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Bean production systems program

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CIAT BEAN PRODUCTION SYSTEMS PROGRAM

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I. INTRODUCTION

Dry beans *(Phaseolus vulgaris L.)* are an important component of the human diet in Latin America, with nearly 35 per cent of world production occurring in this region. Beans are a particularly important source of protein in the diets of middle and low income families who are unable to afford or don't produce animal protein. The region includes the center of origin of the domesticated bean (Miranda, 1967 and Gentry, 1969).

Grain legume yields, especially those of beans, vary considerably. Experimentally, bean yields of up to 5,000 kg/ha have been reported (Pinchinat, personal communication). In replicated variety trials on the farm of the Centro Internacional de Agricultura Tropical (CIAT), near Palmira, Colombia, yields close to 3,000 kg/ha are common. Farm yields are usually lower, ranging from only 200 to as high as 2,800 kg/ha. Yields are highest in developed countries and in areas which permit considerable technological inputs; they tend to be lowest in hillside areas. The Latin American average fluctuated between 580 and 620 kg/ha, in the period 1952-1971 (Table 1). In general, yields and the rate of improvement of yields are much lower than for cereal grains; for example, world rice yields have risen 40 per cent to 2,280 kg/ha over the last 20 years (FAO Production Handbook, 1973).

Table 1. *Production differences of* Phaseolus vulgaris *according to zones and planting seasons, 1971*

Zone	Area planted (1,000 ha)	Yield (kg/ha)
Latin America	6,789	620
Chile	61	1,120
Brazil	3,750	650
Guatemala	161	400
Colombia (Valle), first semester	2.5	834
Colombia (Valle), second semester	1.068	1,236
Colombia (Antioquia), first semester	6.7	567
Colombia (Antioquia), second semester	11.75	572
U.S.A.	549	1,360
World	22,868	510

Sources: Food and Agriculture Organization of the United Nations, *Production Yearbook*, Rome 1972.
Orozco, personal communication, 1974.

Roberts (1970), in reviewing grain legume yields throughout the world, cited the lack of relevant research as a major factor limiting yields. He considered the potential of national and regional grain programs, but concluded that they were insufficient to achieve major yield changes. To support them, he proposed the establishment of integrated grain legume research programs, undertaken through international research centers. CIAT was suggested as the center for bean research studies. Though some staff members had worked on *Phaseolus vulgaris* at CIAT prior to this time, the integrated bean research project was not initiated until the 1972-73 fiscal year. It is one of two CIAT commodity programs not limited to the tropical lowlands.

Currently, this program at CIAT has regional responsibility from the Consultative Group on International Agricultural Research (CGIAR) for research into bean production; it is a major center for bean germplasm; and recently it was requested by the Technical Advisory Committee (TAC) of the CGIAR to develop a coordinated research network throughout Latin America.

This publication describes various aspects of bean production in Latin America. It attempts to identify areas in which more research or similar activity is needed and to which the CIAT Bean Production Systems Program could contribute with comparative advantage. Achievements of the program to date and projected activities are also discussed.

II. PROBLEMS OF BEAN PRODUCTION IN LATIN AMERICA

Bean production in Latin America occurs predominantly on small holdings, often over undulating terrain. In El Salvador for example, more than 95 per cent of bean production occurs on farms of less than 5 ha; in Panama the average farm producing beans is of only 2.6 ha. Usually, beans of the indeterminate climbing type are planted with corn. There is little mechanization, or non-family labor, and technical inputs such as fertilizer, weed control or pesticide applications are usually limited (Gutierrez et al, 1975). The smaller farmers also face marketing difficulties, credit limitations, and poor extension services. These are perhaps the reasons why most countries studied by Pinchinat (1973) considered socio-economic factors a major restraint on production.

There are appreciable areas of Chile, Peru, Brazil, Mexico, and Colombia, however, where yields and technological inputs approach those of the United States. In these areas heavily fertilized and protected bush beans are grown with mechanical land preparation and harvesting, and often under irrigation. It is this system of production which has been most extensively investigated, especially in the United States (see Bean Improvement Cooperative Annual Reports, 1962-1974). By contrast, little is known of the corn-bean production system.

Among various reasons advanced to explain the generally poor bean yields in Latin America (Roberts, 1970; Hernández-Bravo, 1973; and Pinchinat 1973), certainly the most common is that of insufficient and inconsistent research support. As shown in Table 2, the number of bean scientists in Latin America is not great. Most national programs employ breeders, agronomists, and pathologists, but whether this represents the national need or simply the bias placed on these subjects during university education is difficult to say. Few programs have entomologists, economists, physiologists, microbiologists or seed quality and germplasm specialists. While the difficulty of funding such a range of disciplines within small national programs can be appreciated, the need for such scientists is evident in the following sections. An additional factor is that most of the personnel listed in Table 2 work with a range of crop species, while less than half have appropriate research qualifications.

Table 2. *Distribution of bean scientists in 22 Latin American countries according to scientific specialty*

		Number of countries:	
Specialty	**Scientists listed**	**with expertise in specialty**	**lacking expertise in specialty**
Agronomy	65	16	6
Germplasm	7	5	17
Weed control	–	–	22
Economics	4	3	19
Entomology	6	5	17
Physiology	5	4	18
Pathology	22	12	10
Breeding	30	14	8
Soil science	12	8	14
Soil microbiology	2	1	21
Seed quality	5	5	17
Total	158		

Source: Pinchinat, A. M. comp. Lista de investigadores en frijol *(Phaseolus vulgaris L.)* en América Latina. *Turrialba,* Costa Rica, Centro Agronómico Tropical de Investigación y Enseñanza, 1973. 29 p.

Plant improvement has played (and will continue to play) an important part in lifting bean yields throughout Latin America. Of the 13 national programs questioned by Pinchinat (1973), 11 considered varietal improvement of definite practical value in the period 1969-1972. Vieira *et al* (1971) report comparisons over 20 locations in Minas Gerais and Goias in which improved varieties such as Rico 23 and Rosinha da Seca outyielded local varieties by more than 80 per cent.

Despite this, and while the known genetic variability in *Phaseolus vulgaris* is very wide, few national programs have the resources to maintain an adequate germplasm base, or to use one to best advantage in breeding programs. Thus, development of the CIAT germplasm bank is a direct response to national requests for germplasm maintenance as voiced during the 1973 Bean Seminar at CIAT (CIAT Bean Seminar Report, 1973). The major difference in consumer preferences between countries or regions is a complicating factor limiting the transferability of even promising varieties (Scobie *et al* , 1974).

Seed quality is also an important consideration. More than 50 per cent of the major bean diseases, including common mosiac virus, and the organisms causing anthracnose, angular leaf spot and bacterial blight, are seed-borne (Zaumeyer and Thomas, 1957). Given reasonable conditions, these diseases can spread rapidly from the initially infected materials. Despite this threat, most small farmers continue to help promote seed-borne infection by sowing seed saved from a previous harvest (Gutierrez *et al*, 1975). Certified seed is virtually unobtainable among small farmers. It normally constitutes from 1-3 per cent of the material sown (Terra-Wetzel *et al*, 1971). Sanchez and Pinchinat (1974) compared seed samples from 77 farms in Costa Rica and obtained an average germination rate of only 68 per cent. This perhaps is the reason many farmers plant more than one seed per site (Freytag, 1973).

Perhaps the major factor limiting bean yields in Latin America is plant disease. Participants at the 1973 CIAT bean seminar listed bean rust, bacterial blight, root rots, and common and golden mosaic viruses as the most important of the bean diseases. Gutierrez *et al* (1975), in surveying 12 Latin American bean producing countries, found rust, common mosaic, anthracnose, angular leaf spot, and powdery mildew, the most frequently reported problems. Table 3 lists those countries in which these and other diseases are considered important.

Gutierrez *et al* (1975) also list more than 70 insects limiting bean yields in Latin America. The major groups are listed in Table 4, with *Empoasca, Diabrotica,* and cutworms clearly most important. While this finding agrees with the priorities established at the 1973 Bean Seminar, recent field studies by CIAT staff suggest that many additional insects (particularly pod feeders) can cause significant damage in particular localities. An interesting sidelight of the present high bean prices is that even bean farmers with limited finances tend to overspray (Schoonhoven,

Table 3. *Major diseases of* Phaseolus vulgaris *and their importance by country in Latin America*

	Brazil	Colombia	Costa Rica	El Salvador	Guatemala	Haiti	Honduras	Nicaragua	Panama	Paraguay	Peru	Dominican Republic	Frequency Country
Mosaic Virus (Common)	+	+	+	+	+	+	+	+	+	+	+	+	12
Mosaic (Yellow)	–	–	+	+	+	–	–	+	–	–	–	–	4
Common Blight *(Xanthomonas)*	+	+	+	–	+	–	+	+	–	–	–	+	7
Rust *(Uromyces)*	+	+	+	+	+	+	+	+	+	–	+	+	11
Web Blight *(Thanatophorous)*	+	+	–	+	–	–	–	+	+	–	–	–	5
Anthracnose *(Colletotrichum)*	+	+	+	+	+	+	+	+	+	+	–	–	10
Angular Leaf Spot	+	+	+	+	+	+	+	+	+	–	–	–	9
Powdery Mildew *(Erysiphe)*	+	+	+	+	+	+	–	–	+	+	+	–	9

Source: Gutierrez, U. *et al* Descripción de los Principales Aspectos del Desarrollo del Cultivo del Frijol en América Latina. (1975). Centro Internacional de Agricultura Tropical, CIAT Technical Bulletin, in preparation.

+ Disease is of major importance — Disease is of no particular importance

Table 4. *Major insect pests of* Phaseolus vulgaris *and their importance by country in Latin America*

	Brazil	Colombia	Costa Rica	El Salvador	Guatemala	Haiti	Honduras	Nicaragua	Panama	Paraguay	Peru	Dominican Republic	Frequency Country
Cutworms	+	+	+	−	+	−	−	+	+	+	−	−	7
Leaf Hoppers *(Empoasca)*	+	+	+	+	+	+	+	+	+	−	+	+	11
White Fly	−	−	−	+	+	−	−	+	+	−	−	−	4
Leaf Cutters *(Diabrotica)*	+	+	+	+	+	−	+	+	+	+	−	+	10
Leaf Cutters (Gusanos)	−	+	−	−	+	−	+	+	−	−	−	−	4
Podweevils *(Apion)*	−	−	−	+	+	−	−	−	+	−	−	−	3
Spider Mites *(Tetranychus)*	+	+	−	−	+	−	+	−	−	−	−	−	4
Storage *(Zabrotes)*	+	+	+	−	−	−	+	−	+	−	−	−	5

Source: Gutierrez, U. *et al* Descripción de los Principales Aspectos del Desarrollo del Cultivo del Frijol en América Latina. (1975). Centro Internacional de Agricultura Tropical; CIAT Technical Bulletin, in preparation.

\+ Insect pest is of major importance — Insect pest is of no particular importance personal communication). This is perhaps because many national programs emphasize relatively simple routine chemical control (for example, see Costa and Rossetto, 1971).

Currently, high fertilizer prices, particularly for nitrogen and phosphorous (Harre *et al*, 1974), helped by international trade imbalances have pushed up the price of many farm inputs, affecting farmers both large and small. Given the large areas of Latin America known to be deficient in phosphorous (Fassbender *et al*, 1968 and Vieira and Bornemisza, 1968) or to have a high phosphorous fixing capacity (Fassbender, 1969), the high phosphorous requirements of the bean plant are certain to limit yields in many areas. Nitrogen also is important in the nutrition of the bean plant (Malavolta, 1971), so it is disturbing that response to inoculation in *Phaseolus vulgaris* has been shown in very few areas (Brakel, 1966; Brakel and Manil, 1965; and Whiteway and Nduku, 1967). Temperature, soil acidity, and native soil rhizobia have been blamed for this (Graham and Hubbell, 1975).

Planting systems in beans vary widely according to the type of seed to be sown, and to the region. Many farmers do not till the soil, often using the "slash and burn" system described by Freytag (1973). Planting systems can vary from random scattering of seed to precisely controlled, mechanized planting.

The determinate bean (Type I), favored for mechanized planting, has been used widely in population density studies (Guazzelli and Miyasaka, 1971), generally with uneconomic yield returns at densities more than 200,000 plants/ha. Indeterminate but not climbing plants (Type II or III) tested at CIAT generally show no yield change between 200,000 and 400,000 seeds/ha. The optimum planting density for climbing beans, either in monoculture or associated with maize, is not known, although most farmers use spacings for associated plantings better suited to the maize than the beans. In associated cropping, beans may be planted at the same time as the maize. More commonly, however, beans are planted after the maize, or even as the maize is drying. Planting times of maize and beans can reflect differences in rainfall patterns.

III. OBJECTIVES OF THE CIAT BEAN PROGRAM

The CIAT Bean Program has a single major objective, *to increase the yield and productivity of field beans throughout Latin America.* We would hope to achieve this overall goal through technical and varietal improvements developed as part of our experimental program; through the training and support of Latin American scientists working in national programs; and through collaborative research, both by Latin American and by developed area laboratories. Given the low yields currently realizable in much of Latin America, we would hope that yield increases of up to 4 per cent per annum could be achieved. That rate would lead to a Latin American yield average for beans of more than 1,000 kg/ha by 1990.

In the short term, as presented graphically in Figure 1, progress is most likely to be achieved from technology minimizing yield variability. This would include the appropriate use of fungicide, insecticide, and pesticide materials; better phosphorous and nitrogen fertilization practices; better understanding of micro-element deficiencies; the provision of disease-free or at least certified seed; and the adoption of optimum planting densities. In this period, advances would be predominantly with the bush bean grown under reasonable field conditions.

In the intermediate term varietal selection and the insulation of farmers against major fluctuation in the price or availability of inputs would be needed to maintain continued yield improvement. At CIAT, breeding would assume greater significance than previously, with the development of regional yield trials, the

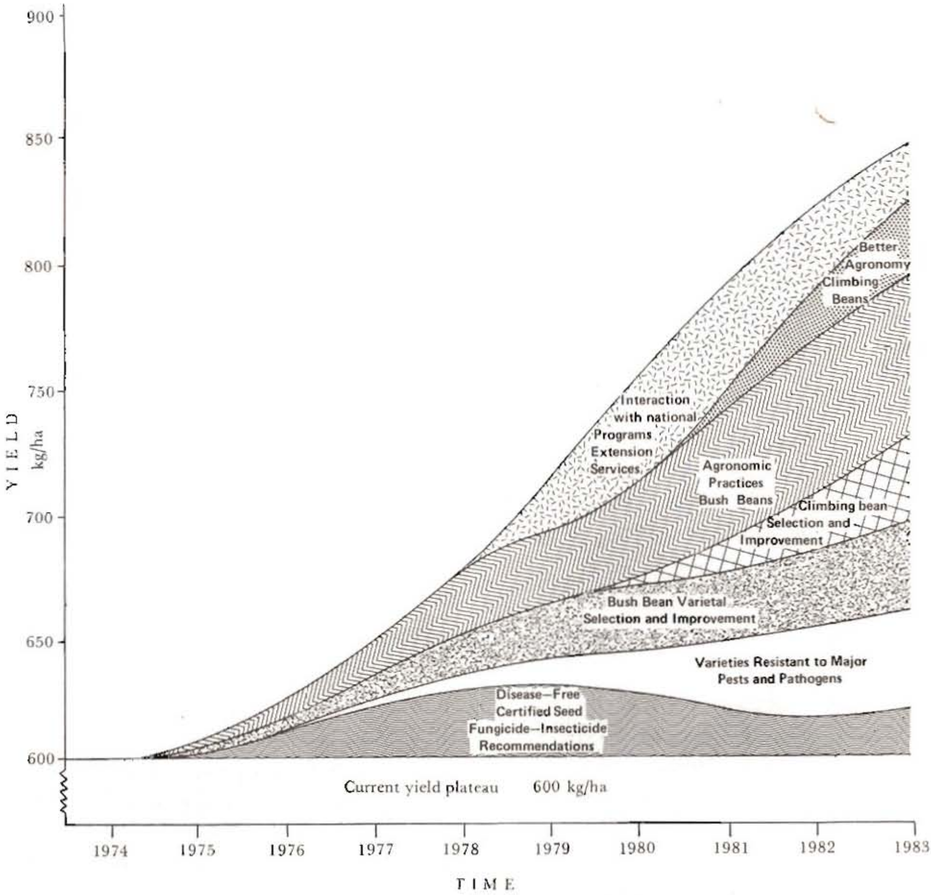


Figure 1. Contributions of the various program components to yield increases in *Phaseolus vulgaris* during the decade 1974-1983.

supply of promising materials to national programs, and the combination of resistance factors against distinct insect and microbial pests, all becoming major program activities. To maintain its planned rate of improvement, CIAT's program would need to be releasing genetically improved selections by 1977, and by 1979-80 to be increasing the number of selections with resistance to a range of disease and insect pests. In view of the major differences in grain size and color between regions (CIAT Annual Report, 1973) it would be impossible to produce finished varieties for all regions.

Yield increases in climbing beans will take longer to achieve; less research has been done with this group, and they are generally grown --as has already been mentioned-- under poorer environmental conditions. The need to consider the compatability of maize and beans is an additional complication. An urgent priority would be to show that climbing varieties rank similarly, independent of support system. Again, a major factor in improving climbing bean yields would be the improvement of agronomic practices. This would include the better understanding of bean-maize planting distances and the interaction between the two crops. Since most farmers growing this bean type have little cash or credit, it would also be essential to maximize the efficiency of technological inputs. This should include an understanding of the contribution of microorganisms to both symbiotic and non-symbiotic nitrogen fixation, and to phosphate solubilization; better fertilizer usage; and a more detailed knowledge of at what level of infestation, insecticide and fungicide applications become essential. Such a technological package could not be available before 1978.

Varietal improvement in climbing beans, especially those for higher altitudes, would depend upon wider germplasm collection. For this reason, it is unlikely that regional yield trials with climbing beans could be developed before 1977-78. Certainly such yield trials would be more difficult to manage than those for the bush bean type. The possibility of growing climbing beans under trellis conditions with the requirements for intensive hand labor but high per unit area yields will demand early attention.

In all of these projects a major difficulty will be the rate at which new technology is accepted. The reluctance to adopt new varieties, for example, has already been referred to. In this area the economics program will be particularly important, and by 1976-77, the limiting factors to technological acceptance at the farm level should have been identified for a number of regions. To ensure acceptance by national programs, it will also be essential that both the collaborative and the training program assume increasing importance. Successful operation of the bean research network will be critical to the transfer of information and technology.

IV. STAFFING OF THE CIAT BEAN PROGRAM

Current funding is for a core staff of seven senior scientists, two of whom are now shared with the Cassava Program. Two additional staff positions, those of the germplasm and seed production specialists, will be financed from 1975 through special fund support from the Interamerican Development Bank (IDB). The disciplinary orientation of the senior scientific staff is shown in Figure 2.

To achieve the progress and the disciplinary developments detailed in Section III, a final core staff of ten senior staff scientists would be desirable from 1977. Funds have not yet been identified for this expansion. Given its current

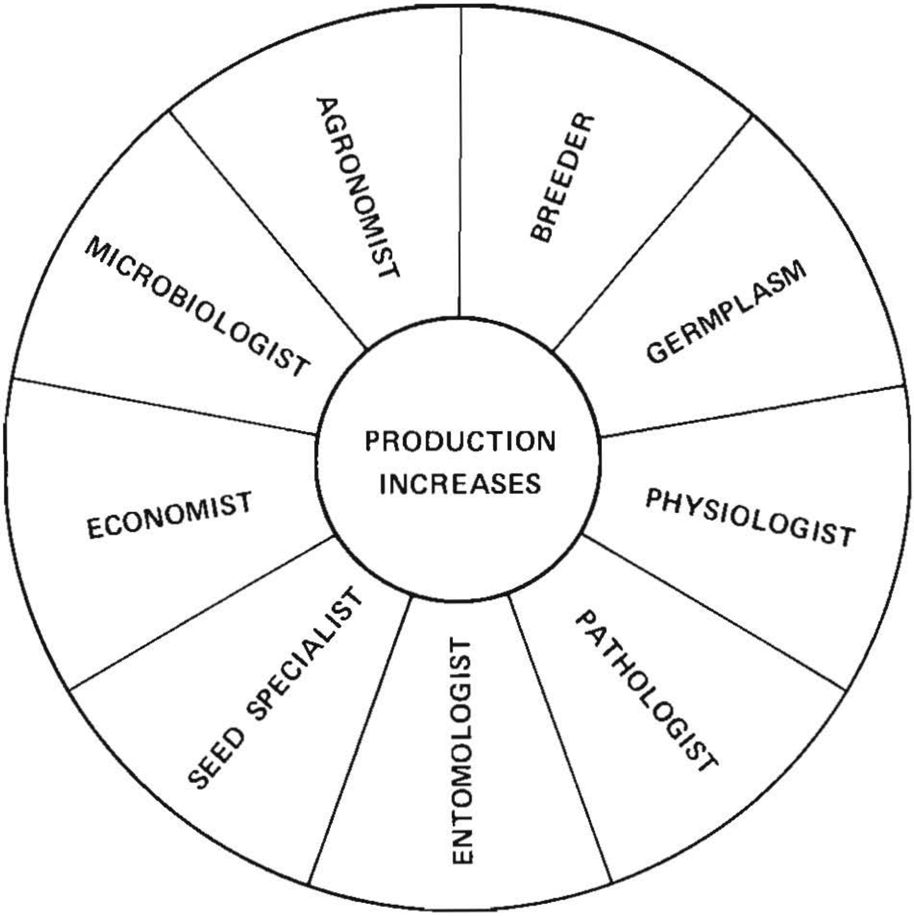


Figure 2. Specialist components of the CIAT Bean Production Systems Program.

regional charter, the program has not yet faced the question of close collaboration with African and Asian centers. Even assuming this staffing level, the program would have to accept certain limitations discussed below.

1. Work would need to be restricted to *Phaseolus vulgaris* or to species which cross with *Phaseolus vulgaris*. Any alternate decision would dilute our research effort and conflict with the prime responsibilities of other international centers.

2. Initial experimentation would be concentrated on four sites representing various temperature, rainfall and soil conditions. These locations are:

a. CIAT headquarters, Palmira, Colombia (03°22'N, 1,000 meters elevation, 23.9°C mean annual temperature, 1,000 millimeters annual rainfall).

b. Monteria, Colombia (08°87'N, 13 meters elevation, 28°C mean annual temperature, 1,200 millimeters annual rainfall).

c. Popayan, Colombia (02°42'N, 1,600 meters elevation, 20°C mean annual temperature, 1,600 millimeters annual rainfall).

d. Boliche, Ecuador (02°20'S, 17 meters elevation, 24.4°C mean annual temperature, 690 millimeters annual rainfall).

Because beans are clearly at a disdavantage when compared to acid-tolerant species such as cowpea or peanut (CIAT Annual Report, 1973), no further work would be done in the extremely acid soils of the Llanos Orientales of Colombia. Collaborative experimentation outside Colombia would depend upon identification of institutes or scientists willing to participate in or contribute to program objectives.

3. Low initial priority would be given to protein quality and balance. Beans already contain 20-30 per cent of relatively well-balanced protein; thus, protein/ha changes are probably better made through yield increases (Bressani *et al*, 1973). The Instituto de Nutrición de Centro América y Panamá (INCAP) in Guatemala would be a more appropriate center for such studies, although CIAT will screen promising breeding material to ensure no major deterioration in protein content or quality.

4. Because research scientists in developed countries are interested in undertaking contract or collaborative research, CIAT should not try to solve problems better done in such research units.

5. Given the considerable travel requirements associated with the research network, it would be important to maintain adequate support staff at the level of visiting scientists or post-doctoral fellows.

V. RESEARCH ACTIVITIES OF THE CIAT BEAN TEAM, 1973-74

1. Germplasm evaluation and plant breeding

The CIAT collection of *Phaseolus vulgaris* is recognized by the Genetic Resources Board of the TAC as the major holding of bean germplasm in the world. The 10,000-plus accessions currently derived from 18 countries (see Table 5) represent a wide genetic variability with regard to plant type, flowering and maturity time, yield components and seed characteristics. Several specific characteristics are contrasted in Figures 3, 4 and 5.

Table 5. *Origin of* Phaseolus *materials now held in the CIAT germplasm bank*

Country	No. of Accessions
Phaseolus vulgaris	
U. S. A.	3,983
Costa Rica	1,096
England	1,367
Brazil	1,027
Honduras	954
Mexico	654
Guatemala	394
Venezuela	313
Colombia	212
Nigeria	169
El Salvador	107
Peru	72
Ecuador	7
Chile	7
Nicaragua	2
Haiti	2
Guayanas (Surinam)	2
Dominican Republic	1
	10,371
Related *Phaseolus* spp.	155
Total:	10,526

Figure 3. Differences in time to maturity between varieties of *Phaseolus vulgaris* grown at Popayan.

Most of the accessions have been grown at CIAT and characterized both agronomically and for resistance to diseases and pests. Promising lines have been retested for adaptability by further sowings at Boliche or/and Monteria. Analysis of the data now available links a number of specific plant characters to yield. Beans having different growth habits also vary significantly in days to maturity, pod number, seed size, raceme number, and seeds/pod (see Table 6).

Among insect pests, resistance screening has concentrated on *Empoasca* species, and to a much lesser extent on spider mites. In plantings from 1973 and 1974 a number of accessions tolerant to *Empoasca* have been identified and a range of tolerance levels shown. Susceptible varieties such as ICA-Calima give up to 37-fold increases when insecticide protected during dry season plantings. On the other hand, tolerant varieties do not require intensive use of insecticides. With these varieties, yield increases, with pesticide use, range from 16-fold (ICA-Tui and Jamapa) to only 5-fold (73 Vul 3624, 73 Vul 3128, 73 Vul 3622, Brazil 1087 and Brazil 343) (see Figure 6). The differences suggest more than one mechanism for resistance and current efforts are directed toward identifying and combining these resistance factors for more effective insect control.

Table 6. *Summary of plant characteristics among 341 selections of* Phaseolus vulgaris

Plant Feature	Mean value per plant type			
	TYPE I (Determinate)	**TYPE II (Indeterminate small guide)**	**TYPE III (Indeterminate long guide)**	**TYPE IV (Climbing)**
Days to maturity	88.4	91.6	90.6	90.2
Days to flower	36.5	39.4	38.9	38.5
Seed size (100 grains)	26.9	23.3	23.1	24.0
Pods / plant	40.18	47.3	61.6	72.0
Racemes / plant	23.01	23.4	36.0	44.2
Pods / raceme	1.75	2.02	1.79	1.94
Seeds / plant	196.1	320.9	327.4	458.1
Seed weight / plant (g)	45.6	55.6	91.2	114.0

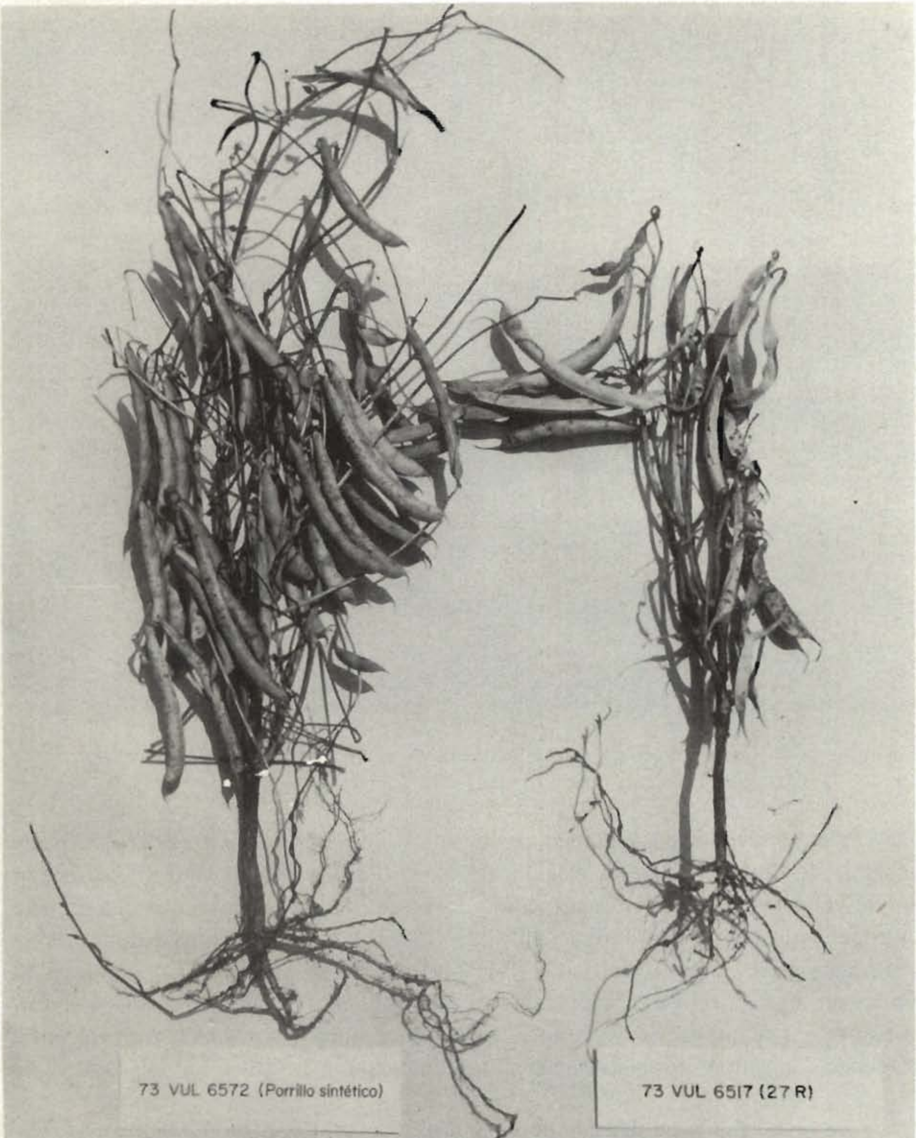


Figure 4. Differences in numbers of pods per plant between the highly promising variety Porrillo sintético and the variety 27 R, in tests at CIAT during 1973.

Priority in pathology has been in screening at CIAT and Monteria for resistance to rust, bacterial blight and web-blight (under field conditions as shown in Figure 7) and for common mosaic virus (glasshouse). Up to 2,000 accessions

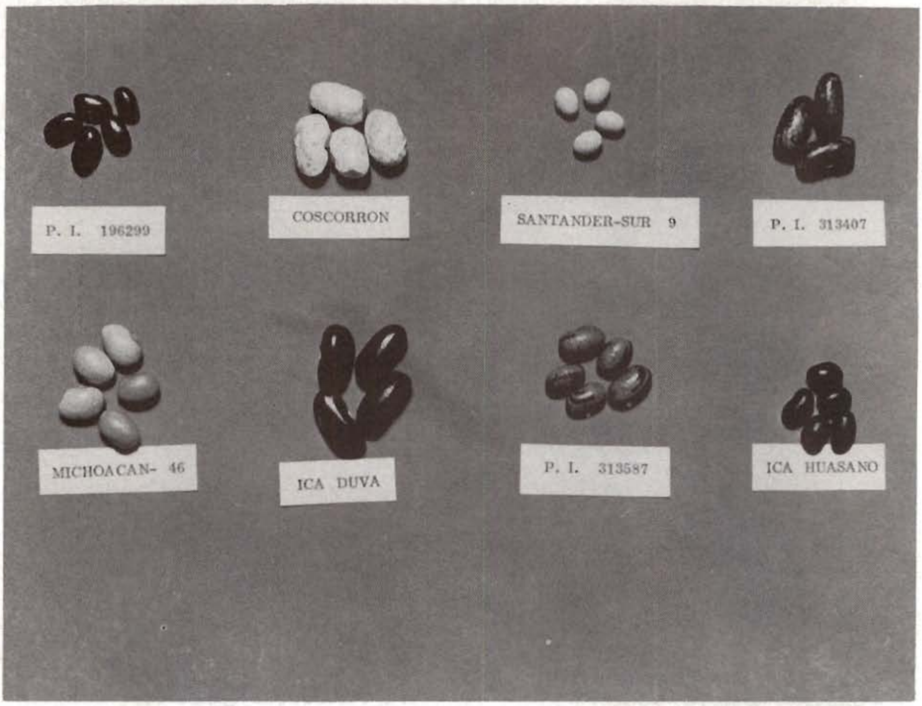


Figure 5. Differences in seed size and color in eight promising lines of *Phaseolus vulgaris*.

have been screened against each pathogen. Promising resistant varieties already located are listed in Table 7. Angular leaf spot has not been considered because of intensive prior study and resistant variety identification at the Instituto Colombiano Agropecuario (ICA) (Cardona and Walker, 1956, and Orozco and Cardona, 1959). Anthracnose does not occur at CIAT, but will be studied in 1975 plantings in Popayan. Collaborative projects have been initiated for some diseases not now present in Colombia. For example, 3,500 accessions from CIAT were recently screened for yellow mosaic resistance in Guatemala.

To make the germplasm material and its characteristics more readily available to national programs, data defining the accessions is stored on computer cards. This system will soon be linked to a data retrieval service. A listing and characterization of 400 selections showing initial promise is being readied for publication; a further listing will detail specific features available in the germplasm bank. From mid 1973 to October 1974, the program forwarded more than 7,000 accessions to 22 different countries, a clear indication of its value to national programs.

An essential second level of the germplasm program is the development of international varietal and resistance nurseries. Screening for rust resistance provides

Figure 6. Resistance of the variety Brazil 1087 to *Empoasca* under dry season conditions. The variety on the right is the susceptible Calima.

an obvious example. Initial screening at CIAT eliminates those varieties susceptible to the local physiological rust races, but doesn't consider races prevalent in other countries. Through a network of international nurseries, promising material from one location is tested at a number of cooperating institutions. A recent rust workshop at CIAT established criteria for a more accurate scoring of symptoms and considered the varieties or accessions to be included in initial nurseries. Because of its germplasm base, clean seed facility, and existing resistance data, CIAT was selected to coordinate and to distribute materials for the first rust nursery. Similar nurseries are being developed for international testing of agronomically promising accessions.

With characterization of the initial germplasm close to completion, an intensive crossing program has been initiated with the most promising materials. Ten selections, the features of which are shown in Table 8, are being used as agronomically promising material and are being crossed with materials selected for time to maturity, photoperiod insensitivity, plant growth habit, resistance to rust,

Figure 7. Method used for screening germplasm accessions for bacterial blight resistance. Accessions under test are sown as single lines and surrounded by border material susceptible to blight infection.

web-blight, common mosaic, bacterial blight and *Empoasca.* Material showing low-level resistance to some pathogens is being intercrossed in the hope of improving resistance levels. Promising material will be made available to national programs at the earliest opportunity.

The apparent superiority of black seeded lines of the "semi-guide" (II) type add to the difficulty of meeting regional preferences. Nearly all *Empoasca* resistant material has this seed color, and in regional yield trials, nine of the ten best yielding varieties have been black. Jáffe and Bucher (1974) also report higher seed protein levels in this group.

2. Physiology and Agronomy

While the genus *Phaseolus* has been studied intensively in temperate regions, physiological and agronomic studies on beans in tropical and semitropical environments are rather limited.

Comparative research on growth, development, yield, and yield components in a wide range of genotypes was initiated in 1974. Indeterminate climbing varieties grown as a monoculture on a wire-string trellis reached experimental

Table 7. *Selections of the CIAT* Phaseolus vulgaris *germplasm bank resistant to major pathogens*

Common bacterial blight

MSU 31112-1, 31128, 31132-2, 32349, 32030, 32033, 4, 27, 94, 98, 206, 213.
CIAT 73 Vul 5174, 72 Vul 24010, 25153, 24454, 24147, 73 Vul 3233, Calima, Tara.

Bean rust

Ecuador 299, México 309, Guatemala 209, 487, Turrialba 4, IAN 5091, 73 Vul 3215, 3231, 3241, 3242, 3248, 3285, 3287.
150, 5375, 3690.
PR 5, 12, 17, 18, 19, 20.

Web blight

73 Vul 7189

Common mosaic virus

146-1-1; 165-M-1, PI 146800

Root rots

73 Vul 3274, 3650, 6525, Cuilapa 72, Zamorano 2, Chimaltenango 3.

yields in excess of 5 ton/ha. Harvest index did not vary appreciably between determinate and indeterminate varieties, but both biological yield and Leaf Area Index (LAI) were much greater for the indeterminate varieties (Table 9). A maximum LAI of 9.0 was achieved with the climbing varieties planted at high densities. In other trials involving mixed maize-bean cropping, maize clearly competed with the climbing bean, limiting bean yield.

Plant density as a factor limiting yield potential was also studied extensively in 1974. In indeterminate climbing beans maximum yields were obtained at population densities of close to 1 million plants/ha (Figure 8), while in most determinate and semi-determinate varieties, optimum yields were obtained at densities of 250,000 to 400,000 plants/ha.

Table 8. *Characteristics of 10* Phaseolus vulgaris *accessions to be used in initial breeding for yield*

Accession	Origin	Seed color	Growth habit	100-grain weight (g)	Flowering time (days)	Resistance factors
PI 307824	El Salvador	Black	II – III	20.6	42.0	*Oidium*
PI 310739	Guatemala	Black	III – IV	21.3	38.0	*Oidium*, Common mosaic
Jamapa	Venezuela	Black	II	17.4	39.0	Web blight, *Oidium*, Common mosaic, *Isariopsis*
PI 310878	Nicaragua	Deep Red	II – III	25.2	40.0	Web blight
PI 310814	Nicaragua	Clear Red	II	24.3	38.5	*Isariopsis*, Web blight
Porrillo sintético	Honduras	Black	II	23.3	37.0	*Oidium*
Tora	U.S.A.	White	II	23.0	—	Bacteriosis
PR 5	Puerto Rico	Black	II	15.0	—	Rust
Porrillo 70	Costa Rica	Black	II	20.2	39.5	Mosaico Dorado, Rust
Cacahuate	Mexico	Speckled	II	36.8	—	Roya

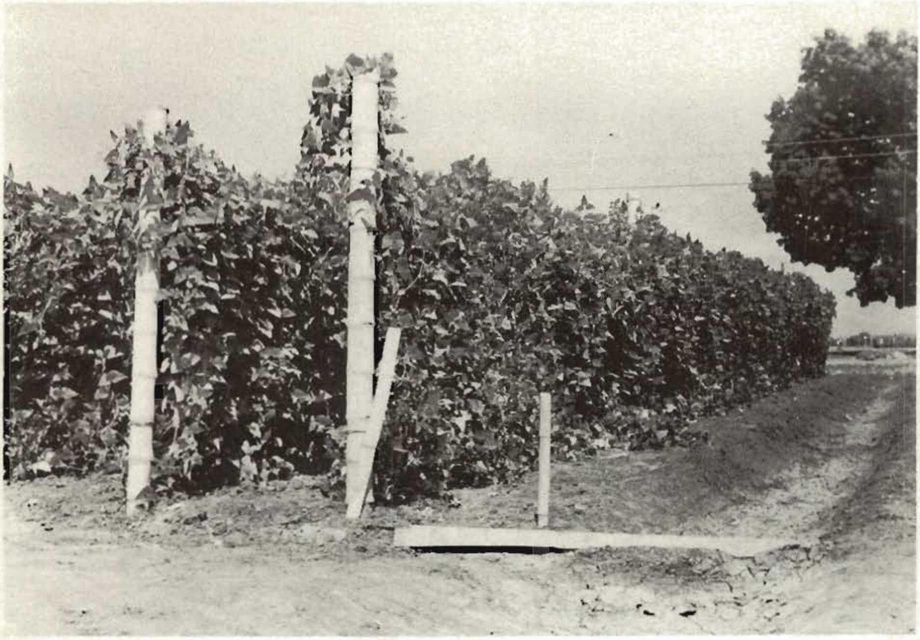


Figure 8. Growth of climbing varieties of *Phaseolus vulgaris* on bamboo-wire trellises and at a high population density. Yields with this variety exceeded 5,000 kg/ha.

Screening of the germ pool for photoperiodic response was also commenced using the field light facilities at CIAT. Photoperiodically insensitive genotypes could be critical in developing widely adapted varieties for national programs.

Replicated varietal trials were initiated in 1974 at CIAT, Monteria, Popayan and Boliche with 40 to 50 promising and commercial accessions being tested in each location. The variety Porillo sintético was clearly superior in three of the four locations (Table 10). In the CIAT trial, grain weight/pod was strongly correlated to yield, but two distinct seed groups were evident (Figure 9). Type I determinate plants had pods with 3-4 seed of high individual grain weight, while most semi-indeterminate varieties were much more variable in seed number/pod, but generally had smaller seeds.

Bean fertilization experiments continued on several fronts. Experiments at four sites in Colombia showed the importance of phosphate fertilization and placement (Figure 10). Phosphate fixation was also important with only the more soluble forms of phosphate available to the plant. Nitrogen responses were also obtained in two locations, but only when adequate phosphorous was supplied. In the presence of available P, inoculated legumes had larger nodules and fixed more

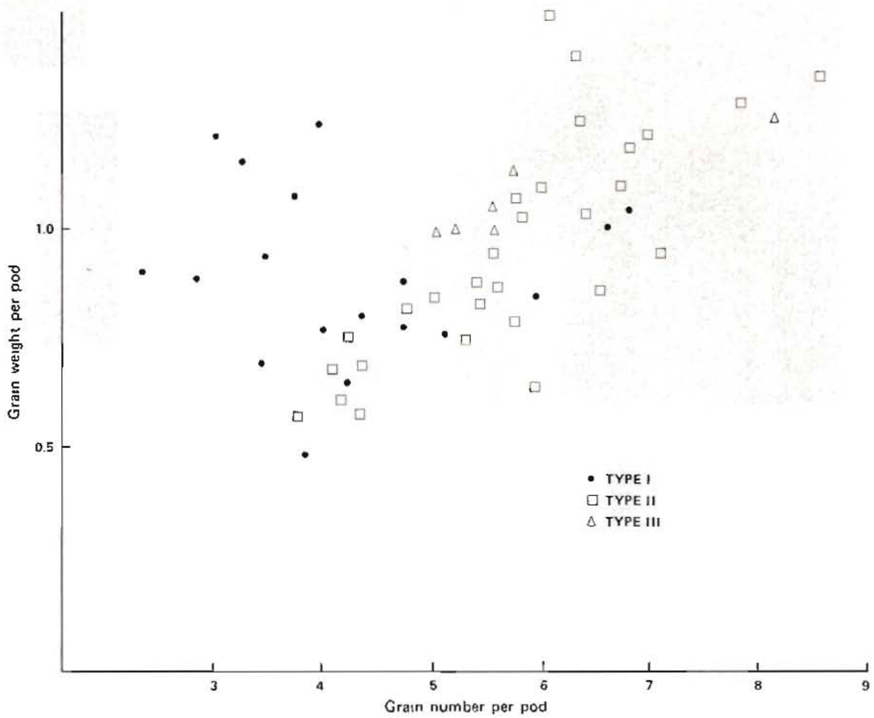


Figure 9. Relationship between grain weight/pod and number of grains/pod in *Phaseolus vulgaris* variety trials at CIAT during 1974. Note the differences according to the growth habits of the varieties.

nitrogen. Studies in progress are considering the P requirements for N-fixation in beans, and also the use of *Thiobacillus* and *Endogone* species to improve soil P availability. Boron and molybdenum fertilization experiments were also undertaken. The program maintains and distributes a wide range of inoculants for *Phaseolus vulgaris*.

3. Plant Protection

The production of disease-free foundation seed was a priority area in 1974. Clean seed initially provided by CIAT raised yields among 80 small farmers in the Las Monjas and San Matias valleys of Guatemala from 515 to 1,545 kg/ha in a single season (Martinez, personal communication). CIAT also cooperated in the "clean seeding" of commercial varieties from Perú and Brazil. By 1975, most promising germplasm lines will have been freed from seed-borne disease, and most trials at CIAT will use only clean seed. Because of national quarantine restrictions,

Table 9. *Bean yield and key physiological characters of eight varieties of* Phaseolus vulgaris *grown at CIAT, first semester 1974**

Variety identification									
	Name	**Trujillo 3**	**Trujillo 2**	**Nep 2**	**PI 310740**	**ICA Guali**	**Rico 23**	**Bayos**	**27 R**
	Number	**8**	**7**	**3**	**6**	**2**	**4**	**5**	**1**
	Type	**IV**	**IV**	**II**	**III**	**I**	**II**	**III**	**I**
Bean yield	(g/m^2)	564	559	380	334	278	276	202	121
Total dry matter[1]	(g/m^2)	1,410	1,290	818	687	637	577	521	406
Harvest index[2]		40	43	47	49	44	48	39	30
Raceme density	($x10^2/m^2$)	3.7	4.0	3.1	2.6	2.0	1.9	2.2	2.5
Bean density	($x10^2/m^2$)	30.2	32.0	24.1	17.5	4.9	16.1	8.8	3.1
Bean weight	(mg/bean)	187	175	158	191	567	171	230	390
Maximum leaf area[3]	(m^2/m^2)	9.0	8.1	3.9	4.5	3.9	3.3	2.8	3.3
Main stem length	(cm)	182	185	44	65	42	33	53	38
Days to flowering		45	47	39	35	31	34	32	34
Days to maturity		96	95	75	64	72	65	62	65
BY efficiency[4]	(g/m^2/day)	5.9	5.9	5.1	5.2	3.9	4.2	3.3	1.9
TDM efficiency[5]	(g/m^2/day)	14.7	13.6	10.9	10.7	8.0	9.8	8.4	6.2
Main stem BY/total BY	(%)	100	100	96	84	71	91	66	83
Main stem DM/total DM	(%)	100	100	97	88	77	91	71	86

* Beans were planted at a density of 100 plants $/m^2$.

1 Total dry matter is equal to weight of stem, petioles, pods and beans at maturity plus maximum leaf dry matter at post-flowering.

2 Harvest index $= \frac{\text{bean yield}}{\text{total dry matter}} \times 100$

3 Maximum leaf area = post-flowering area index

4 Bean yield (BY) efficiency $= \frac{\text{bean yield}}{\text{days to maturity}}$

5 Total dry matter (TDM) efficiency $= \frac{\text{total dry matter}}{\text{days to maturity}}$

Figure 10. Response of *Phaseolus vulgaris* to different levels of P_2O_5 (in kg/ha) applied as superphosphate in trials at La Zapata during 1974.

CIAT's role in this program will be to clean foundation seed and to identify areas within countries where clean seed can be multiplied.

Plant protection studies in 1974 stressed low-cost control of economically important pests. In addition to the *Empoasca* studies mentioned earlier, entomological studies sought an understanding of insect populations and what caused their fluctuations. These studies included regular bean plantings to determine effect of season and rainfall on major insect levels; a study on the infestation levels needed to cause economic damage; and the influence of intercropping systems on the spread of insects in, or between crops. Control of stored grain insects *(Zabrotes)* by non-chemical methods (resistance or storage system) and by using non-toxic pyrethrums was also studied. While a range of insecticides was tested for field control, and recommendations were made, these were done as short-term solutions to insect problems and will not be a major program component after 1974.

Pathological studies were similar. They included: (1) the evaluation of yield losses due to particular diseases and to the times of disease onset; (2) the influence of cultural practices such as planting density on disease incidence, severity and spread; and, (3) an assessment of fungicides in controlling several major pathogens (Figure 11).

Table 10. *Yields, plant types, and seed colors of the highest yielding* Phaseolus vulgaris *varieties and selections in the maximum yield trials*

Location	High Yielding Material	Kg/ha	Plant Type	Seed Color
	Porrillo sintético*	2,743	II	Black
CIAT	150-1-1	2,720	II	Black
56 accessions	6530 Var. 51052	2,653	II	Black
and varieties	141-M-1	2,522	II	Black
	6589-1-T-T*	2,342	II	Black
	ICA-Pijao (Line 32)*	2,341	II	Black
	Porrillo sintético	2,857	II	Black
Popayan	6536-1-T-T	2,714	II	Black
45 varieties	6589-1-T-T	2,657	II	Black
and accessions	6575-M-T-T	2,655	III	Brown
	ICA-Pijao (Line 32)	2,628	II	Black
	Porrillo sintético	1,523	II	Black
Monteria	Tui	1,184	II	Black
36 accessions	6545	1,104	II	Black
and varieties	6544	1,095	II	Black
	Line 29	1,074	II	Black

* Most promising in various locations

4. Economics

As mentioned early in Section II, socio-economic problems limit bean productivity in Latin America. To understand better the technology now available to farmers, and what impact new technology could have, the economics group is surveying bean production in three major areas of Colombia. Details of current farm practices, especially planting systems, mechanization, seed, fertilizer and pesticide use, are being collected and trained agronomists are inspecting crops to detect pests or nutrient problems. Problems associated with marketing and financing production are also being studied. Preliminary results from 72 farms in the study indicate major technological and credit differences between the three areas (see Table 11), and will help in the allocation of CIAT research resources.

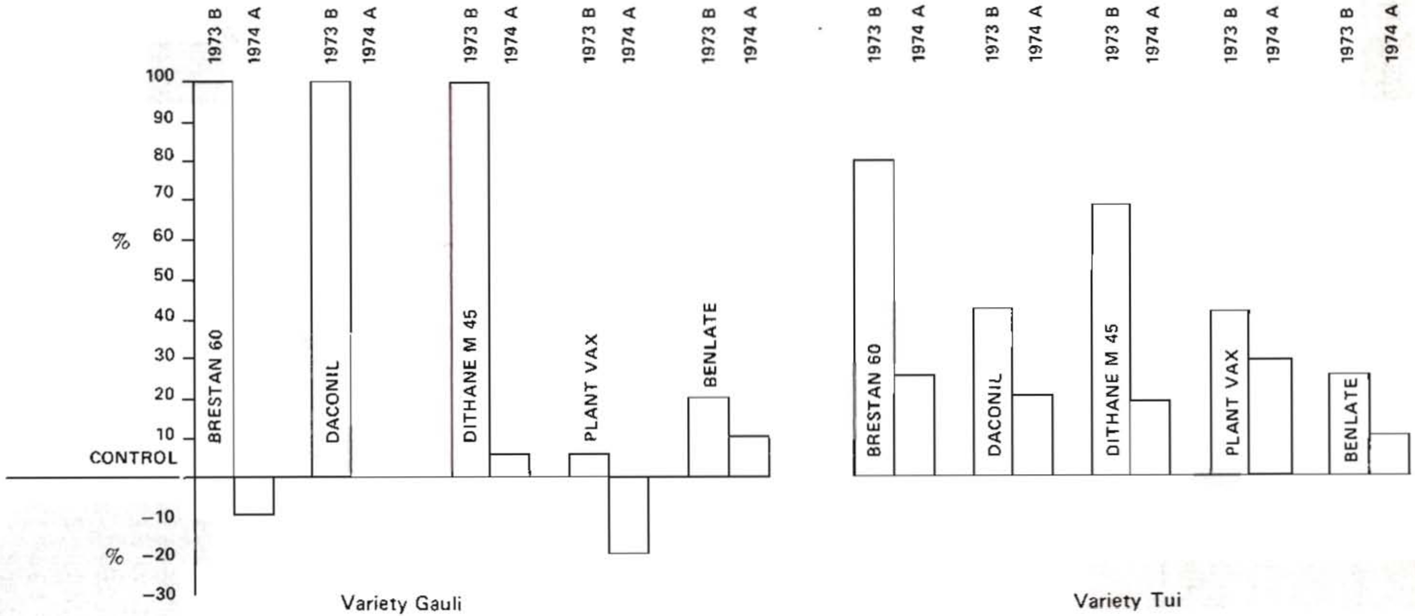


Figure 11. Responses of two varieties of *Phaseolus vulgaris* to various fungicidal treatments during two semesters at CIAT.

Table 11. *General characteristics of bean production in three zones of Colombia*

		Zone	
	Valle	Antioquia	Nariño
Number of farms surveyed	31	22	19
Characteristic			
Average farm size (ha)	50.21	4.45	4.0
Average area in beans (ha)	24.44	2.11	2.0
Percentage of farms using:			
Irrigation	42	0	0
Certified seed	52	0	0
Fertilizer	84	64	0
Weedicide	55	0	0
Insecticide	100	54	0
Fungicide	100	54	0
Credit	84	54	53
Technical assistance	71	18	0
Single cropping	97	0	5
Machinery	100	5	0

VI. INTERNATIONAL COLLABORATIVE ACTIVITIES OF THE CIAT BEAN TEAM

1. The Latin American Bean Research Network

As was mentioned in the Introduction, CIAT has been requested to establish and coordinate a Latin American bean research network. CIAT's Board of Directors, while accepting this request in principle, has asked for an additional one year to consider program developments to date and core program implications for the future. A short-term grant from the IDB currently funds some research network activities.

While there is much talk of cooperative networks in international and national research programs as well as in some disciplines, few function efficiently for one or more reasons. The organizing group may patronize cooperating units, or conversely, not react to their needs. Activities may be duplicated within the network. Lastly, jealousies may exist that cannot be resolved. If a functioning bean network is to develop, it must be on a base of respect between CIAT and regional or national programs. Within the network, CIAT would need to concentrate on activities widely applicable in Latin America, while regional or national programs should seek solutions to location-specific problems. Collaborative experiments such as those shown in Table 12 would help to resolve specific problems outside the disciplinary, technical or germplasm capabilities of national programs.

CIAT working relationships with researchers in Colombia, Ecuador, Guatemala and Peru were excellent even prior to the TAC request. Collaborative activities included: (1) advising governments on bean research requirements and priorities; (2) supplying germplasm and elite materials; (3) training scientists; (4) documentation services; and, (5) collaborative experimentation. This involvement will be continued and expanded in the bean research network. More recently, agencies in Brazil, Chile, Costa Rica and Venezuela have expressed interest in the research network approach.

Table 12. *Collaborative experimentation of the CIAT bean program*

Country	Study	Cooperating institution
Colombia	Web blight screening Anthracnose screening Rhizobium inoculation	ICA Secretaria de Agricultura del Cauca
Ecuador	Planting density Varietal selection Fertilizer requirements Regional yield trials	INIAP
Guatemala	Golden mosiac screening Hybridization of promising materials Rust resistance/web blight nurseries Apion damage	ICTA
Peru	Drought tolerance Rhizobium inoculation Varietal selection Disease-free seed	INIA

Some aspects of CIAT's bean network activities, for example, the germplasm screening and supply, have already been mentioned. This section will concentrate on training activities, technical information services, workshops and collaborative experimentation.

a. **Training Activities of the CIAT Bean Team**

As discussed in Section II, insufficient and inconsistent research support is a major factor in low bean yields. Many countries do not have the specialists they need, nor commonly, an opportunity to train scientists in specialist fields. CIAT stresses postgraduate training, receiving trainees in three categories from a range of national programs and institutions.

Postgraduate interns spend from six months to one year at CIAT receiving discipline-oriented training and instruction in the design and control of experiments, and being incorporated into the overall research program. More than 20 trainees from nine countries received training in the bean program during 1973-74. An essential component of this training is the maintenance of contact between the trainee and CIAT after the training period ends.

Research fellows who do at least the practical component of their higher degree studies at CIAT have been encouraged. Three students for the Ph.D. completed their studies in the Bean Program in 1974, and three students for the M.S. degree as well as additional students for the Ph.D. are funded for 1975.

Production courses to advise agronomists working in extension, credit or government policy of new or modified technology for bean production will begin in 1975. These courses of variable duration will stress both the discussion of, and practical experience with, proposed methods of bean production.

A coordinated training program for bean research workers is essential. At present there are several Latin American centers or programs (CIAT, Centro Agricola Tropical Investigacion y Enseñanza - CATIE, and Emprasa Brasileira de Pesquisa Agropecuaria – EMBRAPA) with the funds and capabilities to train bean research workers. Several developed area universities (Cambridge, Cornell, Florida and Michigan State) are also involved in training students from this region. Programs should be organized according to (a) the level of training required; (b) the available expertise and equipment; and, (c) similarities in climate and production systems between the student's country and the training institution.

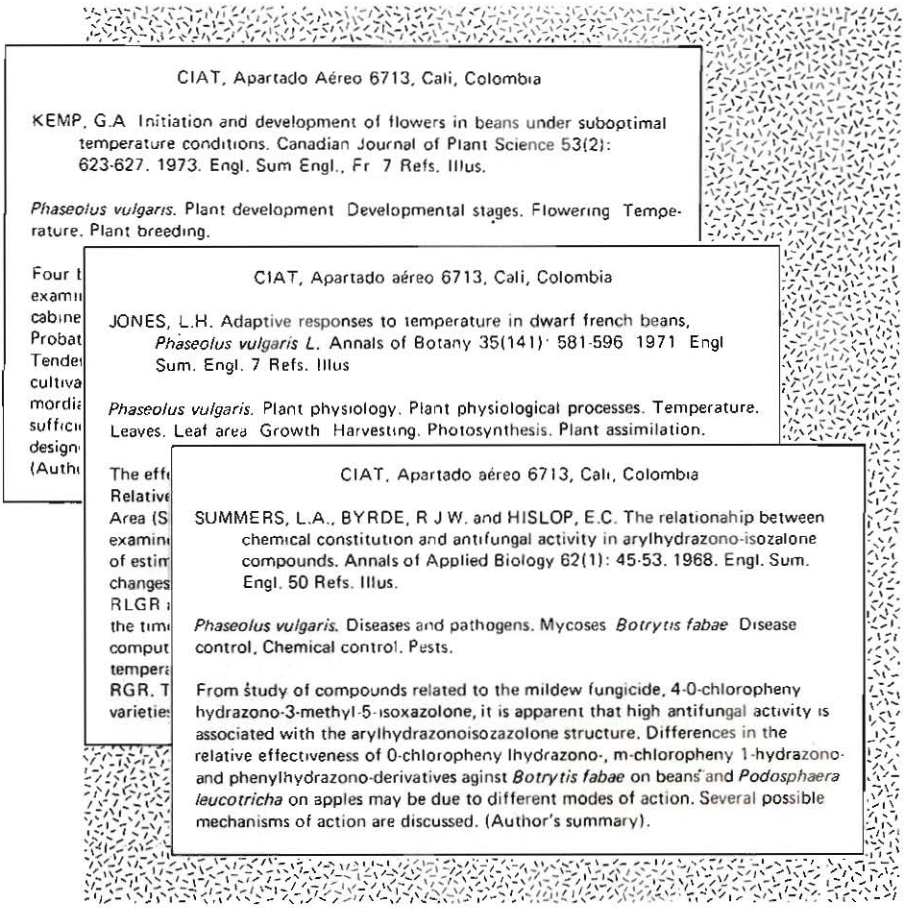
b. **Documentation and Bibliography**

In August, 1974, the Bean Program established a documentation and abstracting service through which interested institutes and scientists can receive at minimal cost citations and abstracts of all bean literature. A typical abstract card is shown in Figure 12. Abstracts will initially be prepared from current journals and, for convenience, will be in English. Journal searches will progressively identify articles back to 1960. Both English and Spanish versions will be available after 1975.

c. Conferences and Workshops

Small, discipline based workshops with 15-25 participants encourage collaboration, improvement of experimental methods, detailed comparisons of

Figure 12. Abstract cards from the Bean Documentation System. Note the method of referencing and the use of key words.



CIAT, Apartado Aéreo 6713, Cali, Colombia

KEMP, G.A. Initiation and development of flowers in beans under suboptimal temperature conditions. Canadian Journal of Plant Science 53(2): 623-627. 1973. Engl. Sum Engl., Fr 7 Refs. Illus.

Phaseolus vulgaris. Plant development. Developmental stages. Flowering. Temperature. Plant breeding.

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JONES, L.H. Adaptive responses to temperature in dwarf french beans, *Phaseolus vulgaris L.* Annals of Botany 35(141): 581-596 1971 Engl Sum. Engl. 7 Refs. Illus

Phaseolus vulgaris. Plant physiology. Plant physiological processes. Temperature. Leaves. Leaf area. Growth. Harvesting. Photosynthesis. Plant assimilation.

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CIAT, Apartado aéreo 6713, Cali, Colombia

SUMMERS, L.A., BYRDE, R.J.W. and HISLOP, E.C. The relationahip between chemical constitution and antifungal activity in arylhydrazono-isozalone compounds. Annals of Applied Biology 62(1): 45-53. 1968. Engl. Sum. Engl. 50 Refs. Illus.

Phaseolus vulgaris. Diseases and pathogens. Mycoses. *Botrytis fabae*. Disease control. Chemical control. Pests.

From study of compounds related to the mildew fungicide, 4-0-chloropheny hydrazono-3-methyl-5-isoxazolone, it is apparent that high antifungal activity is associated with the arylhydrazonoisozazolone structure. Differences in the relative effectiveness of 0-chloropheny lhydrazono-, m-chloropheny 1-hydrazono- and phenylhydrazono-derivatives aginst *Botrytis fabae* on beans and *Podosphaera leucotricha* on apples may be due to different modes of action. Several possible mechanisms of action are discussed. (Author's summary).

results and greater contact between scientists. They also ensure constant exposure of CIAT staff to problem areas. Two workshops are planned each year according to the following schedule:

1975	Plant Protection Workshop
	Bean Breeding and Germplasm Bank Workshop
1976	Bean Agronomy Workshop
	Soil Microbiology Workshop
1977	Economics Workshop
	Bean Physiology Workshop

It is hoped that these workshops will coincide with appropriate research developments as projected in Figure 1. Thus, the 1975 breeding and germplasm workshop should provide an opportunity to discuss recently completed germplasm testing and how national programs could best use the material available. This workshop should also show F_3 progeny from the breeding materials listed in Table 8, and provide discussion on the transition from mainly local yield trials to trials on an international basis. Similarly, the 1977 economics workshop should coincide with the termination of the two limiting factor economics surveys undertaken outside Colombia.

d. **Collaborative experimentarion**

Table 12 shows the areas of collaborative research proposed for 1975. As suggested earlier, these try to resolve location specific problems using CIAT technical expertise or facilities combined with the local knowledge of, and overall supervision by, national program scientists.

The regional yield trials mentioned above are an obvious example. Initial screening at CIAT will identify varieties or lines showing yield promise over a limited range of ecological conditions. To compare such materials with those developed by national programs, integrated yield trials will be established in as many areas as possible. For these trials to be successful, it will be essential to meet with national program leaders wishing to participate in the testing program and to mutually establish what varieties are to be included, what standard fertilizer and pesticide protection should be given, plot sizes and what data is to be taken.

Similarly, CIAT can make available small quantities of clean seed from its germplasm bank, but these can only be built up for farm use by seed multiplication under the control of the interested national program.

The studies on *Apion,* anthracnose and web blight are exceptional in that while they are of major importance to the region as a whole, they cannot readily be studied at CIAT.

2. *Bean Technical Advisory and Steering Committee*

When collaborative bean research network proposals for Latin America were being considered, TAC stressed the need for a scientific advisory committee. It was suggested that such a committee could review regional research needs, help to channel problem areas to CIAT or to appropriate national entities, and also would provide technical criticism of CIAT's research program in beans.

The recent Bean Evaluation Workshop considered the composition and activities of such a committee and nominated the following as founder members:

Dr. Hugh Bunting, University of Reading, United Kingdom
Dr. Dermot Coyne, University of Nebraska, U.S.A.
Dr. Antonio Pinchinat, CATIE, Costa Rica.
Dr. Julio López Rosa, Universidad de Puerto Rico, Puerto Rico.
Dr. Clibas Vieira, EMBRAPA, Brazil.
Dr. Oswaldo Voysest, "La Molina", Peru.

The Director General or Deputy Director General of CIAT will also be a member of this committee. The constitution and activities of the committe will be reviewed and ratified at its first meeting, probably in June, 1975.

3. *Special project research needs*

As mentioned in Section IV, there are numerous areas of bean research which could be better done at laboratories in developed countries or under special contract. These include:

1. Soil temperature studies. Temperature in the soil at CIAT can exceed 45°C for several hours per day, and in certain other areas can approach 60°C. Much lower temperatures have been shown to limit both plant growth and nitrogen fixation in other grain legumes (Dart *et al,* 1973). The temperature effect noted often depends on the variety or strain being studied. CIAT has no facilities to undertake controlled temperature experiments; this phenomenon could best be studied through support research done in better equipped laboratories. Practical measures to reduce soil temperatures –mulching, minimum tillage, associated cropping– will continue at CIAT. Mulching in particular has already shown beneficial results.

With the development of germplasm for high altitudes, low temperatures will be a problem and will require similar study.

2. Seed-borne diseases. Several aspects of seed-borne diseases could be better studied away from CIAT. One problem is the distinction between virus problems with similar symptomatology. There is much confusion between bean yellow mosaic virus (currently present in Chile), golden mosiac virus (in Guatemala) and swollen mosiac virus (in San Salvador). Serological methods to identify these different viruses are desirable, but could not really be justified within the CIAT program. Of major concern to CIAT is the fact that apparently clean-seeded varieties will sometimes show symptoms in subsequent generations. The mechanism by which viruses or bacteria remain viable in the plant without causing visible damage needs to be investigated.

3. Phosphorus fertilization. The importance of phosphorus fertilization and placement has already been mentioned. While CIAT cannot now investigate soil phosphate chemistry, a knowledge of this field could be highly important in developing fertilization practices. The occurrence of endotrophic mycorrhizal fungi in tropical soils, and their importance to phosphate availability, should also be determined.

4. Information handling. If, as seems probable, the CIAT Bean Program becomes the world center for *Phaseolus vulgaris* germplasm, it will be necessary to improve data handling and information retrieval and analysis systems. Germplasm bank data can be used as a powerful tool, for example in the Australian studies of *Stylosanthes* sp. (Burt *et al*, 1971). Rapid sorting procedures are essential to minimize turnaround time in supplying germplasm requests.

5. Protein studies. Given CIAT's lack of emphasis on bean protein quantity and quality, it is desirable that some other center undertake studies on protein yield interactions. Some such work is already being undertaken at Cambridge and at INCAP in Guatemala.

The agreement between CIAT and the universities of Cornell, Hokkaido and Michigan is an example of how such cooperative research can work. Under this agreement, these universities emphasize basic bean physiology, studying factors such as flower drop and pod development, photosynthesis by the bean pod and its contribution to yield, and the reasons for growth habit instability in beans.

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