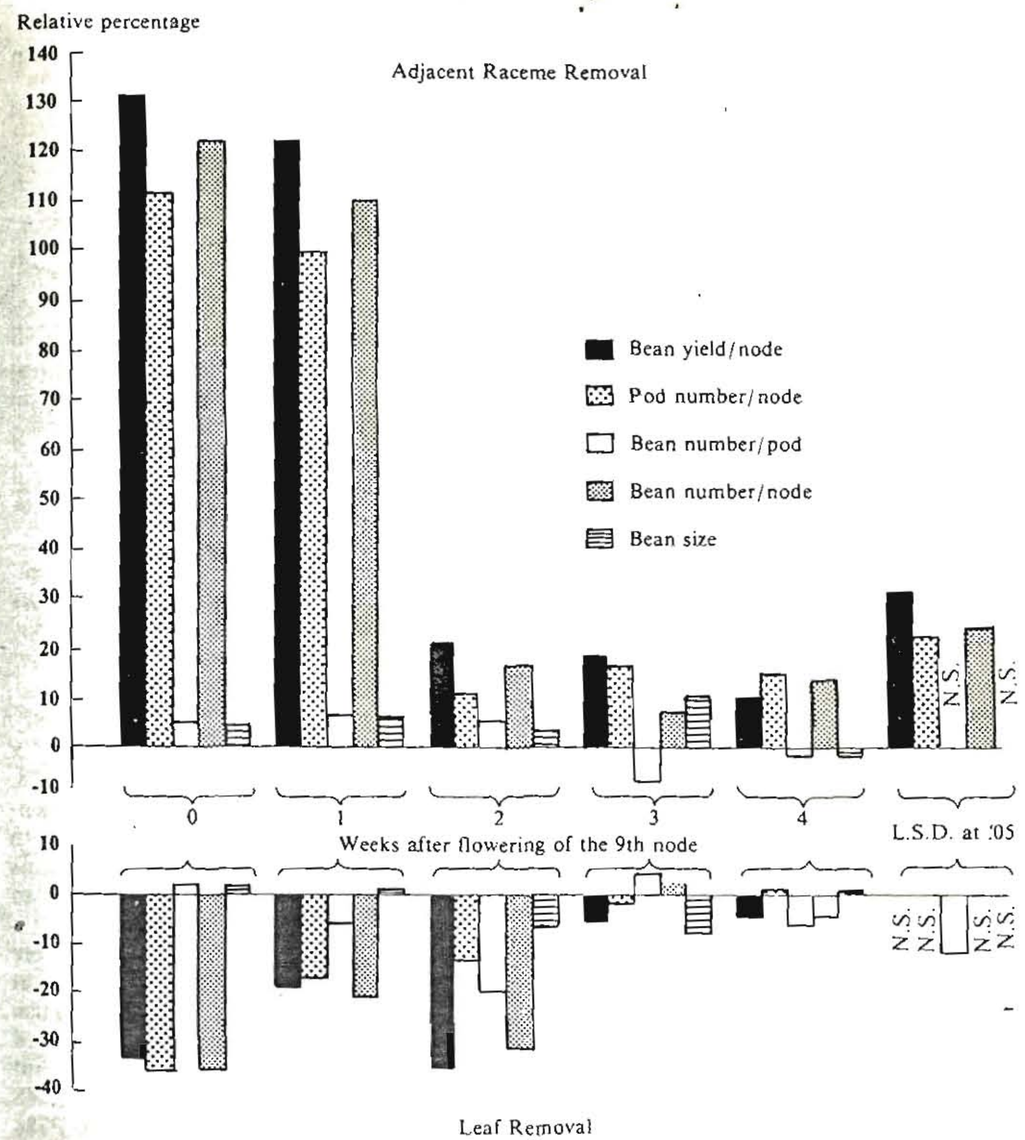


Figure 56. Effect of adjacent raceme removal (at nodes 7,8,10 and 11) and two-thirds leaflet removal (at node 7,8,9,10 and 11) at different growth stages of the 9th node on bean yield and yield components of the 9th node of P566. (Data expressed as relative percentage (control plants: 100%).

The increased pod set at node 9 was due to increased flower set at position 2 on the raceme whereas reduced pod set was due to increased abscission at position 1. The results suggest that pod set is controlled strongly by photosynthate supply. The smaller effects of leaf removal are possibly due in part to the mobility of photosynthate within the plant from leaf area above node 11.

In the same P566 crop leaf removal treatments were applied to three strata: lower (nodes 3-6), middle (nodes 7-10), and upper (nodes 11-14). All leaves were removed (branches included) on the flowering day of the central node in each strata so that source reduction would occur at the same physiological stage. Four days separated this date from the lower to the upper strata. Mean yield results on a whole plant basis for each treatment are presented in Figure 57. Though all leaves of the middle stratum were removed at flowering, the relative importance of the middle stratum was maintained, the earlier pods set at these nodes continuing to act as strong sinks which attracted photosynthate from the upper and lower strata. There appears to be no real independence of each source-sink nodal unit. Photosynthate is highly mobile in the plant, moving during pod growth to the earliest fertilized pods in a highly polarized manner. C^{14} studies will be necessary to confirm these observations. The importance of endogenous hormone production by the young growing pods and seeds in controlling the direction of photosynthate movement is also an important consideration.

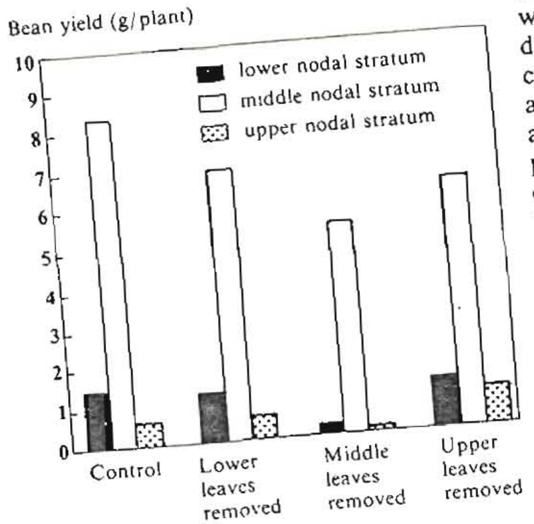


Figure 57. Effect of leaf removal from lower, middle and upper nodal strata on bean yields of each nodal stratum for P566.

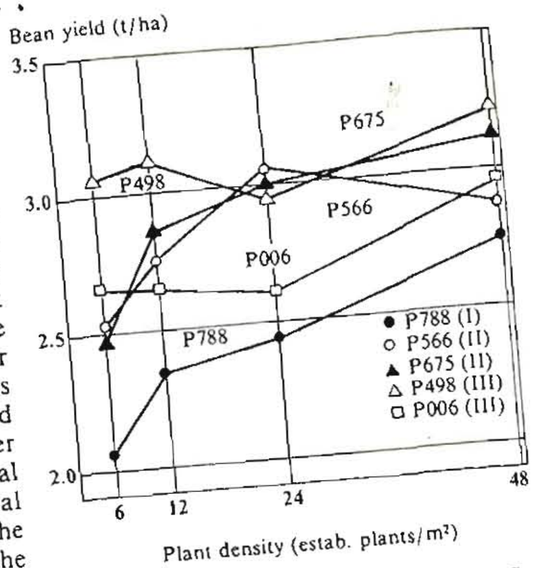


Figure 58. Yield response to plant density in five varieties of beans from growth habits I-III.

Response to Plant Density

The yield results of a plant density x variety experiment are shown in Figure 58. The varieties were selected as representative of the three nonclimbing growth habits (I-III). In two previous experiments with P498 (III) almost no response to density was observed. These results are confirmed in the present experiment where a yield of more than 3 t/ha was obtained at a plant density of 6 plants/m² (60.000 plants/ha). The type II varieties showed density response up to 24 plants/m² but P566 showed a negative response at 48 plants/m². The determinate variety P788 showed a strong response at all densities. This latter result is not typical of density response data from previous experiments. The variety P006, also type III, showed no density response over the range of normal plant densities in the field. These results bear on discussions of plant ideotypes for breeding selections (see page A-67).

Adaptation

Components of adaptation in dry beans are under study at CIAT and elsewhere and include photoperiod sensitivity, drought resistance (La Molina, Peru), resistance to excess water, and stability of growth habit (Cornell University, U.S.A.).

Photoperiod Screening

A further screening of promising lines was conducted in 1975B. Included in this second group were a number of type IV promising lines. The complete results for all material screened to date are presented in Table 29 by growth habit and in Table 30 by days to flowering. The definition of the photoperiod response classifications is given at the top of each table. Of the 278 individual genotypes screened, 40 percent are photoperiod insensitive at CIAT field temperatures (mean 23.8°C). The existence of photoperiod insensitive climbing beans (IV) is an important finding though there appears to be a higher proportion of type II varieties in the insensitive group (4 days delay) than type IV. Further evaluations will be necessary in type IV to confirm these preliminary observations. The search for late (days from planting to flowering) photoperiod insensitive lines continues. Many of the photoperiod insensitive lines shown in Table 30 as being late (>44 days to flowering in 12h 20min days) have not proved stable in this character in different sowings at CIAT.

Growth Habit Stability

Research in progress at Cornell University, in collaboration with CIAT, has shown that the phytochrome reaction directly controls the degree of climbing exhibited by bush bean varieties considered to be unstable in growth habit (CIAT Annual Report, 1974). The provision of a red light break of 15 min was sufficient to induce climbing in some varieties. Indeterminate genotypes showing stable growth habit did not tend to

Table 29. Summary of results for all materials screened in 1975 by photoperiodic response classification and growth habit[1]

Growth habit	Photoperiod response (days of flowering delay)[2]					
	(<4)	(4-10)	(11-20)	(21-30)	(>30)	Total
I	17 (40.5%)	4 (9.5%)	13 (31.0%)	6 (14.3%)	2 (4.8%)	42 100
II	65 (51.2%)	18 (14.2%)	34 (26.8%)	7 (5.5%)	3 (2.4%)	127 100
III	23 (37.1%)	12 (19.4%)	13 (21.0%)	11 (17.7%)	3 (4.8%)	62 100
IV	5 (10.6%)	5 (10.6%)	15 (31.9%)	12 (25.5%)	10 (21.3%)	47 100
Total	110 (39.6%)	39 (14.0%)	75 (17.0%)	36 (13.0%)	18 (6.5%)	278 100%

1 Data in table gives number of genotypes in each group
2 Days of flowering delay in 18h days compared to natural daylength of 12h 20m CIAT 3°N

Table 30. Summary of results for all materials screened in 1975 by photoperiod response classification and number of days to flowering in 12h 20 min natural daylength.[1]

Days to flowering	Photoperiod response: days of flowering delay[2] (<4)	(4-10)	(11-20)	(21-30)	(>30)	Total
25-29	-	-	1 (50.0%)	1 (50.0%)	-	2 (100%)
30-34	14 (73.7%)	1 (5.2%)	3 (15.8%)	1 (5.2%)	-	19 (100%)
35-39	43 (47.8%)	10 (11.1%)	26 (28.9%)	8 (8.9%)	3 (3.3%)	90 (100%)
40-44	44 (43.1%)	11 (10.8%)	29 (28.4%)	12 (11.8%)	6 (5.9%)	102 (100%)
45-49	7 (19.4%)	8 (22.2%)	12 (33.3%)	6 (16.7%)	3 (8.3%)	36 (100%)
50-54	3 (18.8%)	3 (18.8%)	4 (25.0%)	4 (25.0%)	2 (12.5%)	16 (100%)
55-59	2 (25.0%)	2 (25.0%)	1 (12.5%)	1 (12.5%)	2 (25.0%)	8 (100%)
60-64	-	1 (25.0%)	1 (25.0%)	1 (25.0%)	1 (25.0%)	4 (100%)
65-69	-	-	-	-	1 (100%)	1 (100%)
Total	113	36	77	34	18	278
%	41.7%	13.0%	27.7%	12.2%	6.5%	100

1 Data in body of table gives number of genotypes in each group.
2 Days of flowering delay in 18h days compared to natural daylength of ≃12h 20 min, CIAT 3°N

climb with this treatment. The response was reversible with a further period of infrared light. Preparations are under way to evaluate this method as a screening technique for growth habit stability under field conditions at CIAT.

Breeding Implications

Bean production in Latin America occurs under a wide range of climatic conditions, cropping systems and with variable levels of technological inputs.

Such differences must be recognized and plant types suggested which are appropriate to the major growing areas.

Following the experiments described in previous sections, four ideotypes have been defined and suggested to the breeding program as goals for growth habit, plant architecture and maturity selection. A summary of major features in each ideotype follows.

Ideotype A

Ideotype for short growing seasons. A type I variety with maturity of ≃75 days is suggested. The plant would require high seedling vigor and production of 8-10 nodes on an erect main stem before flowering. Branching should be minimal. Plant densities close to 250,000 plants/ha would be required since the low density compensation characteristics of type I genotypes appears poor. The ideotype could be expected to yield no more than 2.5 t/ha under reasonable conditions given the maturity limitations.

Ideotype B

Ideotype for high-yielding commercial conditions. This ideotype is suggested for higher levels of technology where environmental conditions (particularly length of growing season) are good and where plant densities can be maintained close to 250,000 plants/ha. Under such conditions, a late flowering (50 days or more) type II plant allowing high levels of node production prior to flowering, erect main stem and branches and with lodging resistance, seems to offer the best alternative, particularly where monoculture by mechanized means is practiced. P566 has many characteristics that could form a genetic base for the Ideotype B. Research on this variety has identified important yield limiting factors which must be manipulated genetically if higher potential is to be obtained.

Ideotype C

Ideotype for variable growing conditions and/or low technology. This ideotype is needed for variable rainfall conditions both with respect to length of growing season and to rainfall variability within season and/or for conditions of highly variable and often low plant density. Capacity to compensate for low and irregular plant distribution would be necessary, particularly for small farmer production conditions. P498 (Fig. 58) could form the genetic base for a type III ideotype with strong branching characteristics, relatively prostrate growth habit, a long flowering period, and with reasonable water stress resistance to flower abscission. The need for genotypes with different maturity classifications is probably greater in this ideotype than in the other three. The ideotype would need to have stable yield under difficult growing conditions but to respond when growing conditions are favorable. The ability to maintain the pod load out of contact with the soil surface would be an advantage.

Ideotype D

Ideotype for planting in association with maize. Climbing bean research suggests that strong climbing types with a capacity to yield well in association with maize are available. Research on yield limitations in climbing beans in association have commenced with a view to drawing up an ideal plant type in this category.

In all ideotypes it is envisaged that the genotypes would have wide adaptation features such as photoperiod insensitivity, temperature insensitivity (particularly with respect to flowering behavior), water stress resistance, excess soil water resistance and stable growth habit. Research is continuing on these adaptation features. Early results suggest that sources of variation exist for all of these latter characters within the [illegible] of these requirements for adaptation can be evaluated through the international testing of potential parents in the IBYAN and other programs.

BREEDING

Bean breeding focuses information from all program disciplines toward the production of genetic variability, seeking to recombine qualities such as resistance to important diseases and insects with high yield and desirable seed characteristics. It also pursues an orderly management of hybrid progenies which extracts all useful genetic variability from hybridizations.

The Bean Program's short-term breeding emphasis is on greater yield stability in the four major plant groups shown in Table 31. As indicated in this table, and in the agronomy section (page A-33), many black-seeded lines currently yield 2.5-3t/ha under protected conditions. While stabilization of such yields by incorporating disease and insect resistance factors is a reasonable, albeit ambitious goal, raising the yield potential by 0.5 t/ha in the same period would demand greater effort with much lower return. By contrast, the difference between existing and forseeable yields for the non-black beans appears greater, justifying simultaneous improvement for both increased yield and stability. The program expects to obtain red-seeded beans equal in yield to their black counterparts. Climbing bean yields of 2 t/ha in association with maize (see page A-38) are very promising, but given the low input levels of the small farm (where such associations predominate) will be unstable without genetic resistance to insects and diseases. Breeding in the short term for yield stability will benefit the small farmer by increasing yield, the commercial grower by reducing costs.

Table 31 also shows the disease and insect problems to which the breeding program has given major emphasis. Although the major factor determining these priorities was the importance of each problem to Latin American bean production, the availability of suitable resistance (donor) sources, the existence and importance of races/strains, and the ease or difficulty of screening large numbers of progenies with reasonable experimental precision, had also to be considered.

Table 31. Key characters for the short-term imporvement of four important plant groups of *Phaseolus vulgaris*

Bean group	Yield (t/ha) Present	Yield (t/ha) Sought	Key character under improvement
Black Bush	2.5-3.0	3.0 (stable)	CBMV, Rust, *Empoasca*, Variable maturity, Anthracnose.
Colored Bush	1.5-2.3	3.0 (stable)	CBMV, Rust, *Empoasca*, Indeterminate/Variable maturity, Anthracnose
Climbing (different colors)	2.0 [1]	2.5 (stable)	CBMV, Anthracnose, Rust, Photoperiod insensitivity
Commercial varieties	variable	3.0 (stable)	Specific factors requested by national programs

[1] Associated with 40,000 plants/ha maize yielding 4 t/ha

In the intermediate and long term we expect to raise the physiological yield potential of the species significantly, developing cultivars which are more efficient in their architecture, use of the available growing season, and carbohydrate and nitrogen metabolism. A clearer picture of the physiological requirements for higher yields in the different areas and production systems of Latin America is emerging (see page A-67) and already permits increased breeding for yield potential.

Table 33. Range and mean for yield of donors with major gene or field resistance to key production-limiting factors, used at CIAT during 1974-76[1]

Year	Number of donors: Total	Number of donors: With yield data	Yield potential (t/ha): Range	Yield potential (t/ha): Avg.
1974	7	7	1.9-3.3	2.5
1975	29	13	1.2-3.3	2.5
1976	58	27	1.9-3.3	2.7

[1] Donors with resistance to CBMV, rust, anthracnose, or *Empoasca*

Bean Hybridization Program

Both the number of new parents and of new crosses increased substantially in 1976 (Table 32); so too did the emphasis given parents and crosses holding the promise of segregants with desirable genes for multiple factors. To support the priorities shown in Table 31, extra weight has been given recently to common mosaic, rust, anthracnose, and *Empoasca* resistance in crosses and their progenies. Although extensive crossing has not yet been initiated with climbing beans (group 3, Table 31) many of the major gene resistance sources (i.e. P699 and P717 for rust), are of growth habit IV and segregate recoverable climbing types in filial generations.

Continued screening of germplasm collections by pathology has produced resistance sources higher yielding than many of the poorly-adapted sources initially used in crosses (Table 33). Similarly, our confidence in yield sources has increased through continued testing of promising lines and cultivars by the different disciplines, particularly agronomy. The best yielding and most stable representatives of each major color group are well-known, and receive high priority in terms of crossing frequency. Non-black parents combining yield potential with more than one resistance factor are scarce; a high priority has been placed

Table 32. Cumulative number of parents and hybrid progenies with single and multiple resistance factors during 1974-76.[1]

	Common mosaic	Rust	Anthracnose	*Empoasca*	Two factors	Four factors	Total
Parents							
1974	5	2	1	5	5	-	10
1975	16	15	11	31	16	-	100
1976	28	20	22	47	24	-	178
Progenies							
1974	16	8	2	16	-	0	20
1975	433	279	165	461	-	21	835
1976	1,501	1,273	786	1,841	-	192	3,482

[1] Cumulative for both parents and progenies (number of parents and progenies used during 1976 ...

upon recovering such materials from progenies.

Given the large crossing capability of the program, many crosses have been made for national programs. These normally seek to incorporate specific resistances into important commercial varieties. Where practicable these are screened at CIAT under inoculated conditions in the F_2, then delivered directly to the national program for further selection.

Progeny Testing and Selection

Studies conducted by trainees in the breeding program have shown that early generation selection of single plants for yield was not effective. Yields of F_2 single plant selections of five single crosses were not significantly different from those of the best parent and the unselected bulk (Table 34). Results from other studies showed no advantage for double crosses over single crosses.

Given this difficulty, a plan for progressive mass selection has been developed in which early generation screening focuses on the more highly heritable major gene disease resistances (CBMV and rust). Yield, *Empoasca* tolerance and anthracnose resistance are evaluated in later generations where larger quantities of seed and more homozygous families are available (Fig. 59). Improved screening procedures for the latter characters are being developed, and will be applied both to progeny testing and to recurrent selection for higher levels of resistance.

Since it is essential to maintain genetic variability for yield, plant architecture and seed color into advanced generations, the initial stages of progressive mass selection demand a massive effort in terms of seed handling, inoculations, and land. Therefore in November 1976, more than 100,000 F_2 plants were hand-inoculated with CBMV (Fig. 60). The need for such large nurseries should decline rapidly as broad-based progenies homozygous for at least two key resistances are identified. Despite this, the presence of modifier genes in some host cultivars and genetic variability (strains/races) of the pathogen will necessitate reevaluation of some progeny groups and the international testing of some F_4/F_5 families. This is neither surprising nor an inconvenience, as local preferences for seed color and grain type demand evaluation and selection at the national level.

Difficulty has also been experienced in selecting promising plant architectural types from among segregating F_2 populations. As stated earlier, many F_2 populations derive from crosses featuring type IV parents. Screening such segregating populations at normal crop densities results in the elimination of the less competitive genotypes which in several other small grains have ultimately proved to be those materials most responsive to high densities and intensive management. Studies on the differential effects of intergenotypic competition in relation to progeny screening are under way, and aim to develop a planting and genetic management scheme minimizing phenotypic competitiveness (habit-architecture) x environment (spacing) effects on the selection of high yielding genotypes.

Table 34. Yield (kg/ha) of families from F_2 single plant selections, compared to the best parent and the unselected bulk, of five single crosses.[1]

Cross	Best parent	F_2 selection No.	F_2 selection Avg. yield	Bulk	Analysis of variance
2 P006 x P459	2,300	3	2,353	2,327	NS
9 P459 x P568	2,233	7	2,287	2,300	NS
11 P008 x P459	2,233	3	2,087	2,367	NS
16 P004 x P459	2,233	6	2,120	2,540	NS
17 P004 x P566	2,820	3	2,393	1,967	

[1] ... three replications; L.S.D. at .05 = 593 kg, C.V. = 19.6.

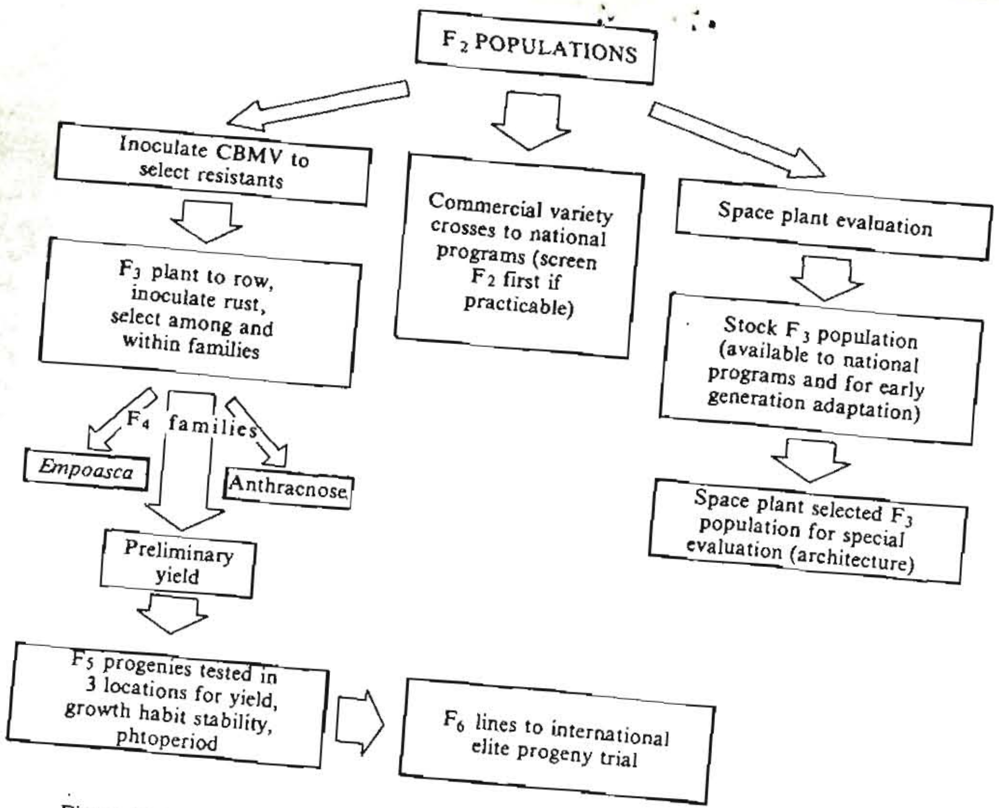


Figure 59. Progressive mass selection scheme used by CIAT bean breeding program.

Until such results are available, F_2 populations are being space planted for simultaneous evaluation by breeder, physiologist, and pathologist (as in Fig. 60). The unidentified bean disturbance (Problem X) observed in the Cauca Valley and under study by pathology and agronomy (see page A-14) has made selection for plant architecture and yield components extremely difficult, primarily because of the varietally specific nature of expressed symptoms.

Bean Information System

Considerable attention was given in 1976 to developing an integrated information system which not only defines the origins of the many crosses being undertaken and the desirable factors to be selected in each hybrid population, but also maintains results from the progeny

Figure 60. Screening for resistance to bean common mosaic virus (BCMV) is the first stage in the mass selection procedure to maintain wide genetic variability in materials uniformly resistant to major pests and diseases. The photos show aspects of field inoculation of F_2 plants with suspensions of BCMV.

testing in a computerized and continuously updated form. This system helps the disciplines in their progeny screening programs, permits the breeder to better plan his crosses, and ensures that maximum advantage is taken of genetic variability in the segregating progenies.

Management of progenies is further facilitated by the use of information cards. which serve as a working field book. These may be photocopied as needed, and physically accompany all seed distributed.

Multi-location Progeny Testing

Several factors demand that, seed supply permitting, progenies be moved rapidly into a system of multi-location testing. These factors include: (a) The importance of seed size and color to national program interests, (b) the atypical behavior of several BCMV resistance sources when tested at Palmira, (c) the existence of major race differences for diseases such as rust in the different areas of Latin America, (d) different needs in maturity time, (e) the need to obtain an active interest and participation from national programs, and (f) the absence of certain important disease and insect pests in Colombia.

By mid-1977, the bean breeding program will generate 2,000 F_4/F_5 families per semester. Plans are under way for two systems of multi-location testing.

(a) A multi-location progeny trial at three locations within or near Colombia, controlled by the program for the purpose of screening large numbers of progenies.

(b) Elite international nurseries, to be distributed according to national program preferences, and coordinated by the bean agronomy group.

This multi-location testing will become increasingly important in 1977 when the breeding program initiates crossing among progenies homogeneously resistant to several key diseases.

ECONOMICS

The principal objective of the bean economics group has been to identify the most important constraints to increasing production and productivity of beans, one approach being the identification of factors influencing bean yields at the farm level. To accomplish this and to better understand bean production systems, intensive field interviews were done in four regions of Colombia in 1974 and 1975. Table 35 summarizes the location of these sites and the number of observations in each. In the 1975 CIAT Annual Report various results were presented on disease and insect incidence, input use and factors affecting bean productivity in the Valle region. This report will focus on the regions of Huila and Nariño.

First, it is useful to review the characteristics of production in the four regions (Table 36). Valle is characterized by large farms with high levels of purchased inputs, producing small black beans primarily for export, and utilizing monocropping. The other three regions are characterized by smaller farms, using fewer purchased inputs, producing large red beans in combination with other crops and having only slightly lower yields in bean equivalent terms[1]. One bean system in Antioquia gave substantially higher bean equivalent yields; however, the entire crop cycle was 14 months compared with only

[1] Bean equivalents convert the other commodities into beans by multiplying these yields by the relative prices. See footnote 3 in Table 36.

Table 35. Number of farms interviewed in four Colombian regions for bean economics survey, 1974/75.

Region	No.
Valle	31
Huila	105
Nariño	19
Antioquia	22
Total	177

Table 36. Characteristics of bean producers in four regions of Colombia.

Mean farm characteristics	Regions			
	Valle	Huila	Nariño	Antioquia
Total area[1] (ha)	91.7	29.5	9.2	4.4
Crop area (ha)	40.5	6.8	3.1	1.7
Bean area (ha)	22.6	4.1	1.8	1.5
Systems of bean production[2]	monocrop	30% monocrop (principally level areas) 70% beans/maize (principally sloping land)	beans/maize	54% beans/maize beans/maize/potatoes 46% beans/maize/arracacha others
Type of bean	black-bush	red-bush	red-bush	red-climbing
Yields for monocropped beans (kg/ha)	906	805	—	
Yields of bean equivalent (kg/ha)[3]	[4]	834	732	723[5] 2,754[6]

1. This is the total area available to the farmer.
2. With more than one system of beans, percentages refer to the number of farmers in each category.
3. Bean equivalents are calculated by utilizing prices of other commodities relative to beans as follows:
Yield (beans) + Price (maize) Yield (maize) = Yield (bean equiv.)
4. The bean crop in the Valle region can be grown in 3.5 months and followed by another crop
5. Refers to the first intercropping combination of beans/maize.
6. Refers to the second intercropping combinations of beans/maize/potatoes, beans/maize/arracacha and others

four months in the Valle. The input use in Antioquia was also very high.

Yields varied substantially among farms in each zone. In Table 37, the average yields of a small sample of five farms from each end of the yield distribution are shown. In all four regions small groups of farmers were already obtaining higher yields than the subjective expected yields[1] from a low-cost technology package for monoculture beans. In several cases, yields higher than were estimated as being possible from a high-cost technology package were obtained by this group of farmers. One policy implication is that an improved understanding of how some farmers obtain higher yields and why other farmers do not, could help orient strategies in the bean program.

Yields are expected to be a function of inputs utilized, cultural practices, native soil fertility, climate, insect, and disease attack. The following regression explained almost two-thirds of the variation in bean yields among farms in the Huila and Nariño regions (Table 38).

It was assumed that the above sample in the regression is representative of the Huila and Nariño area. Using an estimated beans/maize crop area of 23,000 hectares some estimates of total effects from the various factors influencing yields were made for the two regions (Table 39).

The most important factor determining bean yields is the type of cropping system. With increased maize crop density bean yields are reduced. Considering the dis-

1 These subjective potential yield estimates with two types of technologies were obtained from estimates by Bean Program scientists and included a 30 percent discount between experiment station and farm yields. For more details see footnotes 4 and 5 in Table 37.

Table 37. Best and worst yields from the survey sample in four regions of Colombia and potential monoculture yields with low- and high-cost technologies.

	region			
	Valle	Huila	Nariño	Antioquia
Best yields	1,773	1,563	1,193	3,379
Difference between best farmer and average farmer yields (%)	96%	87%[2]	63%	23%[3]
Worst yields[1]	245	239	368	184
Expected farm level yields of improved bean varieties with improved cultural practices, monoculture[4]	1,500	1,000	1,000	1,000
Expected farm level yields of improved varieties, improved cultural practices and high input use, monoculture[5]	2,200	1,600	1,600	1,600

1. Averages for the five best and worse yields were calculated for each region. These are yields for monoculture in the Valle and for multiple-cropping in the other regions. There were no extreme values.
2. Compared with bean equivalent yields.
3. Compared with mean yields for the more profitable crop combinations of beans/maize/potatoes, beans/maize/arracacha and others.
4. These were subjective estimates of mean yields for improved varieties with recommended plant density, time of planting, and the use of clean seed. A 30 percent discount from expected experiment station yields was utilized to adjust for differences in soil quality and management ability.
5. Besides new varieties and improved cultural practices, high input use implies high levels of fertilization and other agricultural chemicals. However, irrigation was not included

tribution of returns, multiple cropping results in lower profits and lower risks so that farmers able to take higher risks gradually shift into monoculture bean production, higher input use, and longer storage periods to avoid the seasonal price collapse[1]. Besides risk reduction multiple cropping may reduce leaching and erosion especially on sloping soils and enable increased nitrogen fixation (see page A-31). For the second most important factor, topography, there is little that the farmer can do other than farm elsewhere so this variable has little policy importance.

Thrips and *Empoasca* can be controlled by spraying systemic insecticides after the pests are identified in the field. Work is also in progress in CIAT on genetic resistance to *Empoasca* (see pages A-15 and A-68). The four diseases excluding mildew led to a combined total production loss of 2,199 tons in the two regions or an average yield reduction of 168 kg/ha. Can these four diseases be controlled with clean, treated seed? This would be a low cost, low risk technology, which would increase average yields by almost 28 percent if the disease did not appear in the field after being removed from the seeds. The yield increment is small: however, average yields are also low and the distribution of clean, improved seed would involve only a small expenditure by the farmer.

Increased aggregate yields in a country can be obtained (a) by helping the rest of the farmers move toward best farmer yields, (b) by introducing adapted varieties of higher yield potential than those currently used by the best farmers, or, (c) a combination of these two strategies. Given

1 Camilo Alvarez P., "Análisis Económico Comparativo de dos Sistemas de Producción de Frijol: Zona Sur del Huila - Colombia". M.S. Thesis, Universidad Católica, Santiago, Chile, 1976. In the sample year multiple cropping produced slightly higher profits; however, considering the entire distribution of returns for the two systems of production, monoculture bean production gave higher returns at higher risk levels. See p.147.

Table 38. Regression results from the analysis of bean yields for the states of Huila and Nariño, Colombia.

Factor	Regression coefficient	Unit	Average value of variable	level of confidence
Maize plant population	- 11.3	1,000/ha	17.9	0.99
Topography of lot	82.5	Dummy[2]	0.62	0.94
Thrips	- 1.9	% of lot	25	0.98
Empoasca	- 0.1	1,000/ha	383	0.99
Potassium content of soil	92.3	Dummy [2]	0.28	0.96
Fallow prior to bean crop	- 63.7	Dummy [2]	0.39	0.90
Virus	-104.6	Dummy [2]	0.76	0.99
Anthracnose	- 4.8	% of pods	4.7	0.98
Mildew	- 6.4	% of foliar area	3.4	0.99
Stem rot	- 8.7	% of lot	2.3	0.99
Angular leaf spot	- 45.9	% of foliar area	0.43	0.99
Rainfall conditions	58.1	Dummy [2]	0.32	0.84
Organic matter content in soil	63.2	Dummy [2]	0.27	0.83
Bean plant population	3.1	1,000/ha	-	0.83
(Bean plant population)[2]	- 0.008	(1,000/ha)[2]	-	0.74
Variable costs [1]	0.067	Col. pesos/ha	1,900	0.99
Phosphorus content of the soil	0.013	ppm	53	0.05

$R^2 = 0.64$

Y = 599 kg/ha of beans

No. of observations = 88

1 This only includes the costs of bean production and serves as a proxy for all inputs. Family labor was priced at the going wage rate.

2 Definitions of dummy variables were the following:

- *Topography of the lot* - 0 sloping; 1 level
- *potassium content of the soil* - 0 deficient; 1 adequate
- *Fallow prior to bean crop* - 0 in crops the previous year; 1 fallow the previous year
- *virus* - 0 no disease; 1 existence of the disease
- *rainfall conditions* - 0 considered excessive or deficient by the farmer; 1 considered adequate
- *organic material content* - 0 deficient; 1 adequate

Note that only the sign of the previous cropping pattern was a surprise. It was expected that the soil would be more fertile if it was not in crops the previous year. Our interpretation is that poor soil preparation after a fallow period resulted in lower yields.

the importance of risk from disease, insects, and price fluctuations, lower cost methods to reduce the risk of stochastic factors such as diseases and insects may have a larger impact on aggregate yields over time than high-cost methods to maximize physiological yield potential.

Results from the Huila-Nariño surveys suggest the potential strategy of breeding bean varieties for resistance or tolerance to a series of diseases, insects, and non-irrigated conditions, so that a low cost, current input package can be developed, which a risk avoiding, small farmer would adopt. With this strategy the public sector (i.e. CIAT and the national governments) makes investments instead of the farmer being obligated to spray and fertilize at high levels and thus be exposed to more risk and the necessity for credit to finance large cash expenditures on inputs.

Table 39. Estimated bean production losses by factor in bean/maize cropping systems in the regions of Huila and Nariño, Colombia, 1975.

Factor	Est. loss in totally affected lot		Est. avg. yield and total production losses		
	kg/ha	%[1]	kg/ha	%[1]	Total production loss (t)[2]
Presence of maize	202	25.2	202	25.2	4.650
Sloping topography	83	12.1	51	7.9	1.176
Thrips	187	23.8	47	7.2	1.078
Empoasca	n.a.	n.a.	46	7.1	1.054
Virus	539[3]	90.0[3]	105	17.4	761
Low potassium of soil	92	13.3	25	4.1	584
Fallow prior to bean crop	64	9.6	25	4.0	572
Anthracnose	484	44.7	23	3.6	521
Mildew	total	100.0	22	3.5	500
Stem rot	total	100.0	20	3.2	463
Angular leaf spot	total	100.0	20	3.2	454
Poor rainfall	58	8.2	18	3.0	421
Low organic matter in soil	63	9.5	17	2.7	387
Non-optimum bean plant population	14	2.3	14	2.3	327

1 Percentage was based upon the estimated loss due to the particular factor divided by the average yield

2 Estimated total production loss is on the basis of a total area of 23,000 hectares with beans/maize intercropping in the two regions.

3 It was not possible with the regression to estimate the losses of totally affected lots. This estimate of 90 percent was based upon experimental data of artificially innoculating the varieties in the same week as the virus was observed. See p C-42 of CIAT 1975 Annual Report.

COLLABORATIVE ACTIVITIES

The Bean Program assumed responsibility from the Consultative Group for International Agricultural Research (CGIAR) to develop and coordinate a Latin American network of bean research workers in 1975. Program scientists felt that each national bean program presented a unique situation to be approached differently according to degree of development, local needs and priorities, and interest in collaborating with CIAT. It was, therefore, agreed to divide the task of maintaining contact with national programs, with each scientist accepting responsibility for collaboration with up to three specified countries (Fig. 61).

To promote better understanding of CIAT activities by scientists in national programs, bean program staff visited their assigned countries and invited research leaders and senior scientists from the national programs to CIAT. Training and documentation services, already major program activities, were increased in 1976. Thirty-eight graduate scientists undertook discipline-oriented training with the program (see the report of the Training and Conferences Program) while documentation cards were forwarded by CIAT's Documentation Center to 417 scientists in 43 countries. To date more than 1,500 articles on beans have been identified and processed.

More concretely, CIAT was able

Figure 61. Latin American country responsibilities for CIAT bean team members, 1976

Figure 62. Locations and types of collaborative activities undertaken by the CIAT Bean Program in 1976.

increase direct germplasm and technical assistance to those programs expressing interest. Details of the first International Bean Yield and Adaptation Nursery (IBYAN) have already been presented (see page p.A-33) Other activities including the second Rust Resistance Nursery (p.A-7) are shown in Figure 62. These included:

(a) Screening of 3,000 germplasm accessions for tolerance to golden mosaic virus at sites in Guatemala, El Salvador and Brazil. BGMV is of limited occurrence in Colombia, but is a major disease in much of Central America and Brazil.

(b) Nineteen accessions reported in the literature as being resistant to the bean pod weevil, *Apion godmani*, were reevaluated in Nicaragua, El Salvador and Honduras. The resistance of Negro 151 and Puebla 152 was confirmed and a crossing program has been initiated to incorporate the resistance into commercial varieties from Central America. A total of 180 cultivars were screened for *Epinotia aporema* resistance in Peru, the accession G 04421 proving resistant both to *Epinotia* and to *Empoasca* sp.

(c) The program organized soil analysis and fertilizer recommendations for the El Paraiso region of Honduras. As all soils proved deficient in nitrogen, cooperative inoculation and fertilization experiments have been prepared for seven sites in the region. Similar experiments are under way in the Dominican Republic, Venezuela and Colombia.

(d) Given the experience, time and facilities involved in crossing for specific features of yield or disease resistance, the Bean Program has been particularly responsive to the breeding needs of national programs.

More than 20 of the 155 parents included in the crossing program have been included at the request of national programs, and segregating materials have already been forwarded to numerous countries. In addition, CIAT has served as an off-season location for the multiplication of early generation material from Chile, Guatemala, and Honduras.

(e) Drought tolerance studies continued in Peru and in collaboration with Cornell University (U.S.A.).

APPENDIX

Cross-reference of CIAT promising accessions mentioned in this report and their Germplasm Bank register numbers, identification and source of the accession.

CIAT Promising No.	CIAT Germplasm Bank Register No.	Identification	Seed Source
P004	02115	PI 310 878	United States
P006	02005	PI 310 739	United States
P008	02056	PI 310 814	United States
P009	02959	Pecho Amarillo	Guyana
P011	03729	Argentina 2	Venezuela
P014	02146	PI 310 909	United States
P017	03719	Mexico 12-1	Venezuela
P039	00093	PI 150 948 Canario	United States
P074	00184	PI 166 066 Shimi	United States
P092	00310	PI 169 855	United States
P199	01220	PI 196 927 Criollo	United States
P209	01259	PI 201 333	United States
P225	04433	PI 207 130 Panameno	United States
P226	01308	PI 207 198 CCGB 44	United States
P235	01362	PI 209 488	United States
P252	01070	PI 281 980	United States
P259	01093	PI 282 063	United States
P261	01101	PI 282 086 Rocha	United States
P278	01679	PI 306 149 Caraota	United States
P302	01820	PI 309 804	United States
P320	01967	PI 310 686	United States
P322	01995	PI 310 724	United States
P325	01999	PI 310 732	United States
P326	02006	PI 310 740	United States
P334	02034	PI 310 784	United States
P337	02045	PI 310 797	United States
P347	02164	PI 311 780	United States
P349	02281	PI 311 930	United States
P352	02326	PI 311 991	United States
P358	02382	PI 312 064	United States
P364	02540	PI 313 653	United States
P381	02935	PI 343 734	United States
P392	04498	Sanilac	United States
P393	03736	I 1012 Alabama 1	Venezuela
P401	03065	Blanco 137	Guyana

Continuation.

CIAT Promising No.	CIAT Germplasm Bank Register No.	Identification	Seed Source
P402	03807	Brasil 2 Bico de Ouro	Venezuela
P417	03696	Colección 12D I-964	Venezuela
P420	03607	CCGB44 I-462 CR12	Venezuela
P432	03153	Frijol de Parra 350	Guyana
P437	03128	Negro 321	Guyana
P443	03223	Negro Cahabon 453	Guyana
P449	03451	Guanajuato 116	Mexico
P458	04454	ICA TUI	Colombia
P459	03645	Jamapa I-810	Venezuela
P464	04354	Mexico 114	Mexico
P466	03852	Miranda 5	Venezuela
P481	04206	N 257 Sal Rico de M Gera	Costa Rica
P527	03874	Trujillo 7	Venezuela
P540	03784	Venezuela 29 I-1071	Venezuela
P559	03733	50600 I-1009	Venezuela
P560	03834	51051 I-1138	Venezuela
P566	04495	Porrillo Sintetico	Honduras
P567	05478	Tara	United States
P568	05479	PR S 70 15 RST B K	Costa Rica
P569	05481	Cacahuate 72	Mexico
P579	02703	PI 313 868	United States
P588	04455	ICA Huasano	Colombia
P589	02525	PI 313 624	United States
P590	05702	Cargamanto	Colombia
P591	00197	PI 167 201 Aysekadin	United States
P597	01222	PI 196 932 P Acutifolius	United States
P598	01239	PI 199 041 I langaza	United States
P634	05683	ICA Duva	Colombia
P635	04452	ICA Guali	Colombia
P637	04523	Linea 17	Colombia
P643	04459	NEP 2	Costa Rica
P646	00881	PI 203 958 N 203	United States
P662	02472	PI 313 343	United States
P667	04191	Coleccion 166 N	Costa Rica
P668	04190	Coleccion 168 N	Costa Rica
P675	04525	Linea 32 ICA Pijao	Colombia
P684	01320	PI 207 262	United States
P685	05694	Cornell 49 242	United States
P692	04494	Diacol Calima	Colombia
P693	05653	Ecuador 299	El Salvador
P694	05477	Great Northern #1 SEL. 27	United States
P698	05476	Jules	United States
P699	05652	Mexico 309	El Salvador
P700	05706	Jalpatagua 72	Guyana

Continuation.

CIAT Promising No	CIAT Germplasm Bank Register No.	Identification	Seed Source
P704	04795	Poccillo 1	El Salvador
P709	04485	Turrialba 1	Guyana
P712	04792	51052	Nicaragua
P714	04505	Top Crop	United States
P716	03738	Baurre D Paulinat	Venezuela
P717	05711	Comp Chimaltenango 2	Guatemala
P737	04456	Jamapa	Costa Rica
P756	04445	Ex Rico 23	Colombia
P757	04461	Porrillo 1	Costa Rica
P758	04446	Puebla 152	Mexico
P760	06334	Vidresco	Holland
P770	02689	PI 313 853	United States

List of CIAT Germplasm Bank reference numbers listed in this report, their identification and the seed source.

CIAT Germplasm Bank Register No.	Identification	Seed source
G00805	PI 197 034	United States
G01212	PI 196 299	United States
G01213	PI 196 462	United States
G01224	PI 196 936	United States
G01540	PI 284 703	United States
G02704	PI 313 869	United States
G04165	Preto 2449 (N-487)	Costa Rica
G04834	Puebla 56-C (Negro)	Mexico
G04835	Puebla 56-C (Blanco)	Mexico
G04835	Puebla 56-C (Blanco)	Mexico
G05086	1886-48 (Brazil 555)	Brazil

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