Bean production systems

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* Assignment between two programs

** Left during 1975.

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Climatic and edaphological data for locations where CIAT's Bean Program has done research work in 1975

Locations	Altitude (meters above sea level)	Mean temperature (°C)	Rainfall (mm|year)	Organic matter (%)	pH	P (Bray II) (ppm)	K (meq|100 g)	Soil texture
Colombia[1]								
CIAT, Palmira (Valle)	1,000	24.0	1,000	6.80	6.9	46.3	0.44	Clay
Popayán[2] (Cauca)	1,760	18.0	2,500	7.56	5.0	2.4	0.44	Clay loam
Nataima (Tolima)	430	27.8	1,479	1.30	6.2	24.7	0 22	Sand
Turipaná[3] (Córdoba)	13	28.0	1,200	3.1	6.8	13.8	0.68	Clay
Tibaitatá[3] (Cundinamarca)	2,250	13.1	606	-	-	-	-	-
Restrepo[4] (Valle)	-	-	-	6.2	6.0	4.9	0.48	Sand loam
Vijes, Yotoco[4] Valle)	-	-	-	7.4	5.9	7.0	0.31	Sand loam
La Zapata (Valle)	1,200	22.7	1,219	6.0	5.0	1.7	0.55	Clay loam
Ecuador: Boliche[5]	50	25.1	727	3.8	4.3	3 0	2.3	Clay loam
Perú: La Molina[6]	200	17.7	5	1 5	8.0	309 0	0.43	Clay loam

[1] Names of departamentos of Colombia are in parentheses.
[2] In cooperation with the Secreterio de Agricultura del Cauca
[3] In cooperation with the Instituto Colombiano Agropecuario (ICA)
[4] In cooperation with the Federación Nacional de Cafeteros
[5] In cooperation with the Instituto Nacional de Investigaciones Agropecuarias (INIAP)
[6] In cooperation with the Ministerio de Agricultura.

Bean production systems

HIGHLIGHTS IN 1975

The Bean Program continued to develop and consolidate in 1975, its second full year of operation. Priorities established after an in-depth analysis of bean production problems in Latin America emphasize: germplasm characterization and supply to national programs; assistance in documentation and training for Latin American scientists; and development of bean production systems which minimize the need for costly fertilizers and chemicals. Staff appointments in physiology and systems agronomy have allowed considerable progress in these areas in 1975. Following are some major highlights for the year.

In the first full year of bean hybridization, 85 parents were used in an intensive crossing program. A total of 4,530 pollinizations representing 1, 266 different hybridizations were made, with 35,400 F_1 and F_2 progeny field tested.

High experimental yields were obtained in both bush and climbing beans, giving promise of farm yields previously thought to be unobtainable in this species. In bush beans, the maximum yield in replicated plots was 4.26 tons|ha; in climbing beans under monoculture, yields consistently ranged between 4.5 and 5.5 tons|ha.

Varietal trials for bush beans continued in 1975, and high yields were again common. Scientists attending the Bean Breeding and Germplasm Workshop helped develop and approved plans to establish an international series of variety trials in 1976.

Nitrogen fixation studies at Popayán showed rates of fixation similar to those reported for soybean. The ten varieties studied fixed an average of 25 kg N|ha over a 120-day period.

An agro-economic study of major Colombian bean growing areas was carried out giving important information on disease incidence and severity, production problems and seed storage and quality.

As part of its new responsibility for coordinating Latin American bean research, the program organized conferences in 1975 to discuss bean breeding, germplasm and disease problems. The Bean Advisory Committee also met to review program activities. Twenty-six trainees, including two PhD and three MS candidates, received training at CIAT.

There were additionally some changes in research emphasis within the program. Germplasm evaluation played a lesser role than in previous years while work with climbing beans and maize-bean associations received more emphasis. Work on spider mites—previously throught to be of major importance in Latin America— was replaced by studies on the **Tarsomenis** mite.

ECONOMICS

An analysis of bean production processes in four regions of Colombia was begun in 1974 (1974 Annual Report). The primary purpose of the analysis is to provide details of the bean production process that will be useful for establishing priorities in agricultural research and public policy. The data collection for three regions, or departamentos,* was completed in 1975 and is being analyzed. While some of the results presented here are for all four regions, the discussion emphasizes the Valle region —for which the data analysis is most advanced.

Agronomic factors of bean production in Colombia

Technology levels and bean yields

The 177 farmers surveyed are located as follows: Valle, 31; Huila, 105; Antioquia, 22 and Nariño, 19. Beans are usually grown as a monocrop in the Valle region, while in Huila, Antioquia and Nariño, they are predominantly grown with maize. In Huila, some area is also planted to beans alone. Other cropping systems include potatoes, peas or peanuts. Table 1 shows the farm size, use of modern technology and yields for the four regions. Valle is characterized by relatively large commercial farms, extensive use of modern technology, monocropping and relatively high bean yields. Nariño, on other hand, consists mainly of small farms, with very limited use of modern technology, mixed cropping and relatively low bean yields. In Valle yields on small farms were only slightly more than half the yields on large farms. Table 2 shows that even within one region, wide differences exist among cropping systems and technology levels employed for bean production. Differences are particularly marked in the use of irrigation, certified seed, herbicides, credit and technical assistance.

These findings would indicate that research efforts to expand and improve

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* A departamento is a political sub-division similar to a state or province.

Table 1. **Characteristics of bean production in four regions of Colombia.**

	Valle	Huila	Antioquia	Nariño
Average farm size (ha)	48.0	25.2	4.5	4.0
Area in beans (ha)	22.6	5.9	1.5	1.8
Percentage of farms using:				
Irrigation	45	3	0	0
Certified seed	52	7	0	5
Fertilizers	94	24	100	0
Herbicides	33	0	0	0
Insecticides	87	23	64	10
Fungicides	97	10	59	0
Credit	87	53	54	58
Technical assistance	71	30	32	32
Mixed cropping	0	74	100	95
Machinery	100	44	5	0
Bean yield (kg|ha)	906	683	509	447
Bean equivalent yield (kg|ha)	906	n.a.*	919	703

* n.a. = not available

Table 2. **Selected characters for bean production farms of three sizes in Valle.**

	Farm size		
	small	medium	large
Average farm size (ha)	2.8	21.0	115.0
Area in beans (ha)	2.4	17.0	47.5
Percentage of farms using:			
Irrigation	18	44	73
Certified seed	18	22	64
Fertilizers	90	100	100
In soil	40	66	64
On leaves	60	78	100
Herbicides	20	33	45
Insecticides	91	78	91
(applied by:)			
airplane	0	22	64
tractor	0	22	27
backpack sprayer	100	89	64
Fungicides	100	100	100
Credit	73	89	100
Technical assistance	27	89	100
Mixed cropping	0	0	0
Mechanization	100	100	100
Bean yield (kg|ha)	683	896	1,118

productivity must consider the specific production system and region toward which the efforts are focused. New technology for large-scale monocropping is likely to be adopted rapidly by the larger, more progressive farmers characterized by the Valle region. Special efforts may be needed to design and diffuse technology to benefit small farmers typical of Nariño and Antioquia.

Diseases and insects

Angular leaf spot, rust and bacterial blight were common in all regions. Other diseases were important for some but not all the regions (Table 3). The yield impact of some of these diseases is discussed in a later section.

A large number of insect species were found in the bean fields under observation with **Empoasca** and thrips among those most frequently found. The percentage of farms affected by each insect species differed greatly among regions (Table 4).

Soils

To assist in understanding fertilizer use and yields, soil samples were collected on each farm of the survey. These samples are being analyzed for organic matter, pH and levels of calcium, magnesium, phosphorus and potassium.

Plant population and seed loss

The average plant population 30 days after planting was estimated to be 387,000 plants|ha in Valle. Plant population per hectare tended to be higher on large farms. A considerable loss of seed or seedlings occurred during the first 30 days after planting. Establishment losses of 50 and 32 percent were found on small and large farms, respectively. The causes of such large losses are being studied.

Using production function analysis and with current seed prices at US $700| ton, the optimum plant population was estimated at 419.500 plants| ha, and max-

Table 3. **Percentage of bean farms in four regions of Colombia where diseases were observed during either of two visits.**

	Region							
	Valle[1]		Huila[2]		Antioquia[3]		Nariño[4]	
Visits:	I	II	I	II	I	II	I	II
Angular leaf spot	74	100	30	78	91	91	32	79
Rust	94	94	63	71	41	68	26	16
Bacterial blight	55	84	40	77	0	9	53	79
Gray spots	0	3	44	63	68	82	63	53
Anthracnose	0	0	50	51	86	100	37	42
Flowery spots	0	0	11	72	73	64	10	47
Powdery mildew	0	0	6	28	50	68	0	0
Virus	10	19	21	6	0	0	21	11
Root rot	39	13	19	1	5	9	37	5
Leaf spot	0	0	21	11	14	9	16	5

[1] Crop season: 80-100 days. Visit I, 20-30 days after planting; II, 50-60 days after planting.

[2] Crop season: 80-120 days. Visit I, 30-50 days after planting; II, 70-90 days after planting.

[3] Crop season: 120-160 days. Visit I, 60-80 days after planting; II, 90-100 days after planting.

[4] Crop season: 90-110 days. Visit I, 30-40 days after planting; II, 60-70 days after planting.

Table 4. **Percentage of bean farms in four regions of Colombia where insects were observed during either of two visits.**

	Region							
	Valle		Huila		Antioquia		Nariño	
Visits:	I	II	I	II	I	II	I	II
Insects attacking seedlings:								
Cutworms	13	0	14	4	0	0	0	0
Crickets	13	0	11	0	0	0	0	0
Sucking insects:								
Aphids	32	6	56	77	18	14	37	53
Thrips	39	36	79	70	36	36	68	63
Stinkbug (**Nezara** sp.)	0	6	0	2	9	0	5	0
Empoasca sp. (adults)	61	97	87	85	68	64	68	79
(nymphs)	36	87	78	83	64	77	63	95
Whitefly	62	26	42	38	36	0	47	26
Gargaphia sp.	0	0	14	30	0	0	0	0
Leaf miners:								
Agromyza sp., **Liriomyza** sp.	26	42	60	57	0	0	58	32
Hemichalepus sp.	0	43	55	30	68	55	47	5
Leaf feeders:								
Estigmene sp.	13	13	3	6	-	5	0	0
Trichoplusia sp.	0	55	16	39	14	45	5	0
Hedylepta sp.	6	16	7	32	0	0	0	0
Urbanus sp.	0	3	9	4	0	0	0	0
Spodoptera sp.	3	3	0	0	0	0	0	0
Chrysomelidae	36	52	12	7	32	0	53	16
Pod damaging insects:								
Heliothis sp.	0	16	0	10	0	0	0	16
Trichoplusia sp.	0	32	0	30	0	0	0	16
Maruca sp., **Epinotia** sp.	0	48	0	52	0	59	0	5
Dipterons	0	0	0	8	0	23	0	26
Stemborers:	0	0	1	0	82	59	0	0
Mites:								
Tetranychus sp.	0	0	16	48	0	0	0	0

imum production was estimated to be obtained at 486,600 plants|ha. Increasing the plant population to the economic optimum level at current seed prices was estimated to add 14 kg|ha to yields.

Labor use

Figure 1 shows estimated labor use in bean production in Valle by production activity and farm size. Bean production in the region is highly mechanized, hence labor use is low relative to other regions. Weed control and cultural practices account for about half of the total labor use. The amount of labor used in the production process is higher for small than for large farms and is particularly pronounced for weeding and cultural practices because fewer small farmers use herbicides. Labor use for pest and disease control also differs because large farmers use tractors to apply insecticides and fungicides while small farmers tend to use backpack sprayers.

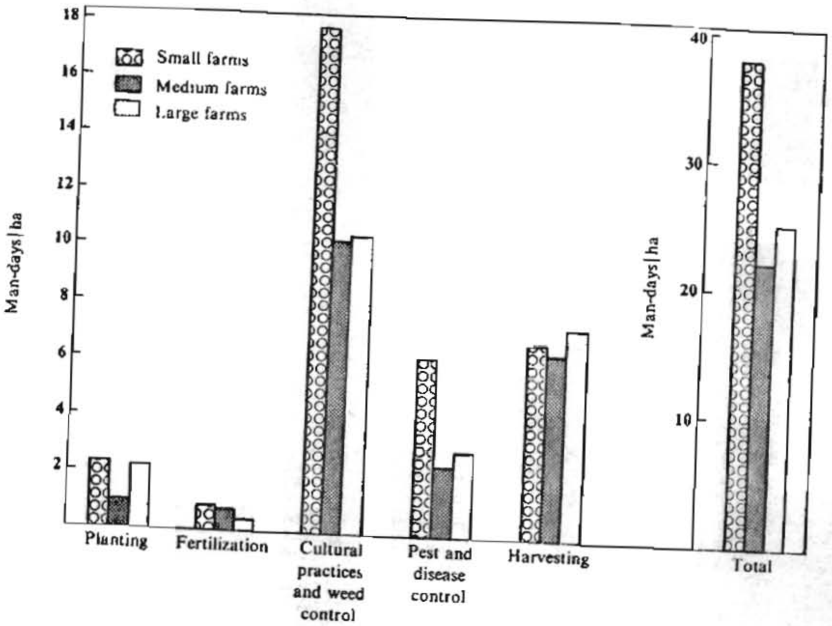


Figure 1. **Labor use in bean production by activity and farm size, Valle, Colombia, 1975.**

Economic factors of bean production in Colombia

Production costs and returns

Table 5 shows estimated variable costs by production activity and farm size. The cost of seed and planting accounts for about 25 percent of total variable costs, followed by disease and pest control (20%) and land preparation (15%). A considerable cost difference was found among size groups of farms. Total variable costs on small farms were estimated to be US $233|ha and for large farms, US $328|ha. The cost differentials among farm size groups were due primarily to the quantity of fertilizers, insecticides, herbicides and fungicides applied, and to a lesser extent, to differences in harvesting costs caused by yield differences.

Table 6 shows estimated gross and net returns from bean production in Valle during the survey period. As farm size increased, yields, total costs and net returns increased. The benefit|cost ratio increased from 1.15 for small farms to 1.45 for large farms.

Table 5. **Estimated variable costs of bean production on three farm sizes, Valle region, Colombia, 1974-75.**

	Farm size					
	small		medium		large	
	(US$|ha)	(%)	(US$|ha)	(%)	(US$|ha)	(%)
Land preparation	33.87	14.5	46.57	17.0	42.70	13.0
Seed and planting	67.57	29.0	61.00	22 2	67.57	20.6
Fertilizer and application	17.37	7.5	22.93	8.3	24.40	7.4
Irrigation, drainage	-	-	3.47	1.3	5.57	1.7
Cultural practices and weed control	36.67	15.8	30.63	11.2	30.70	9.4
Disease and pest control	38.33	16.5	57.50	21 0	74.23	22.6
Harvesting	15.83	6.8	21.67	7.9	45.27	13.8
Other costs	23.23	9.9	30.47	11.1	37.80	11.5
Total	232.87	100.0	274.24	100.0	328.24	100.0

A production function analysis was conducted to determine the optimum levels for variable costs (excluding harvesting costs) and yields per unit of land*. It was found that the current level of variable costs, (US $251.77| ha) was optimum for a product price of US $533| ton. At the average price received by farmers of US $550| ton, net returns would be maximized at a variable cost of US $260| ha, which in return would increase yields by 18 kg| ha and net returns by US $1.27| ha.

Prices received by the survey farmers ranged from US $400 to $720| ton. At these prices, net returns would be maximized at variable costs of US $152 and US $326| ha, respectively. Before planting, reputable private companies offered the farmers contracts with a guaranteed price of US $583| ton. Less than one-fourth of the farmers accepted such contracts. Apparently at the time of planting, farmers expected future prices for beans to be equal to or greater than the contract price, and that this price would form the basis for decisions on minimum levels of input use and variable costs. At the contract price, the optimum variable costs were estimated to be US $277| ha. Hence, it may be concluded that the survey farmers invested slightly less than the optimum amount, whether the actual average or expected minimum prices are considered. However, given the risk and uncertainty associated with bean yields and prices, it appears that the farmers were as close to optimum investment levels as could possibly be expected.

• Harvesting costs were excluded from variable costs in the production function analysis because they are determined by the quantity produced and not vice versa. Hence, since harvesting costs are fixed per unit of output in the region, these costs were subtracted from the product price in the marginal analysis.

Table 6. **Estimated economic results of bean production on three farm sizes, Valle region, Colombia, 1974-75.**

	Farm size		
	small	medium	large
Yield (kg|ha)	683	896	1,118
Value of production (US$|ha)	366	508	626
Total costs (US$|ha)	317	352	432
Net profit (US$|ha)	49	156	194
Benefit|cost ratio	-1.15	1 44	1.45

Sources of yield losses

A production function analysis was carried out to estimate yield losses caused by selected factors. Table 7 shows the estimated yield loss from eight factors assuming a totally affected lot. Also shown is the percentage of the total bean area affected and the total loss to the region. Assuming constant prices, i.e. an infinitely elastic demand, and using average prices received by the survey farmers (US $550| ton), the loss to the region due to adverse rainfall conditions and lack of water control was estimated to have been almost US $1.2 million for the crop cycle beginning in October, 1974.* The loss caused by rust was estimated at slightly less than this. The presence of bacterial blight reduced average regional yields by 137 kg| ha and total regional production by about 1,700 tons. Other important factors limiting yields were the presence of **Empoasca** and angular leaf spot. Certified seed was used on 59 percent of the area. The potential gain from using certified seed on the remainder of the area was estimated to be US $0.5 million. The potential gains from optimizing variable costs and plant populations were quite small.

The estimates presented in Table 7 are gross rather than net losses. To obtain net losses, costs and secondary benefits associated with reducing or eliminating losses need to be estimated. Finally, the estimates in Table 4 should be interpreted with caution because of their preliminary nature, the small number of observations

• Since almost all the black beans produced in Valle are exported and since the quantity accounts for a small proportion of total supplies in the markets to where it is exported, the assumption of infinitely elastic demand is probably valid for the limits considered here.

Table 7. **Estimated losses in bean production from selected factors, Valle region, Colombia, 1974-75.**

Factor	Est. loss in totally affected lot		Area affected (%)	Est. loss, Valle			
	(kg|ha)	(%)*		(kg|ha)	(%)	(tons)	Value (US$1,000)*
Adverse rainfall	416	31 5	42	175	16.2	2,168	1,192
Rust	307	25.3	56	172	16.0	2,130	1,171
Bacterial blight	Total	100.0	12	137	13 1	1,697	933
Empoasca	315	25.8	35	110	10 8	1,362	749
Angular leaf spot	538	37.5	15	81	8.2	1,003	552
Certified seed	186	17.0	41	76	7.7	941	517
Variable costs	-	-	-	18	1.9	223	123
Plant population	.	-	-	14	1.5	173	95

* Percentage based on estimated average yield plus estimated loss due to the particular factor.

** Estimated value of regional loss at constant prices of US$550| ton.

and the severe difficulty in separating the effects of the various factors influencing yields.

BREEDING

Hybridization program

Hybridization among promising selections in the bean germplasm bank began in 1974 using ten progenitors (1974 Annual Report). In 1975, the number of progenitors was increased to 85, widening the number of characteristics being sought and greatly accelerating the hybridization program. By October of this year, 4,530 pollinations representing 1,266 different hybridizations had been completed. During this program, the overall efficiency of pollination rose from the 31.5 percent reported last year to more than 50 percent. This is discussed more in the next section.

Two cycles of intensive crossings have been completed. From the original ten progenitor materials, 23 F_2 single crosses and 51 F_1 double cross populations were developed. These materials were field grown this year and 27 bulked populations and more than 450 individual plant selections made. While it is premature to talk of firm yield figures based on low density plantings, two results deserve comment. (1) P459 proved an excellent parent. All outstanding F_1 double cross materials included this selection as a parent, as did eight of nine F_2 mass selections from single crosses. (2). Preliminary yields in the double cross progeny were, in general, considerably higher than in those from single crosses.

Table 8 shows the parental materials and characteristics sought in the second group of crosses. Emphasis here was on establishing base populations which united different sources of genes for quantitatively inherited characteristics, i.e. rust resistance, common bacterial blight resistance and yield. Combining simply inherited features such as common mosaic resistance in prominent commercial varieties is also stressed. Further crossing and evaluation of hybrids will continue in 1976.

The bean team as a whole, aided by discussions at the breeding workshop in October, devoted much time to developing a methodology for improving and distributing new lines of *P. vulgaris*. It would appear that in the short term, much can be achieved stressing simply inherited characters such as resistance to common mosaic and anthracnose, and combining these into better commercial varieties. This should be achievable by single cross hybridization to incorporate disease resistance coupled to a backcross program to recover desirable seed characteristics. Improving quantitatively inherited characteristics, for example tolerances to common bacterial blight, leafhoppers or golden mosaic virus, and incorporating these into high yield backgrounds will prove much more difficult. Recurrent selection procedures like those shown in Figure 2 for **Empoasca** seem highly appropriate. Here intermating and selfing would both be practiced, with siblines tested first of all for **Empoasca** tolerance (A-factor) and later on for yield (B-factor). Even here, individual disciplines will have to give high priority to developing screening procedures which permit distinction of relatively small differences in resistance or yield levels.

Table 8. **Breeding groups and crosses made for genetic improvement in *P. vulgaris*, CIAT, 1975.**

No. of crosses	Groups of desirable factors under breeding
160	Sources of tolerance (5) to common bacterial blight (*Xanthomonas phaseoli*) and high yield potential
183	Sources of tolerance (6) to web blight (*Thanatephorus cucumeris*) and high yield potential
143	Sources of resistance (5) to common mosaic virus (*Marmor phaseoli*), high yield potential and commercial varieties of Latin America
118	Sources of tolerance (14) to leaf hopper (*Empoasca kraemeri*) and high yield potential
96	Sources of resistance (6) to rust (*Uromyces phaseoli*) and high yield potential
13	Sources of resistance (2) to yellow mosaic and commercial varieties of Chile
37	Sources of tolerance (2) to golden mosaic and commercial varieties of Honduras
31	Sources of resistance (1) to angular leaf spot (*Isariopsis griseola*) and high yield potential
485	Combination of physiologic characters: late flowering (3), insensibility to photoperiod (3), stability in growth habit (3) and high yield potential.

Hybridization techniques

As stated earlier, pollination efficiency was only about 32 percent in 1974. To improve this rate, a study to evaluate crossing methodology was begun this year. Crosses were made in a screenhouse without environmental control using P4 and P5 as female and male parents, respectively. Among the factors studied were: (1) use of p.4-chlorophenoxyacetic acid to prevent abscission of pollinated flowers; (2) placement of wet cotton around the pollinated flowers; (3) time of pollination during the day; (4) removal of all flowers not to be pollinated; (5) the need for repollination; and (6) time of emasculation relative to pollination.

The results are shown in Table 9. Maximum efficiency of 81 percent was achieved using the hormonal applications, making the crosses up to midday, pollinating only one flower per raceme, and removing all flowers not being pollinated. Using the wet cotton around the flower increased flower abscission, as did any situation which permitted competition for nutritients between the fertilized flower and other flowers on the plant. The non-significant increase in efficiency from repollinating does not appear to be practical.

Inheritance studies

Bean breeding trainees are directly participating in a series of studies to obtain information on the inheritance of main limiting production factors.

In rust resistance studies, two independent F_2 populations were evaluated in the field by the use of a local inoculum. The sources of resistance were PR-5 (P568) and Cacahuate 72 (P569). As shown in Table 10, both studies indicated that resistance was dominant and simply inherited.

A genetic study of common bacterial blight tolerance was done in the greenhouse with the resistant line Tara (P567) and CIAT's C-6 inoculum. The average reaction of the foliage to the bacteria is shown in Table 10. The nature of the disease reaction was quantitatively inherited and showed additive gene effects.

GERMPLASM

Evaluation and documentation of the CIAT holdings of *P. vulgaris* and related species continued in 1975. Major activities have been in four areas of work

(1) The germplasm bank includes approximately 1,800 accessions for which only very limited numbers of seeds were supplied. These materials have been planted in the screenhouse to minimize loss of individual accessions, and will be field screened in 1976.

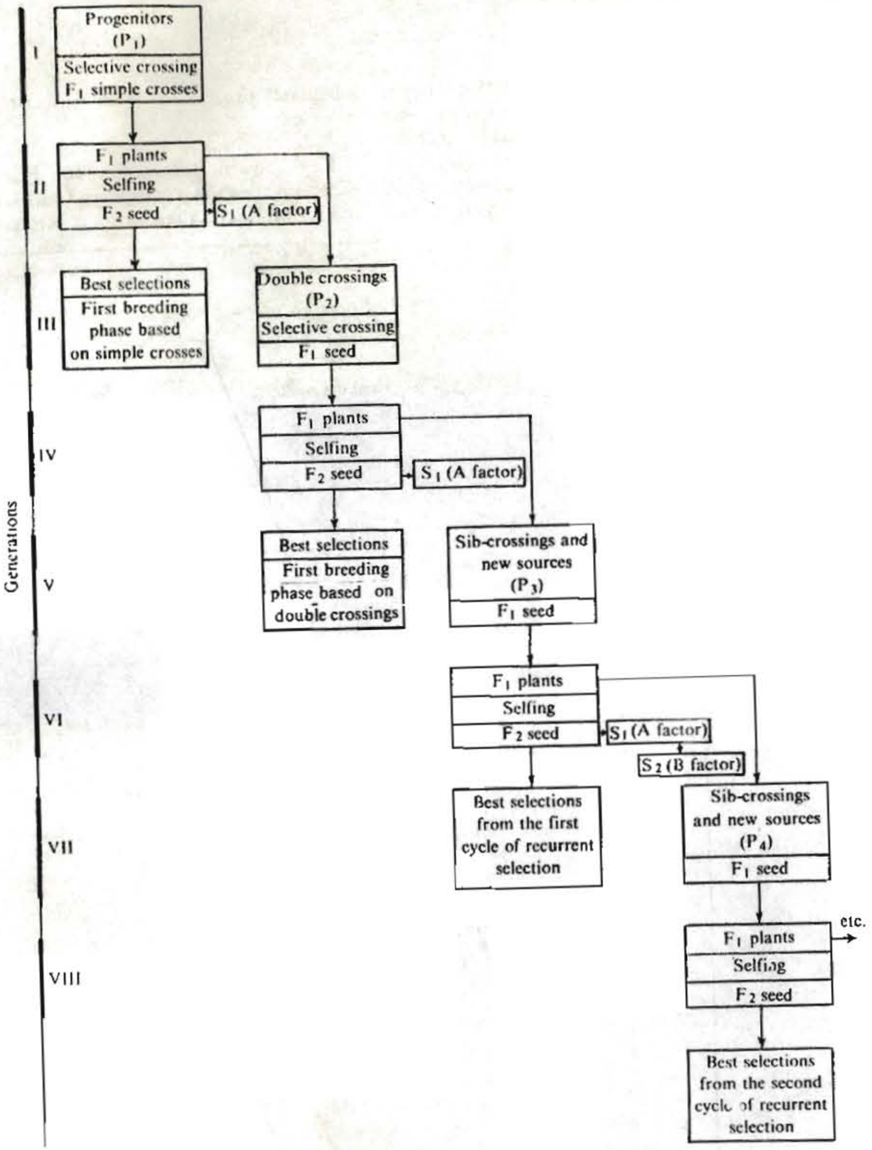


Figure 2. **Recurrent selection process for genetic improvement of *P. vulgaris* to obtain combinations among two polygenic factors from an initial 10-15 progenitors, CIAT, 1975.**

Table 9 **Effects of several treatments for increasing the crossing efficiency in *P. vulgaris*, CIAT, 1975.**

Treatment	Efficiency (%)	Mean temperature (°C)	Mean rel. hum. (%)
Hormone*	81.0	31.0	54.5
Hormone + wet cotton wool	71.0	30.0	53.6
Wet cotton wool	62.0	29.4	52.4
Check	74 0	29.1	57.4
Single pollination (with no competition effects)	63.3	24.6	98.2
Repollination after 24 hr	66.6	24.6	98.2
Presence of other flowers at pollination	40.0	24.0	98.2
Two pollinated flowers per raceme	38.3	29.8	85.1
Emasculation and then pollination after 24 hr	31.4	25.3	96.1

* p.4-chlorophenoxyacetic acid

Table 10. **Inheritance studies of resistance to rust, *Uromyces phaseoli*, and tolerance to common bacterial blight, *Xanthomonas phaseoli*, in *P. vulgaris*, CIAT, 1975.**

Generation	Observed data Resist.	Observed data Susc.	Calculated (3:1) Resist.	Calculated (3:1) Susc.	X^2	P
Rust inheritance						
P_1 (P459)		20				
P_2 (P569)	20	-				
F_1	4	-				
F_2	126	49	131	44	0.840	.50-.30
P_1 (P568)	20	-				
P_2 (P459)	-	20				
F_1	4	-				
F_2	171	73	183	61	3.147	.10-.05

Blight inheritance

Generation	Disease reaction 1	2	3	4	No. of plants	Mean reaction to the disease
P_1 (P459)	-	-	-	8	8	4.00
P_2 (P567)	8	-	-	-	8	1.00
F_1	1	-	-	3	4	3.25
F_2	33	38	45	23	139	2.41

Table 11. **Characteristics determined for *P. vulgaris* germplasm, CIAT.**

1. Days to emergence
2. Plant vigor
3. Hypocotyl length
4. Hypocotyl color
5. Leaf size
6. L.A.I.
7. Effective plant height
8. Node number at flowering
9. Node number at maturity
10. Days to flower initiation
11. Duration of flowering
12. Flower color
13. Sensitivity to photoperiod
14. Growth habit
15. Plant height
16. Stem width
17. No. racemes per plant
18. No. pods per plant
19. No. branches with pods
20. Branch angle
21. Seeds|pod
22. Seed shape
23. Major seed color
24. Secondary seed color
25. Seed gloss
26. Seed weight
27. Yield|plant
28. Harvest index
29. Total dry matter
30. Degree of lodging
31. Yield trial ranking

Resistance to:

32. Rust
33. Angular leaf spot
34. Web blight
35. Anthracnose
36. Root rots
37. Common mosaic virus
38. Golden mosaic virus
39. Chlorotic mottle virus
40. Bacterial blight
41. **Empoasca**
42. Apion
43. White fly
44. Red spider mite
45. Tropical mites
46. **Zabrotes**
47. Bean weevils

Other characters:

48. **Rhizobium** efficiency
49. Other references to accession
50. Mixed seed
51. Clean seed
52. Species

(2) In 1975 it was decided to increase the number of descriptor terms used for the germplasm collection from 26 to 52. The complete list of descriptor terms is shown in Table 11. The additional data needed is being collected from new field plantings of 2,000 accessions per semester. Data for the accessions in now maintained on tape, and is being adapted for use with both the EXIR and SAS data retrieval and analysis systems.

Table 12. **Variation of specified characteristics among 2,216 accessions of *P. vulgaris* evaluated at CIAT, 1975.**

Days to emergence	5 - 12 days
Days to flowering	29 - 72 days
Plant height	22 - 220 cm
Racemes per plant	1 - 29
Pods per raceme	1 - 5
Pods per plant	3 - 47
Seeds per pod	2 - 10
Seed weight	12 - 58 g|100 seeds
Seed weight per plant	1 - 37 g
Days to harvest	61 - 110

(3) To date more than 700 selections have been made which show promise in one or more attributes. A catalogue describing these promising materials is being prepared and will be available early in 1976. In addition, the catalogue will describe the frequency and variation for particular characteristics in the total germplasm collection. The ranges for certain characters are shown in Table 12.

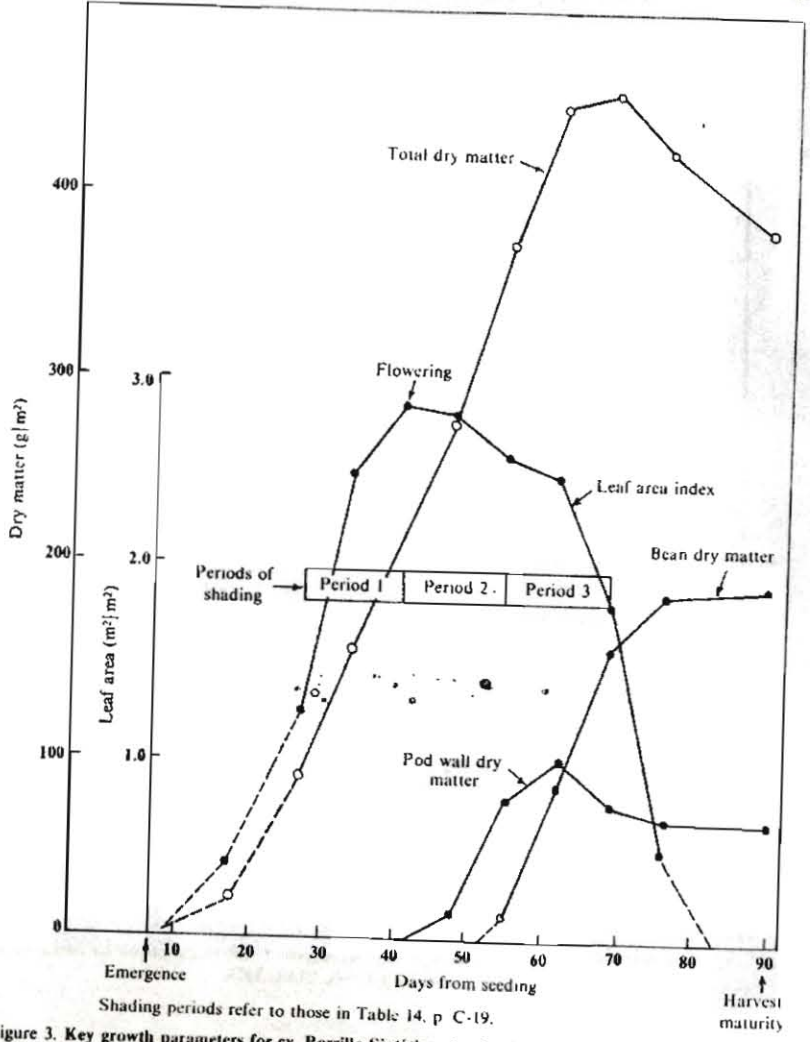
(4) The germplasm bank is continually receiving and shipping seed. In 1975, 1,105 new accessions were received, principally from Mexico and Central America, while samples of 2,832 accessions were forwarded to other centers.

PHYSIOLOGY

Growth and development studies

The varieties ICA Guali, Porrillo Sintético and PI 310740, representing plant types I, II and III, respectively, were analyzed exhaustively in 1975 to better understand *P. vulgaris* growth and development processes under tropical conditions. The experiments were conducted at Palmira at a density of 30 plants|m² with furrow irrigation and adequate protection from insects and diseases.

Key growth parameters for Porrillo Sintético are shown in Figures 3 and 4. Dry matter production reached a maximum of



Shading periods refer to those in Table 14, p C-19.

Figure 3. **Key growth parameters for cv. Porrillo Sintético at a density of 40 plants|m², under fertilized, irrigated and protected conditions at CIAT, 1975A.**

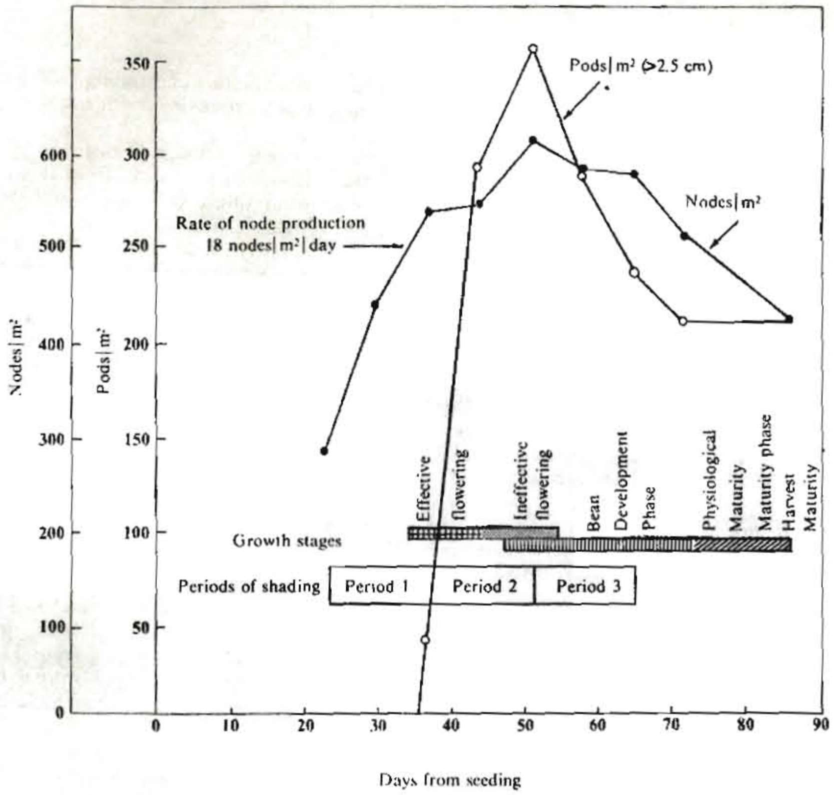


Figure 4. Node and pod density variations in relation to growth stages for cv. Porrillo Sintético for same crop shown in Figure 3.

450 g|m² and declined as leaf fall accelerated after a maximum green leaf area of 3.0 m²|m². Crop growth rate was virtually linear from 20 to 60 days from seeding with flowering occurring at 38 days and physiological maturity at about 80 days. Node production continued well into the flowering phase and reached a maximum rate at preflowering of 18 vegetative nodes produced|m²|day. Pod abscission, even under the excellent growing conditions at CIAT, was severe during the bean development phase.

Flower production and subsequent development was mapped on representative plants of each variety as shown in Figure 5. The pattern of "flower" (pods < 3 cm) and "pod" (> 3 cm) abscission is summarized in Table 13. In the determinate variety ICA Guali, with a maximum of eight nodes on the main stem at flowering, flowers borne directly on nodes 7 and 8 all abscissed as did flowers which formed late in the flowering process on lower branches. The same pattern of abscission was evident in the indeterminate

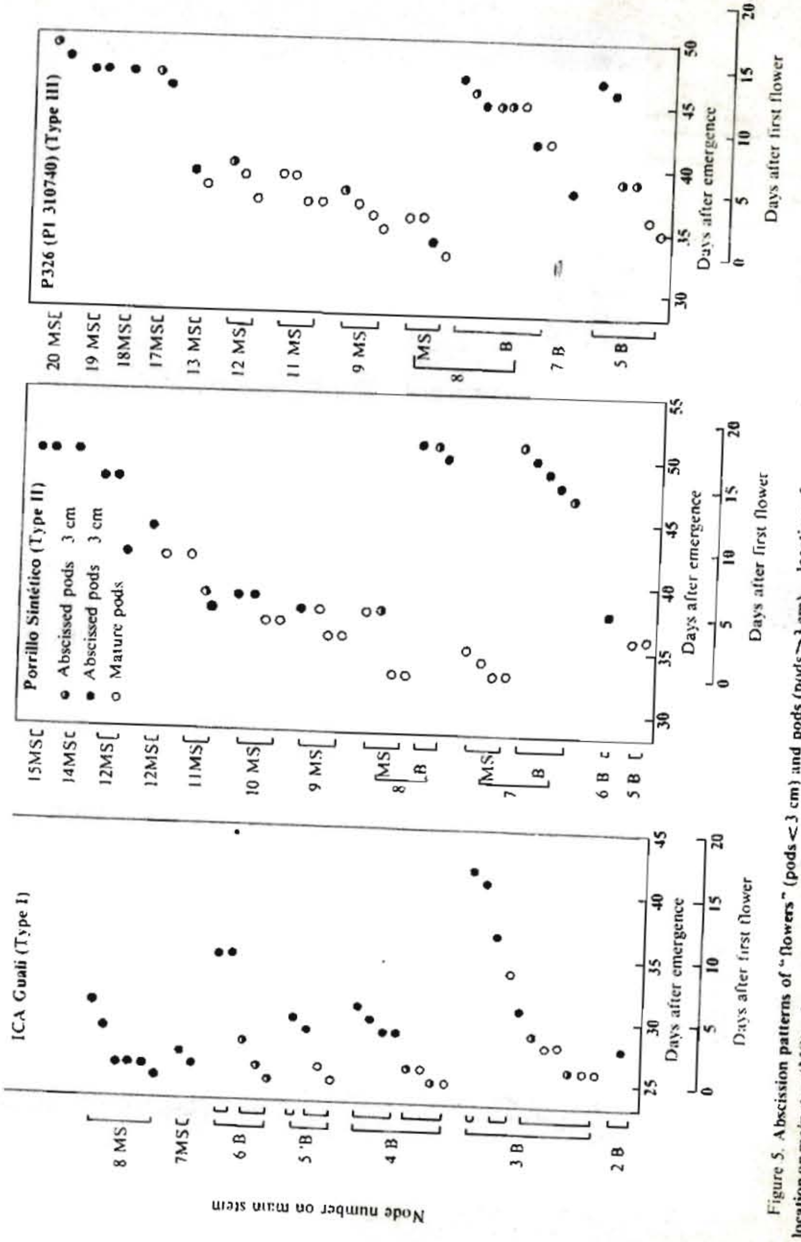


Figure 5. Abscission patterns of "flowers" (pods < 3 cm) and pods (pods > 3 cm), location of mature pods in relation to the time each bud opened, and pod location on main stem (MS) or branches (B) for three varieties of bean with three growth habits. CIAT (1975A).

Table 13. **Summary of flowering and pod abscission data for three varieties of *P. vulgaris*, CIAT, 1975A**

Variety	ICA Guali	Porrillo Sintętico	Pl 31074
Growth habit	I	II	III
Total number of flowers|plant	37	39	39
Pods abscissed < 3 cm	21	20	13
Pods abscissed > 3 cm	7	5	9
Mature pods|plant	9	14	17
Pod set efficiency (%)	24	36	44
Flowering period (days)	18	19	17
Period (A) for first 60% flowers (days)	4	10	10
Pod set efficiency during A (%)	36	60	70
Period (B) for final 40% flowers (days)	14	9	7
Pod set efficiency during B (%)	7	0	6

varieties but in addition, abscission was evident on main stem nodes produced after flowering. Pod set for all varieties was significantly higher in the first-formed flowers, the extreme case being Porrillo Sintético where flowers that formed during the last 16 days produced no pods at all. Clearly, flower and pod abscission is an area needing major research emphasis.

Analysis of the total soluble carbohydrates in the main stem is shown in Figure 6. The pattern of carbohydrate storage was strongly related to growth habit with ICA Guali showing more than 12 percent total carbohydrates (starch plus sugars) during the postflowering phase. By contrast, Trujillo 3 (a Type IV variety included in this analysis) showed a relatively constant and very low carbohydrate level at all growth stages. Carbohydrates decreased rapidly in the determinate variety only when significant bean filling had commenced. It is unlikely that photosynthate stress per se is the direct cause of flower abscission in this variety.

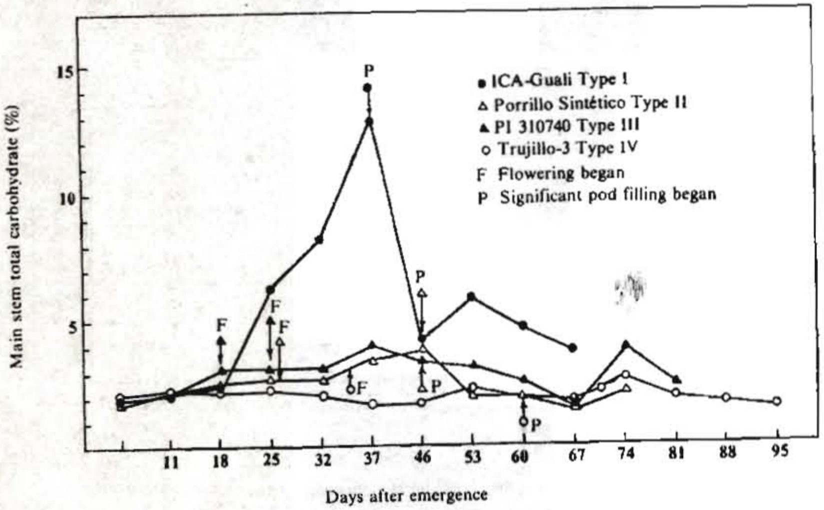


Figure 6. **Total main stem carbohydrate (anthrone method) in four varieties of *P. vulgaris* (Types I-IV) in relation to days from emergence at CIAT (1975A). Initiation of flowering and significant pod filling shown for each variety.**

Source-sink manipulation

A series of experiments with Porrillo Sintético involving shading (48% interception); carbon dioxide fertilization, leaf thinning and photoperiodically induced extension of the preflowering phase, were used to alter the development pattern for the different growth stages shown in Figures 3 and 4. Shading (Table 14) reduced yields in the preflowering (-14 to 0 days before flowering) and flowering (0 to +14 days) phases equally. Yield reduction during preflowering was associated with reduced node density and a subsequent decrease in the number of potential racemes. Shading during flowering did not affect node production but was associated with a lower number of racemes. Yield was not reduced by the postflowering (+14 to +28 days) treatment indicating that preflower node production and pod set efficiency in the flowering phase were the main factors controlling yield potential in this crop-environment situation.

Leaf thinning (Table 15) in the late-flowering (+13 days from flowering) and bean filling (+22 days) periods reduced yields significantly, but considering the severity of the treatment, yield reduction was not great. In this case, yield reduction was associated with lower mean bean weight, as would be expected when a major proportion of the leaf system is removed during the period of active bean filling.

Applying carbon dioxide to field canopies to alter source sink balance has proved an excellent physiological tool in other crops. Preliminary studies in which CO_2 was applied preflowering increased yields 19 percent. This will be further studied in 1976.

When the photoperiod sensitive variety Porrillo Sintético was grown at photoperiods ranging from 13-19 hours, flowering was delayed by up to 6 days with a consequent 71 percent yield increase, to 3,388 kg|ha (Table 16). This increased yield was associated with a 26 percent increase in node density|m² at flowering and a 58 percent increase in final bean

Table 14. **Effect of shading (48% interception) during three growth stages on yield and associated parameters of cv. Porrillo Sintético, CIAT, 1975A.***

	Growth stage		
Parameter	Preflowering (-14 to 0)**	Flowering (0 to + 14)	Postflowering (+ 14 to + 28)
Grain yield	78.2	74.3	91.2
Total dry matter	79.7	79.3	93.7
Harvest index	97.1	92.4	96.9
Racemes|m²	80.4	78.0	88.4
Pods|m²	81.2	81.1	101.2
Beans|pod	95.2	90.1	94.0
Bean weight (mg|bean)	99.5	99.0	96.5
Nodes|m²	79.0	98.0	92.0
Racemes|m²	80.0	78.0	88.4

* Data expressed as percentage of nonshaded control plot; mean control yield was 205 g|m² (14 percent moisture)

** On day 0, 50 percent of plants have at least one flower

Table 15. **Effect of leaf thinning at three growth stages on yield and associated parameters of cv. Porrillo Sintético, CIAT.***

Time of thinning	Bean yield (g|m^2)	No. of pods|m^2	Bean wt. (g|pod)	Bean wt. (mg|bean)
Control	274 (100)	236	1.16	228 (100)
Day 0**	222 (81)	213	1.03	205 (90)
Day 13	152 (55)	174	0.80	182 (80)
Day 22***	181 (66)	220	0.82	172 (75)

* Mean of treatments with 33, 66 and 100 percent of leaves removed at growth stage.

** On day 0, 50 percent of plants have at least one flower

*** Bean filling commenced on day 14.

density per m^2. Total dry matter production and bean size also increased. The rate of vegetative node production during the extra six days before flowering was 19.3 nodes|m^2|day, a rate similar to that for the normal preflowering development phase. The increased pod set appears to be due to decreased abscission, particularly on those nodes (on main stem and branches) which normally would have been produced after flowering. The results of three treatments applied during the preflowering phase are summarized in Table 17. These data confirm the importance of increased node structure by the time flowering commences. An increase in the length of the preflowering phase could be the most rapid means to achieve improvement.

Yield potential in a wide range of genotypes

Physiological data was taken on 193 genotypes representing all four growth habits (Type IV varieties supported on 2-meter trellis). A correlation matrix showing the interrelations of a wide range of characters is shown in Table 18. These results are further evidence that node density (in this case measured at maturity) is the first sequential determinant of yield. The positive correlations of node density with raceme density and bean density and the nonsignificant relationship between node density and other pod characters, i.e. pods|raceme and bean number|pod.

Table 16. **Effect of photoperiod control of the preflowering phase on yield and other parameters of cv. Porrillo Sintético, CIAT, 1975A.**

Parameter	Photoperiod		Control
	16 hr 30 min. (1-4 m)[1]	16 hr 30 min (4-8 m)[1]	12 hr 30 min[2]
Yield (kg|ha, 14% moisture)	3,388 (171)	3,053 (154)	1,978 (100)
Days to flowering[3]	39	35	33
Days to physiological maturity[3]	75	71	68
Days of postflowering	36	36	35
No. of nodes|m^2 at flowering	560 (126)	473 (106)	444 (100)
Bean weight (mg|bean)[4]	172 (107)	168 (105)	160 (100)
Bean no.|m^2	1,693 (158)	1,560 (145)	1,070 (100)
Dry matter|m^2, at maturity[5]	498	488	377
Harvest index	0.58	0.54	0.45
Bean yield efficiency (g|m^2|day)	3.88	3.69	2.50

[1] Distance from line of illumination.

[2] Normal daylength, Palmira: 3°N

[3] Days from emergence (planting to emergence was 7 days)

[4] Dry matter basis

[5] Excluding petioles and leaves at maturity.

Table 17. **Effect of three preflowering treatments on yield and associated parameters of cv. Porrillo Sintético at plant density of 30-40 plants|m^2, CIAT, 1975A[1].**

Treatment	Yield (g|m^2)		Nodes|m^2 (% of control)	Pods|m^2 (% of control)
	Control	Treatment		
CO$_2$ fertilization[2]	217 (100)	258 (119)	97	117
Shading[3]	222 (100)	171 (78)	79	81
Extension of period[4]	198 (100)	339 (171)	126	158

[1] Preflowering period: 38 days emergence to flowering.

[2] 700 ppm applied for 2 weeks prior to flowering.

[3] Shading (48%) for 2 weeks prior to flowering.

[4] 16 hr 30 min photoperiod applied in preflowering period only

Table 18. **Correlation matrix of bean yield and other parameters for 193 varieties of four growth habits CIAT, 1974B[1 2 3].**

	Pod density|m^2	Bean density|m^2	Bean weight (mg|bean)	Node density|m^2	Raceme density |m^2	Pod no.|raceme	Bean yield|raceme	Bean no.|pod	Pod wall weight|pod	Pod wall ratio	Total dry matter (g|m^2)	Harvest index
Bean yield|m^2	.70	.64	.21	.42	.63	.04	.46	.18	.32	-.18	.94	.3
Pod density|m^2		.80	-.29	.51	.78	.29	-.28	.17	-.19	-.02	.70	14
Bean density|m^2			-.56	.41	.53	.32	-.15	.66	-.04	.01	.69	06
Bean weight (mg|bean)				-.09	-.04	-.36	.70	-.63	.45	-.16	.13	.26
Node density|m^2					.58	-.15	-.09	.04	-.08	-.02	.48	-.11
Raceme density|m^2						-.30	-.11	-.06	-.13	-.08	.59	.20
Pod number|raceme							-.27	.20	-.13	19	.11	-.15
Bean yield|pod								.07	.69	-.23	.39	.34
Bean number|pod									.14	02	.28	-.01
Pod wall weight|pod										.47	.40	-.14
Pod wall ratio[4]											.02	-.66
Total dry matter|m^2												.07

[1] Mean of two replications, plot size 1 x 2 meters.

[2] Type IV varieties supported on 2-meter trellis.

[3] Values underlined are significant at $P = 0.05$

[4] Pod wall weight|total pod weight.

suggest that node numbers can be increased without negative compensations in other yield components formed later in the sequence. The negative correlation between bean density and weight (-0.56) or pod density and bean yield per pod (-0.28) suggest that postflowering photosynthate limitations could be limiting yield potential in those varieties with high sink size, i.e. pod density|m².

The strong positive correlation of total dry matter with yield (0.94) and the rather poorer correlations with harvest index were also apparent last year. Increased node structure and leaf area obviously lead to increased dry matter production.

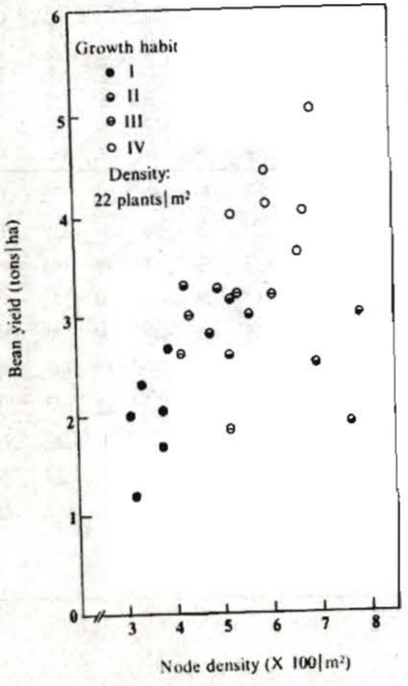


Figure 7. **Bean yield of 26 varieties of *P. vulgaris* in relation to vegetative node density (main stem plus branches) at flowering.**

When yields of 26 varieties were compared there was a strong relationship between node density at flowering and bean yield (Figure 7). Only three bush varieties with high node density did not follow this trend. In this experiment, yields were high with climbing beans producing up to 5 tons|ha and bush beans 3 tons|ha. Further studies with climbing beans, either in monoculture or associated with maize, are reported on page C-53.

Photoperiod insensitivity

One hundred seventy-three promising accessions from types I, II and III were screened for photoperiod sensitivity in the first semester of 1975 using an illumination system previously described (1973 Annual Report). Thirty-nine percent were insensitive to the 18-hour photoperiod regime in the field at CIAT (Table 19). No correlation is evident between photoperiod response and growth habit or maturity group. Insensitive varieties occurred in each growth habit group and in material with a wide range in number of days to flowering.

Table 19 **Number of photoperiod insensitive varieties indentified in 18-hour photoperiod from among 173 promising *P. vulgaris* varieties, in relation to growth habit and days to flowering. CIAT, 1975A.**

Days to flowering**	Growth habit I	II	III	Total
30-34	5	2	2	9
35-39	5	1	-	6
40-44	4	30	3	37
45-49	2	6	3	11
50-54	1	2	-	3
55	-	2	-	2
Total	17	43	8	68
Total screened	40	98	35	173
Percent insensitive	42	40	22	39

* Mean temperature 23.8°C, normal daylength 12 hr 20 min.

** Days from sowing.

Photoperiod insensitivity has contributed to wide adaptation and has been a feature of international research in wheat, rice and other crops. The wide range of potential sources of insensitivity identified in this study will allow breeders considerable flexibility in ensuring that elite materials produced at CIAT will be insensitive. The existence of late-flowering, insensitive accessions could lead to high yielding materials with high node density and wide adaptation to photoperiod.

The influence of temperature, particularly night temperature, in altering the photoperiod is being considered in a collaborative study at Cornell University.

Drought tolerance screening

An experiment similar to one described in 1974 was conducted at La Molina, Peru. Twenty genotypes were tested. Two irrigation regimes were imposed: (a) one irrigation approximately 13 days after flowering commenced, and (b) four irrigations over the 80 to 110-day growth cycle. In general, stress plot yields were lower in 1975 (Table 20). Lower overall yields were associated with a low plant density due to the irrigation system used which required planting in wide furrows.

Of those showing reasonable resistance in 1975, P750 appeared to escape the stress by having an extended flowering period and producing pods on later formed flowers. P729, P730 and CIAT G-03836 apparently can withstand stress during the flowering period since they did not have an extended flowering period.

Stability of growth habit

Results obtained in 1974 demonstrated the importance of growth habit stability in promising materials grown in a range of climatic conditions. In 1975, in collabora-

Table 20. **Field evaluation of drought tolerance (1975A), and stress: control yield ratios (1974A), La Molina, Peru.**

Identification: CIAT No.	Promising No.	Control yield (tons|ha) 1975A	Stress: control yield ratio* 1975A	1974A
G 00073	-	0.61	0.49	0.69
G 01643	P 748	0.66	0.50	1.02
G 01951	P 729	1.13	0.61	0.74
G 02206	P 730	0.91	0.57	1.16
G 03790	P 747	1.22	0.36	0.90
G 03836	-	0.52	0.63	0.87
G 05704	P 689	1.03	0.52	-
G 04109	P 735	0.82	0.51	0.58
G 04115	-	1.34	0.45	1.08
G 04498	P 392	0.91	0.36	-
G 02409	P 359	0.65	0.53	0.49
G 03241	P 734	0.66	0.28	-
G 04118	-	0.92	0.27	1.04
G 04128	P 750	0.84	0.62	0.89
G 04198	-	1.21	0.38	-

* Ratio of stressed yield to irrigated control yield

tion with Cornell University, five type II selections showing stable growth habits across widely differing conditions in Colombia and Ecuador have been compared with five varieties showing unstable growth habits (variable expression of apical dominance). Eight regimes of temperature, daylength and light intensity were utilized. The results support the field evaluations for stability. Further studies on this character are in progress.

MICROBIOLOGY

Variety-strain interaction

Microbiology studies during 1975 again emphasized varietal response to inoculation, rather than strain testing.

Preliminary experiments at Popayán compared 60 accessions of *P. vulgaris*, either inoculated with the strain CIAT 57, or uninoculated. Differences between accessions varied widely in nodule number, nodule dry weight, yield and percent N (Table 21). In addition, some accessions, for example 72 Vul 26549, appeared to nodulate more easily with soil- or seed-borne rhizobia than did others. Plant nitrogen increased up to eight-fold in some accessions after inoculation (Fig. 8), while overall, yield increased 10 percent.

Ten accessions, including the most promising selections from the above experiment, were then compared at Popayán. The accessions differed in growth habit, nodulation characteristics, flowering and maturity times and maximum LAI. Two blocks of each line were sown, one inoculated with the strain CIAT 57 and lime pelleted; the other pelleted but not inoculated. Replicate samples were taken from each block at weekly intervals through most of the growing season and were tested for reduction of acetylene, nodule number and dry weight, leaf and stem dry weight, seed weight and percentage nitrogen and carbohydrate. The method for measuring acetylene reduction is shown in Figure 9.

Fixation rates of up to 20 μM C_2H_4 produced|plant|hour were achieved (Fig. 10). This level is comparable to fixation rates found in other grain legumes. The maximum levels of specific nodule activity (SNA) obtained, 100-120 uM C_2H_4 produced|g nodule dry weight|hr, also compare favorably with levels reported elsewhere. The duration of fixation was, however, much shorter than has been reported for peanut and soybean with most lines fixing little nitrogen before day 39, or at day 74. Despite this, fixation gains for the ten varieties averaged more than 25 kilograms N_2 fixed|ha, during the 120-day growth period, and inoculated plots

Table 21 **Response of selected lines of *P. vulgaris* to Rhizobium inoculation.**

	Unmoculated				Inoculated			
Line	Nodules|plant	Nodule dry wt. (mg|plant)	Yield (g|plant)	N (%):	Nodules|plant	Nodule dry wt. (mg|plant)	Yield (g|plant)	N (%)
20972	40.1	91.0	7.55	4.21	105.0	340.0	13.02	4.50
25093	10.5	20.0	3.02	3 67	223.0	627.0	5.36	3.61
25146	1.8	34.0	3.92	3.68	26.3	30.0	1.26	4.99
26259	49.3	29.4	0.67	3 17	47.5	70.0	1.42	4.53
26549	70.9	118.0	4.44	3.13	112 0	396.0	8.38	4.93
26689	4.3	11.0	12.07	3 53	61 5	228.0	16 09	4.71

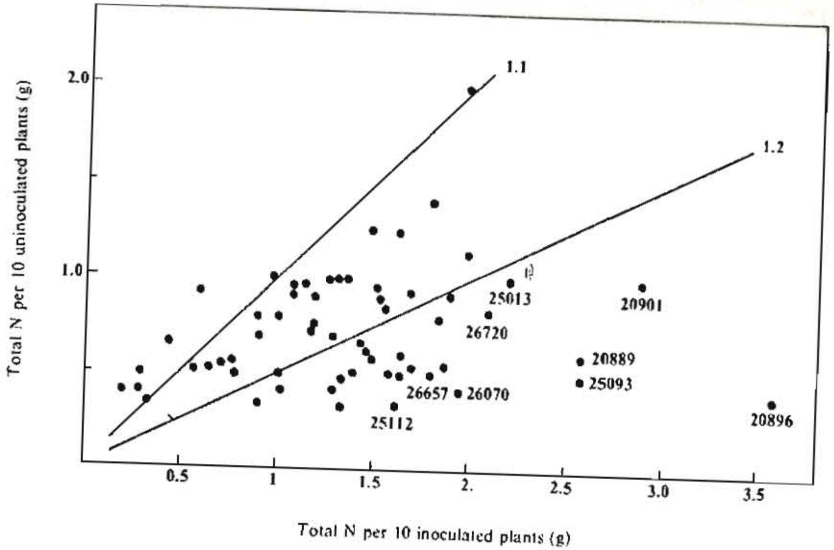


Figure 8. **Increase in total N among 60 accessions of *P. vulgaris*** as a result of inoculation. **Each dot represents the response of a single accession. Accessions below the 1:2** line more than doubled total N **after inoculation and are the most promising for increasing N fixation. Exceptional accessions are named.**

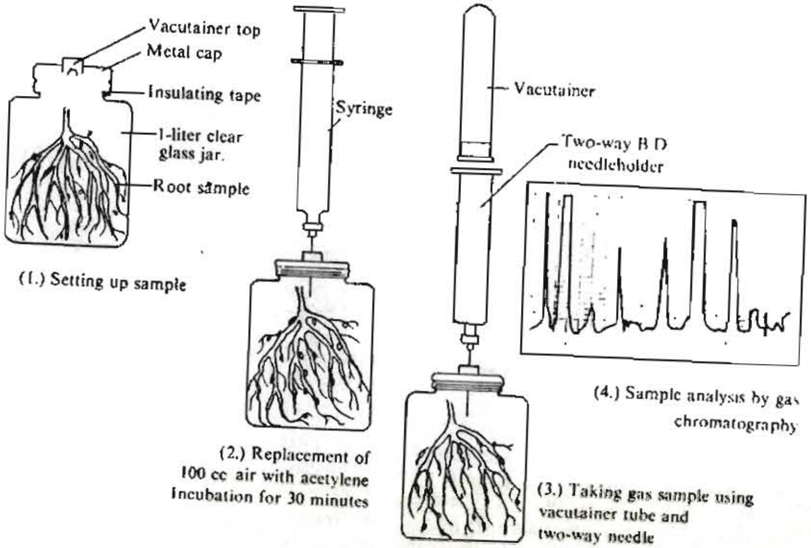


Figure 9. **Measuring N fixation by acetylene reduction.**

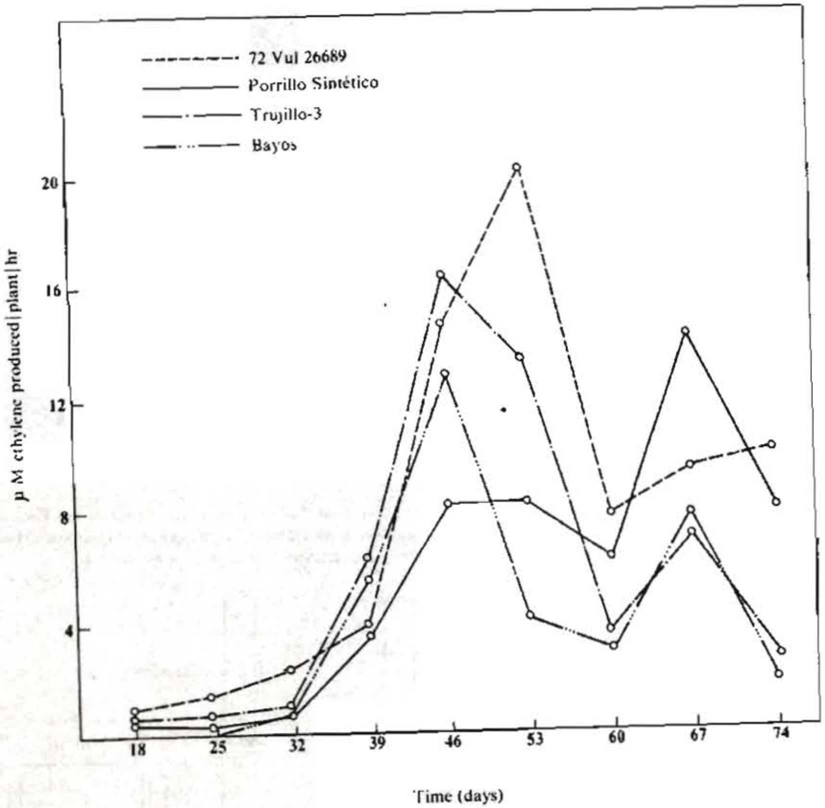


Figure 10. **Acetylene reduction in four varieties of *P. vulgaris* at different stages in the growing season.**

outyielded those without inoculation by 20 percent. Total N accumulation rates, averaged for the 10 accessions, are shown in Figure 11.

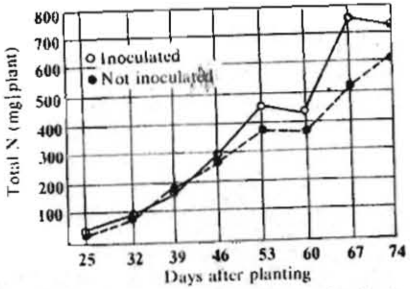


Figure 11. **N accumulation per plant in *P. vulgaris* as a result of inoculation, (averaged for 10 varieties studied).**

The balance and movement of energy in the plant clearly influenced nitrogen fixation by the ten accessions. Thus, (a) fixation | plant and per unit nodule weight dropped near flowering, the decline in specific nodule activity being most dramatic (Fig. 12); (b) accessions which flowered early (i.e. Bayos) fixed much less nitrogen than did late-maturing selections, for example 72 Vul 26689 (Fig. 13); (c) in the preflowering phase nitrogen fixation levels correlated with leaf weight; and (d) levels of fixation | unit leaf weight also differed considerably between varieties with P 566A being low in efficiency of energy utilization for nitrogen fixation (Fig. 14).

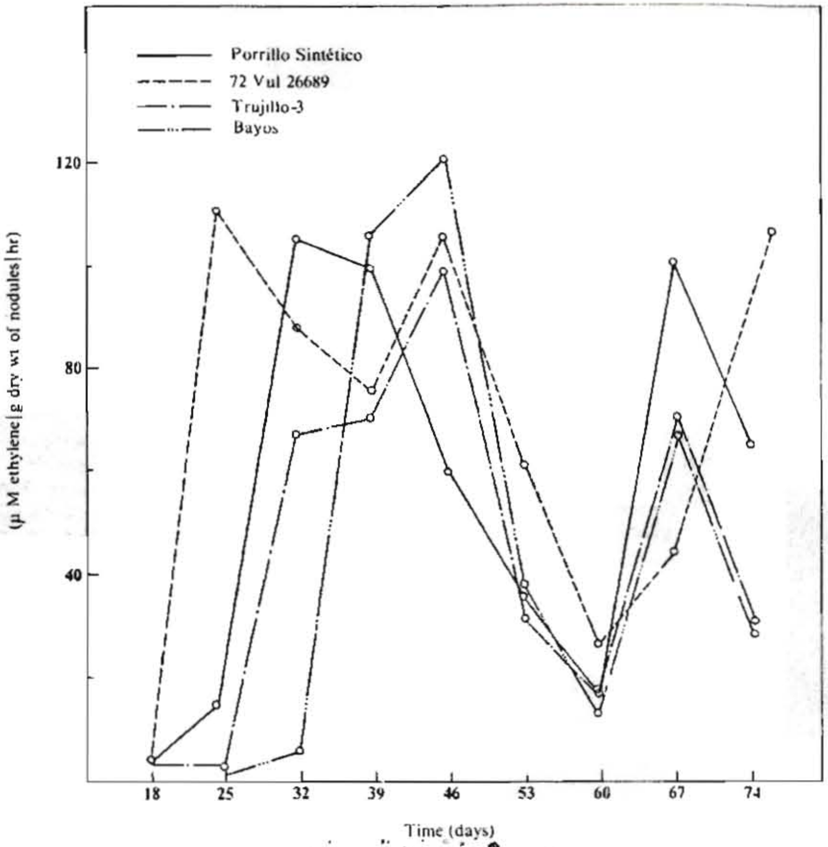


Figure 12. Change in specific nodule activity (u M ethylene produced | g dry weight of nodules | hr) during the growing season for four common *P. vulgaris* varieties.

Shading (Table 14) and time to maturity studies in beans have demonstrated the importance of sink-source relationships to final yield. Similar balances appear to control nitrogen fixation. Studies in progress are concentrating on the translocation of energy from leaves to roots, and on how growing habits, flowering patterns, and maturity characteristics affect the energy available for fixation. It is of note that CHO levels obtained in these experiments were very similar to those reported in Figure 6.

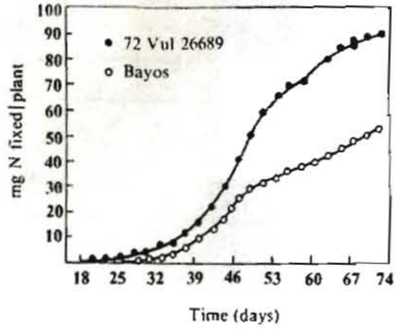


Figure 13. **Cummulative N fixation curves for precocious (Bayos) and later flowering (72 Vul 26689) accessions.**

Results obtained in the glasshouse correlate flowering time to nodule development in *P. vulgaris* (Fig. 15). The microbiology and physiology groups will collaborate in furthering these studies.

Comparison of nitrogen fixation in beans and soybeans

Since *P. vulgaris* is generally considered inferior to soybean in symbiotic nitrogen fixation, an experiment was undertaken at CIAT, to compare fixation in the bean varieties Trujillo 3 (Type IV) and Porrillo Sintético (Type II) with that in the soybean variety Pelikan. Plants were grown in a soil-sand bed and sampled every ten days. Characteristics considered were the same as reported in the experiment on page C-24.

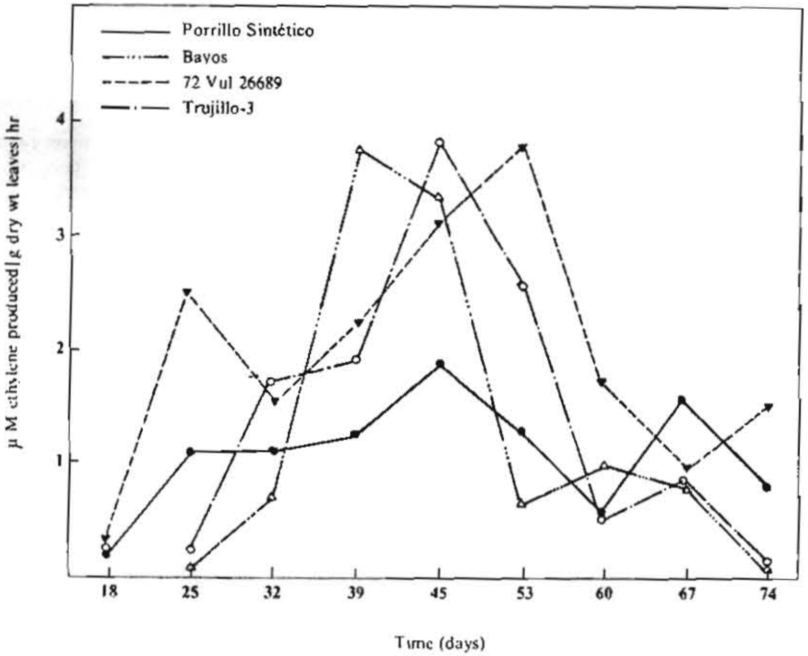


Figure 14. **Acetylene reduction per unit leaf weight in four varieties of *P. vulgaris* during different stages of the growing season.**

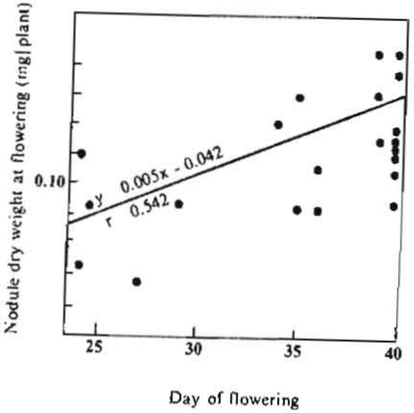


Figure 15. **Relation between days until flowering and nodule dry weight in *P. vulgaris*.**

Although Pelikan nodulated slowly, by the 38th day after planting it had developed significantly more nodule tissue than either bean variety, finally producing more than twice the weight of nodules found in Porrillo Sintético or Trujillo 3. Nitrogen fixation also was considerably greater in the soybean (Fig. 16), both bean varieties responding poorly to inoculation under CIAT conditions. Experiments are in progress to determine if this was due to high temperatures. In view of the probable dependence of small farmers on climbing varieties with limited nitrogen applied as fertilizer, the poor performance of Trujillo 3 at both Palmira and Popayán is worrying. Studies are continuing to determine whether other Type IV plants respond similarly to inoculation.

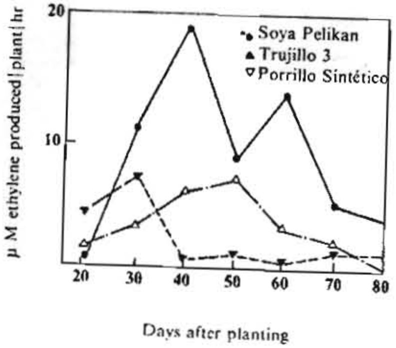


Figure 16. **Levels of acetylene reduction in two bean varieties and one soybean variety during the growing season.**

Strain trials

Strain trials using the host variety ICA-Pijao were repeated in 1975, the strain CIAT 57 again being most efficient in nitrogen fixation as measured by acetylene reduction. Yield differences were, however, not significantly different.

Inoculant supply

As in previous years the soil microbiology group continued to supply a wide range of **Rhizobium** cultures to both scientists and farmers in Latin America.

ENTOMOLOGY

Empoasca kraemeri

Resistance selection

Screening of accessions in the germplasm bank for leafhopper (*Empoasca kraemeri*) resistance continued to have high priority; screening of all materials for which seed was available was completed this year. About 1,000 lines were selected for further testing. Of those, 395 will also be screened for nymphal populations in the hope of detecting resistance mechanisms other than tolerance. The 14 most promising lines have been selected for diallel crossing to raise resistance levels and measure which parents form the best combinations for this. The lines are P6C, P231, P346, P458A, P478, P511A, P512A, P560B, P680A, P681A, P682A, P722, P723A and PI 200-974.

Resistance levels of 54 varieties were measured in the wet season to compare with results from last year's dry season (Table 22). The yield reduction in wet

Table 22. **Levels of resistance of selected accessions of *P. vulgaris* to *E. kraemeri*, as determined by yield increases resulting from pesticide protection (wet season planting).**

Accession	Yield per plant (g) Not Protected	Yield per plant (g) Protected	Increase (%)
73 Vul 3624	10.88	9.76	-11
PI 200-974	9.03	9.28	3
72 Vul 25221-1	9.58	10.60	11
PI 208-769	7.99	10.42	30
Bunzi	7.95	10.59	34
Line 32	10.06	14.61	45
Brazil 1059	7.19	11.30	57
Brazil 1074	5.52	9.37	70
Brazil 1089	9.98	17.15	72
72 Vul 25299 M	7.89	14.71	86
Brazil 1031	2.34	7.41	217

season plantings was much less, and selection 73 Vul 3624 actually yielded more without pesticide treatments. This suggests that the resistance level found in some lines thus far may be sufficient for a low intensity of **Empoasca** attack. Some lines, however, ranked among the best in the dry season, but performed poorly in the wet season. Specific adaptations probably play a role in these types of experiments.

No high level of resistance to *E. kraemeri* has been found so far within *P. vulgaris*. For this reason other species were tested for resistance in the hope that interspecific crossing might incorporate this resistance into common beans. In preliminary screening higher levels of resistance were found in other species, i.e., in *P. mungo* (Table 23), but the variation in resistance levels in these species also was large. Other materials of species crossable with *P. vulgaris* are being evaluated.

Table 23. **Resistance range expressed in nymphal counts in selections of** Phaseolus **species to** *E. kraemeri*

Species	Selection no.	No. of nymphs/10 leaves at days after planting 20	35	50	Avg
P. acutifolius	1	3	5	4	4.0
	2	17	54	13	28.0
P. lunatus	1	5	11	2	6.0
	2	14	102	37	51.0
P. aureus (*V. radiata*)	1	0	0	1	0.3
	2	1	2	3	2.0
P. mungo (*V. mungo*)	1	0	0	0	0.0
	2	0	0	0	0.0
Controls					
Calima	(Susc.)	17	54	18	30.3
73 Vul 299	(Resist.)	3	19	9	10.3

Table 24 **Average number of *E. kraemeri* nymphs emerging per entry in free-choice oviposition tests, and number of males in feeding preference test.**

Accession	Oviposition test Free-choice	Oviposition test No-choice	Feeding test (no. of males)
Diacol-Calima	71.7 a*	75.0	4.6 a
P 680	54.3 ab	58.7	3.3 ab
Brazil 1087	50.0 ab	81.0	2.3 b
ICA-Pijao	46.3 b	53.7	3.6 ab
Brazil 343	36.3 b	67.7	3.3 ab
ICA-Tui	30.3 b	60.0	1.3 c

* Data within columns followed by the same letter are not significantly different at 5 percent level.

Resistance mechanism against E. kraemeri

More detailed studies were made on the resistance mechanism of six bean varieties with different resistance levels. In free-choice oviposition and feeding tests (the latter with males only), a significant oviposition and feeding preference existed for Diacol-Calima, a susceptible variety, compared to ICA-Tui, a tolerant variety and the least preferred (Table 24). However, the nonpreference disappeared when the leafhoppers were confined to one variety only, and equal numbers of nymphs emerged per variety. This indicates that the level of nonpreference is low. Antibiosis was not found in these six varieties (Table 25), nor in 54 additional accessions tested. Tolerance, although found in field screening, could not be measured accurately in laboratory trials.

In trials with excised leaves in nutrient solution, seven adults on each excised leaf caused grade 5.0 damage on Diacol-Calima, after 3 days, and 3.1 on ICA-Tui (scored on a 1-9 scale). Although the observed variation in response was too great for this technique to be used in screening for increases in resistance on individual plants in segregating populations, further studies are in progress to obtain a more precise screening methodology (see also page C-33).

Table 25. **Test for antibiosis in six *P. vulgaris* accessions.**

Accessions	Duration of nymphal stage (days)	Adult survival in 6 days (%)	Avg. weight (µg)
Diacol-Calima	11.0	94	144
Brazil 343	10.7	79	140
Brazil 1087	11.2	86	133
ICA-Pijao	10.7	94	144
P 680	11.0	92	141
ICA-Tui	10.6	92	141

Table 26. **Life cycle and reproduction of *E. kraemeri* under laboratory conditions on Diacol-Calima plants.**

Development stage	No. of days		
	Min	Max	Avg
Egg	9	10	9.1
First instar	1	2	1.9
Second instar	1	2	1.8
Third instar	1	2	1.2
Fourth instar	2	2	2.0
Fifth instar	3	3	3.0
Preoviposition period	4	7	5.2
Lifespan	13	86	64.8
	14	80	58.2
No. of eggs	13	168	107.2

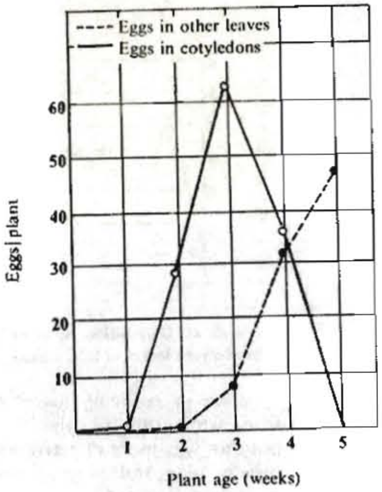


Figure 17. **Distribution of eggs on leaves of Diacol Calima plants during the first five weeks.**

Biology of E. kraemeri

Because bean entomology literature lacks much information on the biology of *E. kraemeri*, a study was made on some aspects of its biology, using the susceptible variety Diacol-Calima as the host. The egg stage lasted almost as long as the nymphal period (Table 26). The period from egg to egg lasted 24.2 days and adults lived an average of two months. The adults preferred the petioles over the leaves as oviposition sites. On line 73 Vul 3624, 82 percent of the eggs were found in petioles and only 18 percent in the leaf blades. A remarkably high percentage of the total eggs per plant were found in the cotyledons. During the first four weeks, more than half the eggs per plant were found in these leaves(Fig. 17). Egg counts were made under the microscope after clearing the leaf tissue with lactophenol.

A relatively high level of egg parasitism by **Anagrus** sp. (Myrmaridae) was found. When plant samples were cleared of insects and subsequent numbers of newly emerged nymphs and parasites were recorded, 60 to 66 percent egg parasitism was found (Table 27). These may be overestimates as some of the eggs are infertile and newly emerged parasites may oviposit in developing eggs.

Table 27. **Level of egg parasitism of *E. kraemeri* by Anagrus sp. (Myrmaridae).**

Treatment	Avg. no. of emerged insects		Parasitism (%)
	E. kraemeri nymphs	**Anagrus** adults	
Field collected plants	11.6	28.5	66
Field exposed plants (4 days)	9.2	14.2	60

The relative damage caused by different developmental stages of *E. kraemeri* was also studied using excised leaves in nutrient solutions. Ten insects in each developmental stage were caged on the leaf, and the number of days until leaves started to curl and dry along the margins was recorded.

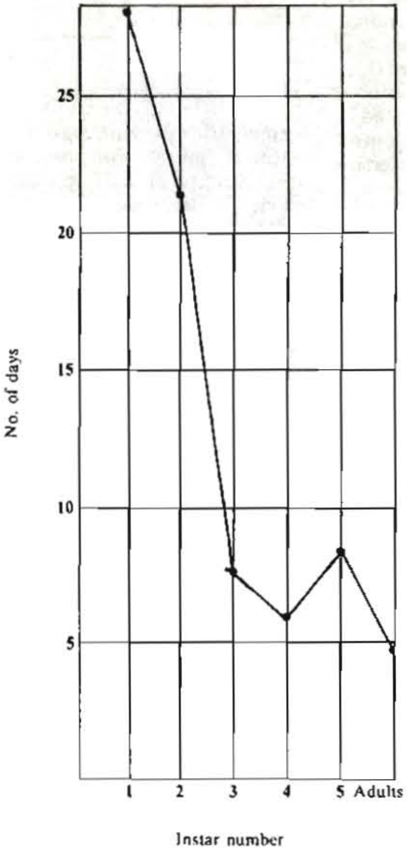


Figure 18. **Days required by 10 insects of each of the six developmental stages to cause a leaf of Diacol Calima to curl and fold along the leaf margins (by Boyliantes).**

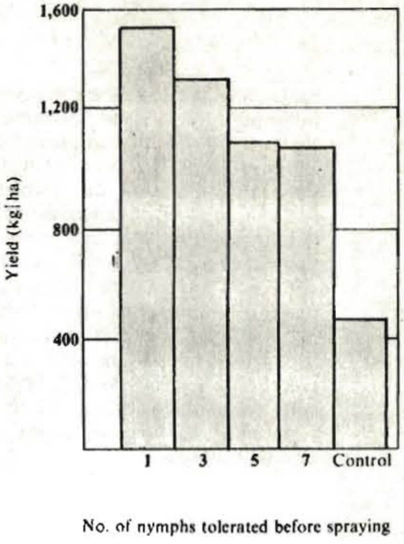


Figure 19. **Yield (kg|ha) of Diacol Calima when azodrin (0.35 liter a.l.|ha) was sprayed when the nymphal population had reached one, three, five or seven insects per leaf (avg. of three replications).**

Preliminary results indicate that adults are more damaging than nymphs and that the fourth nymphal instar is more damaging than the fifth (Fig. 18). In the field there was a close correlation between damage caused by **Empoasca** and the number of nymphs per leaf (Fig. 19). In this experiment monocrotophos (0.35 liter| ha) was applied each time the nymphal population reached one, three, five or seven nymphs per leaf. The frequency of sprays in the treatments with five or seven nymphs per leaf was the same, as after the first application the population did not reach seven per leaf again. These data indicate that for each additional nymph per leaf, yields are reduced by 7 percent. However, the relationship appears non-linear at high nymphal populations.

The plant growth stage most susceptible to **Empoasca** attack was determined by not controlling the insects during one of the following growth stages: planting to first trifoliate formed; first trifoliate formed to 15 days thereafter; from that stage to flowering; from flowering to pod-filling; and from pod-filling to harvest. It appears that beans are most susceptible to **Empoasca** damage from the time the first trifoliate is formed until 15 days thereafter. Control of **Empoasca** up to flowering is essential if yields are to be maintained (Fig. 20). These results are similar to those recorded in Tables 14 and 15. These studies will be used to better define control treatments that are timely and effective against **Empoasca**.

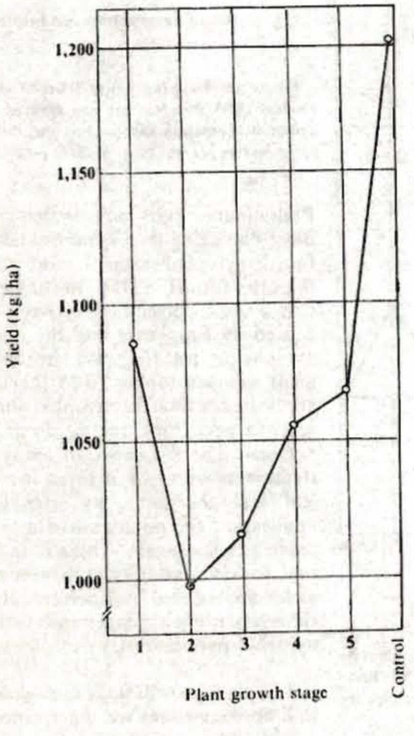


Figure 20. **Yield (kg|ha) on an average of four bean varieties when no insecticides were applied during one of each of five growth stages of the plant.**

Table 28. **Yield reduction by *P. latus* on selected infested and uninfested plants of Diacol-Calima beans.**

No. of plants	No. of pods|plant	Seed|plant (g)
86 uninfested	10.1	13.1
93 infested	5.6	5.8

Mites

Emphasis this year was on the Tarsonemid mite, *Polyphagotarsonemus latus*. Studies of its importance on an individual plant basis showed 56 percent yield loss following mite attack (Table 28). Damage caused by the mite is severe and is often mistaken for virus attack.

The mite multiplies extremely rapidly, passing from egg to egg in only five days under laboratory conditions (Table 29). Each female produces an average of 48.3 eggs (Fig. 21). Chemical control of the mite was effective with carbaryl and monocrotophos.

Whitegrubs

Whitegrubs, Phyllophaga sp., sometimes cause problems on newly cultivated land. A chemical control study showed that carbofuran (3% granular), furrow applied under the seed, and incorporation of disulfoton, aldrin or toxaphene-DDT, in that order, were most effective in reducing losses of seedlings from whitegrubs (Table 30). While carbofuran was more effective applied in the furrow, endosulfan gave better control when incorporated.

Table 29. **Average length of developmental stages of *P. latus*.***

Stage		Duration range (days)	Avg. duration (days)
Egg		2 - 3	2.03 ± 0.1
Larvae		1 - 2	1.03 ± 0.1
Pseudopupa		1	1.00
Adult	♀	7 - 18	15.06 ± 3.1
	♂	11 - 14	12.50 ± 2.1

* On variety ICA-Pijao in the laboratory (22-28°C)

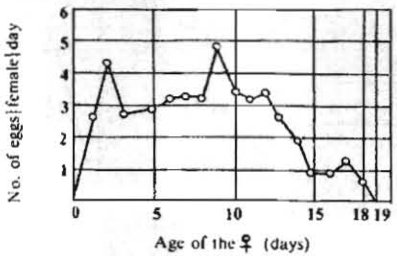


Figure 21. **Oviposition curve of *P. latus* in the laboratory on leaves of ICA Pijao.**

Stored bean insects

The search for resistance to *Zabrotes subfasciatus* was continued because some promising sources like PI 309-709 lost resistance when seed was planted, harvested and retested. From 296 additional lines tested in 1975, 70 were selected as showing promise of resistance expressed as either a low oviposition rate, low percentage adult emergence or slow development. Some examples are presented in Table 31.

Z. subfasciatus can be controlled by storing beans in the pods. Eggs were found on pod walls and larvae penetrated the pods, but died inside without entering the bean seeds (Table 32). The artificial damage to the pods consisted of cutting the pod tips to allow adults to enter at one end.

Chemical control studies were continued with pyrethrin compounds. Dosages of 1.5 ppm gave 120 days protection, while 2.5 and 4 ppm provide longer protection.

Malathion powder (4%) and the fungicide thiram formulated as a mixture of thiram (70%) and methoxychlor (2%) gave good control of **Zabrotes** (Table 33). The critical dosage of thiram for preventing oviposition is around 50 ppm while the commercial dosage for prevention of damping-off is about 638 ppm. Studies are continuing on the use of thiram without the methoxychlor addition.

Table 30. **Number of seedlings killed by whitegrubs following insecticidal treatments. Avg. 4 replicates. CIAT, 1975.**

Material	Rate a.i.|ha	Type of application	Avg. no. seedlings killed
carbofuran 3 g	0.9 kg	furrow, underseed	7.3 a*
carbofuran 3 g	0.9 kg	incorporated	27.3 abc
disulfoton 5 g	0.9 kg	incorporated	19.0 ab
aldrin 2 5	1.25 kg	incorporated	20.0 a
toxaphene-DDT (40-20)	1.6 0 8	surface spray	24.5 abc
Cebotox	40.0 kg	incorporated	27.3 abc
endosulfan 3 g	0.9 kg	furrow, underseed	40.0 cd
endosulfan 3 g	0.9 kg	incorporated	29.8 bc
fensulfothion 5 g	2.0 kg	incorporated	26.8 abc
Dotan 5 g	0.5 kg	incorporated	35.3 bc
Check	—	—	68.3 d

* Values followed by the same letter are not significantly different at the 5 percent level

Table 31. **Examples of selections expressing different degrees of resistance in preliminary tests to *Z. subfasciatus*.***

Selection	Selected for:	No. of eggs	Emergence (%)	Developm period
Brazil 1034	Low oviposition	9 0	38.8	46.7
P 364 B	Low % emergence	41.5	20.5	52.2
P 514	Slow development	95.0	47.4	51.2
Diacol-Calima (Susc. check)		100.0	84.0	48.8

* Average of two replications, 50 seeds infested with four pairs of adults|replication.

Table 32. **Infestation of *Z. subfasciatus* after exposing undamaged and damaged pods and shelled seed.***

Treatment	No. of eggs| replication	No. of adults| replication
Undamanged pods	0 8	0.8
Damaged pods	162.0	111.7
Shelled beans	203.7	162.8

* 100 seeds of Diacol-Calima per replication seven pairs of adults in each replication.

PLANT PATHOLOGY

Common bacterial blight

Screening for resistance

Field screening for tolerance to common bacterial blight was continued. During the first semester, 366 varieties from CIAT and Michigan State University were tested by inoculating with *Xanthomonas phaseoli*, isolate C6, using methods similar to those reported in 1974. Tolerance of the varieties Jules, Tara and PI 207-262, which were screened previously, was confirmed (Table 34). P561 and seven MSU lines were highly tolerant to common bacterial blight. Some question remains, however, as to the virulence of the C6 isolate.

Table 33. **Control of *Z. subfasciatus* with malathion and thiram|methoxychlor.***

Treatment level (ppm a.i)	Mortality at five days (%)	No. of eggs| replication	No. of adults| replication	Emergence (%)
malathion powder (4%)				
0	27.8	259.0	131.8	50.9
5	91.4	12.0	2.4	20.0
10	100.0	9.4	0.0	0.0
20	100.0	5.8	0.0	0.0
40	100.0	6.8	0.0	0.0
thiram powder (75%) and methoxychlor powder (2%)				
0	2.9	236.4	100.4	42.5
113	50.0	3.2	0 0	0.0
375	85.7	0.0	0 0	0 0
638	98.6	0.0	0 0	0 0
900	100.0	0.0	0.0	0.0

* Average of five replications, seven pairs of adults|replication, on Diacol-Calima

Screening method using excised leaves

A rapid method for screening tolerance to common bacterial blight was sought. Trifoliate leaves of nine varieties were excised and petioles inserted in distilled water in Erlenmeyer flasks. The leaves were inoculated with *Xanthomonas phaseoli*, isolate C6, by the water soaking method and maintained in a humid chamber. Symptoms appeared at seven days and observations were made ten days after inoculation. The same reactions as in the field were observed in all varieties tested, with the exception of Duva (Table 35). Further work needs to be done on aspects such as inoculum level, leaf age and medium for maintaining leaves, but the method seems valuable in detecting foliage reactions to the disease.

Table 34. **Foliage reaction of bean varieties and lines to *Xanthomonas phaseoli*, isolate C 6, at CIAT.**

Variety or line	Reaction
Jules	1.5*
Tara	1.5
P561	1.5
P458	1.5
MSU 42.772	1.5
MSU 42.842	1.5
MSU 42.935	1 5
MSU 42.950	1.5
MSU 42.954	1.5
MSU 42.964	1.5
MSU 43.009	1.0
Seafarer (susceptible check)	4.0
Vigna sinensis (cowpea)	0.0

* Rating: 0 = no visual symptoms; 1 = highly tolerant; 2 = tolerant; 3 = slightly susceptible; 4 = susceptible; and 5 = highly susceptible.

Table 35. **Foliage reaction of field-grown plants and excised leaves of bean varieties to *Xanthomonas phaseoli*, isolate C 6.**

	Foliage reaction	
Varieties	Field	Excised leaves
Tara	T*	T
Jules	T	T
G.N. # Sel. 27 R	T	T
PI 207-262	T	T
Red Kidney	I	I
Sanilac	S	S
Gratiot	S	S
Seafarer	S	S
Duva	S	I

* Rating: T = tolerant; I = moderately susceptible, S = susceptible

Rust

Screening for resistance

In 1975 an evaluation was made of 1,500 accessions from the germplasm bank; 196 were resistant and will be incorporated into an International Bean Rust Nursery (IBRN) to be tested against races of the fungus not found at CIAT.

An IBRN of 108 entries, resistant to rust in various countries, was sent to 14 cooperating institutions during the year. Twenty sets were shipped, and results are already available for six. The accessions Ecuador 299 and Compuesto Chimaltenango 2 were resistant in all six countries.

In the IBRN planted at CIAT, 13 races of *Uromyces phaseoli* var. **typica** were reported. The evolution of races of the fungus was studied in a continuous screening nursery. Races 3,8, 10, 28, 29, 32 and 33 were found, the most prevalent being 29 and 33. Based on their reaction with the differential variety US 814, two biotypes were identified, one corresponding to race 3 and the other to 29.

Losses due to rust

In an experiment similar to that described in the 1974 Annual Report, ICA Tui and ICA Pijao, susceptible and tolerant varieties, were infected with rust spores at different stages of plant development.

The yield of the susceptible variety Tui was reduced 85 percent when the infection occurred the first week after emergence and 82, 80, 77, 24, 18 and 11 percent, respectively, during successive weeks, as compared to the tolerant Pijao, which was reduced 34 and 31, 28, 21, 14, 10 and 4 percent, respectively.

Chemical control

To determine the best chemical control for rust, the variety ICA Tui was planted and then sprayed with various protectants 15, 25 and 35 days after emergence. A preliminary evaluation was made five days after the last application. Plots protected with maneb (3 kg|ha) yielded 100 percent more than the control. Chlorothalonil (2.5 kg|ha) and fentin acetate (0.8 kg|ha) increased yields 85 percent, whereas triforine (1.5 liters|ha), pyracarbolid (3.0 liters|ha), carbendazim (1 kg|ha) and oxycarboxin (1 kg|ha) yielded 55, 52, 40 and 30 percent, respectively, more than the control. In one of the two semesters in which the experiment was carried out, benodanil performed as well as triforine, pyracarbolid and oxycarboxin.

Mixtures of the best fungicides were tested. Oxycarboxin plus captafol increased the yields of Porrillo Sintético 64 percent, as compared to increases of 48 percent in mixtures of oxycarboxin with chlorothalonil, fentin acetate and maneb or tridemorph with fentin acetate.

Anthracnose

Screening for resistance

Using a screening technique similar to that for rust, 100 accessions, selected from among accessions reported to be resistant in other countries, were tested at Popayán (1,600 m) and Bogotá (2,600 m). Preliminary results indicated that Cornell 49.242, Widusa, Preto 141 and 145 and P459 were resistant at both sites. The reaction of some accessions differed from one site to another, suggesting the presence of different races of the fungus *Colletotrichum lindemuthianum*.

Losses due to anthracnose at Popayán

Diacol Nima and Diacol Andino were used as susceptible and tolerant varieties, respectively. The plots, replicated four times, were inoculated weekly for seven weeks after emergence. The absolute control was protected with benomyl (0.5 kg|ha), applied weekly. The inoculated plots were also protected up to 15 days before the inoculation. The inoculum (50,000 conidia|ml in distilled water) was applied as a low-pressure spray, late in the afternoon when the relative humidity was about 100 percent.

Yields of the susceptible variety Diacol Nima were reduced 95 percent when infection occurred one week after emergence. During the next four weeks, losses remained constant at around 88 percent and then declined to 38 and 27 percent after the sixth and seventh weeks. This pathogen causes serious losses during the whole growing period, not only due to foliar infections but also to stem and grain infections. In the tolerant variety Diacol Andino, the weekly losses were 10 percent less than in the susceptible Nima. When the environmental conditions for infection were not particularly suitable, loss patterns were similar to those for rust.

Chemical control

As shown in the agronomy section (p. C-50), more careful chemical control of anthracnose is required for second-semester plantings in Popayán than for those of the drier first semester (Table 36).

Table 36. **Chemical control of anthracnose in the variety Diacol Nima (Popayán, 1974B, 1975A).**

Fungicides	Dose (kg|ha)	Yield (kg|ha)		% of increase over the control	
		1974B	1975A	1974B	1975A
captafol	3.5	1,157	1,602	2,471	393
benomyl	0.5	960	1,283	2,033	295
carbendazim	0.5	871	1,845	1,936	468
maneb + zinc ion	3.0	724	1,406	1,509	333
carbendazim	1.0	711	1,617	1,480	398
chlorothalonil	2.5	595	1,003	1,222	209
fentin acetate	0.8	523	1,539	1,062	374
captan	3.5	279	1,287	520	296
thiabendazole	0.5	175	632	289	94
sulfur	3.0	126	331	180	2
copper hydroxide	2.0	115	641	155	97
oxycarboxin	1.0	41	491	9	52
quintozene	4.0	37	561	18	73
Control	-	45	325	0	0

The increases obtained were spectacular. Captafol, benomyl and carbendazim raised yields to 2,471, 2,033 and 1,936 percent for the second-semester crop and 468 percent for the first semester. This pathogen is the major yield-limiting factor at Popayán

Common bean mosaic virus (CBMV)

Seed contamination

Because CBMV is transmissible through seed, the use of virus-free seed makes it possible for farmers to raise their yields significantly (1974 Annual Report). However, the reproduction of this seed requires special care, which is difficult for farmers to do themselves. Experiments were therefore designed to establish the recontamination of seed under field conditions. When plots were planted with clean seed, away from sources of contamination, the harvested seed remained free of virus. However, in plots planted close to contaminated plants, transmission was 16 and 15 percent for the susceptible varieties ICA Guali and ICA Duva and 8 and 6 percent for the tolerant ICA Tui and P459, when the few aphids present in the field were not controlled. When the vector was chemically controlled, the level of contamination was significantly reduced.

Seed transmission in various promising materials observed varied from 10 to 60 percent.

Screening for resistance

Some accessions resistant and tolerant to CBMV were retested with various strains of the virus. The varieties Top Crop, Monroe, Jubila, Widusa, Amanda, Pinto 114 and the CIAT accessions P393, P323, Perú 0257 and PI 146-800 were selected as sources of resistance to be incorporated into the breeding program.

Losses due to CBMV

The long-term study of economic losses resulting from CBMV was concluded this year; the methods used are given in the 1974 Annual Report. Yield reductions of 94, 95, 85, 68, 43 and 20 percent were determined for the two red varieties, ICA Guali and ICA Duva, as compared with 89, 79, 36, 34, 29 and 16 percent for the two black varieties, ICA Tui and Jamapa, for the plots artificially inoculated with the virus every week for seven weeks after germination.

Bean golden mosaic virus (BGMV)

Screening for resistance

No source of resistance to BGMV has been identified in the 3,700 accessions studied to date. An International BGMV Nursery has been established to test further tolerant collections selected in collaboration with the Instituto de Ciencias y Tecnología Agrícola (ICTA) in Guatemala. Seed multiplication is being carried out for the 144 collections included. The IBGMN will be planted in several locations in Brazil, Puerto Rico, Jamaica, Guatemala, El Salvador, Costa Rica, Colombia, the Dominican Republic, Nigeria, Kenya and India. The first IBGMN was planted only in Guatemala, and some materials with apparently higher tolerance than Turrialba 1 and Porrillo 1 were selected. These materials were CIAT P747, P474, G-02689, P516, P657, P675, P544, P-5 and Guatemala 417.

Identification and purification of BGMV

CIAT is attempting to develop a means of identifying the numerous viruslike diseases of beans in Latin America, which would not involve carrying living material from one country to another. A bank of antisera is being built up for this purpose for those viruses found in Latin America and the Caribbean islands.

Bean golden mosaic, isolated from El Espinal (Colombia) and Santa Tecla (El Salvador), was studied in 1975. Mechanical transmission was highly improved, and 100 percent infectivity was obtained by grinding 15- to 20-day-old infected leaves in phosphate buffer, 0.1M, pH 7.5, plus 1 percent 2-mercaptoethanol. The plants were inoculated in both primary leaves, which had been previously dusted with 600-mesh carborundum. The concentration of the virus in the plant dropped dramatically 40 days after inoculation; the molarity of the buffer also played an important role in its stability.

The virus was kept viable in dessicated tissue over $CaCl_2$ at 4°C for up to three months. It was found to have a thermal death point of 55°C, a dilution end point of 1:128 and an aging in vitro at 23°C of 72 hours. The virus was stable in the buffers phosphate, herpes and borate at 0.1 M, pH 7.5; less so in Tris. HCl; and not at all in EDTA.

The virus was purified by treatment with 7 percent n-butanol, precipitation with Baker polyethylene glycol 6000 plus NaCl (6 and 1 percent, respectively), and centrifugation on sucrose density-gradient columns. A zone formed at 2.3 cm from the meniscus contained the causal agent of the bean mosaic disease, as shown by repeated infectivity assays. Samples from healthy extracts taken at the same depth did not show any infectivity.

The particles of the BGMV have a special morphological structure; they appear in dimers, and the bonded sides of the paired particles have a flattened appearance (Fig. 22). Almost no single particles were seen (100:1). The bonded particle measured about 32 x 19 mm.

Antiserum prpared against the Colombian form of BGMV will be used to compare the virus forms present in the different countries of Latin America and the Caribbean islands.

Bean chlorotic mottle virus (BCMV)

This virus is transmitted by *Bemisia tabaci*. The natural host is *Rhinchosia minima*, a common tropical weed. In

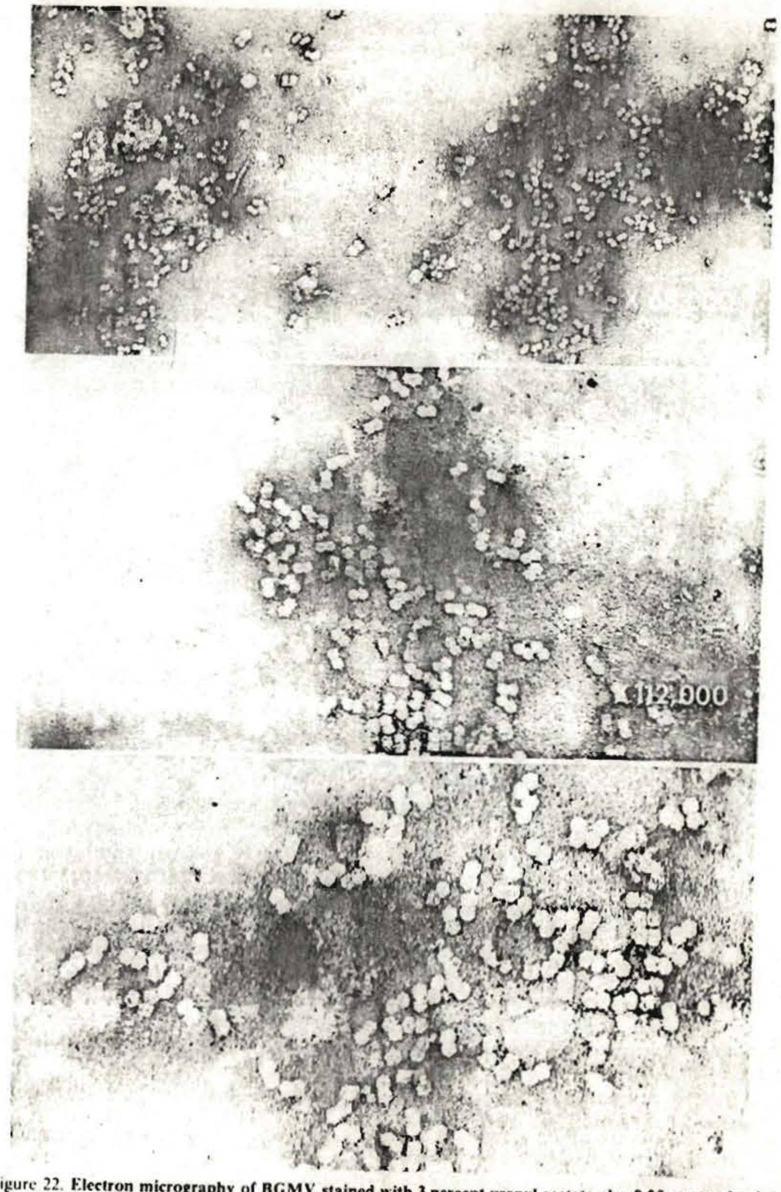


Figure 22. Electron micrography of BGMV stained with 3 percent uranyl acetate plus 0.05 percent bovine serum albumen. Note the numerous paired particles, the bonded side of which have a flattened appearance.

soybeans, it causes a disease with symptoms similar to those of BGMV in beans. The symptoms of the virus on beans are chlorotic mottled patches and some curling and deformation of the leaves. In some varieties it causes witches'-broom and severe stunting symptoms. Studies are under way to determine whether chlorotic mottle, Rhincosia mosaic, mottled dwarf, crumpling, Abutilon mosaic, Euphorbia mosaic and Sida mosaic diseases are caused by the same virus. An International Uniform Host Nursery, ready to be sent to different collaborators in Latin America, the Caribbean islands, Africa and Asia, will help in the identification of this complex in the near future.

Screening for resistance

Resistance to chlorotic mottle was not difficult to find. The CIAT collections P-6, P458, P527, P225 and P457 are highly resistant to this virus; Panamito 27R and ICA Duva are highly susceptible.

Rugose mosaic (RMV) and swelling mosaic (SMV) viruses

The RMV and the SMV, transmitted by several beetles, are increasing in importance in Guatemala and El Salvador. The 1974 studies on identification and characterization have been continued by trainees from El Salvador and Mexico. The two diseases belong to the same group of multicomponent viruses, and antisera against all the strains found in Guatemala, El Salvador, Costa Rica and Colombia have been prepared. They show that all these diseases may be caused by the same virus, consisting of several strains. There are several sources of resistance that could be incorporated into new varieties.

Artificial defoliation to estimate disease losses

Percentage of defoliation versus time of defoliation

These experiments, started in 1973, were concluded this year. The results (Fig. 23) confirmed previous observations on the varieties ICA Gualí (red) and Porrillo Sintético (black). It is clear that the most critical stages are initiation of flowering and the pod-filling period, following the seedling stage. After the initiation of the physiological maturity, defoliation has little effect on yield. These results fully support those obtained in physiological studies (p. C-19).

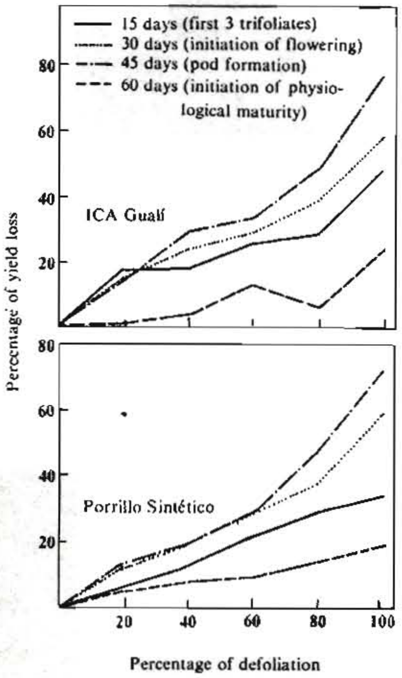


Figure 23. **Losses due to artificial defoliation in the varieties ICA Gualí and Porrillo Sintético at CIAT, (1975).**

Seed pathology

Production of seed free from pathogens

The rationale and benefits from the use of clean seed have been presented in previous annual reports. Cleaning seed of seed-borne pathogens continued as a priority project. A total of 1,453 varieties and collections were cleaned in the screenhouse. Included were promising materials for the breeding program, differential varieties of several pathogens, the IBRN, as well as varieties from Colombia, Guatemala, Peru, Honduras, Ecuador, Mexico and Chile. A total of 1,008 were further increased in field plantings.

The search for areas to produce clean seed continued, and cooperative projects are under way in Brazil, Peru, Guatemala, Ecuador and Colombia. Studies are also considering the possibility of producing seed of certain varieties in regions unfavorable to particular pathogens rather than to send it back to the original location.

Internally seed-borne fungi

Seed collected as part of the agroeconomic survey reported on page C-3 was assayed for percentage of germination and internally seed-borne fungi. An assay was made of 100 seeds from each of nine seed lots per departamento.* Internally seed-borne fungi representing the following genera and species were recovered from the seeds: *Aspergillus niger*, **Aspergillus** spp., **Penicillium** spp., *Fusarium oxysporum*, **Fusarium** spp., *Rhizoctonia solani*, *Colletotrichum lindemuthianum*, **Phomopsis** spp., **Alternaria** sp., **Rhizopus** sp., **Monilia** sp., **Cladosporium** sp., **Peyronellaea** sp., *Isariopsis griseola*, *Macrophima phaseoli*, **Botrytis** sp., **Acrostalogmus** sp., *Sclerotinia sclerotiorum*, **Pestalotia** sp. and several other unidentified fungi

Of the 3,600 seeds assayed in this study, 1,154 (32 percent) contained internally seed-borne fungi. Of the seed that contained fungi, 823 (71 percent) did not germinate. **Fusarium** spp. were isolated from 32 percent of the nongerminated seeds, followed by Phomopsis sp. (13 percent), *Colletotrichum lindemuthianum* (9 percent) and *Rhizoctonia solani* (8 percent). A typical screening for internal seed-borne fungi is shown in Figure 24, which compares seed from Huila with CIAT clean seed.

Seed from Huila had more internally seed-borne fungi and less germination than seeds from the other three departamentos (Table 37). Of 900 seeds assayed from Huila, 737 (81 percent) contained fungi and 536 (60 percent) did not germinate. Seed lots from Huila had as much as 100 percent infection by fungi and only 8 percent germination. This study indicates that internally seed-borne fungi are an important factor in reducing seed quality and germination.

Fungicide seed treatment

Movement of fungicides into seeds and their effect on internally seed-borne fungi and bean germination

Poor-quality commercial seed of the variety Tui was studied in detail. The percentage of seeds with internally seed-borne fungi and the percentage of germination were 88 and 41, respectively. Fungi representing seven genera were located within the seed coat (testa) tissues and occasionally in embryo tissues (cotyledons). When captan and thiram were applied to the seeds, they penetrated the seed coat tissues and occasionally the embryo; they effectively controlled fungi within the seed coat (Table 38). Benomyl (a systemic fungicide) also penetrated the seed coat and the embryo and was effective against fungi. Fungicide seed treatment significantly increased the percentage of germination on PDA and emergence in sterile soil and in the field and significantly reduced the percentage of fungi in seeds. The use of fungicides for seed treatment would be beneficial where poor-quality seeds must be used for planting.

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* A Colombian political division similar to a state or province

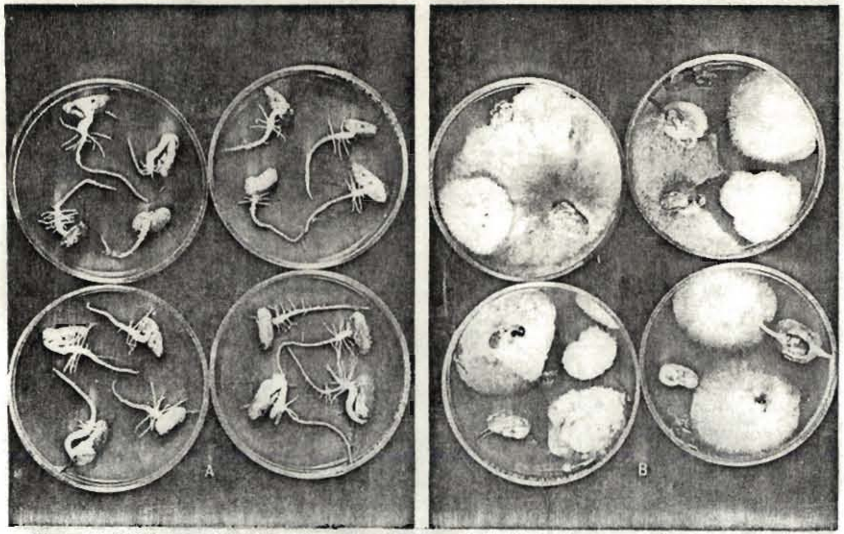


Figure 24. CIAT clean seed (a) and diseased seed (b) from Huila. Notice the amount of seed-borne fungi in the Huila lot.

When high-quality, disease-free seeds were treated with various fungicides, there were no benefits; however, when low-quality, diseased seeds were treated with the same fungicide, significant increases in percentage of emergence and stand were obtained.

AGRONOMY

Varietal trials

The testing of accessions for yield potential under experimental conditions was intensified during 1975 with 14 yield trials sown to date. Three levels of testing have been used:

(1) In Preliminary Variety Trials large numbers of materials are screened at CIAT, then sometimes screened a second time at the higher altitude location of Popayán. Accessions are grown under competitive conditions with replications.

Of the 750 promising selections the bean team has identified to date, 331 were selected for high yield potential and are of the non-climbing type. One hundred twenty-six of these have passed through Preliminary Variety Trials. Seed of the remaining materials is being cleaned and/or multiplied for testing during 1976. Most high yielding varieties are black seeded, but some promising accessions of other colors have also been identified. Evaluation for common bean mosaic virus, rust and bacterial blight are included in these trials.

Table 37. **Mean percentage of germination in vitro, total fungi and seeds with fungi that did not germinate from seeds from four departamentos in Colombia.***

Departamento	% of germination	% of total fungi	% of nongerminated seeds with fungi
Huila	40	82	60
Valle	91	10	7
Antioquia	88	17	10
Nariño	86	19	11

* Based on 100 seeds per each of nine seed lots per departamento

Table 38. **Percentage of internally seed-borne fungi, germination in vitro (PDA), and emergence in sterile soil (greenhouse) and in the field of poor-quality seed (*P. vulgaris* cv. Tui), either nontreated or treated with captan, thiram, or benomyl.**

	Germination in vitro (PDA)	Emergence		Total fungi
		Sterile soil	Field	
captan	73	68	53	14
thiram	72	66	52	15
benomyl	73	65	47	12
Control	41	33	35	88
LSD 5%	19	18	8	13
1%	29	28	12	21

(2) Uniform Variety Trials, using the same 40 high yielding varieties in each, have been planted at CIAT, Popayán, and Montería in Colombia and at Boliche, Ecuador. The major aim of these trials is to test adaption of promising materials to different environmental conditions.

The Uniform Variety Trials from CIAT, Popayán and Boliche have been harvested; the highest yielding varieties from each location are shown in Table 39. Four of the best five varieties from 1974 trials (five locations) are again among the highest yielding varieties this year. The highest yielding varieties with the best adaptation were P459 (Jamapa), P302 (PI 309-804), and P511 (S-182-R), while P675 (ICA-Pijao) and P560 (Var 51051) were high yielders in only some of the locations. The variety P566 (Porrillo Sintético), the highest yielder in the 1974 trials, suffered severely from bacterial blight and ranked only tenth in 1975.

(3) International Variety Trials are intended as a collaborative activity in which promising lines from CIAT or national bean breeding programs would be tested over many locations.

During the second semester, five trials were seeded in various locations in Colombia and Ecuador to determine the most appropiate methodology for these trials. The format used is shown in Table 40. This experimental methodology as proposed by the CIAT bean team, was discussed during the Bean Plant Breeding Workshop in October. Suggestions from workshop participants will be taken into consideration, with the modified International Variety Trials to be sent to collaborating institutions in early 1976.

Bean fertilization studies

Boron fertilization

Earlier studies on boron deficiency, a major problem on the CIAT farm are reported in the 1973 and 1974 Annual Reports. In 1975 a few additional studies were undertaken, mainly to determine residual effects of B applications and varietal differences. Figure 25 shows the effect of B applications on yields of three

Table 39. **Highest yielding bean accessions in three Uniform Yield Trials in 1975, compared with 1974 trials.**

Location	CIAT accession no.	Name	Yield (tons|ha)	Growth type	Color
CIAT (1975B)	P-459*	Jamapa V.	3.32	II	black
	P-737	Jamapa CR.	3.09	I	black
	P-511*	S-182-R	3.07	II	black
	P-302*	PI 309-804	2.98	II	black
	P-560*	Var 51051	2.96	II	black
	P-506	73 Vul 6542	2.95	II	white
Popayan	P-498	Puebla 152	3.09	III	black
	P-302*	PI 309-804	3.04	II	black
	P-512	S-166-A-N	2.84	II	black
	P-588	ICA-Huasano	2.82	II	black
	P-326	PI 310-740	2.80	III	black
	P-459*	Jamapa V	2.78	II	black
Boliche	P-302*	PI 309-804	2.56	II	black
	P-459*	Jamapa V.	2.52	II	black
	P-445	Guat. 2226	2.47	II	black
	P-675*	ICA-Pijao	2.46	II	black
	P-418	Col. 12-E	2.42	II	black
	P-511*	S-182-R	2.37	II	black
1974 Trials**	P-566	Porrillo Sint.	2.3 - 2.8	II	black
	P-675*	ICA-Pijao	2.3 - 3.1	II	black
	P-737*	Jamapa CR.	1.9 - 2.7	I	black
	P-459*	Jamapa V.	1.8 - 2.6	II	black
	P-560*	Var. 51051	2.1 - 2.5	II	black

* Among best materials in at least two trials.

** Yields are the range for trials at the three above locations.

Table 40. **Proposed experimental methodology for International Bean Variety Trials.**

Number of entries: 25, of which 20 are common to all sites and 5 are local varieties or selections; of the 20 common varieties, 10 are black and 10 are of other colors.

Design: Triple lattice, with three replications.

Plot size: 3 x 5 = 15 m², consisting of 6 rows of 5 meter length with 50 cm between rows; the area to be harvested is 2 x 4 = 8 m².

Plant Population: By thinning adjusted to 250,000 plants|ha.

Insect and disease control: As locally recommended for good bean production; one additional replication or two split replications can be planted without insect and|or disease control for local observations on disease and insect resistance.

Fertilization, weed control, and irrigation: As locally recommended for good bean production.

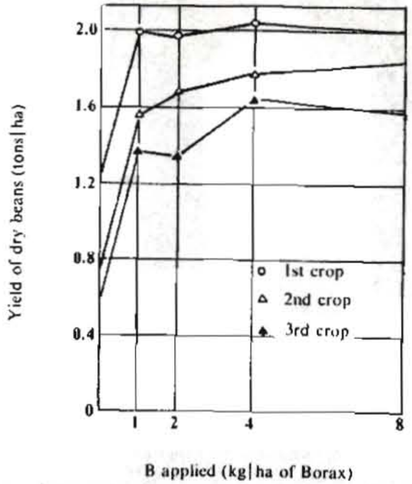


Figure 25. **Effects of one soil application of various rates of B on yields of ICA-Tui beans in three subsequent seedings, CIAT.**

subsequent crops of the variety Tui. During the initial seeding, 1 kg B|ha was sufficient to attain maximum yields. However, in later seedings the residual effect of this application was insufficient and maximum yields were attained only from the initial application of 2-4 kg B|ha. Since symptoms of B toxicity have been observed at the seedling stage in several fields at CIAT following applications of 2-3 kg B|ha, especially during dry weather, it is recommended to apply only 1-2 kg of B|ha, and if necessary, to repeat the application the following semester.

To determine the need for B fertilization, critical levels of B in leaf tissue and soil must be established. Correlations between bean yield and B content of leaves and soil showed that yield increases may be expected from B applications if the B content of the upper leaves at flowering is less than 25 ppm and if the hot-water soluble B content of the soil is less than 0.4 ppm.

The seeding of 14 promising varieties with three levels of applied B revealed greater susceptibility to B deficiency in 11 black-seeded varieties than in the two red-seeded varieties tested (Fig. 26). Mung bean (*Phaseolus mungo*) actually showed a negative response to B fertilization. The critical B level of 20-25 ppm in leaf tissue was confirmed for the 11 black bean varieties.

When B deficiency is not severe enough to inhibit initial growth, foliar applications may be a more economical alternative to soil application. In one trial highest yields were obtained with three foliar applications of 0.1 percent B in solution, equivalent to about 1 percent Borax or 0.5 percent Solubor. Concentrations of 0.2 and 0.4 percent B resulted in severe toxicity symptoms and yield reductions.

Phosphorus fertilization

Phosphorus is the main element limiting bean production in many soils of Latin America. Figure 27 shows the response of

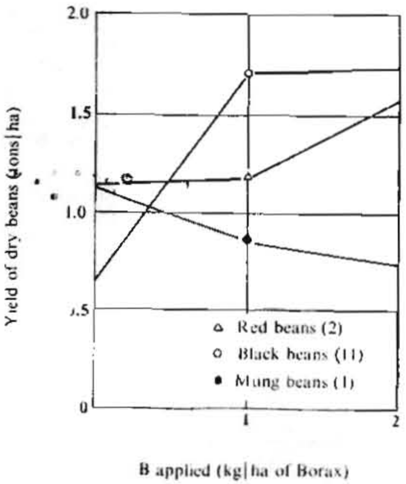


Figure 26. **Effects of soil applications of B on yields of two red and 11 black bean varieties (*Phaseolus vulgaris*) and one mung bean (*Phaseolus mungo*).**

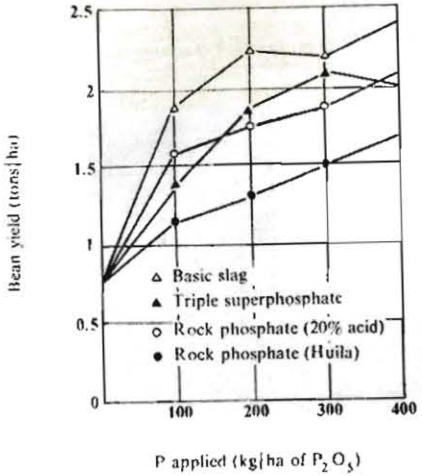


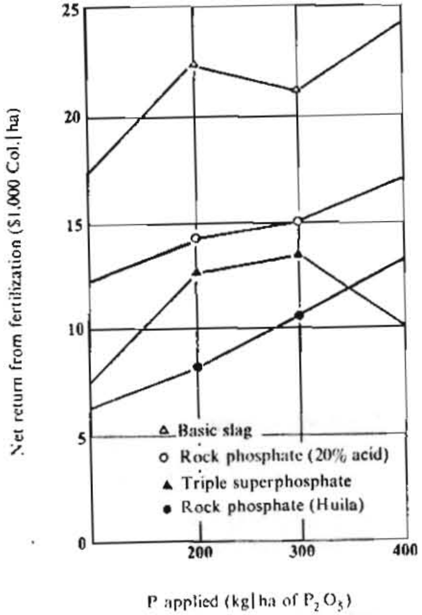
Figure 27. **Response of Porrillo Sintético bean to several levels of P from four sources, Popayán (1975A).**

beans to P in the extremely P-deficient volcanic ash soil of Popayan. Using the soluble source triple superphosphate (TSP), highest yields were obtained with 300 kg P_2O_5| ha. With less soluble sources such as basic slag, rock phosphate and rock phosphate 20 percent acidulated with sulphuric acid, beans responded to up to 400 kg P_2O_5| ha. Basic slag was the most effective source when all sources were broadcast and incorporated. Band placement of TSP would probably have improved its efficiency. Rock phosphate from Huila was the least effective source, but at high rates, it was definitely beneficial and economical. The partial acidulation of rock phosphate increased its efficiency to that of TSP. This treatment, which can be done on the farm, increases the cost of the fertilizer from Col. $4.6 to Col $9.5| kg P_2O_5 but makes it a very attractive P source in comparison with TSP which presently costs as much as Col $24.5| kg P_2O_5 (Figure 28). Basic slag, being extremely effective as well as cheap (Col $4| kg P_2O_5) is the most economical source, but its production is limited and can't satisfy the present fertilizer P requirements.

Two additional sources, fused magnesium phosphate and rock phosphate plus sulfur were studied. Yields with fused magnesium phosphate were not significantly different from those with TSP, and the rock phosphate + S mixture was not much different from rock phosphate alone. These two sources are thus not shown. A correlation between bean yield and percentage of P in the upper leaves at time of flowering showed a critical P content in the leaves of 0.35 percent.

Nitrogen fertilization

Previous trials by INIAP established that nitrogen is the major limiting element for beans in Boliche. A cooperative trial was established to study levels, sources, times and methods for applying N. Levels as high as 800 kg N| ha were used to determine possible negative effects on yield as well as to determine the true yield potential of Porrillo Sintético under the favorable climatic conditions of this station. Figure 29 shows that a maximum yield of 3.76 tons| ha was obtained with this bush bean variety, and that N fractionation had no positive effect on yield. This corroborates results reported in the 1974 Annual Report. Figure 30 shows no significant differences between urea and ammonium sulphate, but indicates that band placement was considerably inferior to broadcast applications at all N levels. Beans responded positively to rates as high as 200-400 kg N| ha, with no negative response up to 800 kg N| ha.



· Figure 28. **Net return (Col.$) from bean fertilization with various sources and levels of P, Popayán (1975A).**

N x P interaction

The effect of N and P fertilization on yield and protein quality of three bean varieties was studied in four locations during two semesters. The yield responses of the variety Tui in Popayán, La Zapata, and Carimagua are shown in Figure 31. In the high organic matter, volcanic ash soil of Popayán beans responded principally to P and only when the P-need was satisfied was there a clear response to N. In the highly infertile oxisols of Carimagua beans responded principally to N, and only when the N-need was satisfied was there a response to P. In the volcanic ash-influenced soil of La Zapata, with intermediate organic matter and low P content, beans responded equally well to N and P. In all locations, maximum response to P was obtained at the high N level and maximum response to N was obtained on the high P level.

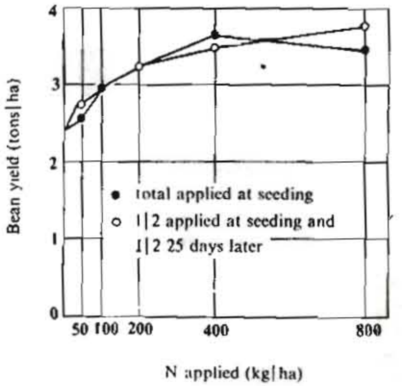


Figure 29. **Response of Porrillo Sintético bean to several levels of N applied at seeding or as split applications, Boliche, Ecuador (1975A).**

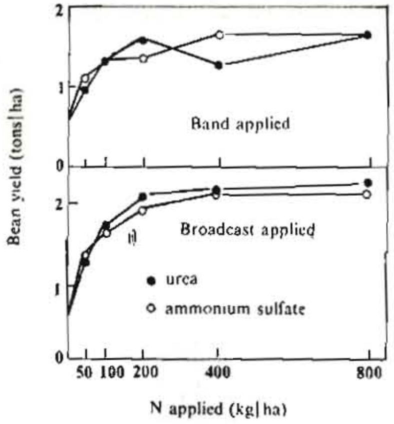


Figure 30. **Response of Porrillo Sintético bean to several levels of N as urea or ammonium sulfate and applied by banding or broadcasting, Boliche, Ecuador (1975A).**

Agronomic practices

Time of seeding

The time of seeding trial in Popayán reported in the 1974 Annual Report was continued. Figure 32 shows that with insect and disease control, excellent yields can be obtained seeding beans from December through March when monthly precipitation is about 150-200 millimeters. Extremely poor yields were obtained with seedings from May through October,

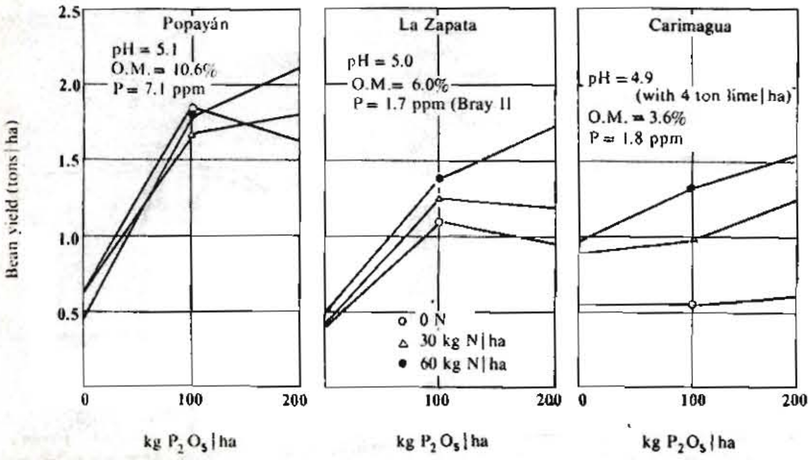


Figure 31. **Response of bean variety ICA Tui to N and P at Popayán, La Zapata and Carimagua.**

because rainfall was limited from May to August but excessive from October to December. With the exception of seedings in March and April, insect and disease control was essential for reasonable yields. In the second semester, high rainfall increased anthracnose to the extent that practically no grain could be harvested. It is possible that insect populations and disease infections built up more severely in this experiment than is normally encountered when beans are seeded only once or twice a year. The results may thus represent an extreme situation. They do indicate, however, that commercial bean production is most likely to be successful during first semester plantings.

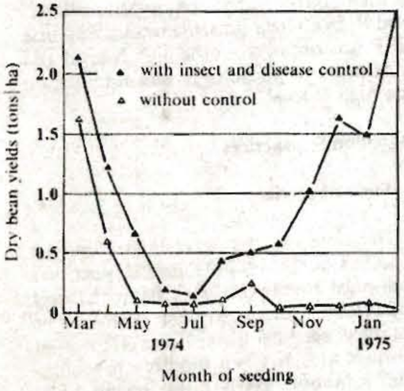


Figure 32. **Effect of month of seeding on yields of bean variety ICA Tui grown with or without control of insects and diseases, Popayán (1974-75).**

Mulching

Two trials were seeded at CIAT to study the effects of mulching with crop residues on weeds, soil temperature, humidity, fertility and yields of beans. Table 41 shows that highest yields were obtained with a soil cover of maize residues, rice straw, and dead **Amaranthus** weeds. The latter significantly increased the soil P and K levels, possibly eliminating P deficiency (critical P-level in soil is about 15 ppm). All mulch treatments greatly reduced weed growth, plantain leaves being most and **Amaranthus** least effective. The treatments decreased soil temperature about 2-2.5ºC but had little effect on humidity.

Table 41. **Effect of soil cover on production of beans, weed growth and soil characteristics.**

Treatment	Bean yield (tons | ha)	Weeds[1] (g | m²)	Soil temp.[2] (ºC)	Soil humidity (%)[3]	Soil analyses[4] (ppm P)	(meq K | 100 gm)
Weedy check	1.80	948	26.7	20.8	12.6	0.44
Weed-free check	1.92	292	26.2	20.3	-	-
Maize residues	2.06	208	24.2	21.1	11.8	0.44
Rice straw	2.05	336	24.6	20.8	14.4	0.49
Plantain leaves	1.94	184	24.0	20.6	13.8	0.46
Sugarcane leaves	1.95	304	24.5	20.7	12.7	0.71
Dead weeds (Amaranthus)	2.23	728	25.2	21.7	23.1	0.71

[1] Weeds collected at time of harvest

[2] Average of four determination at 10-cm depth

[3] Average of three determinations at 20-cm depth

[4] Soil analyses after harvest.

Contact herbicides for hastening maturity

High rainfall during maturation can cause plants to resprout and reflower at a time when previously formed pods are drying. The newly formed leaves prevent the proper drying of these pods and pod rotting may result. Under these conditions the application of a contact herbicide like paraquat can increase defoliation and hasten maturity. One application of paraquat (1.5%) 10-20 days before harvest was the most beneficial of several treatments and had no detrimental effects on seed germination of the two varieties tested.

Weed control in beans

Maize or beans grown alone were compared to maize and beans grown in association, to determine whether weed control inputs were equivalent in the three systems.

Maize and beans were planted on the same day in beds 1.8 meters wide with either two rows of maize and three rows of beans or two rows of maize and one row of beans per bed. A brachytic maize and bush bean variety were used. Treatments included no weeding, one or two hand weedings and use of a pre-emergence herbicide.

Twenty days after planting there were fewer weeds in the monoculture bean plots than in the maize or maize and bean plots, reflecting the competitive ability of a dense population of beans (240,000 plants | ha). This relationship persisted until harvest (Table 42). Intercropped maize likewise had fewer weeds than maize alone. For the weed species present, one hand weeding gave adquate control in all systems. On this basis, there was no advantage to intercropping.

Bean yields were reduced 83 percent both for beans alone and associated with maize, when no weeding was performed. Yields of monocropped maize were reduced 68 percent when not weeded, while in association with beans, the loss was only 47 percent. This suggests that maize is more tolerant of competition from beans than from weeds.

Another trial was conducted to determine which herbicides can be used safely in a maize-bean association. Maize (hybrid H-253) was planted and nine herbicides

Table 42. **Effects of weed control method on weed numbers and control and crop yields in maize and beans alone or intercropped.**

Weed control system	Population* (no.|m²)			Yield (tons|ha)			
						Intercropped	
	Maize	Beans	Intercropped	Maize	Beans	Maize	Beans
One hand weeding	43	12	30	5.4	1.77	2.7	0.94
Two hand weedings	29	16	20	5.5	1.77	3.0	1.03
Herbicides	20	4	9	5.6	1.80	3.4	0.96
Weedy check	120	52	68	1.8	0.30	1.6	0.16

* Weed population at harvest time

were applied. Beans (variety Calima) were planted two weeks later. All treatments except DNBP gave acceptable grass control, while broadleaf control was less effective (Table 43). No herbicide caused any observable injury to either maize or beans.

Plant density studies

Bush beans

In experiments on appropriate planting densities for bush beans, yield plateaus were observed for densities above 200,000 plants|ha. This plateau was independent of plant type and planting system (Fig. 33), row distance (Fig. 34), and bean variety (Table 44). Yields from 2 to more than 3 tons|ha were obtained. The results confirm information presented in the 1974 Annual Report. Again, only limited variety|density interactions were found among the varieties and systems tested. Populations losses during the growing season complicated the evaluation of response to planting density in bush beans. In one trial, established densities of 20, 40, 60 and 80 plants|m² were reduced to approximately 14, 26, 36 and 46 plants|m², respectively, at harvest.

Table 43. **Effect of nine pre-emergence herbicides on percentage weed control and yield of maize and beans grown in association.**

Herbicide	Rate (kg|ha)	Grass control* (%)	Broadleaf control** (%)	Yield (tons|ha)	
				Beans	Maize
fluorodifen	3.5	85	75	.910	3.4
linuron	1.0	90	40	.886	2.7
chloramben	3.0	80	60	.775	3.8
DNBP	3.0	20	90	.770	1.9
trifluralin	1.5	90	70	.850	3.2
dinitramine	0.75	70	70	.935	3.2
butralin	1.5	90	80	.885	2.8
penoxalin	1.5	85	60	.825	3.3
H-22234	3.0	80	60	.940	3 2
Weedy check	-	0	0	.165	0.7

* 40 days after application. Predominant species were *Eleusine indica, Echinochloa colonum* and *Leptochloa filiformis*

** 30 days after application. Predominant species were: *Amaranthus dubius, Momordica charantia, Portulaca oleracea, Euphorbia hirta*

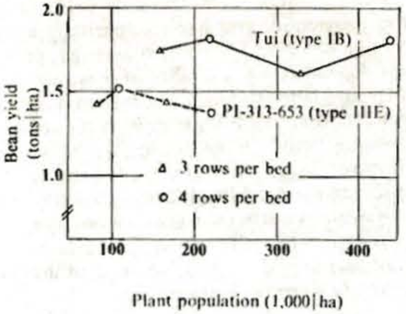


Figure 33. **Yields of two bean varieties at four densities in two planting systems, CIAT.**

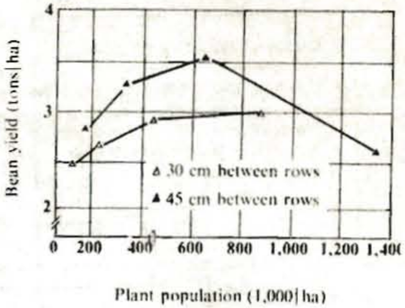


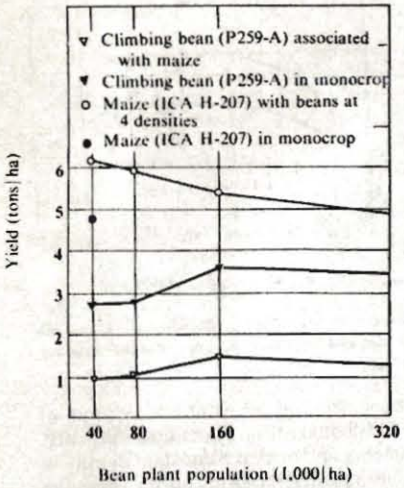
Figure 34. **Yields of Porrillo Sintético at two row spacings and four plant densities, Boliche, Ecuador, (1974B).**

Climbing beans

The need for more detailed evaluation of planting density in climbing beans was stressed in the 1974 Annual Report. Results this year confirm the need for plant densities higher than those conventionally used, but suggest that desirable planting densities are less than the 40 to 80 plants|m² originally considered. Under farmers' conditions, it is common to plant both maize and beans at a maximum of 40,000 plants|ha. To evaluate this practice, maize was planted at a constant density of 40,000 plants|ha with bean densities ranging from 40,000 to 320,000 plants|ha. These treatments were compared to monocrop beans planted on a trellis support system of bamboo, wire and twine, over the same range in densities. In this system there was one meter between trellises and two rows per trellis. Figure 35 shows a reduction in maize yield with increasing bean population, as well as an increase in maize yield when both crops were planted at 40,000 plants|ha in

Table 44. **Effect of plant population on the yield of beans of nine promising varieties, CIAT.**

	Yield (tons|ha)			
Plants|ha:	200,000	300,000	400,000	Avg.
ICA-Pijao	3.18	3.12	3.08	3.13
73 Vul 6586	3.25	3.02	3.04	3.10
141-M-1	3.27	3.12	2.92	3.10
Tui	2.58	2.52	2.54	2.55
Porrillo Sintético	2.66	2.29	2.70	2.55
6530 var. 51052	2.70	2.41	2.24	2.45
73 Vul 6589	2.71	2.66	2.05	2.47
Porrillo # 1	2 21	2.42	2.39	2.35
150-1-1	1 94	1.77	1.65	1.79
Avg. all varieties	2.72	2.59	2.51	



(Maize density uniform at 40,000 plants|ha).

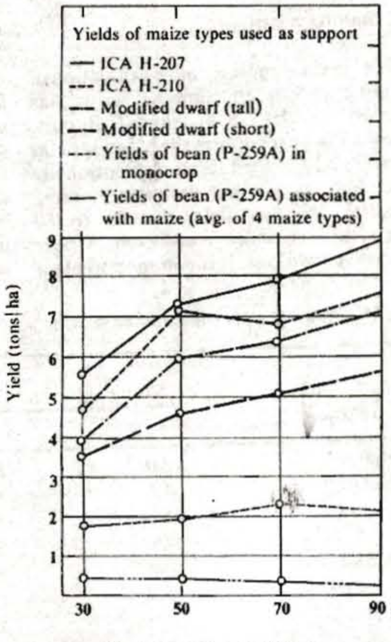
Figure 35. **Yields of bean and maize in monocrop and in association at four bean densities.**

association. There is no apparent system|density interaction, as the bean yields in both monocrop and associated crop systems were highest at 160,000 bean plants|ha. The difference in bean yields between the two systems was significant at all densities. Figure 36 compares yields for maize and beans when four maize types were used as supports for the Chilen variety P259-A. Yields of this variety in monocrop leveled at 2.0 tons|ha.

In agronomic trials comparing maize versus trellis or stake support systems, total crop value of beans or beans plus maize increased appreciably at higher plant densities, and were almost independent of the crop system (Fig. 37). Maximum crop values were obtained from the monoculture system at bean densities over 80,000 plants|ha, and from the maize|-bean association at bean densities over 60,000 plants|ha. Net profit from these systems is a function of costs of the initial installation (monocrop climbing beans), seed (varies with density), planting and crop protection, and harvest (partially a function of yield). The number of crops per year depends on availability of irrigation water and labor to install the system. It is probable that small farmers with limited resources could profitably utilize either monocrop beans on artificial supports or associated maize and high-density beans to achieve high returns from family labor on a small area. The early harvest of maize as green ears would facilitate more than the normal two crops each year.

Multiple cropping

Research on the bean|maize system produced tentative conclusions on relative planting dates, densities, spatial orientation of plants, and design of the system.



(Maize density increases 1:1 with bean density)

Figure 36. **Monocrop yields of beans and yields of intercropped beans and maize at four plant densities.**

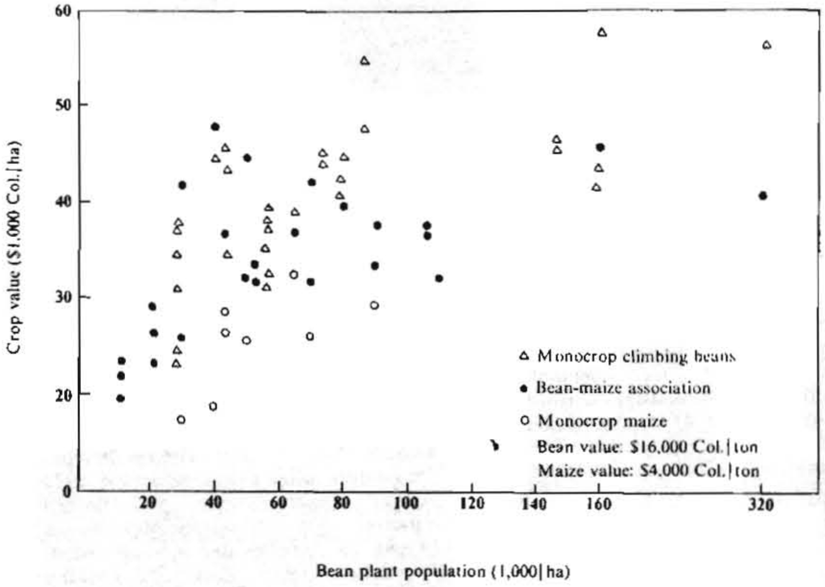


Figure 37. **Value of maize and beans monocropped and in association for several plant densities.**

The optimum planting date for bush beans (200,000|ha) is 15 days before maize (40,000|ha), at CIAT. In this association, bean yields were not reduced significantly from the monocrop level, nor was maize yield affected. This relationship must be tested at higher plant densities and yield levels. Preliminary observations of climbing beans with maize indicate that simultaneous planting is optimum for bean production, with only a minimum effect of competition on maize yields.

At a given density, maize planting system and spatial row arrangement were shown to affect bean yields (1974 Annual Report). To further reduce the effect of maize competition for light, trials are in progress to intercrop paired rows of maize with four rows of beans. Climbing beans still have an adequate support system, being at the most only 40 centimeters from the maize rows.

The effects of crop association of fall army worm (*Spodoptera frugiperda*) attack in maize are illustrated in Figure 38. The association of maize with bush beans planted six days before the maize retarded infestation, compared to the monocrop maize check. With a climbing bean planted seven days after the maize, this difference was drastically reduced. This same pattern of differential infestation persisted over three consecutive observation dates, and even after the Spodoptera infestations had been chemically treated. This reduced incidence of a principal maize insect may be one of the reasons small farmers use these multiple cropping systems to assure a harvest and minimize risk at low levels of technology.

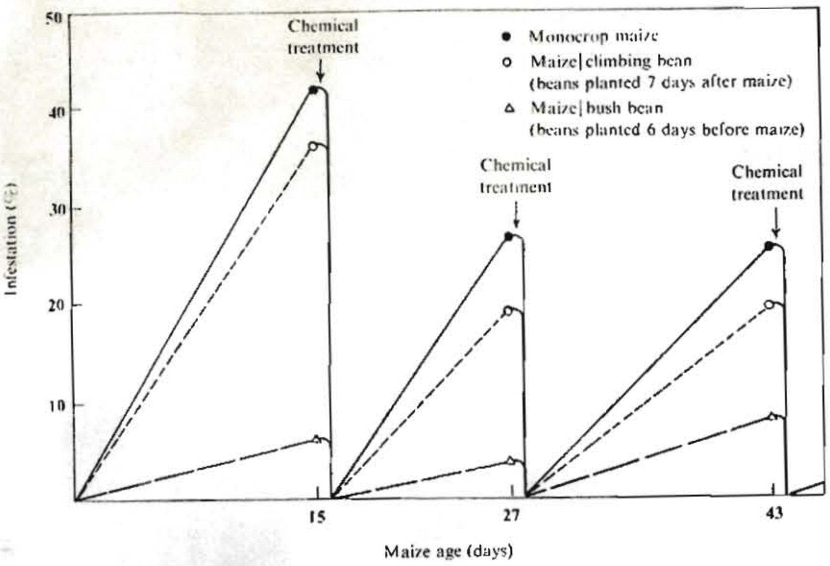


Figure 38. **Fall armyworm infestation in maize at three ages, in three cropping systems, CIAT.**

COLLABORATIVE ACTIVITIES

During 1975 the CIAT Board of Trustees agreed to the proposal by the Technical Advisory Committee of the Consultative Group for International Agricultural Research that the CIAT Bean Program coordinate the establishment of a Latin American Bean Research Network. With this goal in mind, the Bean Program has accelerated its collaborative experimental program and has established firm contacts with most national bean research programs in Latin America. Activities during 1975 have been in five areas.

(1) **Training:** During the year, the program received three post- and two predoctoral students, three students for the MS degree, and a total of 18 other postgraduate becarios. For the first time, five becarios from the same country were trained at CIAT as a multidisciplinary group. An intensive one-month training course in bean production for experimental studies, is planned for 1976.

(2) **Documentation.** Documentation of available bean literature was again emphasized in 1975 with more than 1,000 cards distributed to over 320 scientists in the bean research field. Literature on symbiotic nitrogen fixation continued to be distributed by the microbiologist.

(3) **Conferences.** Two conferences were organized during the year, the first on bean breeding and germplasm, the other on aspects of plant protection. A major result of the breeding-germplasm workshop was a better definition of how CIAT should manage its breeding program to satisfy a multiplicity of demands from national programs (see page C-11). Details for an international series of variety trials were also presented at this meeting, and accepted in principle (see Table 40). This will begin when sufficient clean seed becomes available in 1976.

(4) **Review meeting.** An external review of the Bean Program was held from Oct. 21-23, 1975. Current research, research trends and staffing pattern and requirements were reviewed by a committee in which Latin Americans predominated, and where the major question to be answered was the relevance of the CIAT program to other areas of South and Central America.

(5) **Collaborative research** is under way in several countries of South and Central America, and referred to frequently in the preceeding text. Major activities have been the varietial evaluations in Ecuador; rust resistance nursery screening in 14 countries; the evaluation of golden mosaic tolerance in Guatemala; and **Rhizobium** and fertilizer studies in several parts of Colombia. ICA and the Secretaria de Agricultura del Cauca both were prominent in these studies. The agro-economic study reported on page C-3, depended heavily upon support from several collaborating institutions.

Additional collaborative projects with several developed country institutions are under way, generally, in areas where the CIAT program has insuffucient equipment or expertise to undertake the studies. Thus students at Cornell University are studying stability of growth habit in beans (1974 Annual Report) and photoperiod-temperature interactions. Michigan State University and Hokkaido University are also involved in this program.

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