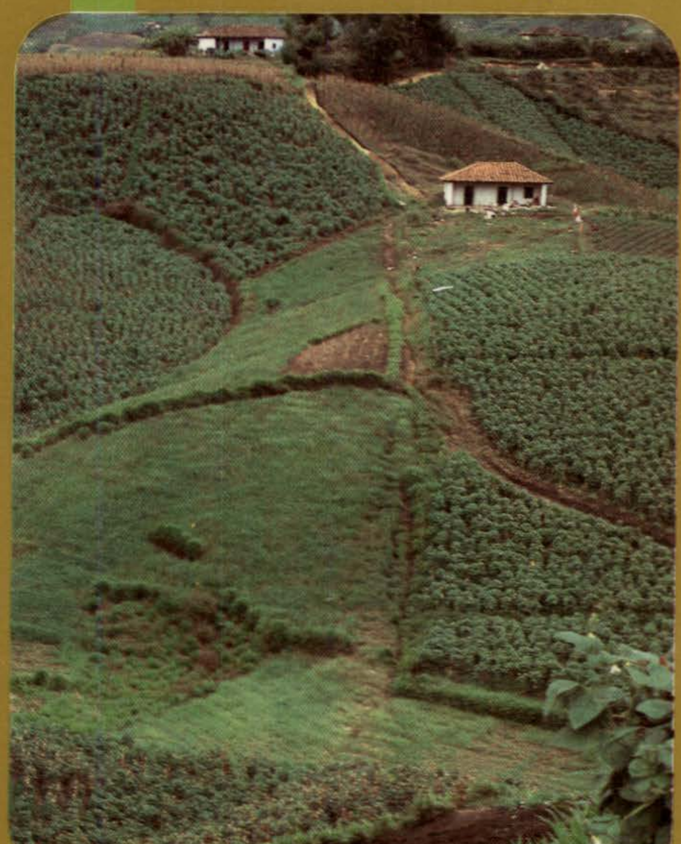
# CIAT

# bean program



# 1978

CIAT is a nonprofit organization devoted to the agricultural and economic development of the lowland tropics. The Government of Colombia provides support as host country for CIAT and furnishes a 522-hectare farm near Cali for CIAT's headquarters. In addition, the Fundación para la Educación Superior (FES) makes available to CIAT the 184-hectare substation of Quilichao, situated near Santander de Quilichao, Departamento del Cauca. Collaborative work with the Instituto Colombiano Agropecuario (ICA) is carried out on several of its experimental stations and similar work is done with national agricultural agencies in other Latin American countries. CIAT is financed by a number of donors represented in the Consultative Group for International Agricultural Research (CGIAR). During 1979 these donors are: the United States Agency for International Development (USAID), the Rockefeller Foundation, the Ford Foundation, the W.K. Kellogg Foundation, the Canadian International Development Agency (CIDA), the International Bank for Reconstruction and Development (IBRD) through the International Development Association (IDA) the Inter-American Development Bank (IDB), the European Economic Community (EEC) and the governments of Australia, Belgium, the Federal Republic of Germany, Japan, the Netherlands, Norway, Switzerland and the United Kingdom. In addition, special project funds are supplied by various of the aforementioned entities plus the International Development Research Centre (IDRC) of Canada and the United Nations Development Programme (UNDP). Information and conclusions reported herein do not necessarily reflect the position of any of the aforementioned agencies, foundations or governments.

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# Bean Program 1978 Report

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* Left during 1978

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## Appendices

# Bean Program

Previous reports of this Program have documented the search for outstanding germplasm, and the gradual strengthening of bean hybridization activities at CIAT. The year 1978 marked new gains for the Program with the movement of large quantitites of hybrid material toward advanced generation testing. A total of 1464 materials of which 937 were selections from the breeding program were screened in the Bean Team Nursery (VEF) and 700 materials, including 200 breeding selections, were evaluated in the Preliminary Yield Trial (EP). The screening of these lines for factors as diverse as yield, tolerance or resistance to rust, anthracnose, common bacterial blight (BCMV), and *Empoasca,* as well as sensitivity to photoperiod demanded excellent coordination and cooperation, and demonstrated again the integrated multidisciplinary approach adopted by the bean team. Results from the EP in particular were spectacular, demonstrating major gains in yield among colored materials and a very high proportion of breeding lines resistant to BCMV. Many lines demonstrated multiple disease resistance with gains in this area generally greater than had been anticipated.

The program continued to emphasize international yield and disease resistance testing. In 1978, 150 International Bean Yield and Adaptation (IBYAN) nurseries were distributed (88 color, 62 black) to 34 countries. Ninety-five different varieties have been included so far in these trials, with the 1978 IBYAN being notable for a marked increase in the number of CIAT-bred materials included. Rust, bean golden mosaic virus (BGMV) and common bacterial blight nurseries were also distributed.

Other major advances included: (1) initiation of a breeding program for climbing cultivars to be grown in association with maize; (2) establishment of temperature conditions likely to limit nitrogen fixation by bean root nodules; (3) identification of bean cultivars tolerant to low soil P; (4) micro-regions of bean production in Latin America were identified and an agro-climatology survey initiated; (5) on-farm trials demonstrated that low cost agronomy practices could increase farm yields 50%, and were profitable in the main production zones of beans in Colombia; and (6) intensification of the breeding work for anthracnose, angular leaf spot, and other conditions common to cooler climates.

As in previous years much emphasis was given to postgraduate training and to documentation. Two bean courses were held, with participation by 59 scientists from 14 countries.

# BEAN PROGRAM ACTIVITIES IN 1978

The principal objective of the bean program is to increase yields of *Phaseolus vulgaris* in Latin America. Given the comparative advantage of international centers in germplasm evaluation and manipulation, and the need for additional trained scientists and research support in national bean programs, it is hoped to achieve this goal through four strategies:

(1) The production of improved germplasm having high yield and with resistance to the important pathogens and pests of the region. Initial focus has been toward bean rust *(Uromyces phaseolis)*, anthracnose *(Colletotrichum lindemuthianum)*, bean common mosaic virus (BCMV), common bacterial blight *(Xanthomonas phaseoli)* and the leafhopper, *Empoasca kraemeri*. The improved materials must additionally be acceptable to the consumer in grain type and cooking quality.

(2) The development of a complementary package of agronomic practices, suited to the improved germplasm but based on simple agronomic practices and using the minimum technical inputs to obtain good yields.

(3) The training of scientists from national institutes to facilitate their work in bean research and extension.

(4) Close collaboration with national bean programs and with other institutions working with the crop.

To fulfill these strategies the Bean Program in 1978 was active in seven major areas: (1) screening of cultivars for desired traits; (2) hybridization of promising materials and evaluation of their progeny; (3) evaluation and improvement of current agronomic practices; (4) in-depth studies of specific problem areas; (5) validation of technology in on-farm trials; (6) postgraduate training; and (7) collaboration with national programs and other institutions.

Since many of the areas of research undertaken depended upon the multidisciplinary cooperation of bean team members this report is not presented by discipline areas, but by research topic.

# SCREENING OF CULTIVARS FOR DESIRED TRAITS

In 1976 the International Board for Plant Genetic Resources (IBPGR) designated that CIAT would be responsible for the collection, management, evaluation, and distribution of *Phaseolus* germplasm. The germplasm bank facility at CIAT now contains approximately 21,000 entries, more than 11,000 of which have been extensively characterized. While the urgency for germplasm evaluation abated somewhat in 1978, it still remained a major component of the research program, with inputs from virtually all disciplines. Major activities are detailed in the following sections.

# Screening for Resistance to Pathogens and Pests

## Resistance to Pathogens

Initial studies in this area sought materials with resistance to bean common mosaic virus (BCMV), rust, anthracnose, common bacterial blight and angular leaf spot (CIAT Annual Reports, 1974-1977). As reliable resistance sources have been identified for these pathogens, emphasis has also been placed on screening for resistance to bean golden mosaic virus (BGMV), *Ascochyta, Cercospora* and web blight *(Thanatephorus cucumeris).* Distinction between available resistance sources has been sought using genetic studies and international disease nurseries. Finally, there has been a continued improvement in screening methods, and a consideration of strain frequency in the continent.

*Improved Methods for BCMV and Anthracnose Evaluations.* The contamination of BCMV-inoculated plants with bean rugose mosaic virus, and the low inoculation efficiency obtained on BCMV-susceptible materials has complicated the evaluation of germplasm accessions and breeding lines in past years. The method detailed below limits these problems.

To avoid contamination with other viruses, the inoculum was obtained from 12-day-old Diacol Calima seedlings grown from BCMV-infected seed and was serologically assayed for the presence of bean rugose and bean southern mosaic viruses. For the inoculation, the virus was then extracted (1:10, w/v) in 0.01 *M* potassium phosphate buffer, pH 7.6, and inoculated (wearing disposable gloves) with the aid of a sterile cheesecloth pad (Fig. 1). In the field, the inoculum was poured into 150-ml plastic bottles, and dispensed using a sterile cheesecloth pad attached to the mouth of the bottle (Fig. 2).

Figure 1. Inoculation of bean plants in the screenhouse using sterile cheesecloth pads.

Following this methodology 1158 materials (approximately 16,000 plants) were manually inoculated and evaluated

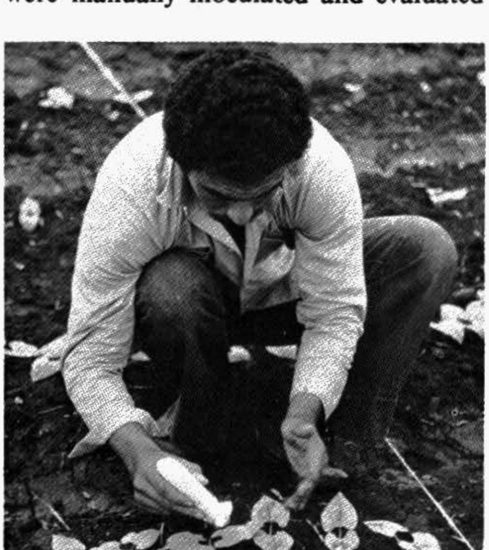


Figure 2. Field inoculation of bean plants using plastic bottles stoppered with sterile cheesecloth pads.

under glasshouse conditions without a single case of contamination, and with an inoculation efficiency of 95-100% in susceptible materials. In order to expand present glasshouse capacity (limited to 10,500 plants/20-day cycle) a study to determine the reliability of screening under semi-controlled conditions was undertaken; 21,500 plants being manually inoculated under screenhouse conditions. Efficiency was equal to that obtained in the glasshouse.

For field screening the use of bottles to dispense the inoculum facilitated the inoculation and evaluation of 4684 bush and climbing bean materials in 1978B, and resulted in infection rates of between 80 and 90%. The use of containers and disposable sterile cheesecloth pads kept contamination in field screenings to 0.1% of the inoculated materials. The contaminant virus was serologically identified as southern bean mosaic virus, a seed-borne pathogen.

To further facilitate the screening of germplasm and breeding materials the practicality of multiple inoculation (BCMV and anthracnose) under controlled conditions was studied.

Nearly 300 entries (10 seeds each) were planted in flats in the glasshouse, inoculated seven days later with BCMV and 24 hours later with a mixture of anthracnose races, incubated for 12 days in a moist chamber at moderate temperatures, and evaluated for resistance to the composite inoculation.

Materials which were resistant to BCMV and anthracnose were efficiently detected within 20 days after planting. Selections could then be successfully transplanted for seed production or subsequent field trials. It was impossible to deteremine the reaction of every entry to both pathogens since some entries were killed by the anthracnose fungus before BCMV symptoms could be expressed. However, this method is very useful in a practical program designed to efficiently identify resistance to multiple pathogens.

*Sources of Resistance to the Florida Strain (USA 5) of BCMV.* Recent studies have shown the Florida strain (USA 5) in natural infections of beans grown at CIAT. Since this strain can overcome the resistance of two groups of cultivars not attacked by the type strain of BCMV used in initial screenings, a search for resistance to BCMV USA 5 has been undertaken among CIAT germplasm materials. In 1978B, 290 promising lines, 104 other germplasm accessions, and 35 other materials were screened. Of these, 120, 54 and 15 respectively, proved resistant (or symptomless) to strain USA 5 of BCMV.

*Methodology for Evaluation of Resistance to Angular Leaf Spot.* For evaluation of resistance to angular leaf spot, a spore preparation is obtained from plates of V-8 agar grown 10-15 days in the dark at 19°C. Conidia are harvested in water by rubbing the sporulating colonies with a soft wire brush. A spore concentration of $10^4$/ml is used in the inoculations with Triton or gum arabic added to obtain uniform infection. A disease evaluation scale based on the percentage leaflet area affected is utilized to measure resistance. On a 1-5 scale, immune materials (1) show no infection; (2) resistant materials have less than 2% of the actual leaflet area infected; (3) intermediate, 3-10% actual leaflet area infected; (4) susceptible, 11-25% actual leaflet area infected, and sometimes limited chlorosis; and (5) very susceptible, more than 26% actual leaflet area infected, and often accompanied by chlorosis and/or defoliation.

*Sources of Resistance to Powdery*

*Mildew.* A natural and severe epiphytotic of powdery mildew *(Erysiphe polygoni)* occurred in a nursery of over 1400 germplasm accessions planted in Popayan (Fig. 3). Subsequent disease evaluations identified the following 18 accessions which were highly resistant: G-1841, 2092, 2325, 2351, 2546, 3038, 3716, 3777, 3783, 3791, 3988, 4721, 5508, 6636, 6638, 6640, 6641 and 7464.

*Root Rots.* CIAT has been developing methodology to evaluate germplasm and progenies for resistance to infection by *Rhizoctonia solani, Sclerotium rolfsii, Fusarium* sp. and *Pythium* sp. Field and glasshouse inoculations and natural infestation trials were utilized to select evaluation scales which would be most efficient and practical for the Bean Program to utilize during progeny development.

Evaluation of resistance to infection by *R. solani, S. rolfsii,* and *Pythium* spp. (primarily *Pythium aphanidermatum* and *Pythium debaryanum)* was most efficiently accomplished by measuring the percentage germination and survival of plants when subjected to natural or artificial inoculum pressure in the glasshouse or field. No correlation was found between lesion depth and/or frequency and yield loss magnitude because of the increased growth compensation and reduced plant competition between surviving plants in inoculated trials.

Evaluation of resistance to infection by *Fusarium solani* f. sp. *phaseoli* was most efficiently accomplished by determining the depth of lesion development in seedling hypocotyls according to the following scale: (1) Resistant, no lesion development; (2) Intermediate, shallow lesions confined

Figure 3. Susceptible and resistant reactions to a natural epidemic of powdery mildew in a germplasm nursery planting at Popayan.

to the outer 50% of the cortical tissue; (3) Susceptible, lesion development extended to the midpoint of the cortex or beyond, but not into the vascular system; and (4) Very susceptible, lesion development extended into the vascular system and/or pith region. Resistant parental materials are being utilized by the breeding program, and seedlings will be evaluated in advanced generations with replicated family testing at a planting density of 20-30 plants/m² under the high natural field infestation present in CIAT-Palmira fields. Indirect selection pressure against progeny susceptible or highly susceptible to *Fusarium solani* and/or other root rot pathogens is being exercised in earlier generations.

Other evaluation methods utilized during flowering or post-flowering stages were discarded because of confounding effects caused by physiological root senescence, planting depth, root wounds and secondary infection internally, adaptation, and environmental factors. Additional studies are required to determine the correlation between seedling and adult plant resistance, especially with regard to *S. rolfsii*.

### Resistance to Insect Pests

*Empoasca kraemeri*. Evaluations for resistance to the leafhopper *(Empoasca kraemeri)* were conducted on approximately 4000 materials derived from screening work in the various disciplines of the Bean Program.

The following groups of materials were evaluated: International Bean Yield and Adaptation Nursery (IBYAN); International Bean Golden Mosaic Nursery (IBGMN); the Preliminary Yield Trial-$F_3$ (Climbing Beans); the 1978 Preliminary Yield Trial (EP) and the 1978 Bean Team Nursery (VEF); as well as introductions of *Phaseolus acutifolius* and *Phaseolus filiformis* and other cultivars in various stages of selection for resistance to *Empoasca*. The best materials selected from the different nurseries and selection stages are being used to form part of the International Nursery for *Empoasca*.

Of all the materials studied, about 400 (10%) showed high levels of resistance to leafhopper damage. Table 1 lists the cultivars classified as being most resistant to *E. kraemeri* in 1978. Among the 27 best materials, 63% are black-seeded. As in previous years not many sources of resistance were found among red beans. It should be emphasized that there were some non-black beans which had visual damage classifications less than 2. Climbing materials studied showed low resistance levels; the majority of them changed their growth habit from Type IV to II in the presence of *E. kraemeri* attacks.

*Tetranychus desertorum*. In 1977, screenhouse evaluations were initiated on bean varieties and cultivars for resistance to the red mite *(Tetranychus desertorum)*. The optimum period of infestation of these materials was found to be 15 days after seeding and a visual scale was developed to evaluate mite damage. A total of 561 varieties were studied of which 124 were very susceptible and 139 were selected for more detailed studies.

This year for the first time, varietal resistance to the red mite was studied in the field, beginning with a group of 64 varieties. The materials P- 83, 84, 85, 179 and 301 showed resistance while P- 52, 172, 217, 277 and 363 were classified most susceptible. This experiment included the varieties Oregon 58 and 58R and CRIA-1, which had been evaluated as resistant in Peru. In the screenhouse, they exhibited more resistance than other lines but in the field Oregon 58 and 58R were susceptible, suggesting that it is necessary to do studies

Table 1.

**Cultivars and varieties of *Phaseolus* showing the highest grades of resistance to *Empoasca kraemeri*, during 1978 evaluations.**

| Nursery or other source | Identification | Primary color | Average classification[1] | Total materials: Evaluated | Resistant[2] |
|---|---|---|---|---|---|
| Rust Nursery (IBRN) (1976-77 plantings) | G124 | White | 1.4 | 135 | 27 |
| | G4463 | Black | 0.9 | | |
| | G5773 | Black | 1.2 | | |
| | G5942 | Black | 1.1 | | |
| Selection Stages | G8058 | White | 1.2 | 296 | 92 |
| | G8059 | White | 1.0 | | |
| | G8062 | White | 1.2 | | |
| | G8475 | Black | 1.0 | | |
| International Golden Mosaic Nursery (IBGMN) | Sucre 7 | Black | 1.8 | 235 | 21 |
| | G1257 | Black | 1.8 | | |
| | G1157 | Mottled Cream | 1.0 | | |
| 1978 Bean Team Nursery (VEF) | 78 VEF 89 | Black | 1.2 | 2221 | 204 |
| | 78 VEF 92 | Black | 1.2 | | |
| | 78 VEF 276 | Cream | 1.1 | | |
| | 78 VEF 460 | Black | 1.2 | | |
| | 78 VEF 846 | Black | 1.4 | | |
| | 78 VEF 1006 | Variable | 2.0 | | |
| 1978 Preliminary Yield Trial-Bush Beans (78 EP) | P14 | Black | 1.7 | 780 | 36 |
| | P785 | Black | 1.8 | | |
| Preliminary Yield Trial-$F_3$, Climbing Beans | FF0016-23-3-CM-CM-CM | Brown | 2.0 | 300 | 4 |
| | FF0594-7 | Black | 2.0 | | |
| | FF0611-1 | Black | 2.0 | | |
| | FF0623-29 | Black | 2.0 | | |
| Other *Phaseolus* spp. | | | | | |
| *Phaseolus acutifolius* | G3568 | Black | 1.2 | 93 | 23 |
| | G4401 | Black | 1.2 | | |
| | G5917 | White | 1.3 | | |
| *Phaseolus filiformis* | NI-31 | Cream | 1.6 | | |

1 Average of two replications and three observations, on a scale of 0-5: 0 = high grade of resistance; 5 = no resistance.
2 Resistant: average classification ≤ 2.

correlating evaluations from the screenhouse, field and laboratory and determining which selection methods should be followed.

Also this year, the species *P. acutifolius* var. *acutifolius* and *P. acutifolius* var. *latifolius* were evaluated in the field for mite resistance. Generally, these materials showed a higher grade of resistance than *P. vulgaris*. Some *P. acutifolius* accessions had little damage up to the end of the vegetative period.

## Germplasm Evaluation for Architecture and Yield

### Bush Bean Cultivars

During 1978 more than 6000 germplasm accessions were evaluated for lodging resistance, foliage type, maturity, and pod and seed characteristics.

Type II and III lines with medium to large seeds, small foliage, outrigger (multipodded) inflorescence, and one line (G8063) with male sterility were identified from germplasm bank growouts (Table 2) but minimal variation for lodging resistance and delayed maturity was found. Some selections from breeding nurseries were identified for the latter two characters and a lanceolate leaf type was also identified and appears promising. However, these are associated with exceptionally low productivity. Purification and determination of their genetic worth is underway.

### Climbing Bean Cultivars

Though the available collection of climbing beans in CIAT (1950 accessions) had been adequately screened at Palmira in previous years, little was known of its performance at other altitudes. To study this all cultivars were planted at three highland locations, Popayán, La Selva, and Obonuco, using monoculture, relay cropping and direct association with maize, respectively.

A preliminary screening in the first semester with 30 materials demonstrated that in selected materials any imagineable response of growth habit to temperature and other climatic factors could be found (Figure 4). For example, G2540 (white) climbed more than average at all three locations; G413 (yellow) was better adapted in climbing response to cool

Table 2.

*Phaseolus vulgaris* **selections made for interesting architecture and yield characters.**

| Character | Growth habit | No. of entries | Sources |
|---|---|---|---|
| Lodging resistance | II | 7 | Breeding nurseries |
| Small foliage | II, III | 9 | Germplasm bank |
| Lanceolate leaf | II | 2 | Breeding nurseries |
| Delayed maturity | I, II, III | 7 | Breeding nurseries |
| Early maturity | I, II | 6 | Germplasm bank |
| Outrigger inflorescence | I | 2 | Germplasm bank |
| Medium to large seed | II, III | 22 | Germplasm bank |
| Male sterility | III | 1 | Germplasm bank |

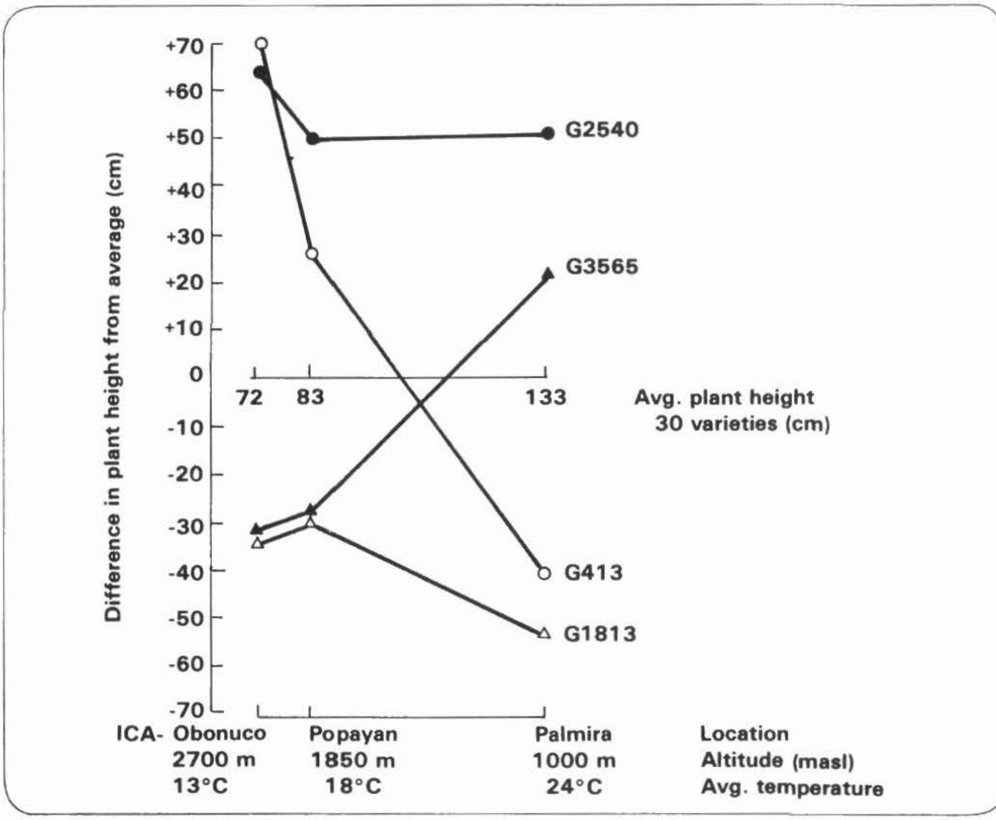



Figure 4. Change in height of growth for four climbing bean varieties caused by differences in locational altitides.

temperatures whereas G3565 (white) was better adapted to warm temperatures. G1813 (yellow) showed a stable response to temperature, but climbed less than average at all locations. Flowering response was also highly variable: only two materials (G3371 and G2545) demonstrated satisfactory pod set and growth habit stability at all locations.

The complete screening of all materials was planted in the second semester in unreplicated hill-plots, using three bean plants plus, where associated, three maize plants in the same hill This has proved to be a very cheap and effective means of evaluating large quantities of material in a small land area. The nurseries were not protected against diseases except that any plants showing BCMV were rogued out. Evaluations were made for climbing adaptations, earliness, pod set and disease incidence. The first results from ICA-La Selva in relay cropping have shown that 24% of the collection climbed well (true type IV). Those demonstrating exceptional highland adaptation originated mostly from Mexico, Turkey and South Africa. There are, however, relatively few accessions available to date from Andean zone countries.

## Screening for Tolerance in Moderately Acid Soils

While beans are not normally grown under highly acid soil conditions they are often planted in circumstances of low phosphorus and moderate soil acidity.

Preliminary screening of the promising bean varieties (P-lines) for tolerance to low levels of soil phosphorus was carried out at the Popayan site. From this screening it appears that dry beans *(P. vulgaris)* can be divided into four categories of P requirement: (1) inefficient at low P level and non-responsive to applied fertilizer; (2) inefficient at low P level but responsive to fertilizer; (3) efficient at low P level but non-responsive to fertilizer; and (4) efficient at low P level and also responsive to fertilizer.

Plants in category 1 may be rejected as worthless for breeding and/or agronomy. Category 3 plants would be of value only when they have other advantageous characteristics.

Screening for low soil P and acid soil tolerance in 1978 was carried out at the CIAT-Quilichao substation. The experiment included both lime and P treatments and was designed to permit evaluation of both tolerance to low P and to soil acidity and Al toxicity.

The results from the screening of 188 CIAT promising lines for tolerance to low soil P at Quilichao are plotted in Figures 5, 6 and 7, according to the seed color. The efficiency factor plotted on the ordinate axis is specific for the semester of testing, and P source, and is derived from the formula:

$$\frac{\text{Yield at high P level - Yield at low P level}}{\text{Difference in units of } P_2O_5 \text{ applied}}$$

Since bean yields are subject to soil and climatic variation, yields will vary every planting season. Only beans that remain in the upper right-hand quadrant are chosen as tolerant to low soil P. These correspond

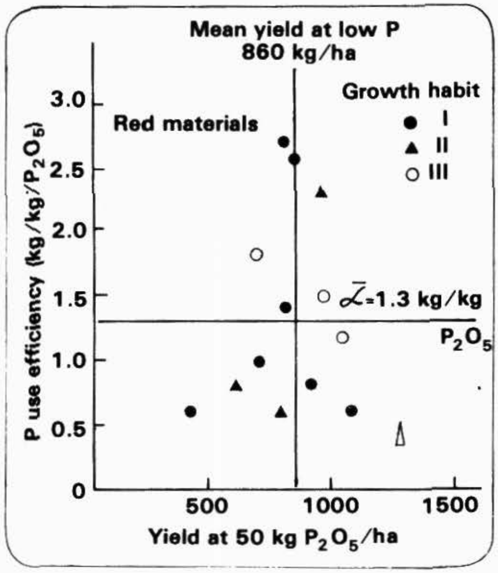


Figure 5. Evaluation of promising lines at low and high P applications, at CIAT-Quilichao, 1978A.

to the category 4 plants previously mentioned.

The two ICA materials, P692 (Diacol Calima) and P637 (Linea 17) both with red seed and of growth habit I have a high efficiency factor in using applied P and their yields at low P were also reasonable. Other good materials from the 1978A screening are listed in Table 3.

Only 11 of 188 materials tested survived and yielded more than 100 kg/ha in unlimed plots (pH 4.1, 4.1 meq. Al/100 g) (Table 4). To determine more realistic lime levels for screening, 60 bean varieties (30 blacks and 30 colored) were planted in plots limed with 0, 0.5, 2 and 6 t lime/ha as calcitic lime. Initial Al content in this test was lower than in the other experiment (3.5 meq./100 g). Figure 8 shows the average response and the response of the variously colored beans to liming. As in previous experiments (CIAT Annual Report, 1973) black-seeded cultivars proved more tolerant to acid soils than cultivars of other

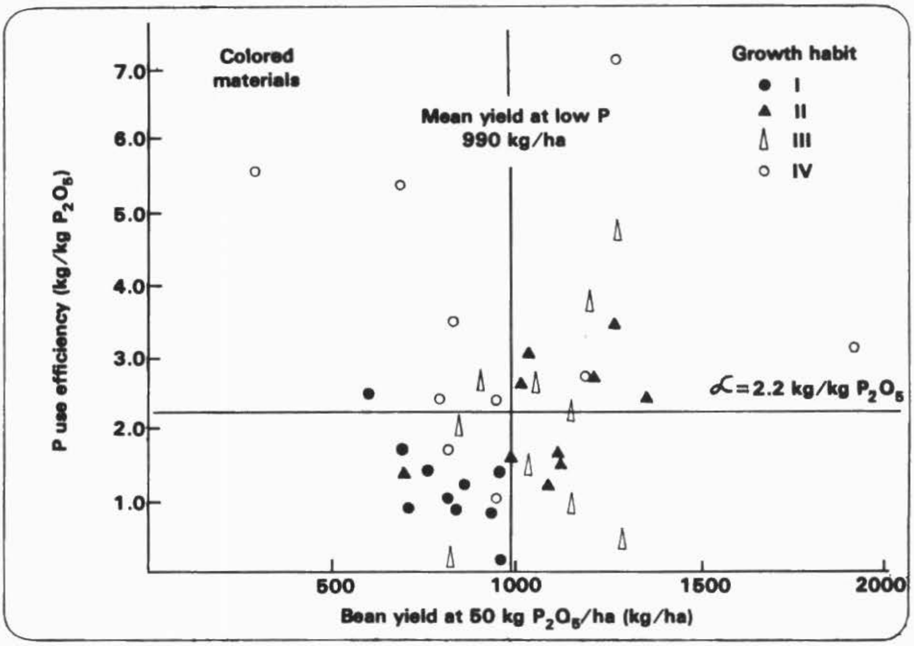



Figure 6. Evaluation of promising bean lines at low and high levels of P application, at CIAT-Quilichao, 1978A.

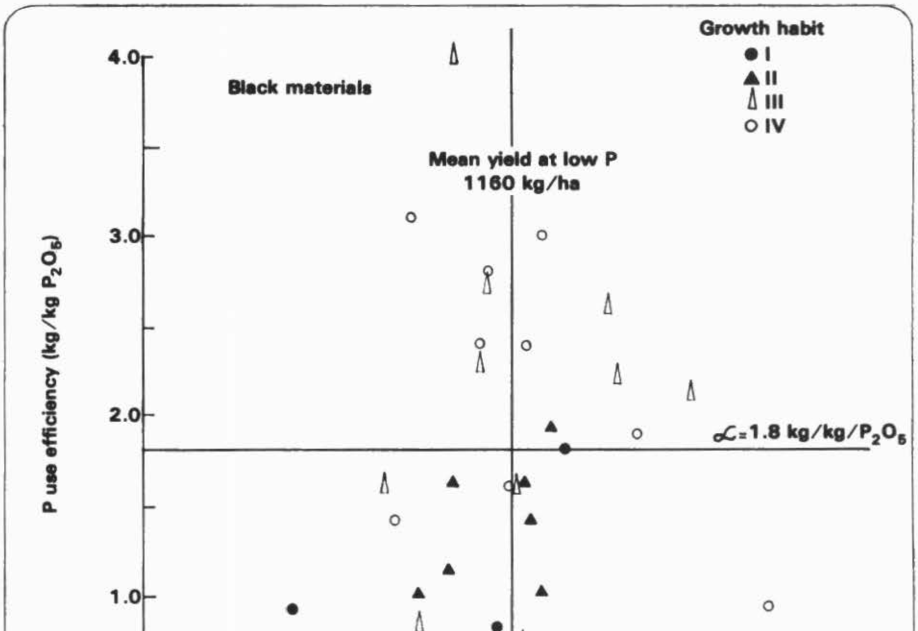



Figure 7. Evaluation of promising bean lines at low and high levels of P application, at CIAT-Quilichao, 1978A.

Table 3.

*Phaseolus vulgaris* **materials tolerant to low levels of soil P selected from 188 cultivars tested at CIAT-Quilichao, during the first semester 1978.**

| Seed color | CIAT Promising No. | Growth habit | Country of origin | Yield (kg/ha) 50 kg $P_2O_5$/ha | Yield (kg/ha) 330 kg $P_2O_5$/ha | Eff. factor[1] |
|---|---|---|---|---|---|---|
| **Red** | P4 | IV | U.S.A. | 1050 | 1360 | 1.2 |
| | P543 | II | Venezuela | 960 | 1540 | 2.3 |
| | P637 | I | Colombia | 860 | 1500 | 2.6 |
| | P692[2] | I | Colombia | 820 | 1490 | 2.7 |
| **Black** | P6 | III | U.S.A. | 1390 | 1930 | 2.2 |
| | P9 | III | Guatemala | 1590 | 2110 | 2.1 |
| | P337[2] | II | U.S.A. | 1310 | 1760 | 1.8 |
| | P382 | II | Venezuela | 1490 | 1940 | 1.8 |
| | P420 | III | Venezuela | 1370 | 2020 | 2.6 |
| | P423 | II | Venezuela | 1470 | 2030 | 2.2 |
| | P499 | III | Mexico | 1300 | 1830 | 2.1 |
| | P527 | IV | Venezuela | 1450 | 1920 | 1.9 |
| | P566 | III | Honduras | 1190 | 1500 | 1.2 |
| | P700[2] | II | Guatemala | 1230 | 1880 | 2.6 |
| | P717 | IV | Guatemala | 1450 | 2270 | 3.3 |
| | P752 | II | Chile | 1300 | 1840 | 2.2 |
| **Colored** | P46 | III | U.S.A. | 1220 | 2140 | 3.7 |
| | P260 | IV | U.S.A. | 1940 | 2720 | 3.1 |
| | P402 | I | Venezuela | 1360 | 1970 | 2.4 |
| | P476[2] | II | Costa Rica | 1280 | 2120 | 3.4 |
| | P482[2] | III | Costa Rica | 1290 | 2460 | 4.7 |
| | P589 | IV | U.S.A. | 1290 | 3070 | 7.1 |
| | P654 | II | Costa Rica | 1220 | 1900 | 2.7 |
| | P749 | IV | U.S.A. | 1200 | 1880 | 2.7 |

1 Efficiency factor: Efficiency of use of P fertilizer expressed as ratio of

$$\frac{\text{Yield at high P level - Yield at low P level}}{\text{Difference of fertilizer units between high and low levels}}$$

2 Also tolerant to extreme acid soil conditions.

colors. Average bean yields increased from 0.5 t/ha at pH 4.0 to 1.6 t/ha at pH 5.0 (6.0 t/ha $CaCO_3$ applied). There was marked variation in yields at lower lime levels and it was not possible to establish a critical level at which effective screening for acid soil tolerance could be undertaken.

## Screening for Tolerance to Drought

Research has continued on the development of a screening method for the identification of water stress-tolerant

Table 4.

*Phaseolus vulgaris* **materials that survived the extreme acid soil stresses (86% Al saturation and pH 4.1) at CIAT-Quilichao, during screening in the first semester 1978.**

| Seed color | CIAT Promising No. | Growth habit | Country of origin | Yield (kg/ha) without lime | Yield (kg/ha) with 5 t/ha of lime |
|---|---|---|---|---|---|
| **Red** | P623 | I | Costa Rica | 130 | 970 |
| | P692 | I | Colombia | 190 | 1490 |
| **Black** | P337 | II | U.S.A. | 120 | 1760 |
| | P699 | IV | El Salvador | 170 | 1930 |
| | P700 | II | Guatemala | 140 | 1880 |
| | P709 | II | Guatemala | 150 | 1810 |
| **Colored** | P166 | I | U.S.A. | 280 | 940 |
| | P476 | II | Costa Rica | 350 | 2120 |
| | P482 | III | Costa Rica | 170 | 2460 |
| | P473 | III | Brazil | 170 | 1220 |
| | P786 | III | Brazil | 200 | 1610 |

germplasm. Results are available for two large screenings (100 and 168 materials) during the two dry seasons at CIAT-Palmira. The method used was a field screening in which the entries were sown so that all commenced flowering over the same three-day period. Irrigation was suspended in the stress treatment just prior to flowering (50% of plants with one or more flowers per plant) and control plots were irrigated to avoid stress. The number of stress days applied differed in the two experiments due to the incidence of 10 mm of rainfall in three light falls in experiment 7818 during the stress period. A total of 14 stress days were applied in experiment 7728 and 29 in 7818. The yield reductions were more severe in 7728 compared to 7818. A series of problems including, principally, lateral soil water movement in 7818, chlorotic mottle in susceptible entries in 7728 and variable plant density with some varieties, caused variability between replications in the stress treatment. Comparative yield reduction percentages due to stress for 19 cultivars included in the two experiments, as controls, are shown in Figure 9. Data were excluded for three varieties which suffered from the problem of lateral movement of water from the non-stressed to the stressed plots, in 7818. The consistency of these data suggests that the

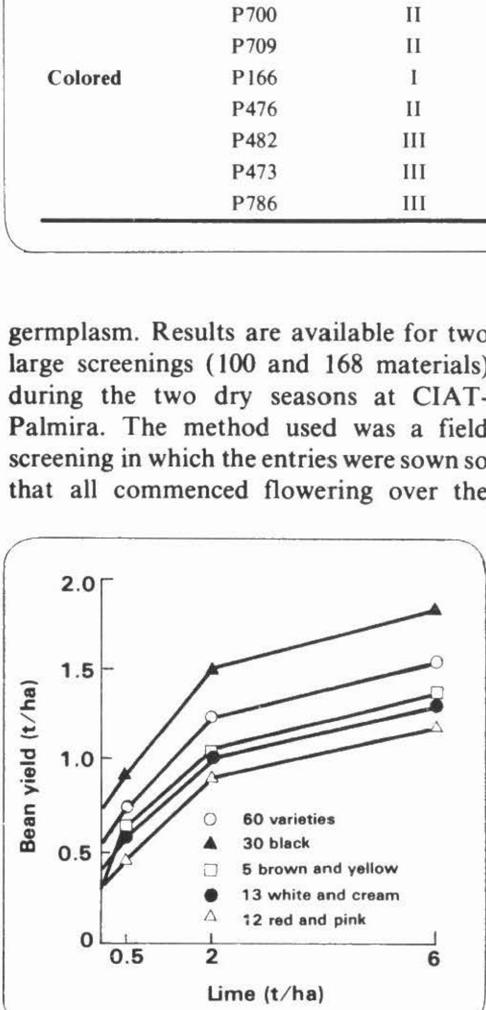



Figure 8. Average response of beans of various colors and of various colors and of total number of varieties to lime applications at CIAT-Quilichao.

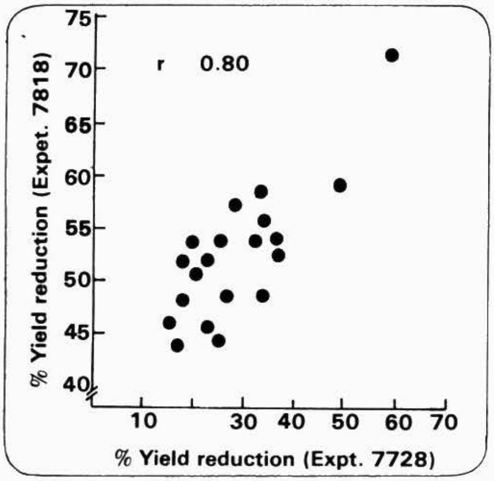



Figure 9. Comparison of yield reduction (control yield - stress yield)/(control yield) due to water stress for 19 control varieties in two screenings at CIAT-Palmira. (Three entries excluded from the data set due to explainable variability between replications in one trial.)

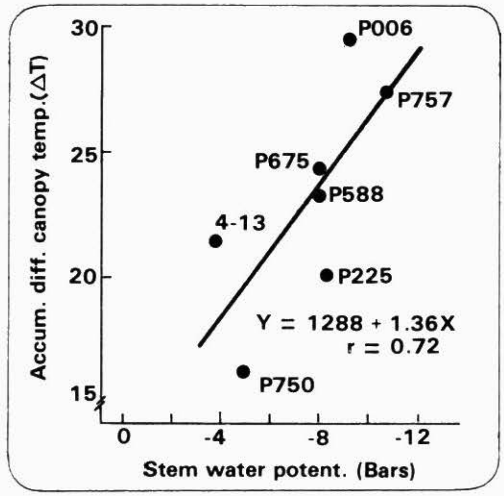



Figure 10. Relationship between accumulated differential conopy temperature (ΔT) for six days during the drying cycle for seven cultivars versus the mean (n = 8) stem water potential measured during four hours around noon, for one day during the cycle, Experiment 7728.

screening method may be reliable and that relative water stress tolerance does exist in *Phaseolus* germplasm

On most of the stress days during the drying cycle, canopy temperatures for the wet and dry plots (on either side of a 1-m path) were determined using infrared thermometry between 1100 and 1400 hours each day. The daily difference in canopy temperature ($\Delta T°C$) was summed for the whole stress period ( $\Sigma\Delta T$) and is used here as an index of the stress received by each stressed plot during the drying cycle. The relationship of $\Delta T$ to stomatal resistance and plant water potential is shown in Figures 10 and 11. These data suggest that $\Delta T$ can be used as an index of internal water stress levels. The scatter diagram of percentage yield reduction versus $\Sigma\Delta T$ for 127 cultivars in experiment 7818 is shown in Figure 12. The number of entries in each quadrant is shown in the body of the figure. The materials with low yield reduction and low stress are in the bottom left quadrant of the diagram. While soil variability could account for some of the low stress experienced in these latter materials these data do suggest that large differences in yield reduction due to stress was present among these entries. P730 has been

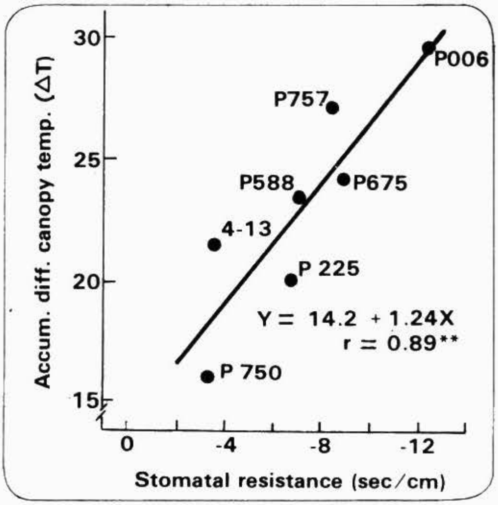



Figure 11. Relationship between differential canopy temperature (ΔT) for six days during the drying cycle for seven cultivars versus mean stomatal resistance (n = 16) of exposed canopy leaves measured four hours around noon, for one day in the cycle, Experiment 7728.

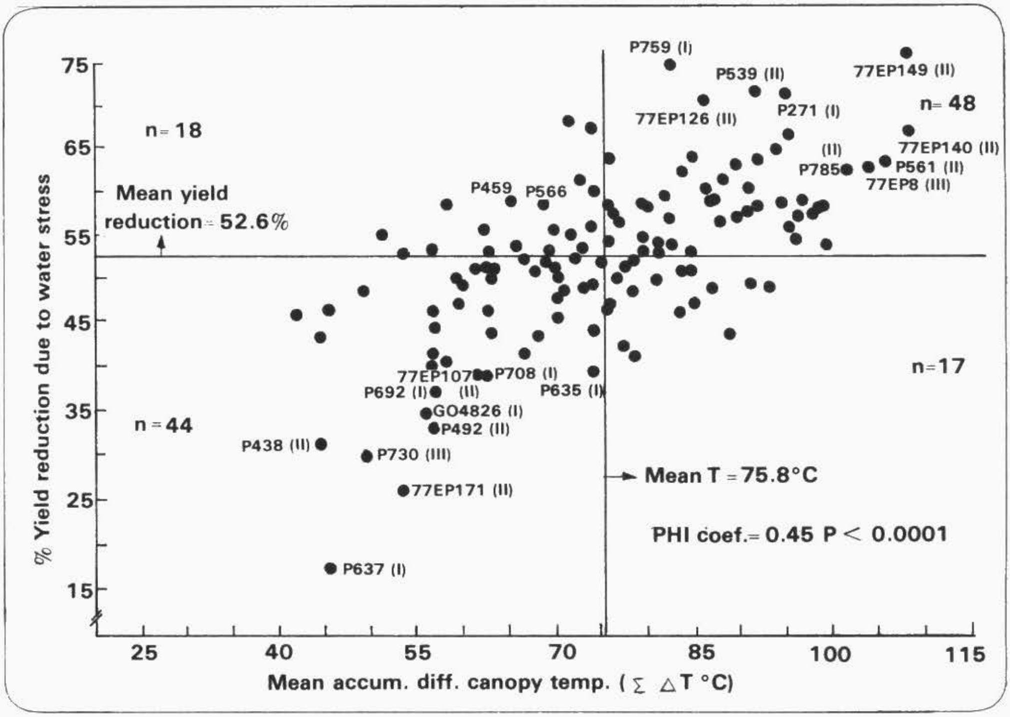



Figure 12. Yield reduction due to water stress in 127 entries versus mean accumulated differential canopy temperature, Experiment 7816. Data for 41 entries were excluded due to problems of soil variability and/ or due to recuperation after stress was relieved. (Mean of three replications for each entry.)

previously identified as stress tolerant. P637 has not been identified in previous experiments. Confirmation of the relative stress tolerance of these materials will be necessary with further experimentation. The direct use of Σ ΔT methodology as a primary screening technique for stress tolerance in advanced materials appears to have promise.

Data in Table 5 from experiment 7818 show materials which had a high degree of stress tolerance and a generally low stress index. Contrasting materials with a low degree of tolerance are also shown for comparison. Certain cultivars not shown in Figure 12 or Table 5, mainly from Type III, proved to have a high degree of flower abscission under stress but showed a strong yield recuperation through pod set on secondary flowers once the stress was relieved. The final maturity date was considerably delayed in the stress plots in these latter materials.

Continued methodological research is required before conclusive data on water stress tolerance in *P. vulgaris* can be obtained. Precautions to avoid the sources of variability mentioned here are planned for future screening experiments. Soil textural changes, particularly in relation to variable occurrence of sand layers in the subsoil, may be an added source of variability which will need to be considered in siting future screenings.

## Screening for Temperature Adaptation

A series of replicated experiments were conducted at six sites at various altitudes in Colombia (Table 6) during 1978, with 250 selected promising germplasm accessions

Table 5.

**Mean control yield, stress yield, percentage yield reduction and accumulated differential canopy temperature (Σ ΔT) for 23 days during a 29-day post-flowering drying cycle for 10 entries showing low yield reductions due to stress compared to four entries with high yield reductions. (Experiment 7818, CIAT-Palmira, 1978).**

| Indentification | Yield (kg/ha) Control | Yield (kg/ha) Stress | Yield reduction (%) | Σ ΔT (°C) |
|---|---|---|---|---|
| **Stress tolerant group** | | | | |
| 77 EP 107 | 378 | 230 | 39 | 62 |
| P438 | 372 | 255 | 31 | 45 |
| G4826 | 369 | 240 | 35 | 56 |
| 77 EP 171 | 360 | 265 | 26 | 54 |
| P692 | 355 | 224 | 37 | 57 |
| P637 | 345 | 286 | 17 | 46 |
| P708 | 340 | 208 | 39 | 63 |
| P730 | 335 | 234 | 30 | 50 |
| P635 | 266 | 161 | 40 | 75 |
| P492 | 254 | 170 | 33 | 57 |
| **Stress susceptible group** | | | | |
| P539 | 441 | 127 | 72 | 92 |
| P271 | 273 | 78 | 71 | 96 |
| 77 EP 149 | 410 | 99 | 76 | 109 |
| 77 EP 140 | 431 | 143 | 67 | 109 |
| Mean of 127 | | | 53 | 76 |

and advanced breeding materials from CIAT. All four growth habits were represented. The objective of this work was to define the overall temperature adaptation to a wide range of temperature conditions (mean temperatures 12° to 27°C) in a large, representative group of *P. vulgaris* germplasm. The experimental

Table 6.

**Locations in Colombia selected for temperature adaptation studies of bean germplasm.**

| Location | Departamento | Collaborator | Altitude (masl) | Mean temperature (°C) |
|---|---|---|---|---|
| Santa Fé | Antioquia | Univ. Nal. de Medellin | 350 | 27.0 |
| El Estrecho | Cauca | Private farmer | 520 | 26.0 |
| CIAT-Palmira | Valle | - | 1001 | 23.9 |
| Popayán | Cauca | Sec. de Agricultura | 1880 | 17.6 |
| Manizales | Caldas | Univ. de Caldas | 2350 | 16.0 |
| Pasto | Nariño | ICA - Obonuco | 2710 | 12.7 |

conditions were designed to minimize disease, insect and differential soil effects and to optimize the water environment, through irrigation, where necessary. The physiological effects of temperature *per se* could then be evaluated without the confounding influence of other environmental effects. Data for 1978A for three locations where these conditions were largely met are available and are shown in Table 7. The complete data set for all six locations will be analyzed when available.

At the low temperature site only 67 of the 250 entries actually set seed with reproductive failure occurring at all stages up to failure to fill apparently fertilized embryos in some lines. The higher yielding cold tolerant group included material from Colombia (P637, P590 and G5772) and from Kenya (G8042). The Kenyan and Colombian highlands are homoclimatic, and further evaluation of the Kenyan collection at high altitude is planned.

Table 7.

**Yield data for the highest yielding *Phaseolus vulgaris* materials from among 250 entries at each of three locations having different temperature regimes,[1] in Colombia.**

| Identification | Growth habit | Yield (t/ha, 14%) at: | | |
|---|---|---|---|---|
| | | Santa Fé | Popayán | Pasto |
| Group 1: Highest yielders at high temperatures (Santa Fé) | | | | |
| P589 | IV | 2.23 | 3.10 | 0.00 |
| P518 | II | 2.22 | 2.72 | 0.00 |
| P723 | II | 2.14 | 2.63 | 0.00 |
| P757 | II | 2.14 | 2.66 | 0.00 |
| FF00036-3 | II | 2.12 | 2.87 | 0.00 |
| Group 2: Highest yielders at moderate temperatures (Popayán) | | | | |
| P449 | IV | 1.22 | 3.32 | 0.00 |
| P693 | IV | 0.96 | 3.28 | 0.53 |
| G3144 | IV | 1.53 | 3.27 | 0.19 |
| P738 | II | 2.10 | 3.22 | 0.00 |
| G2227 | IV | 0.96 | 3.21 | 0.14 |
| Group 3: Highest yielders at low temperatures (Pasto) | | | | |
| P637 | I | 1.63 | 2.02 | 1.41 |
| G5752 | I | 0.02 | 1.88 | 1.32 |
| G8042 | I | 0.64 | 1.32 | 1.04 |
| P590 | IV | 0.02 | 1.83 | 0.94 |
| P706 | IV | 1.26 | 2.72 | 0.92 |
| Site mean yield | | 1.26 | 2.38 | |
| L.S.D. | | 0.47 | 0.69 | |
| C.V. (%) | | 23.5 | 17.9 | |

1 Temperatures (°C): Santa Fé— Mean, 26.7, Max., 31.3, Min., 22.1; Popayán—Mean, 17.9, Max., 23.9, Min., 11.0; Pasto—Mean, 12.7, Max., 16.4, Min., 9.7.

A very large break in adaptation exists between 17.9° and 12.7°C, exemplified by the highest yielding group out of the 250 entries at Popayan which yielded very poorly or failed to set seed at Obonuco. By contrast, materials such as P589 (IV) and P518 (II) performed quite well at both Santa Fe and Popayan.

The complete data for the temperature adaptation study at the six locations will be used to further define the most appropriate strategy with respect to future screenings for "wide" adaptation to temperature in advanced materials. Preliminary target area study data (see page 49) suggest that the majority of beans are in fact grown over a relatively narrow range of mean temperature conditions compared to the range in this study.

# HYBRIDIZATION OF PROMISING MATERIALS AND EVALUATION OF THEIR PROGENY

## Mainstream Breeding Activities

In 1977 the Bean Program developed a system for the sequential evaluation of hybrid materials. This is outlined again in Figure 13. Virtually all phases of this program were in operation for the first time in 1978 with advanced generation testing at the Bean Team Nursery (VEF) the Preliminary Yield Trials (EP) and International Bean Yield and Adaptation Nursery (IBYAN) levels. This activity required major inputs from virtually all team members, and other Center Staff including the Data Services Unit, and called for a major logistic and coordination effort and the development of several new testing methodologies. These challenges not withstanding, results were excellent.

### Mainstream Crossing Program

In 1978, the number of hybridizations effected at CIAT was somewhat lower than anticipated due to difficulty in obtaining screenhouse space. During the year 558 $F_2$ populations were evaluated at CIAT. Emphasis in early generation testing remained on resistance (I gene) to bean common mosaic virus (BCMV), rust and anthracnose (screened at Popayan) and tolerance to *Empoasca*. Materials also had to demonstrate good plant architecture and yield potential. As a result of these evaluations 185 families have been selected for inclusion in the 1979 EP.

### Bean Team Nursery

The 1978 Bean Team Nursery (VEF) included 1464 materials of which 510 were promising new accessions from the germplasm bank, 937 were selected advanced generation breeding materials and 67 materials had been suggested by national bean programs. Within the trial, accessions were evaluated simultaneously for resistance to BCMV, rust, anthracnose, common bacterial blight and *Empoasca* and for adaptation at CIAT-Palmira and Popayan. Table 8 summarizes results from these evaluations and Table 9 characterizes some of the most promising materials.

Major points observed from results included: (1) virtually all materials showed

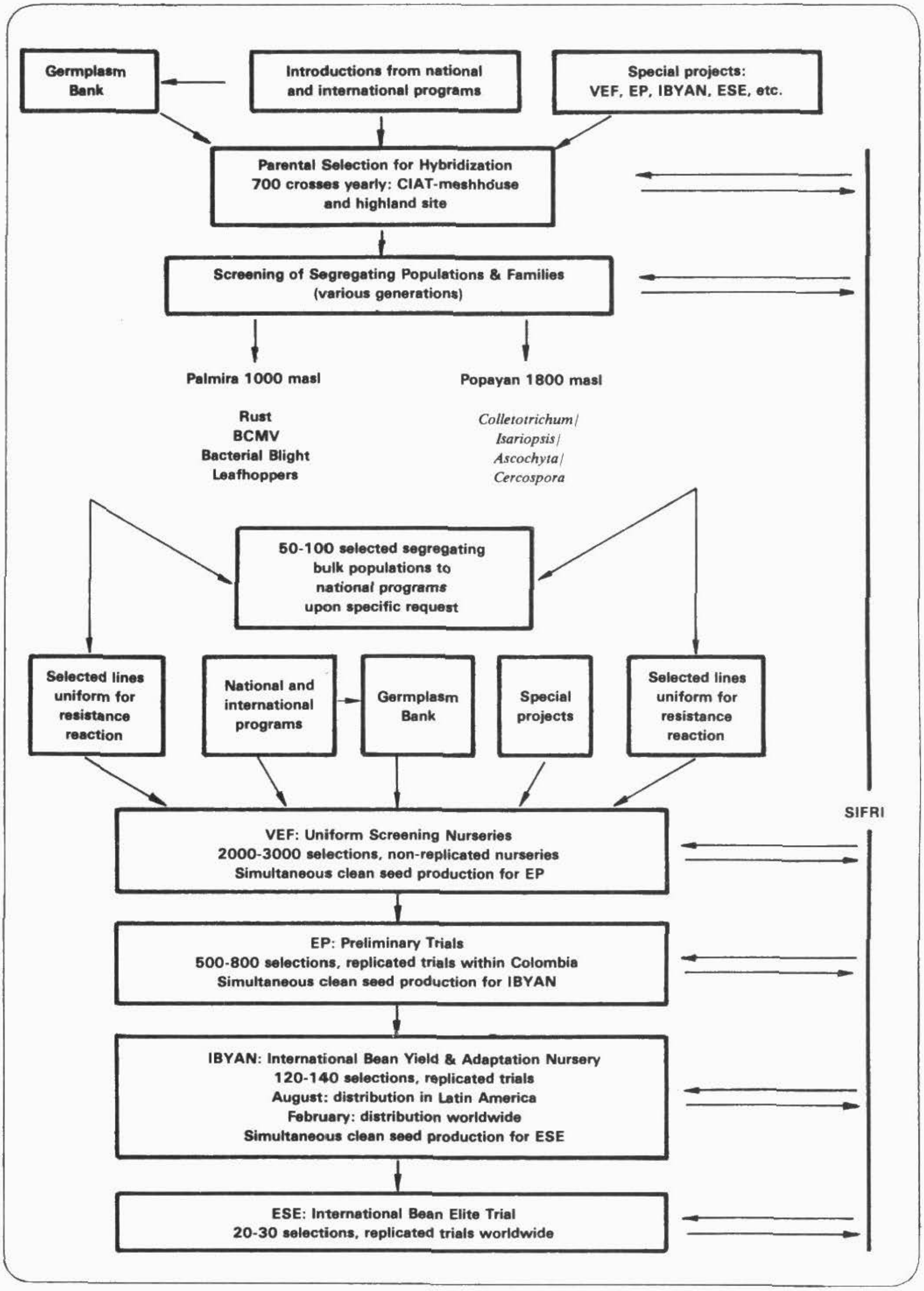



Figure 13. Program for simultaneous and sequential development and evaluation of bean germplasm proposed by the CIAT bean program in 1977.

Table 8.

**Summary of evaluations for 1464 entries in the 1978 Bean Team Nursery (VEF).**

| Category | Insect and Disease Evaluations | | | | |
|---|---|---|---|---|---|
| | Leafhoppers | Bean common mosaic virus | Common bacterial blight | Rust | Anthracnose[1] |
| Resistant | 15 | 1211 | 5 | 206 | 188 |
| Intermediate | 165 | 0 | 35 | 67 | 59 |
| Susceptible | 1282 | 180 | 1373 | 782 | 1173 |
| Variable | 0 | 65 | 0 | 407 | 17 |
| Not evaluated | 2 | 8 | 51 | 2 | 27 |
| | Adaptation Evaluations | | | | |
| | CIAT-Palmira | | | | Popayan |
| Excellent | 0 | | | | 0 |
| Good | 12 | | | | 9 |
| Average | 539 | | | | 305 |
| Poor | 805 | | | | 446 |
| Very poor | 91 | | | | 687 |
| Not evaluated | 17 | | | | 17 |
| | Agronomic Evaluations | | | | |
| | Seed size/Color | | | | |
| Large/Variable colors | 12 | | | | |
| Medium/Variable colors | 187 | | | | |
| Small/Black | 622 | | | | |
| Small/Red | 100 | | | | |
| Small/Other colors | 543 | | | | |

1 Reaction to mixed inoculation to two isolates each of the beta and gamma races.

resistance to BCMV; (2) resistance or immunity to the rust races present at CIAT occurs in 24.3% of the materials; (3) high levels of resistance to bacterial blight have been obtained, but the number of materials possessing this resistance is limited; and, (4) good materials exist in a range of seed coat colors.

One hundred eighty-five of the materials evaluated will pass to the 1979 Preliminary Yield Trial (EP). All selected materials have resistance to BCMV, while 73.5, 38.9 and 17.8% are resistant to rust, anthracnose and *Empoasca,* respectively. Sixteen of the selected lines are well-adapted at both CIAT and Popayan and resistant to BCMV, rust and anthracnose; five of these lines also show resistance to angular leaf spot.

Table 9.

**Characteristics of the best entries for major grain types recorded in the 1978 Bean Team Nursery (VEF).**

| Character | 1978 VEF No. | | | | | |
|---|---|---|---|---|---|---|
| | 1681 | 1064 | 1740 | 2068 | 1787 | 1176 |
| Origin | Hybrid | Hybrid | Hybrid | Germ. Bank | Hybrid | Hybrid |
| Seed color | Red | White | Cream | Pink mottl. | Brown | Black |
| Seed size | Small | Small | Small | Medium | Small | Small |
| Days to flower | 38 | 41 | 39 | 35 | 38 | 42 |
| Growth habit | 3 | 3 | 2 | 2 | 3 | 2 |
| BCMV | R | R | R | R | R | R |
| Bacterial blight[1] | 4 | 3 | 2 | 4 | 2 | 3 |
| Rust | R | R | R | Ip[3] | S | IP |
| Leafhopper[1] | 2.3 | 2.7 | 3.7 | 3.7 | 3.2 | 3.5 |
| Adaptation:[2] | | | | | | |
| CIAT-Palmira | 4 | 3 | 4 | 3 | 3 | 3 |
| Popayan | 3 | 3 | 3 | 4 | 4 | 3 |
| Anthracnose | R | S | R | R | R | R |
| Angular leaf spot[1] | 3 | 3 | 1 | - | - | - |

1 Scored from 1-5; 1 = resistant, 5 = fully susceptible.
2 Scored from 1-5; 1 = highly adapted, 5 = poorly adapted.
3 Intermediate with small pustules.

## Preliminary Yield Trial, 1978

While the first Preliminary Yield Trial (EP) contained more than 700 materials, within the range suggested in Figure 13, approximately 500 of these were promising germplasm selections and only 200 advanced hybrid lines from the breeding program. Materials were evaluated for yield (at CIAT-Palmira and Candelaria) and for photoperiod sensitivity, resistance or tolerance to BCMV, rust, angular leafspot, bacterial blight and *Empoasca,* and adaptation (at CIAT-Palmira and Popayan). Results for the trial are summarized in Table 10.

The results show significant gains in several areas: including the following. (1) Virtually all hybrid selections included in the trial showed resistance to BCMV. Almost 99% of the selections made for further study have this property. This has made it possible for the program to implement the decision that all CIAT materials to be included in international trials must have this trait. This will eliminate the possibility of accidental seed transmission of the pathogen. (2) There was a major shift in the proportion of red and colored lines yielding in excess of 2.0 t/ha. While approximately 7% of the germplasm accessions from these color groups yielded over 2.0 t/ha, 46-48% of the breeding selections did. The best yielding materials in each color group are shown in Tables 11 and 12.

At both locations CIAT advanced breeding materials, in all seed colors, outyielded promising lines and germplasm bank materials. Some of these promising lines are the progenitors of the CIAT advanced materials. Furthermore, of the

Table 10.

**Percentage frequency of selected traits in germplasm and hybrid selections evaluated by Bean Program disciplines in the 1978 Preliminary Trial (EP).**

| | Selected germplasm | | | | Hybrid selections | | | |
|---|---|---|---|---|---|---|---|---|
| | Seed color | | | No. of | Seed color | | | No. of |
| Character | Black | Red | Other | entries | Black | Red | Other | entries |
| 1. Yield $>200$ $g/m^2$ [1] | 37.0 | 7.0 | 7.2 | 455 | 61.5 | 46.4 | 48.5 | 277 |
| 2. Adaptation $>2.5$ [2] | 44.4 | 2.2 | 10.5 | 498 | 29.1 | 7.1 | 13.9 | 277 |
| 3. Bacterial blight $<3.5$ [3] | 11.5 | 49.4 | 31.3 | 472 | 44.3 | 71.4 | 47.5 | 278 |
| 4 Intermed. or Resist., Rust | 6.4 | 28.4 | 14.1 | 401 | 57.1 | 35.7 | 34.7 | 278 |
| 5. Resist. or Segreg. Resist., BCMV | 72.6 | 5.6 | 40.3 | 208 | 99.3 | 88.9 | 96.0 | 274 |
| 6. Angular leaf spot $\leq3.0$ [3] | 67.8 | 28.2 | 41.5 | 464 | 29.3 | 68.4 | 48.5 | 267 |
| 7. Leafhopper $\leq3.0$ [3] | 64.1 | 14.3 | 21.1 | 493 | 65.8 | 32.1 | 29.7 | 278 |
| 8. Photoperiod insensitive or slightly sensitive | 95.8 | 54.6 | 86.8 | 150 | 81.8 | 56.3 | 62.3 | 206 |
| 9. 1 + 2 + 3 + 5 + 7 | 0 | 0 | 0 | 500 | 19.5 | 10.7 | 5.9 | 278 |
| 10. 1 + 2 + 5 + 6 | 0 | 0 | 0 | 500 | 4.0 | 1.0 | 3.5 | 278 |

1 Combined average of replicated trials in two locations.
2 Rating scale: 5 = excellent; 1 = poor.
3 Rating scale: 5 = highly susceptible; 4 = susceptible; 3 = resistant; 2 = highly resistant; 1 = immune.

10 best materials in each color group at least 50% have good resistances to at least two major disease pathogens or insect pests. This suggests that substantial progress has been achieved in incorporating good resistance with high yield ability. This is especially true in the red and colored materials whereas the improvement in yield of the black seed color lines was not as dramatic. Growth habit II dominated in the best CIAT breeding materials, however, there were a few outstanding type III lines in the top 10. Many of the promising lines are inferior to the CIAT advanced lines and the germplasm accessions, suggesting that the addition of new parental material to the breeding program would be advantageous.

The best yielders at CIAT-Palmira were not necessarily best at Candelaria. This suggests that factors besides temperature or altitude may need to be taken into account in evaluating the materials for wide adaptation. (3) Table 12 gives the breakdown of the results for photoperiod sensitivity in 353 advanced breeding lines, 206 of which were from the EP trial. While photoperiod response is not being used as a strict selection criterion at this stage, it is interesting to note a marked increase in the proportion of insensitive lines in the advanced breeding material compared to the combined data for previous screenings of germplasm collections. There is, however, some indication of a decline in the proportion of photoperiod insensitive material from the select germplasm to the advanced breeding lines (Table 10). Although not part of the EP system a total of 541 other promising lines and breeding selections were evaluated in yield trials during 1977-78. Outstanding entries are listed in Table 14.

Table 11.

**Average yields, compared to the means of the group, of outstanding materials included in 1978 Preliminary Trials (EP), at CIAT-Palmira.**

| | Yield (t/ha) of: | | | |
|---|---|---|---|---|
| | CIAT breeding materials | Promising lines | Germplasm materials | ICA breeding materials |
| **Red materials** | | | | |
| Best material | 2.94 | 1.87 | 2.24 | 2.34 |
| Mean of 10 best materials | 2.05 | 1.48 | 1.44 | 1.60 |
| Mean of all materials tested | 1.72 | 1.19 | 0.97 | 1.25 |
| | (22)[1] | (12) | (12) | (30) |
| L.S.D. (0.05) | 0.60 | 0.48 | 0.45 | 0.66 |
| C.V. (%) | 21 | 24 | 28 | 32 |
| **Black materials** | | | | |
| Best material | 2.62 | 2.24 | 2.05 | 2.11 |
| Mean of 10 best materials | 2.33 | 2.02 | 1.82 | 1.75 |
| Mean of all materials tested | 1.84 | 1.51 | 1.41 | 1.45 |
| | (122) | (110) | (47) | (32) |
| L.S.D. (0.05) | 0.68 | 0.53 | 0.73 | 0.60 |
| C.V. (%) | 23 | 22 | 31 | 24 |
| **Colored materials** | | | | |
| Best material | 2.55 | 2.00 | 1.78 | 2.24 |
| Mean of 10 best materials | 2.20 | 1.73 | 1.48 | 1.87 |
| Mean of all materials tested | 1.79 | 1.23 | 1.09 | 1.33 |
| | (64) | (51) | (36) | (35) |
| L.S.D. (0.05) | 0.54 | 0.56 | 0.49 | 0.51 |
| C.V. (%) | 19 | 28 | 27 | 23 |

1 Values in parentheses are the numbers of materials tested in the group.

## International Bean Yield and Adaptation Nursery

The network of international yield trials of beans was initiated in 1976 when the International Bean Yield and Adaptation Nursery (IBYAN) program was put into action. During the three years that this research network has operated, 48 countries have participated and a total of 348 experiments have been distributed throughout the world. Eighty percent of the trials have been sent to countries in Latin America (Table 15).

During the first two years of operation of the network, the principal source of experimental materials was the CIAT *Phaseolus* germplasm bank. In 1976, 20 varieties were tested, all of them having been furnished by national programs; in 1977, 39 new entries were tested with only two of them being lines developed by CIAT. In 1978, however, 36 new materials

Table 12.

**Average yields, compared to the means of the group, of outstanding materials included in 1978 Preliminary Trials (EP), at Candelaria.**

| | Yield (t/ha) of: | | | |
|---|---|---|---|---|
| | CIAT breeding materials | Promising lines | Germplasm materials | ICA breeding materials |
| **Red materials** | | | | |
| Best material | 2.91 | 2.20 | 2.03 | 1.84 |
| Mean of 10 best materials | 2.50 | 1.91 | 1.82 | 1.62 |
| Mean of all materials tested | 2.34 | 1.54 | 1.51 | 1.35 |
| | (13)[1] | (30) | (20) | (23) |
| L.S.D. (0.05) | 0.82 | 0.82 | 0.66 | 0.33 |
| C.V. (%) | 21 | 37 | 27 | 15 |
| **Black materials** | | | | |
| Best material | 3.55 | 2.75 | 3.01 | 2.44 |
| Mean of 10 best materials | 2.88 | 2.66 | 2.79 | 2.29 |
| Mean of all materials tested | 2.02 | 2.12 | 2.24 | 2.06 |
| | (117) | (92) | (43) | (31) |
| L.S.D. (0.05) | 0.71 | 0.45 | 1.05 | 0.29 |
| C.V. (%) | 23 | 13 | 29 | 9 |
| **Colored materials** | | | | |
| Best material | 2.92 | 2.83 | 2.48 | 2.20 |
| Mean of 10 best materials | 2.69 | 2.20 | 2.20 | 2.04 |
| Mean of all materials tested | 2.08 | 1.61 | 1.58 | 1.63 |
| | (64) | (18) | (35) | (32) |
| L.S.D. (0.05) | 0.67 | 0.97 | 1.04 | 0.28 |
| C.V. (%) | 20 | 36 | 40 | 10 |

1 Values in parentheses are the numbers of materials tested in the group.

were evaluated and 30 of them were CIAT breeding lines. In summary, up to now this testing network has evaluated 95 materials, including 32 lines from CIAT, under a wide range of agroclimatic conditions (Fig. 14).

Table 16 shows the results for the 3rd IBYAN (1978) of colored grain, locally planted in the first semester at CIAT-Palmira and Popayan. Yields of the CIAT lines were excellent, with levels attained that previously were only reached by black-seeded beans. The five best colored lines from CIAT in these two trials exhibited yields as high as ICA-Pijao, the best black variety now commercially available in Colombia. The varieties for temperate zones— Pinto Dorado and Tórtola Diana—are not suitable for the environmental conditions at either CIAT-Palmira or Popayan, although both materials are excellent yielders in Chile, their zone of origin.

The 1978 IBYAN for black-seeded materials showed a group of very promis-

Table 13.

**Summary of photoperiod screening results for advanced breeding lines (EP stage) at CIAT-Palmira, 1978A, compared to the distribution of photoperiod sensitivity in all germplasm collections previously screened.**

| Growth habit | Classification of photoperiod response[1] <4 1 | 4-10 2 | 11-20 3 | 21-30 4 | >30 5 | Total |
|---|---|---|---|---|---|---|
| I | 25[2] | - | - | - | - | 25 |
| | (100) | | | | | (100) |
| II | 194 | 28 | 46 | 3 | 4 | 275 |
| | (71) | (10) | (17) | (1) | (1) | (100) |
| III | 29 | 6 | 13 | 4 | 1 | 53 |
| | (55) | 11 | (25) | (7) | (2) | (100) |
| Total | 248 | 34 | 59 | 7 | 5 | (353) |
| | (70) | (10) | (17) | (2) | (1) | (100) |
| % Distribution[3] in germplasm collection | 41 | 12 | 23 | 12 | 12 | (100) |

1 Range of days of flowering delay in 18 h days compared to natural daylength (12 h 20 m).

2 Data in body of table is number of entries in each classification by growth habit and the percent for each growth habit in brackets.

3 See Table 34, page B-37, Annual Report 1977.

ing breeding lines including FF2-6-3-M-M, FF24-1-M-CB-M, FF26-6-1-M-M-M and FF28-6-1-M-M-M. The first yielded particularly well at both CIAT-Palmira and Popayan and the last one yielded the highest of all materials at Popayan (Table 17).

Table 14.

**Best promising materials and breeding selections in yield tests during 1977-78.**

| Identification | Growth habit | Seed color | Yield (t/ha) | Site | Trial mean (t/ha) |
|---|---|---|---|---|---|
| FF 28-6-1 | II | Black | 3.4 | Popayan | 2.8 |
| P300 | II | Black | 3.3 | Popayan | 2.8 |
| FF 26-6-1 | II | Black | 3.3 | Popayan | 2.8 |
| ICA Linea 39 | II | Black | 3.1 | Popayan | 2.4 |
| FF 1964-1-CM (8-C) | II | Cream | 3.1 | Popayan | 2.3 |
| FF 2-6-3 | II | Black | 2.9 | CIAT | 2.5 |
| FF 16-20-1-M.M. | II | Red | 2.8 | Popayan | 2.3 |
| FF 28-6 | II | Black | 2.8 | Popayan | 2.4 |

Table 15.

**Number of trials of the International Bean Yield and Adaptation Nursery (IBYAN) dispatched during 1976-1978.**

| | | | Trials dispatched | | | |
|---|---|---|---|---|---|---|
| | 1976 IBYAN | | 1977 IBYAN | | 1978 IBYAN[1] | |
| Region and country | Trials dispatched | Data received | Colored seed | Black seed | Colored seed | Black seed |
| **South America** | | | | | | |
| Argentina | - | - | - | 1 | 2 | 2 |
| Bolivia | 3 | - | - | - | 1 | 1 |
| Brazil | 15 | 9 | 3 | 11 | 16 | 16 |
| Chile | 4 | 3 | 2 | 3 | 3 | 2 |
| Colombia | 7 | 6 | 8 | 4 | 4 | 4 |
| Ecuador | 5 | 2 | 1 | 2 | 1 | - |
| Guyana | - | - | - | 1 | 1 | - |
| Peru | 6 | 5 | 1 | 2 | 5 | 3 |
| Uruguay | - | - | - | 1 | - | 1 |
| Venezuela | 4 | 1 | - | 3 | - | 3 |
| Total | 44 | 26 | 15 | 28 | 33 | 32 |
| **Central America and Mexico** | | | | | | |
| Belize | 1 | - | 1 | 1 | 3 | 1 |
| Costa Rica | 1 | - | 2 | 4 | 4 | 5 |
| El Salvador | 5 | 5 | - | 4 | 5 | 4 |
| Guatemala | 2 | - | - | 5 | - | 5 |
| Honduras | 4 | 3 | 5 | 2 | 11 | 3 |
| Mexico | 3 | 3 | 1 | 1 | 3 | 5 |
| Nicaragua | 3 | 2 | 1 | - | 2 | - |
| Panama | 1 | - | - | - | 2 | - |
| Total | 20 | 13 | 10 | 17 | 30 | 23 |
| **Caribbean** | | | | | | |
| Cuba | - | - | - | 1 | 3 | 3 |
| Dom. Republic | 3 | 2 | 3 | - | 3 | - |
| Haiti | 1 | - | 1 | - | 2 | - |
| Jamaica | - | - | 2 | - | 2 | - |
| Puerto Rico | - | - | - | 1 | 1 | 1 |
| Trinidad & Tobago | 1 | - | 2 | - | 1 | - |
| Total | 5 | 2 | 8 | 2 | 12 | 4 |

1 Through Nov. 30, 1978.

continued

Table 15. (continued)

| Region and country | Trials dispatched | | | | | |
|---|---|---|---|---|---|---|
| | 1976 IBYAN | | 1977 IBYAN | | 1978 IBYAN[1] | |
| | Trials dispatched | Data received | Colored seed | Black seed | Colored seed | Black seed |
| **North America, Europe and Oceania** | | | | | | |
| Australia | 1 | 1 | - | - | - | - |
| Bulgaria | - | - | 1 | - | - | - |
| Canada | 1 | 1 | 1 | - | 2 | 1 |
| Great Britain | 2 | 2 | - | 1 | - | - |
| Portugal | - | - | 1 | 1 | - | - |
| Russia | 1 | - | - | - | - | - |
| Spain | - | - | 1 | - | - | - |
| United States | 2 | 2 | 2 | 1 | 1 | 1 |
| Yugoslavia | 1 | - | - | - | - | - |
| Total | 8 | 6 | 6 | 3 | 3 | 2 |
| **Asia** | | | | | | |
| India | - | - | - | 1 | - | - |
| Iran | 1 | 1 | - | - | 1 | - |
| Israel | 1 | 1 | 1 | - | - | - |
| Japan | 2 | 1 | - | - | - | - |
| The Philippines | 1 | 1 | 6 | 6 | - | - |
| Syria | - | - | - | - | 1 | - |
| Thailand | 4 | 1 | - | - | - | - |
| Total | 9 | 5 | 7 | 7 | 2 | - |
| **Africa** | | | | | | |
| Cameroons | - | - | - | - | 1 | - |
| Egypt | - | - | 1 | - | 1 | - |
| Gabon | - | - | - | - | 3 | - |
| Lesotho | - | - | - | - | 1 | 1 |
| Malawi | 1 | 1 | 1 | - | - | - |
| South Africa | - | - | 1 | 1 | 1 | - |
| Swaziland | - | - | .1 | - | 1 | - |
| Tanzania | 3 | 1 | - | - | - | - |
| Total | 4 | 2 | 4 | 1 | 8 | 1 |
| **Grand Total** | 90 | 54 | 50 | 58 | 88 | 62 |

1 Through Nov. 30, 1978.

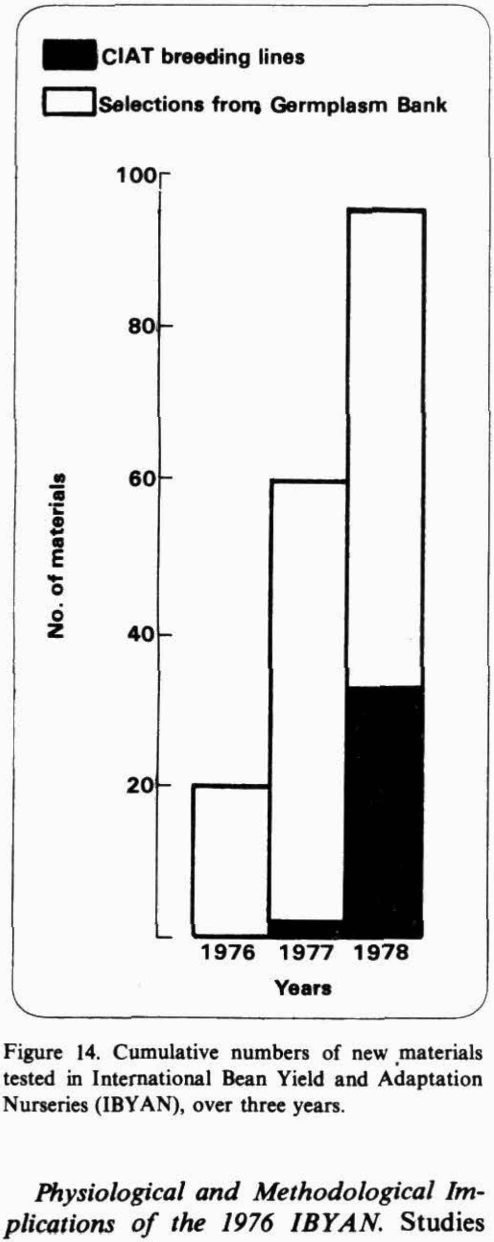



Figure 14. Cumulative numbers of new materials tested in International Bean Yield and Adaptation Nurseries (IBYAN), over three years.

*Physiological and Methodological Implications of the 1976 IBYAN.* Studies have begun on physiological implications of results obtained in the 1976 IBYAN. As a first step in this evaluation, the flowering phenologies of the 20 international entries were grouped for similarity of performance across world locations (latitude range 0° to 53°). The cluster groups defined by the cluster analysis on days to flowering are shown in Figure 15. The growth habit observed for each line at CIAT and the photoperiod classification are shown to the left of the cluster groups. The clustering had been very efficient at discriminating both growth habits and the photoperiod classification groupings within a growth habit. This means that cultivars within each cluster group behaved similarily in terms of phenology at world locations and that the clustering was in agreement with the independent photoperiod screenings at CIAT. The position of some outlying cultivars, e.g., P643 and P539, can be explained in terms of days to flowering differences measured at CIAT or as a result of photoperiod/temperature interactions. These data open the way for the development of phenological models which will be used as an integral part of the target area study and possibly, at a later stage, in defining adaptation zones for advanced material following photoperiod screening at CIAT.

Similarly, the data in Figure 16 shows the mean yield for the 20 international entries in the 1976 IBYAN at each of 41 locations versus the mean growing season temperature at those locations. The mean temperature conditions at the two principal CIAT bean research locations in Colombia (Palmira and Popayan) are shown as vertical lines. The hand-drawn curve represents the approximate limits of the data with the exception of one tropical Mexican location (sub-humid, irrigated). The highest yielding locations,Chile (CHI) and Israel (ISR),both have Mediterranean climates with warm days, cool nights, high radiation and relatively disease-free conditions. The three lowest yielding locations— coastal El Salvador (ELS) and the Philippines (PHI)—had high temperatures, high humidity and high disease pressure. The high-temperature Colombian location (Santa Fe) was sub-humid and disease free but irrigation was not adequate to prevent severe stress.

Table 16.

**Yield for non-black varieties and advanced lines in the Third International Bean Yield and Adaptation Nursery (IBYAN), grown at CIAT-Palmira and Popayan in 1978A.**

| | | | | Palmira | | Popayan | |
|---|---|---|---|---|---|---|---|
| Entry | Pedigree or name | Seed color | Growth habit | Yield (t/ha) | Rank order | Yield (t/ha) | Rank order |
| **Best 5 CIAT breeding lines**[1] | | | | | | | |
| FF 16-3-M | P459 x P4 | Yellow | | 3.4 | 1 | | |
| FF 16-3-1-M | P459 x P4 | Yellow | | 3.3 | 2 | | |
| FF 16-26-2-M | P459 x P4 | Red | | 2.8 | 7 | | |
| FF 12-13-1-M | P459 x P567 | White | | 2.8 | 8 | 2.8 | 7 |
| FF 16-10-2- CM-M | P459 x P4 | Red-Brown- Yellow | | 2.8 | 9 | | |
| FF 16-10-1- CM-M | P459 x P4 | Red | | | | 2.9 | 1 |
| FF 16-20-1-M | P459 x P4 | Brown-Yellow | | | | 2.9 | 2 |
| FF 16-20-2-M | P459 x P4 | Brown-Red | | | | 2.9 | 3 |
| FF 16-20-3-M | P459 x P4 | Pink-Yellow | | | | 2.8 | 5 |
| Mean | | | | 3.0 | | 2.9 | |
| **Standard P-line entries**[1] | | | | | | | |
| P402 | Brasil 2 | Brown | I | 3.2 | 3 | 2.7 | 9 |
| P756 | - | White | II | 2.7 | 10 | 2.7 | 13 |
| P692 | Diacol Calima | Red (mottled) | I | 2.6 | 19 | 2.6 | 14 |
| Mean | | | | 2.8 | | 2.6 | |

1 Common entries for every trial.

continued

Table 16. (continued)

| Entry | Pedigree or name | Seed color | Growth habit | Palmira Yield (t/ha) | Palmira Rank order | Popayan Yield (t/ha) | Popayan Rank order |
|---|---|---|---|---|---|---|---|
| **Entries from national programs**[1] | | | | | | | |
| INIA-Chile | Pinto Dorado | Cream (mottled) | I | 2.4 | 24 | 2.6 | 16 |
| INIA-Chile | Tortola Diana | Grey | III | 1.9 | 25 | 1.9 | 25 |
| Mean | | | | 2.2 | | 2.2 | |
| **Local checks** | | | | | | | |
| | ICA-Pijao | Black | II | 3.1 | 4 | 2.7 | 12 |
| | C-63 S-630-B | Cream | II | 3.1 | 5 | 2.6 | 17 |
| | Puebla 152 | Brown | III | 3.0 | 6 | 2.8 | 4 |
| | Flor 76 | Red | I | 2.7 | 15 | - | |
| | Porr. Sintetico | Black | II | 2.6 | 18 | 2.4 | 23 |
| | Neo-2 | White | I | | | 2.7 | 10 |
| Mean | | | | 2.9 | | 2.6 | |
| Mean of 25 materials | | | | 2.7 | | 2.6 | |
| L.S.D. (0.05) | | | | 0.5 | | 0.4 | |
| C.V. (%) | | | | 11.28 | | 8.71 | |

1 Common entries for every trial.

Table 17.

**Yield for black varieties and advanced lines in the Third International Bean Yield and Adaptation Nursery (IBYAN), grown at CIAT-Palmira and Popayan in 1978A.**

| Entry | | Pedigree or name | Growth habit | Palmira Yield (t/ha) | Palmira Rank order | Popayan Yield (t/ha) | Popayan Rank order |
|---|---|---|---|---|---|---|---|
| **Best 5 CIAT breeding lines[1]** | | | | | | | |
| FF 2-6-3-CM-M | $F_7$ | P459 x P6 | III | 2.9 | 3 | 2.8 | 3 |
| FF 49-1-1-M-M | $F_5$ | (P459 x P8) (P8 x P568) | III | 2.8 | 4 | | |
| FF 24-9-1-M-CB-M | $F_6$ | (P459 x P488) (P459 x P568) | II | 2.8 | 5 | | |
| FF 831-CB-CM-CM | $F_5$ | P346 x P720 | II | 2.7 | 7 | | |
| FF 1282-CB-CM-M | $F_5$ | (P538 x P337) (P556 X P685) | II | 2.6 | 9 | | |
| FF 28-6-1-M-M-M | $F_6$ | (P459 x P568) (P488 x P568) | II | | | 3.0 | 1 |
| FF 26-6-1-M-M-M | $F_6$ | (P566 x P568) (P459 x P568) | II | | | 2.8 | 2 |
| FF 551-CB-CM-M | $F_5$ | P511 x P5 | II | | | 2.6 | 6 |
| FF 45-2-M-M-M-M | $F_5$ | (P459 x P568) (P8 x P568) | III | | | 2.6 | 8 |
| Mean | | | | 2.8 | | 2.8 | |
| **Standard P-line entries[1]** | | | | | | | |
| P675 | | ICA-Pijao | II | 2.9 | 2 | 2.3 | 18 |
| P737 | | Jamapa | II | 2.6 | 10 | 2.4 | 15 |
| P566 | | Porrillo Sintetico | II | 2.3 | 18 | 2.1 | 24 |
| Mean | | | | 2.6 | | 2.3 | |
| **Entries from national programs[1]** | | | | | | | |
| INIA-Chile | | Negro Argel | II | 2.8 | 6 | - | |
| ICA 77A 10103 | | Venezuela 44 x Jamapa | II | 2.7 | 8 | 2.4 | 13 |
| Mean | | | | 2.8 | | 2.4 | |
| **Local checks** | | | | | | | |
| | | Ex Rico | II | 3.0 | 1 | 2.8 | 4 |
| | | ICA-Tui | II | 2.5 | 12 | 2.6 | 7 |
| | | S-166-A N-555 | II | 2.5 | 13 | 2.4 | 14 |
| | | PI 309 804 | II | 2.5 | 14 | 2.7 | 5 |
| | | Venezuela 2 | II | 2.1 | 23 | 1.4 | 25 |
| Mean | | | | 2.5 | | 2.4 | |
| Mean of 25 materials | | | | 2.5 | | 2.4 | |
| L.S.D. (0.05) | | | | 0.5 | | 0.4 | |
| C.V. (%) | | | | 12.46 | | 9.37 | |

1 Common entries for every trial

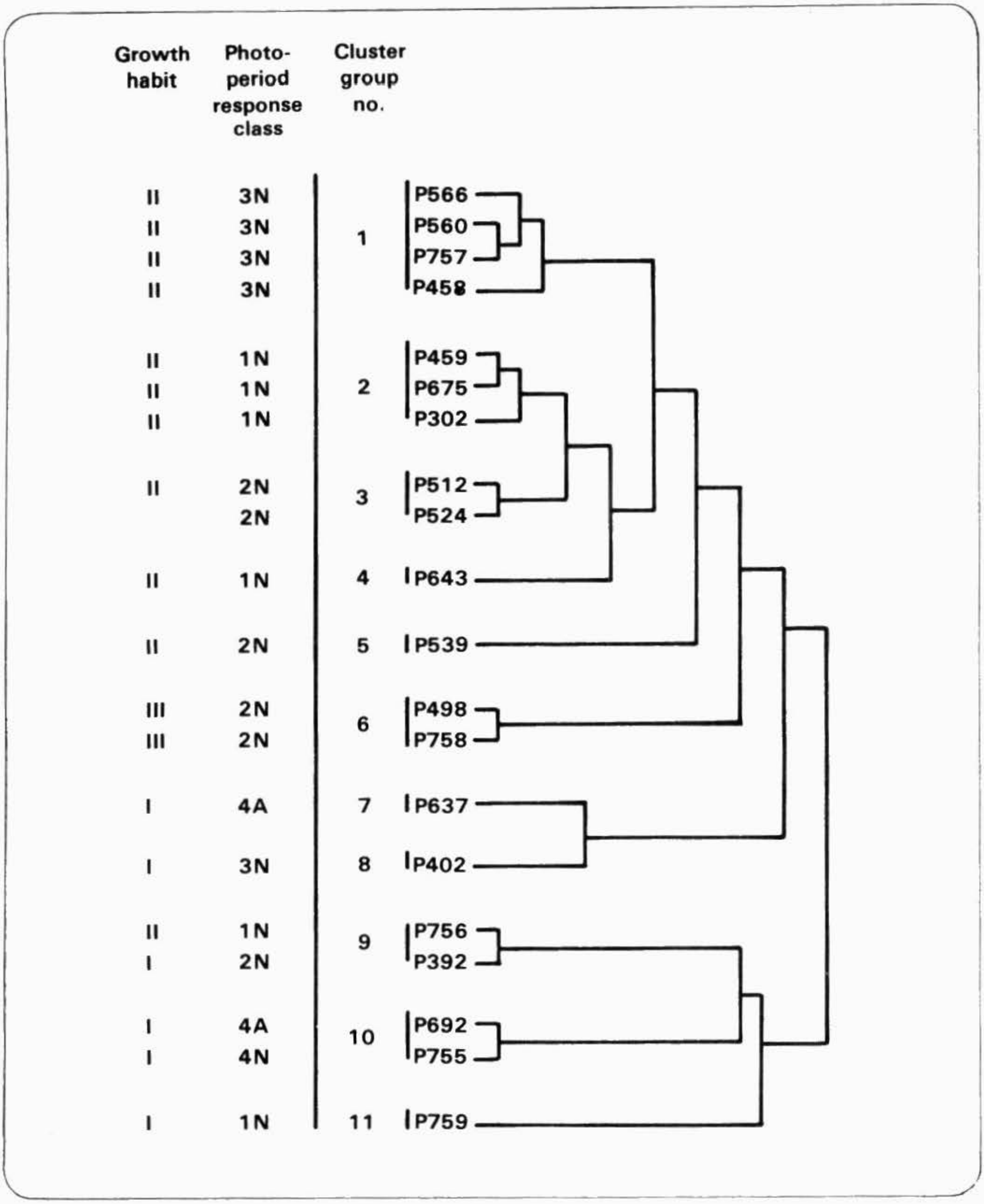



Figure 15. Cluster analysis diagram of similarity of flowering phenology at 27 world locations of the 1977 IBYAN (right of vertical line) compared to independent evaluation of photoperiod sensitivity at CIAT (left of line). Photoperiod classes: 1 = <4 days flowering delay in 18 hours (h) compared to 12 h 20 min; 2 = 4-10 days; 3 = 11-20 days; 4 = 21-30 days; 5 > 30 days. N = normal flowering (in 18 h) when flowering commences; A = abnormal flowering with abscission.

The position of most of the Brazilian and Peruvian locations at "optimum" temperatures but with very low yields suggests that other factors were operating such as disease and soil problems in Brazil and possibly low radiation at the Peruvian irrigated sites. The position of many of the other data points can be explained on the

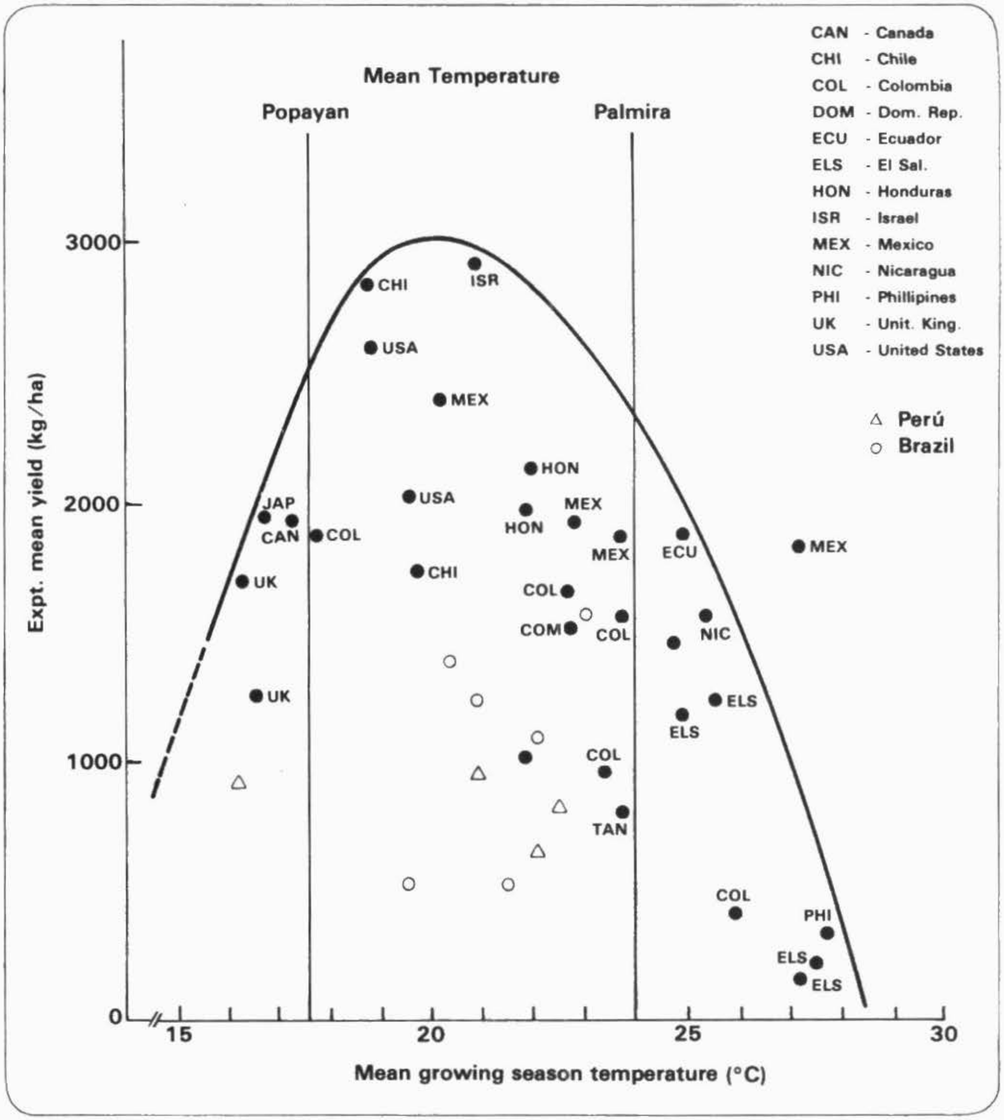



Figure 16. Mean yield across 20 common entries in the 1976 IBYAN versus growing season mean temperature for each of 41 locations where temperature data were provided. Data points for Brazil (BRA), Peru (PER) are separately identified. Chile (CHI) and Israel (ISR) have the two highest yield levels. Other countries identified by first three letters.

basis of agronomic problems encountered at each location. The cooler high latitude locations in the United Kingdom (UK), Japan (JAP) and Canada (CAN) are grouped closely together. The predominance of the locations between the mean temperature limits set by CIAT-Palmira and Popayan suggest that these two sites are probably ideal for the evaluation of adaptation to temperature in advanced materials, at least for bush beans. The analysis of individual cultivar responses to temperature within the IBYAN data set will assist in defining the relationship between yield evaluations in Colombia and world performance.

## Bush Bean Breeding — Specific Problem Activities

Separate projects have been developed for several traits where evaluation of the germplasm available has failed to reveal adequate diversity. It is planned that these projects will enhance levels of disease or insect tolerance, and build architecturally better plants having enhanced yield potential.

### Common Bacterial Blight

Crosses are being evaluated from the intermating of selections from P698 and P684 progenies and several mainstream families that demonstrated blight resistance. Breeding activities are being intensified to increase genetic resistance to *Xanthomonas phaseoli,* which appears to be one of the most widespread and yield-limiting factors for bean production in Latin America. Results from screening an array of germplasm from the bank and hybrid progenies, suggest that black materials do not enjoy the same advantage as in other diseases.

### Bean Golden Mosaic Virus

The national program in Guatemala has conducted replicated yield trials, under BGMV pressure, of $F_4$ and $F_5$ families from selections of the first group of crosses evaluated in Central America (CIAT Annual Report, 1977). Results of those black-seeded progenies, tested by the Instituto de Ciencia y Tecnología Agrícola (ICTA) in monoculture and in association with maize, appear very promising.

A total of 766 $F_2$ and $F_3$ populations were distributed among four collaborating countries during 1977. Greater priority has been given to increasing BGMV resistance in non-black materials. Additional crosses have been made to recombine the resistance of ICTA-CIAT selections with resistance reported by Brazilian workers.

An integrated breeding, selection, and progeny testing scheme for BGMV improvement was developed during 1978 with the collaboration of national program scientists (Figure 17), with the objective of obtaining a complete cycle of recurrent selection and intermating each year.

### Empoasca kraemeri

Breeding for resistance to *Empoasca kraemeri* has progressed through three generations of intermating and recurrent selection since the initial single and double crosses were made (Table 18). $F_1$ progenies are divided into screenhouse (female) and field (male) groups, utilizing $F_2$ seed from the previous cycle to progeny test under *Empoasca* pressure in the field. Parents are selected and intermatings made on the basis of the progeny test.

A field comparison was made of materials produced by different amounts and methods of selection (Table 19). Each material was evaluated visually for *Empoasca damage* (0 = no damage, 5 = highly susceptible) and dry seed yield per plant. The superiority of more highly selected materials is apparent. The mean squares variances are sufficiently similar between groups to be regarded as coming from a single population for the two characters evaluated. Comparisons between groups indicated that pedigree selections from the base population, and selections used as females for the third crossing cycle, were superior to the base population.

The relatively poor performance of selections used as males for the third crossing cycle is perhaps explained by confounding effects from a heavy attack of chlorotic mottle in the nursery where these selections were made. Results from *Em-*

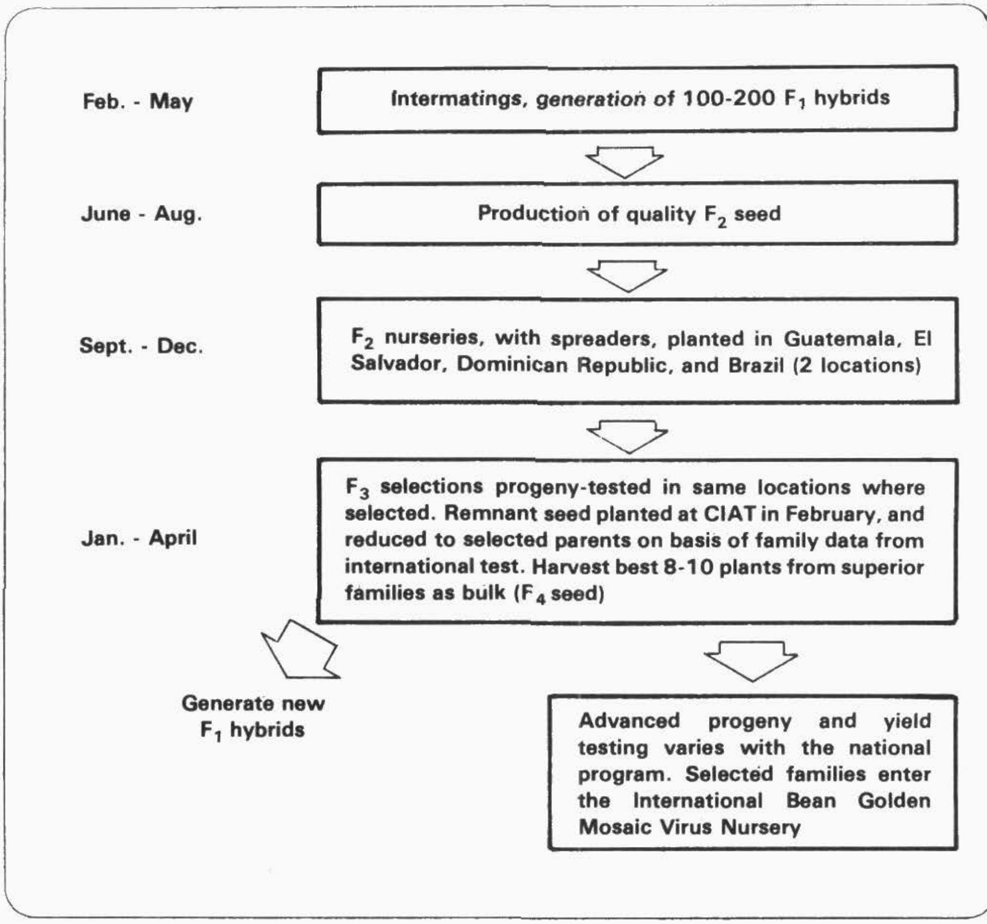



Figure 17. Genetic improvement for resistance of beans to bean golden mosaic virus.

*poasca* breeding are most encouraging when one considers that selection pressure is being exerted in favor of non-black offspring, while most of the *Empoasca*-resistant parents are black-seeded or mulatinho (beige).

## Plant Architecture

Based on available germplasm, improvement projects were initiated in the 1978B season for: lodging resistance, small foliage, early maturity, and delayed flowering and foliage senescence. Numbers of parents used and crosses made are shown in Table 20. About 400 $F_3$ families and 128 $F_2$ populations, primarily interesting for architectural characters, were screened at Popayan during the 1978B season. Approximately 45 $F_3$ families and 483 single plant selections from 48 $F_2$ populations with anthracnose resistance and good adaptation were selected for further evaluations.

## Drought Tolerance

Materials with moderate levels of drought tolerance were identified by the team physiologist. Based on those results

Table 18.

**Stages in development of intermating and recurrent selection for resistance to *Empoasca* spp.**

| | |
|---|---|
| 1976-77 | - 224 single and double crosses among original *Empoasca* parents.<br>- 1000 selections evaluated 1977.<br>- 54 families to 1978 VEF. |
| 1977 | - 175 intermatings and three way crosses.<br>- 15 new parents added from germplasm.<br>- Initiated intermating and progeny testing.<br>- Best 30 families to 1979 VEF.<br>- Inheritance studies inititated. |
| 1978 | - 135 intermatings.<br>- Progeny tested in field 1978B.<br>- 28 best families to 1979 VEF. |
| 1979 | - Intermating, progeny testing, and selection.<br>- Emphasis to larger, non-black grain types.<br>- Examine related *Phaseolus* species. |

and additional observations, 12 sources of drought tolerance and 4 leading cultivars grown in the target areas were selected to initiate the breeding project. Six crosses were made for improvement of drought tolerance, however, the current screening technique appears inadequate to evaluate segregating populations and early generation families.

## Climbing Bean Breeding

During the year the climbing bean breeding program has developed rapidly. It is aimed mainly at breeding bean varieties suitable for associated cropping systems with maize. Within the range of temperatures most important for bean production in Latin America (see p. 49), production from climbing beans tends towards the cooler end of the scale. That is, they are mostly found at present in the highland regions of Central and South America, planted in direct association or relay cropping with maize. The most important temperature range for South America is thought to be covered by two locations in Colombia, Popayan (1850 m) and ICA- La Selva (2200 m), and for Central America by CIAT-Palmira (1000 m) and Popayan. A fourth location, ICA-Obonuco (2700 m) is being used to test materials for extreme highland adaptation, thus covering almost completely the whole temperature range of probable production.

### Crossing Program and Early Generation Selection

During the year a total of 231 climbing bean crosses were made, all of them simple crosses involving two parents only and divided into projects according to preferred colors for which later selection is directed (Table 21). A backcrossing program in collaboration with ICA (Colombia) was also begun for highland adapted climbing beans of favored commercial grain type for the Andean countries and the highlands of Mexico and some Central American countries. The recurrent parents selected were: Cargamanto (large grain cream/red mottled); Ecuador 51 (large grain yellow); and ICA L.32980 M (4) (large grain red). These varieties have useful agronomic characteristics for relay cropping and association with maize at mean temperatures below about 20°C. The backcrossing program aims to introduce resistance to anthracnose and BCMV to the varieties mentioned.

Table 19.

**Mean *Empoasca* scores and yields of eight groups of materials representing different stages of selection, evaluated under *Empoasca* pressure at CIAT-Palmira.**

| Germplasm group | *Empoasca* score[1] No. | Avg. | Mean squares | Yield (g/plant) Avg. | Mean squares |
|---|---|---|---|---|---|
| Parents and single crosses | 59 | 2.39 | .812 | 15.4 | 46.63 |
| Initial parents[2] | 19 | 2.34 | 1.008 | 16.3 | 58.42 |
| Double crosses | 40 | 2.44 | .884 | 16.8 | 41.57 |
| Mass selection from double crosses | 40 | 2.16 | .870 | 17.6 | 68.07 |
| Pedigree selections from single crosses | 40 | 2.08 | .851 | 17.9 | 60.51 |
| New germplasm[3] | 15 | 2.33 | 1.062 | 14.9 | 82.39 |
| Males for fourth crossing cycle | 67 | 2.26 | .861 | 18.6 | 49.15 |
| Females for fourth crossing cycle | 37 | 1.91 | .909 | 19.7 | 58.00 |

1 Rating scale of 1-5: 1 = highly resistant; 5 = highly susceptible.
2 Considered as the base population.
3 New bank accessions introduced to crossing block.

A total of 129 $F_2$ hybrid populations were also planted and evaluated for BCMV, rust and anthracnose resistance. Plants showing resistance or tolerance were selected individually for plant type, pod type and seed color.

Table 20.

**Summary of parents used in field crossing work by the Bean Program, 1978.**

| Project | No. of parents used | No. of crosses |
|---|---|---|
| 1. Anthracnose resistance | 22 | 107 |
| 2. Lodging resistance | 4 | 14 |
| 3. Small foliage | 5 | 8 |
| 4. Drought tolerance | 4 | 6 |
| 5. Heterosis | 15 | 14 |
| 6. Miscellaneous | 29 | 142 |
| Total | 79 | 291 |

## Progeny Testing and Preliminary Yield Trials

A total of 300 progenies from single plant selections made in CIAT-Palmira were tested in the first semester of 1978 in parallel evaluations: in the screenhouse for

Table 21.

**Hybrids made according to project color in the climbing bean crossing activities, CIAT Bean Program, 1978.**

| Project color | No. of hybridizations | Percentage of total |
|---|---|---|
| Black | 111 | 48 |
| Red | 57 | 25 |
| Yellow | 23 | 10 |
| Cream | 18 | 8 |
| Coffee | 15 | 6 |
| White | 7 | 3 |

Table 22.

**Some selections of climbing beans made from progeny testing and preliminary yield trials, in 1978.**

| Identification | | | Reaction to: | | | Yield (kg/ha) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Climbing bean code | Cross | No. of $F_2$ single plant selections | Leaf-hopper[1] | BCMV[2] | Anthrac-nose[3] | Palmira[4] | Popayan[5] | Growth habit | Color[6] |
| 16 | P459 x G2115 | 4 | 2.5 | R | U | 503 | 1801 | III b | Red |
| 248 | G3762 x G3738 | 9 | 2.5 | R | R | 2004 | 1342 | IV b | Black |
| 259 | G5710 x G3736 | 6 | 5.0 | R | R | 1452 | 1042 | IV a | Cream mottl. |
| 615 | G1813 x G3738 | 5 | 3.8 | R | R | 1574 | 1111 | IV a | Yellow |
| 623 | G3130 x G3738 | 15 | 2.2 | R | R | 1573 | 1123 | IV a | Black |
| 623 | G3130 x G3738 | 20 | 3.2 | R | S | 1590 | 2257 | IV a | Black |
| 623 | G3130 x G3738 | 29 | 2.0 | R | S | 1262 | 1991 | IV a | Black |
| 3632 | G881 x G2540 | 16 | 2.8 | R | S | 1385 | 1478 | IV b | White |

1 Mean of three ratings; values up to 3 indicate acceptable tolerance.
2 Glasshouse seedling test; R = uniform resistance.
3 Under field inoculation; R = resistant, U = uncertain, S = susceptible.
4 Sown at 40,000 plants/ha with maize at same density, with two insecticide applications only.
5 Sown at 40,000 plants/ha below mature maize stalks at same density, with two insecticide applications only.
6 Uniform color, bulk selected at harvest.

BCMV; in the field (Popayan) for anthracnose; in the field (Palmira-dry season) for *Empoasca;* and in preliminary yield trials two replications) in Palmira and Popayan. This methodology is only possible given the large quantity of seed produced by climbing bean single plant selections.

Of these materials 74% proved fully resistant to BCMV and 22% had acceptable levels of tolerance to *Empoasca.* Data for some outstanding selections are shown in Table 22.

### International Bean Climbing Trials

The first International Bean Yield and Adaptation Trial for climbing beans (IBYAN-climbers) was organized during 1978. While based on the methodology already developed for bush beans, the collaborator may either plant simultaneously with local maize, or in relay cropping depending on the common practice or most appropriate system for the area. It is believed to be the first ever international trial of varieties selected for associated cropping.

Its objectives are to make available to national programs the best materials selected by CIAT from the germplasm bank or from breeding, and to evaluate progress from year to year of CIAT-selected materials relative to local control varieties in a wide range of environments.

Because of strong local consumer preferences the trial is divided according to color : Black, with nine varieties and one control; Red, with nine varieties and one control; and other colors, 24 varieties and one control.

The trials are being distributed in September of every year. In September 1978, 19 trials were sent to 13 countries, mainly in Latin America.

# EVALUATION AND IMPROVEMENT OF AGRONOMIC PRACTICES

## Response to Plant Density

To evaluate how plants of different growth habit respond to plant density 55 cultivars of growth habits I, II and III were grown at 8 established plants/$m^2$ (a density common in farmers' fields) and 24 plants/$m^2$ (a value commonly found to be optimum in CIAT bean trials). Yields for the 55 varieties at each plant density are shown in Figure 18. In general, type I cultivars responded strongly to higher densities while type II cultivars showed a moderate density response, although again the two highest yielders at low density (P498 and P758) were of this growth habit.

In further studies on this topic the spatial relationships of plants at any given density was shown to be important. Thus for a type I plant with limited branching the yield at 20 plants/$m^2$ varied from 1300 kg/ha when rows were 1. 0 m apart and seeds packed within the row, to almost 1900 kg/ha when rows were 0.4 m apart (Fig. 19). A similar result occurred with the type II Porrillo Sintetico (P566) but was much less noticeable in the case of P498.

## Maize/Bean Association

### Growth and Development of Maize and Beans

Analysis of growth and development for a type IV bean variety grown in direct

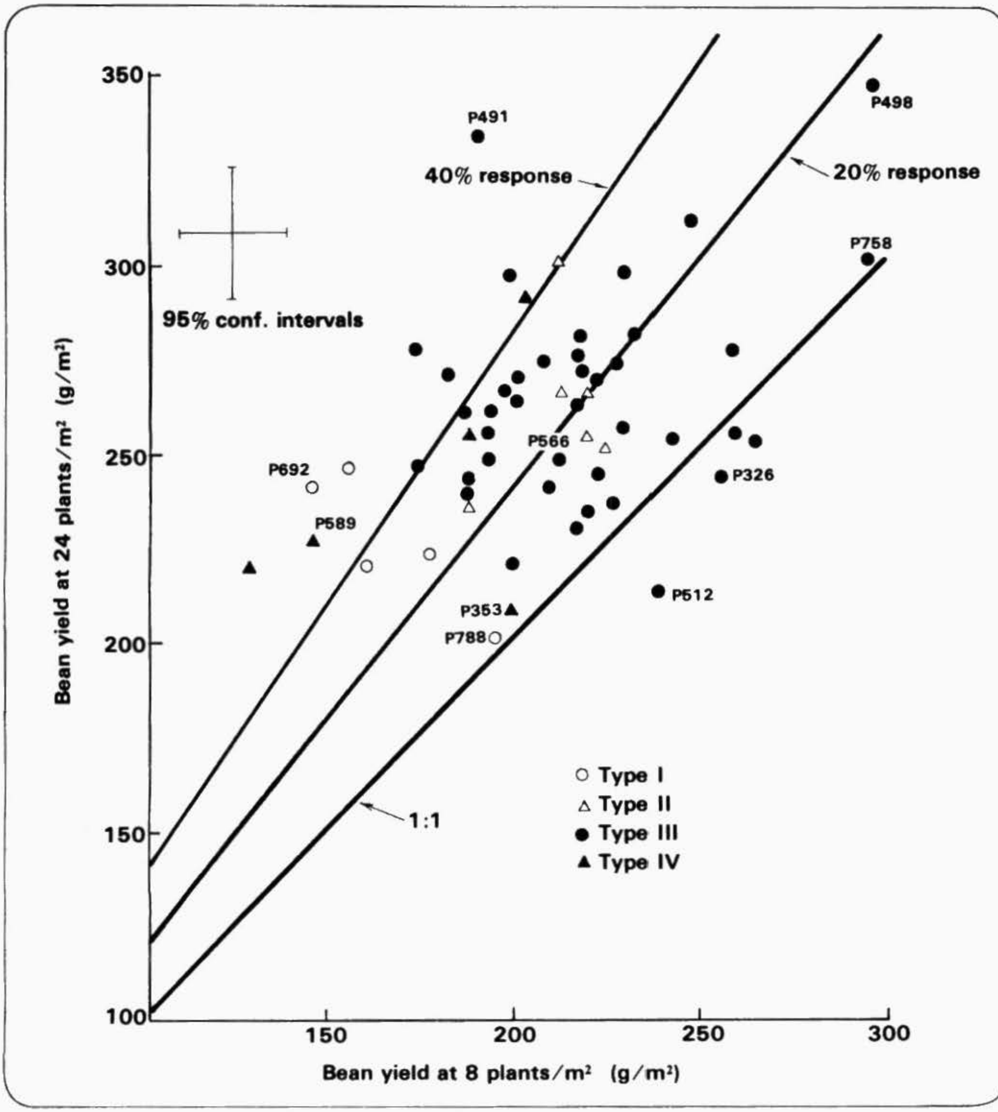



Figure 18. Yield of selected cultivars from growth habits I-IV in monoculture without support when grown at 8 plants/m$^2$ compared to yield measured at 24 plants/m$^2$, at CIAT-Palmira, Experiment 7807, 1978A.

association with maize (an ICA brachytic hybrid was used to ensure lodging resistance) was studied in 1977-78. Yields of both crops decreased heavily when grown in association (Table 23). The bean variety climbed vigorously on the relatively short-statured maize with a resulting 45% decrease in yield of maize. In recent experiments at CIAT-Palmira with normal height maize, maize yield reductions of 20-30% have been recorded. On the other hand, the 51% yield reduction in beans is a common figure in most direct associations. Leaf area curves for the two species are shown in Figures 20 and 21. The early competition from the maize was associated with a slower rate of leaf area development in beans and lower maximum leaf area compared to monoculture. Leaf area duration (LAD) was reduced in beans by

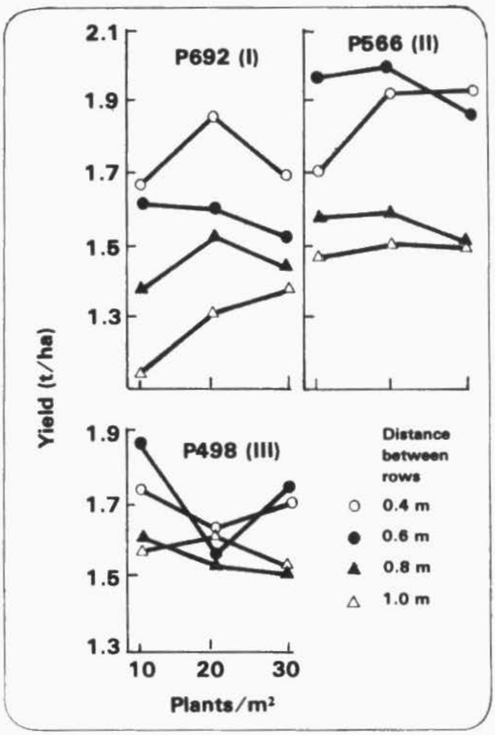



Figure 19. Response of three bean cultivars of different growth habits to various planting densities and between-row distances.

the maize competition while maize had a lower LAD after flowering, presumably due to more rapid leaf senescence arising from the bean competition. A comparison of the reduction in LAD and yield/LAD values for the two species suggests that the beans suffered a greater reduction in the LAD but less relative reduction in efficiency of the LAD. The vertical profile of the bean leaf area, placed above the majority of the maize leaf area in the later phase of growth, probably contributed to shading and more rapid senescence of the maize leaves with a resulting greater reduction in maize leaf efficiency.

In a second trial three maize genotypes (ICA H-210, the brachytic maize used in the previous experiment; Suwan I, a CIMMYT selection of intermediate height; and La Posta, a tall maize from CIMMYT) were grown in association with 10 bean genotypes. In associated culture with 40,000 maize plants/ha, La Posta consistently out-yielded Suwan 1, with the

Table 23.

**Yield and other key parameters for the direct association of maize (var. ICA H-210) and a climbing bean (P589) compared to monoculture of both species, CIAT-Palmira, 1977B.**

| Parameter | Monoculture maize | Association | | Monoculture beans |
|---|---|---|---|---|
| | | Maize | Beans | |
| Yield, (kg/ha)[1] | 5734 | 3185 ( 55)[2] | 1943 ( 49)[2] | 3925 |
| Cobs or pods/m² | 4.1 | 2.8 ( 68) | 163 ( 63) | 258 |
| Grains/cob or pod | 453 | 280 ( 62) | 5.6 ( 81) | 6.9 |
| Bean size (mg/bean) | - | - | 183 ( 97) | 189 |
| Harvest index (%) | 32.6 | 29.6 ( 91) | 57.4 ( 94) | 60.9 |
| Days to silking/flowering | 59 | 62 (105) | 49 (102) | 48 |
| Days to physiological maturity | 117 | 129 (110) | 102 (109) | 94 |
| Yield per day (kg/ha/day) | 49.0 | 24.7 ( 50) | 19.0 ( 46) | 41.7 |
| Leaf area duration[3] (LAD) | 176 | 141 ( 80) | 119 ( 64) | 185 |
| Yield/LAD[4] | 3.25 | 2.26 ( 70) | 1.63 ( 77) | 2.12 |

1 Grain moisture content; 15% maize, 14% beans.
2 Percent of values in monoculture of each species.
3 LAD emergence to physiological maturity (m² days/m²).
3 Leaf area efficiency (g/m² days/m²) (yield on 14 or 15% basis).

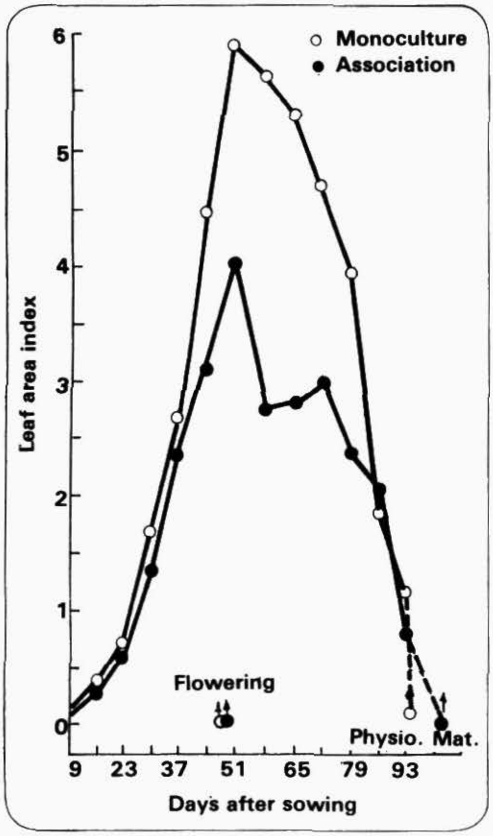



Figure 20. Leaf area growth curve for bean cultivar P589 (IV) when grown in monoculture and in association with maize (ICA H-210), at CIAT-Palmira, 1978A.

ICA hybrid generally lowest yielding (Fig. 22). In contrast bean yields were generally greatest when planted in association with Suwan 1. Two extremely vigorous bean cultivars, G2258 and P503 (Type IVb) performed extremely well in association (Table 24).

The price differential of beans:maize in Colombia is more than 3: 1. At above 2.5:1 it was more economical to use Suwan 1 in association than the higher yielding La Posta (Fig. 23). When a price ratio of 3:1 was assumed, there was no difference in net income between the type IV and IVb bean cultivars. However the type IVb showed increasing advantage as the bean:maize price differential increased (Fig. 24). Type

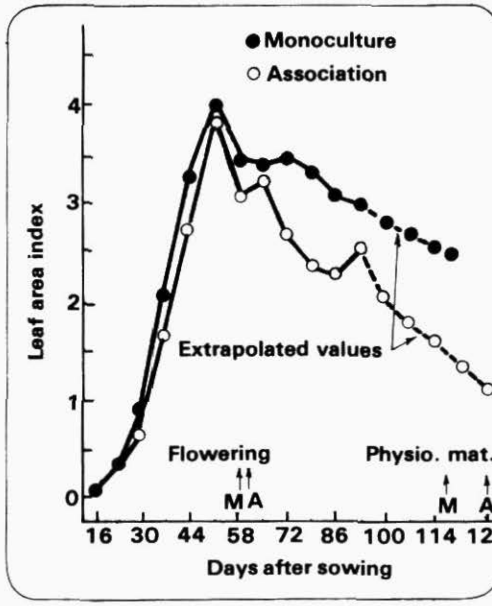



Figure 21. Leaf area growth curve for ICA-H210 brachytic maize hybrid when grown with bean cultivar P589 (IV) in association and in monoculture, at CIAT-Palmira.

IVa plants were more productive in monoculture and may therefore be preferred for relay cropping with maize.

## Effect of Maize Genotype

A trial was carried out with several

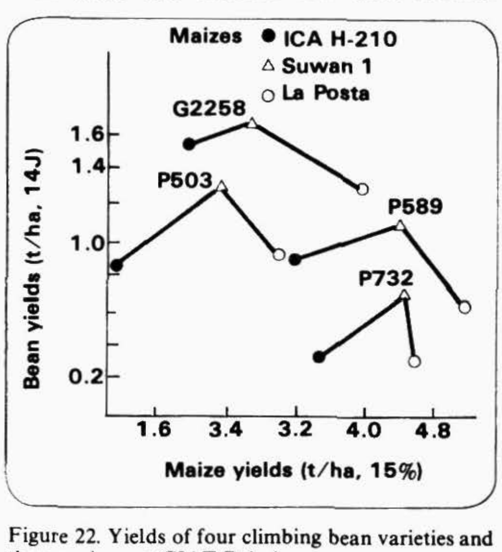



Figure 22. Yields of four climbing bean varieties and three maizes, at *CIAT-Palmira.*

Table 24.

**Yields of 10 climbing bean cultivars in monoculture (on trellises) and in association with three maize varieties, at CIAT-Palmira, 1978.**

| Identification | Growth habit | Yield in monoculture (kg/ha) | Yields (kg/ha) in association with: H-210 | Suwan-1 | La Posta | Mean yield in association (kg/ha) | Association/monoculture yield (%) |
|---|---|---|---|---|---|---|---|
| G2258 | IV b | 3499 | 1563 | 1669 | 1298 | 1510 | 43 |
| P503 | IV b | 2062 | 856 | 1320 | 924 | 1033 | 50 |
| P589 | IV a | 3610 | 902 | 1108 | 636 | 882 | 24 |
| P105 | IV a | 3214 | 1205 | 526 | 668 | 799 | 25 |
| P326 | III a | 3513 | 893 | 762 | 656 | 770 | 22 |
| G2801 | IV a | 3872 | 821 | 825 | 640 | 762 | 20 |
| P526 | IV a | 3263 | 851 | 737 | 603 | 730 | 22 |
| P758 | III b | 3310 | 597 | 509 | 476 | 527 | 16 |
| P732 | IV a | 1762 | 343 | 704 | 321 | 456 | 26 |
| P472 | III b | 1757 | 371 | 313 | 268 | 317 | 18 |
| Mean | | 2986 | 840 | 847 | 649 | 779 | |
| L.S.D. (0.05) | | 519 | 364 | 364 | 364 | 210 | |
| F test | | 21.15*** | 7.99*** | 10.14*** | 5.25*** | 20.03*** | |

maize genotypes in direct association with the climbing bean, P589, to determine an ideal maize type for association. While maize yields were reduced in every case as

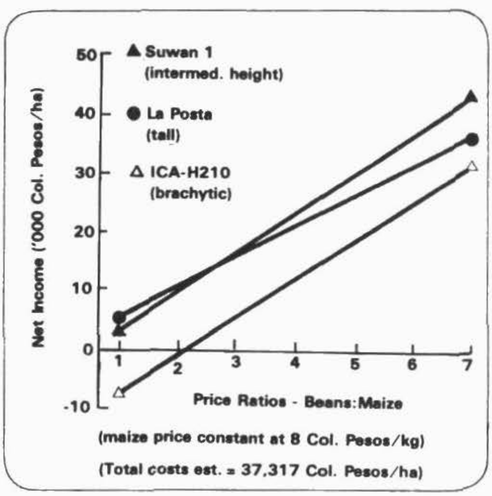



Figure 23. Net income at various bean: maize price ratios for three maize genotypes in association with 10 climbing bean varieties, (Mean yield data).

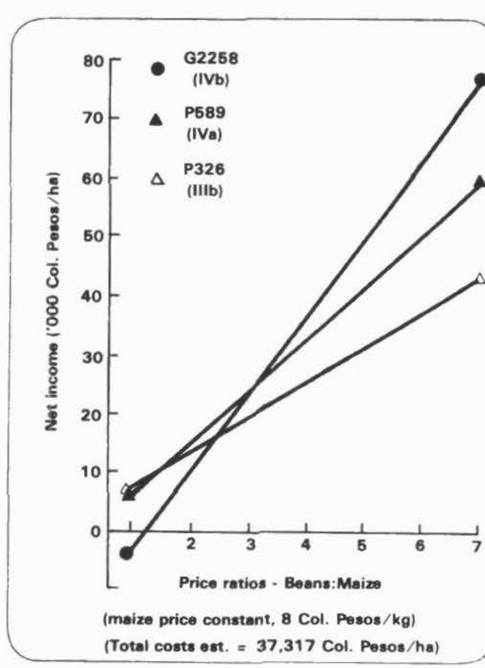



Figure 24. Net income at various bean:maize price ratios for the highest yielding bean varieties of each plant type in association with the maize Suwan 1.

shown above, taller maizes did not suffer as much as the shorter or brachytic maizes and maizes with a high percentage of root lodging tended to do relatively better in association (Table 25). Root lodging was greatly reduced by association in almost every case, due to a physical anchoring effect of climbing beans planted on either side of the maize. Stem lodging, on the other hand, increased in association in almost every case. Maize genotypes for association should, therefore, be reasonably tall and as resistant as possible to lodging.

## Evaluation of Herbicides

Previous studies have shown that for local conditions at CIAT-Palmira, the combination of linuron and fluorodifen, in pre-emergent applications, adequately controls the majority of weeds that develop in bean fields.

In order to find the most economical formula for controlling weeds, an experiment was conducted during the first semester of 1978. Five compounds were evaluated in various combinations and compared with manual weeding at different ages of the crop. The bean variety Diacol Calima was seeded in beds with 0.5 m between the ridges. All the chemical treatments were in pre-emergent applications.

Practically all the combinations of herbicides were equally effective in controlling weeds. Bean yields with the chemical treatments were statistically similar to hand weeding up to time of flowering (Table 26).

## Phosphorus Fertilization of Beans

Studies at Popayan (CIAT Annual Report, 1977), using rates of fertilization from 0-2060 kg $P_2O_5$/ha as triple superphosphate, showed beans to have a high P requirement. When these plots were planted a third time to assess residual effects, yields were maximum at 1280 kg $P_2O_5$/ha.

The external P requirement, calculated as 95% of maximum yield, was determined to be 0.06 ppm P in soil solution, the same as for maize and not very different from the 0.056 and 0.08 ppm determined in 1977

Table 25.

**Relationship of yields of seven contrasting maize genotypes in association with the climbing bean variety P589 to maize yields in monoculture, at CIAT-Palmira, 1978.**

| Maize variety | Yield association/ monoculture (%) | Mono-culture height (cm) | Stalk lodging (%) | | Root lodging (%) | |
|---|---|---|---|---|---|---|
| | | | mono. | assoc. | mono. | assoc. |
| ICA H-209 | 139 | 262 | 1 | 4 | 77 | 17 |
| La Posta | 76 | 256 | 1 | 6 | 43 | 25 |
| Antigua x Rep. Dominicana | 89 | 246 | 2 | 9 | 81 | 51 |
| Amarillo subtropical | 81 | 232 | 1 | 26 | 87 | 41 |
| ICA H-210 | 65 | 191 | 1 | 0 | 2 | 2 |
| Mezcla Tropical Blanco | 78 | 240 | 3 | 1 | 22 | 8 |
| ICA-7431 Br. 2 | 79 | 228 | 1 | 0 | 6 | 2 |

Table 26.

**Effects of combinations of several herbicides applied pre-emergence on grain yields of Diacol Calima beans, at CIAT-Palmira, 1978A.**

| Treatment | Application rate (kg/ha, a.i.) | Percentage control of: grassy weeds, 14 days after application | grassy weeds, 21 | grassy weeds, 28 | broadleaf weeds, 14 | broadleaf weeds, 21 | broadleaf weeds, 28 | Toxicity index[1] | Yield[2] (t/ha) |
|---|---|---|---|---|---|---|---|---|---|
| fluorodifen + linuron | 2.1 + 0.5 | 99.3 | 99.3 | 98.3 | 100 | 98.3 | 95.0 | 0 | 2.0 a[3] |
| penoxalina + linuron | 0.66 + 0.5 | 99.3 | 100 | 93.3 | 97.6 | 99.3 | 94.0 | 0 | 2.0 a |
| penoxalina + nitrofen + DNPB | 0.66 + 1.44 | 97.6 | 99.3 | 95.6 | 95.0 | 92.3 | 76.6 | 0 | 2.0 a |
| metolachlor + linuron | 0.66 + 0.5 | 98.3 | 97.6 | 98.3 | 99.0 | 98.3 | 92.6 | 0 | 1.9 a |
| fluorodifen + nitrofen + DNPB | 2.1 + 1.44 | 100 | 100 | 95.0 | 99.3 | 97.3 | 91.6 | 1.6 | 1.8 ab |
| metolachlor + nitrofen + DNPB | 0.66 + 1.44 | 100 | 100 | 100 | 96.0 | 90.0 | 85.0 | 0.3 | 1.8 ab |
| Hand-weeded at 7, 14 and 21 days | | | | | | | | | 2.0 a |
| Hand-weeded at 21 days | | | | | | | | | 1.8 ab |
| Hand-weeded at 28 days | | | | | | | | | 1.8 ab |
| Hand-weeded at 14 days | | | | | | | | | 1.7 abc |
| Unweeded control | | | | | | | | | 1.3 c |

1 Toxicity scale: 0 = no toxicity, 10 = complete kill.
2 Average of four replications.
3 Means followed by the same letter are not significantly different at the 0.05 level.
Major grass and broadleaf weeds included: *Echinochloa colonum, Leptochloa filiformis, Portulaca olearacea* and *Amaranthus dubius.*

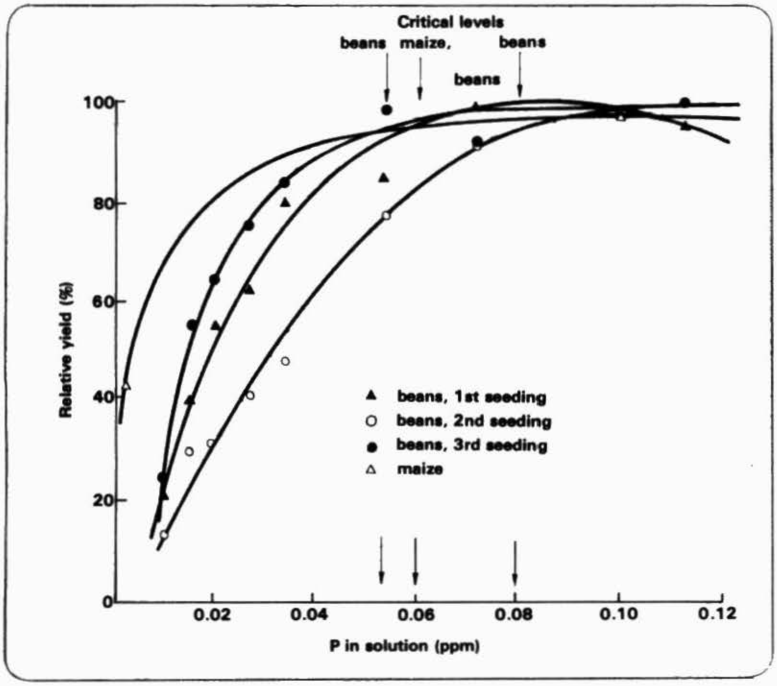



Figure 25. **Relative yield of maize (data from Hawaii) and three consecutive seedings of beans (at Popayan)**, as affected by concentration of P in solution determined by sorption isotherms.

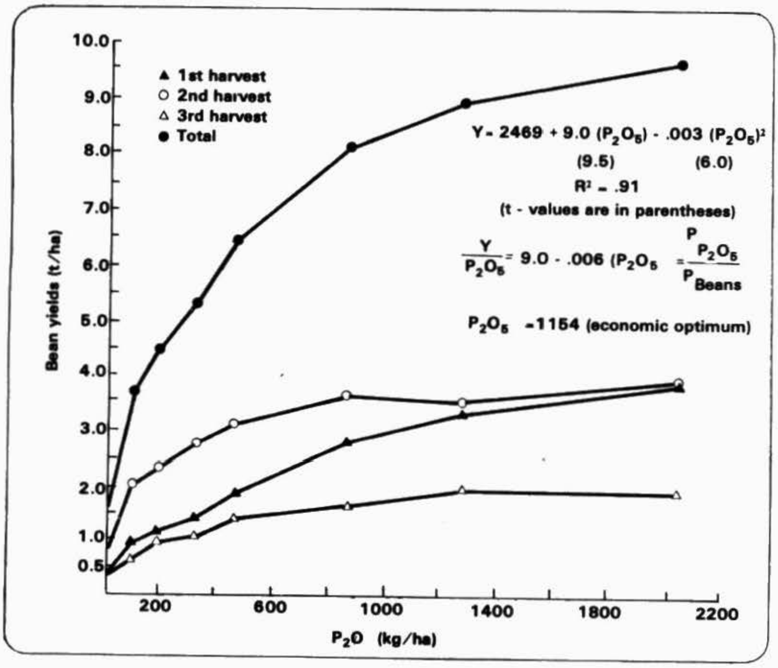



Figure 26. Response of beans (var Huasano) over three harvest to **applications of $P_2O_5$, at Popayan. (Data from** R.H. Howeler and A. Leon).

(Fig. 25). Although maize and beans seem to have a similar external P requirement, beans are more seriously affected by sub-optimal P levels than is maize.

A similar trial at CIAT-Quilichao obtained maximum yields of 1.93 t/ha with the application of 1680 kg $P_2O_5$/ha, but 80% of the maximum yield was obtained when only 76 kg $P_2O_5$/ha was supplied. The critical P content of leaves was estimated to be 0.39% P, a value very similar to those reported earlier for Popayan.

Results from the Popayan trial were subjected to economic analysis. From this analysis, and taking into account residual effects, an economic optimum of 1/1154 kg $P_2O_5$/ha was obtained (Fig. 26). While banding of fertilizer to improve efficiency could probably reduce this requirement to perhaps 300 kg $P_2O_5$/ha, near optimum yields could only be obtained at a production cost of 60,000 Col. Pesos/ha. While this would return a net income of 15,000 Pesos/ha, it is doubtful that risk-avoiding farmers would consider this type of investment. Thus, while this type of experiment provides useful data on critical concentrations of P it is unlikely to have much application in bean program target areas.

### Interaction of Nitrogen and Phosphorus in CIAT-Quilichao

A systematic design trial was planted with variety Diacol Calima to determine the interaction of N and P in CIAT-Quilichao. Twenty levels of N, from 0 to 400 kg/ha, were combined with 20 levels of P from 0 to 400 kg $P_2O_5$/ha by systematically increasing the two elements in perpendicular directions. Plots were 1 $m^2$ each with two bean rows 1 m long.

Highest yields were obtained with 380 kg N and 390 kg $P_2O_5$/ha. However, near maximum yields were obtained with 160 kg N and 200 kg $P_2O_5$.

Figure 27 indicates the average response to P and N. It is clear that the P response was much more marked (from 0.3 to 1.7 t/ha) than the N response (from 1.0 to 1.7 t/ha). Although yields increased about one t/ha by P application in the absence of N (but not by N application in the absence of P), it is clear that maximum yields are obtained only with the balanced application of both elements at this site.

## Target Area Agro-climatology Study

The purpose of this study is to provide a data management and analysis capability to answer questions on various aspects of bean production areas in Latin America. It is envisaged that enquiries will be made at two distinct levels. First, the goal orientation level— to decide on research and breeding priorities or tactics; and second the product dispersal level— to determine the probable impact and region of adapta-

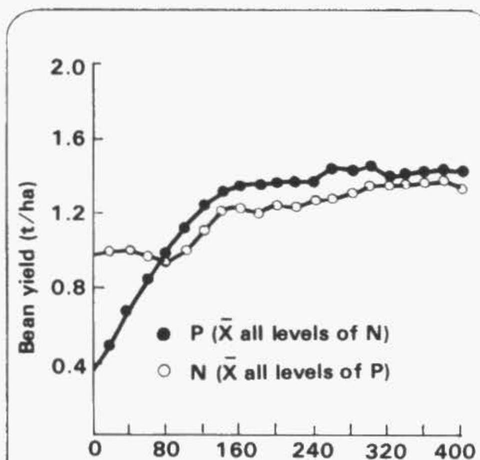



Figure 27. Average response of Diacol Calima to applications of P and N at CIAT-Quilichao.

tion of new CIAT products, either germplasm, technology or a combination of both.

The method chosen was to define more or less uniform, bean growing, micro-regions as a basic unit for data collection and analysis. Each micro-region can then be categorized by climatic, edaphic, agronomic and economic parameters. Using this information on a micro-region basis it will be possible to estimate both the extent of current practices and problems and the possible agronomic consequences of changes to the system. The data fall into two basic types described in the next sections.

### Meteorological Data

The long-term mean meterological data have a readily specified numeric form, but may be used in many different ways. Therefore, a task-specific data retrieval system has been developed to store these data in minimum space and to deliver them to an applications programmer with minimum difficulty. A series of direct access files hold information on the station, institute and country of origin of the data, and the data themselves, linked by keys within and between files for fast access. The data are stored as coefficients of a 12-point Fourier transform and can be very quickly reconstituted to form an array of means for periods of any length required by the applications programmer. Long-term monthly mean data from a wide variety of sources have been processed into a system of sequential work files and are at present being edited and transferred to the retrieval system, where they will undergo further rigorous check for consistency and accuracy.

In later developments of the study it is intended to collect representative daily meteorological records where available for each micro-region for use in more exact studies of seasonal variation and crop hazards.

### Agronomic and Edaphic Micro-region Data

In this section two main tasks present themselves. The first is the implementation of a retrieval system for the data. This needs to be a system capable of accepting data with relatively diverse structures and that can make efficient use of empty data space. To this end the CDC data language INFOL is being translated to run on the IBM 370 system available to CIAT. The second main task is the geographical definition of the bean growing micro-regions. These units, defined by geographical coordinates, will constitute the basic element for the data files. This task is now in progress as a cooperative team effort.

### Data Interpretation

The ability to derive quantitative results from the data depends, in many cases, on being able to calculate the effects of climatic and agronomic practices in each micro-region considered. The first priority is to be able to define the growing season length in terms of crop phenology. This depends on photoperiod and temperature and the relationship changes from cultivar to cultivar. Predictive equations for these relationships are being developed, using data from the IBYAN trials.

### Preliminary Results

Although the data are not yet in efficient machine retrievable form, some tentative results have been compiled. Figure 28 shows a breakdown of bean production of Central and South America by mean daily temperature during the growing season. As these results were compiled from

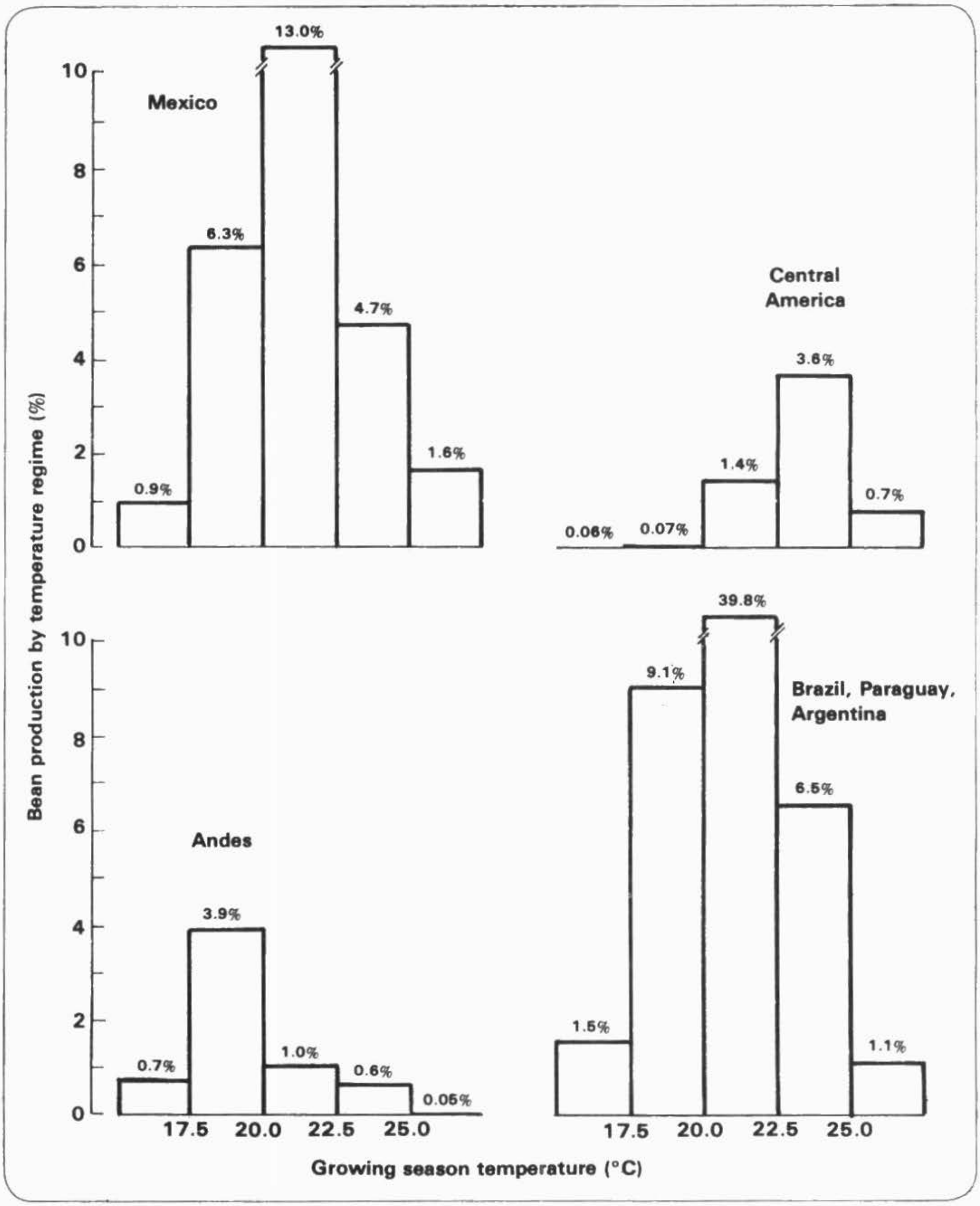



Figure 28. Proportion of total bean production in Central and South America, by regions and temperature regimes within regions.

preliminary estimates of the bean growing micro-region boundaries they should be regarded as preliminary. However, it is felt that the overall form of the distributions shown should be quite reliable. The total distribution for the area (Fig. 29) shows the magnitude of the bean production which was not allocated to specific growing regions. This residual is grown in small areas that could not be accurately estimated or included in the analysis and may well be distributed about the margins of the temperature distribution, although even in this worst case the overall relationships will change little from that shown.

Not unexpectedly, the distribution for Central America shows a tendency towards a slightly higher modal temperature regime, whereas that for the Andean countries tends to a cooler regime. The majority of the production, particularly from Mexico and Brazil falls within the range 20°-22.5°C. The overall temperature range proved to be much narrower than expected, and suggests that undue emphasis on screening for extreme temperature adaptation may be unwarranted for all but the marginal situations.

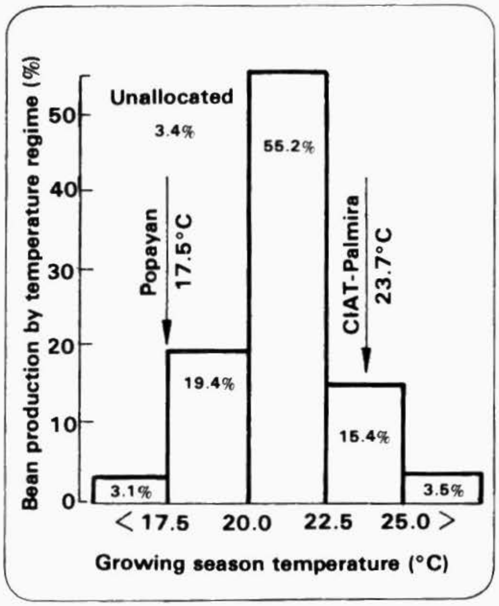



Figure 29. Proportion of total bean production in the target area which falls within five growing temperature regimes.

# IN-DEPTH STUDIES OF SPECIFIC PROBLEM AREAS

## Physiology of Yield

### Comparative Studies with Other Legumes

Research elsewhere has suggested that *Phaseolus vulgaris* is an inefficient species with respect to grain production.

A comparative growth analysis study of five grain legume species was conducted under irrigation' at CIAT-Palmira to evaluate this hypothesis. Adapted representative genotypes (Table 27) for each species were chosen on the basis of varietal evaluations previously conducted by the CIAT Special Studies Unit and others. Yield and associated parameters are shown in Table 27. The two most efficient entries on a yield/day basis were the cowpea and the common bean while the dwarf pigeonpea had the highest absolute yield. Leaf area duration (LAD) from emergence to physiological maturity was highly correlated with yield ($r = 0.90$), implying that the efficiency of the available leaf area (yield/LAD) was relatively similar for the five species. Leaf area growth curves of the five species are shown in Figure 30. The rapid growth of leaf area in *Phaseolus* is notable and contrasts with the very slow growth of leaf area in the small-seeded pigeonpea. The common bean variety had the highest harvest index and the lowest dry matter production (minus leaves and petioles at maturity). Based on these limited data it would appear that, among these grain legumes, the representative of *P. vulgaris* was an extremely efficient producer of economic yield. Experimental conditions were not ideal due to periods of poor

Table 27.

**Yield and other selected parameters measured on five grain legumes species for comparative growth analyses, CIAT-Palmira, 1978A.**

| Species[1] | Total yield 14% (kg/ha) | Daily yield[2] (kg/ha/day) | Days to: flowering | Days to: physio. maturity | Total dry matter[3] (kg/ha) | Harvest index[4] (%) | Maximum node no.[5] ($1/m^2$) | LAD[6] ($m^2$ day/$m^2$) | Yield/LAD (g/$m^2$ day/ |
|---|---|---|---|---|---|---|---|---|---|
| *Cajanus cajan* (pigeonpea) | 2693 | 22.6 | 73 | 119 | 5776 | 39.6 | 1684 | 192 | 1.40 |
| *Phaseolus vulgaris* (common bean) | 2560 | 29.8 | 40 | 86 | 3250 | 66.9 | 801 | 154 | 1.66 |
| *Vigna ungiculata* (cowpea) | 2423 | 30.7 | 49 | 79 | 4397 | 46.8 | 691 | 175 | 1.38 |
| *Glycine max* (soybean) | 2297 | 21.9 | 35 | 105 | 3706 | 52.7 | 610 | 176 | 1.30 |
| *Vigna radiata* (mungbean) | 1653 | 24.0 | 41 | 69 | 3271 | 42.9 | 213 | 95 | 1.74 |
| L.S.D. (0.05) | 551 | 6.2 | - | - | 800 | 13.1 | - | 52.3 | - |
| C.V. (%) | 12.6 | 13.0 | - | - | 10.4 | 14.2 | - | 17.5 | - |
| r (versus yield) | - | 0.46 | 0.40 | 0.58 | 0.61 | 0.26 | 0.81 | 0.90 | 0.54 |

1 Cultivars and sources: Pigeonpea—3D8111, from IITA; Common bean—Puebla 152 (P498), from Mexico; Cowpea—Tvn 201-1D, from IITA; Soybean—ICA-Tunia, from ICA-Colombia; and Mungbean—2010M-314, from AVRDC.

2 Days from sowing to final physiological maturity.

3 Minus leaves and petioles at maturity.

4 Yield/total dry matter.

5 Vegetative node number from growth analysis samples.

6 Integrated area under fitted leaf area curve from emergence to physiological maturity.

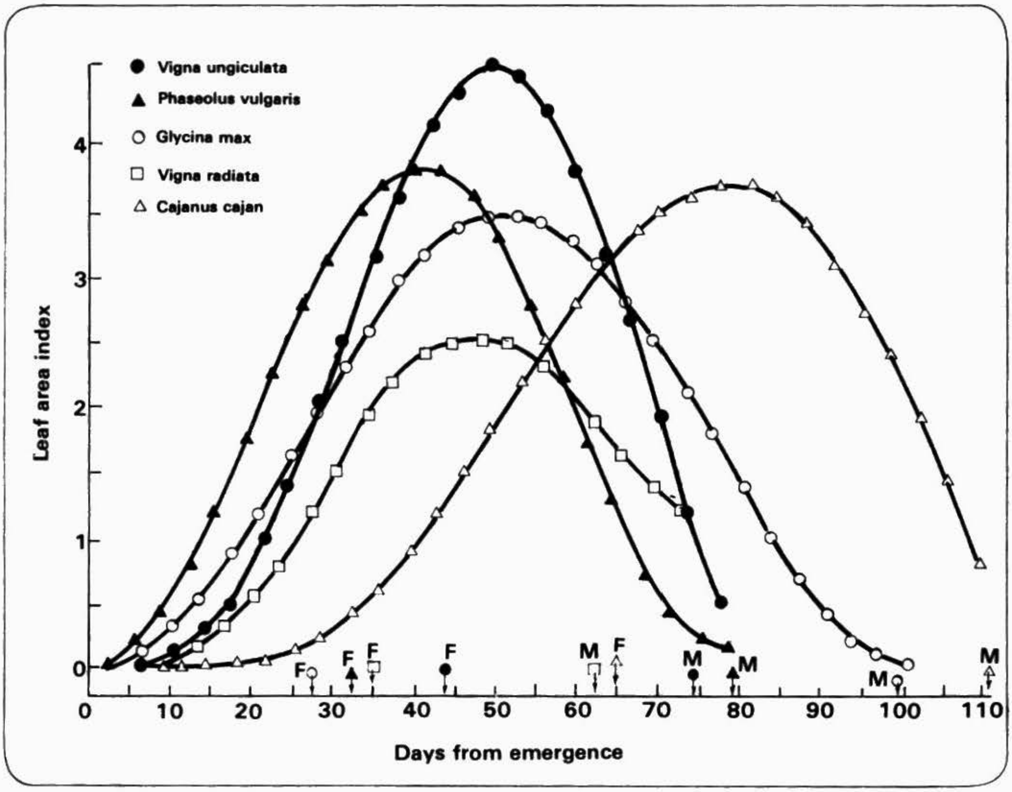



Figure 30. Leaf area growth curve for five grain legume species versus days from emergence; curves derived from predicted value of equations of the form LAI = at + b sin t + c sin 2t + d cos t + e cos 2t, where t = time and a-e are coefficients. $R^2$ values for all species ranged from 0.95 to 0.96 with replication (n = 3) effects removed. Data points are predicted values at each sampling date.

drainage. The experiment will be repeated in 1979, particularly in view of the rather poor performance of the soybean entry.

## Growth Analysis Experiments on Phaseolus vulgaris Germplasm

Ten selected cultivars from growth habits I and II were evaluated to check earlier preliminary conclusions about the importance of physiological characters in yield determination in beans. The overall yield level in the experiment was not as high as normal, due to periods of poor drainage and a moderate attack of common blight. A summary of key parameters is presented in Table 28. As a group the type II varieties out-yielded the type I lines. Yield per day, total dry matter and total green leaf area duration were all highly correlated with yield. Harvest index was only slightly higher, on average, in the type II lines. Differences in maturity were not sufficient to explain the yield differences. The higher leaf area duration of the higher yielding lines was associated with higher dry matter production (r = 0.87). Thus, where maturity differences were not very great, there were large differences in leaf area duration (LAD) leading to high yield per unit area and per unit time in material with high LAD. The marked inferiority of type I materials is again clear in these data. IBYAN data for 1976 (CIAT Annual Report, 1977) support this conclusion for a number of locations.

The maintenance of a high leaf area index for as long as possible, i.e., within the environmental limits, is one of the key

Table 28.

**Physiological parameters for 10 *Phaseolus vulgaris* cultivars from a comparative growth analysis experiment, CIAT-Palmira, 1978A.**

| Cultivar | Growth habit | Yield 14% ($g/m^2$) | Daily yield[1] ($g/m^2/day$) | Total dry matter[2] ($g/m^2$) | Harvest index (%) | Days to: flowering | Days to: physio. maturity | LAD[3] ($m^2$ days/$m^2$) | Yield/LAD ($g/m^2$ days/$m^2$) |
|---|---|---|---|---|---|---|---|---|---|
| P548 | II | 186 | 2.41 | 277 | 58 | 39.2 | 76.8 | 156 | 1.19 |
| P566 | II | 172 | 2.24 | 264 | 56 | 38.7 | 76.7 | 159 | 1.08 |
| P756 | II | 158 | 2.10 | 242 | 56 | 34.0 | 75.0 | 108 | 1.46 |
| P643 | II | 156 | 1.95 | 263 | 51 | 38.7 | 80.0 | 128 | 1.22 |
| P524 | II | 148 | 1.96 | 210 | 62 | 39.7 | 75.2 | 129 | 1.15 |
| P759 | I | 127 | 1.80 | 215 | 52 | 31.5 | 71.0 | 101 | 1.26 |
| P788 | I | 127 | 1.77 | 213 | 51 | 31.0 | 71.5 | 88 | 1.44 |
| P402 | I | 113 | 1.61 | 202 | 48 | 37.7 | 70.0 | 91 | 1.24 |
| P635 | I | 103 | 1.36 | 214 | 43 | 31.2 | 75.5 | 109 | 0.94 |
| P392 | I | 75 | 1.10 | 116 | 56 | 34.2 | 68.5 | 60 | 1.25 |
| Mean, habit | II | 164 | 2.13 | 251 | 57 | 38.0 | 76.7 | 136 | 1.22 |
| Mean, habit | I | 109 | 1.53 | 202 | 52 | 33.1 | 71.3 | 90 | 1.23 |
| L.S.D. (0.05) | | 27 | 0.35 | 57 | 10 | 1.0 | 1.3 | 27 | 0.28 |
| C.V. (%) | | 13.7 | 13.3 | 17.6 | 11.8 | 1.9 | 1.2 | 16.5 | 15.8 |
| r (versus yield) | | | 0.99 | 0.85 | 0.47 | 0.58 | 0.74 | 0.87 | 0.05 |

1 Days from sowing to final physiological maturity.
2 At harvest, minus leaves and petioles.
3 Area under fitted leaf area curve from planting to physiological maturity.

factors necessary to increase yield, at least in bush beans. This can be achieved either by increasing the leaf area within the same time frame or by increasing the length of the growth cycle (see previous CIAT Annual Reports for a fuller discussion of these conclusions).

## Temperature Effects on Symbiotic Nitrogen Fixation

Studies in previous years have suggested that high soil temperature could be a major limiting factor to $N_2$ fixation in beans. To evaluate this possibility, controlled environment studies were undertaken at the Biotron facility, University of Wisconsin (U.S.A.).

Preliminary studies evaluated growth and $N_2$ ($C_2H_2$) fixation in five bean cultivars inoculated with different strains of *Rhizobium*. Thirty days after planting, $N_2$ ($C_2H_2$) fixation at 30° - 20°C day-night temperature was considerably above that at 35°-25°C, but little difference in plant weight was observed. There was a strong strain-temperature interaction (Table 29).

The growth, $N_2$ ($C_2H_2$) fixation and N accumulation of the cultivars P498, P566 and P635 were further studied using weekly sampling to establish profiles of development and $N_2$ fixation under three different growth temperature regimes. Temperature influenced both the onset, intensity and duration of $N_2$ ($C_2H_2$) fixation. Thus while maximum fixation increased from 33.8 $\mu$mol $C_2H_4$ produced/plant/hour at 35°-25°C day-night temperature to 73.0 $\mu$mol $C_2H_4$ produced/plant/hour at 25° - 15°C, this peak in fixation was increasingly delayed as growth temperature was reduced (Fig. 31). In the 25° - 15°C treatment, this delay in the onset of fixation led to falling leaf N concentrations and visible N-deficiency symptoms at the 28-day harvest (Fig. 32).

In this study the influence of temperature on N fixation by beans was less than anticipated, and given the average growth season temperatures for beans discussed on page C-48 is not likely to be a major limiting factor for bean production under field conditions. It is possible, however, that delaying the onset of fixation at lower temperatures might necessitate the use of starter N dressings. This possibility is being investigated.

Table 29.

**Variation in *Rhizobium* strain response to temperatures. (Means of five *Phaseolus vulgaris* cultivars.)**

| Temperature (day/night) | *Rhizobium* strain | | | | Not inoculated |
|---|---|---|---|---|---|
| | CIAT 57 | CIAT 161 | CIAT 137 | CIAT 632 | |
| **Measured by acetylene reduction ($\mu$mol/plant/hour)** | | | | | |
| 35°/25°C | 19.62 | 13.91 | 11.10 | 0.92 | 0 |
| 30°/20°C | 28.14 | 23.19 | 16.77 | 17.88 | 0 |
| **Measured by plant weight (g/plant)** | | | | | |
| 35°/25°C | 3.73 | 5.23 | 4.99 | 2.06 | 3.03 |
| 30°/20°C | 3.75 | 4.73 | 4.27 | 4.58 | 2.48 |

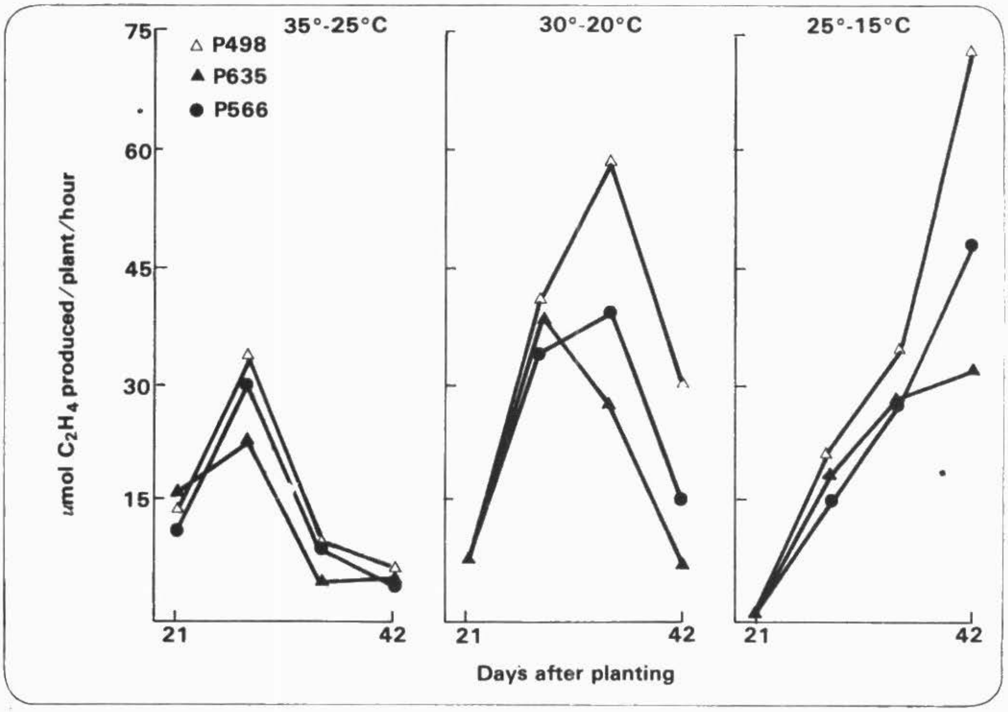



Figure 31. Nitrogen ($C_2H_2$) fixation in three bean cultivars as influenced by day/night temperatures.

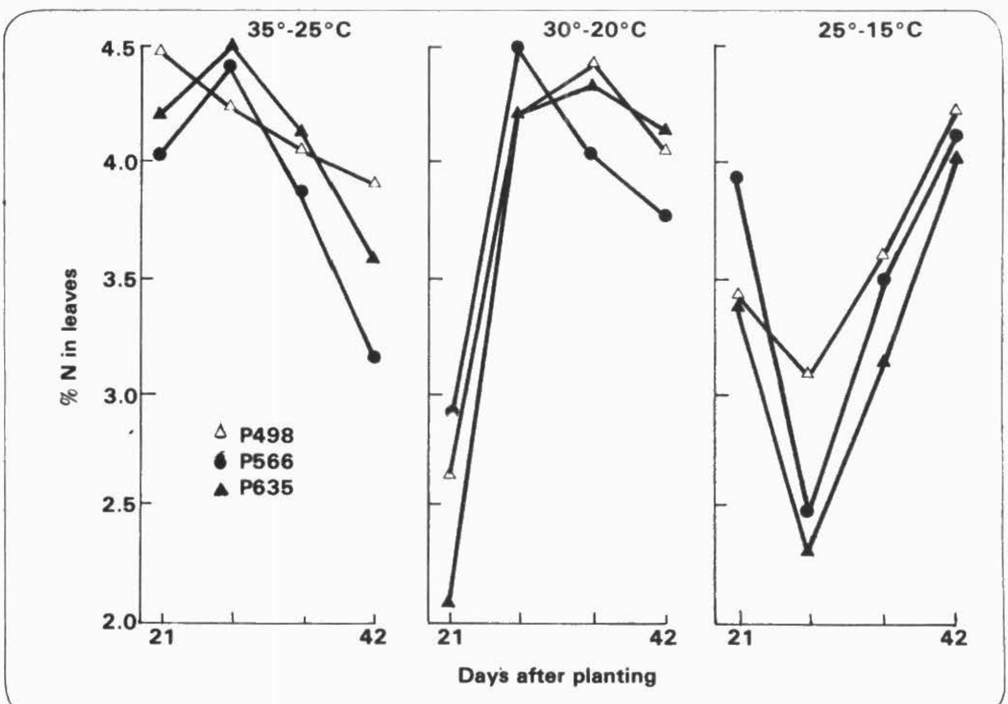



Figure 32. Nitrogen content of leaves of three bean cultivars as influenced by different day/night temperatures.

## Importance of Nematodes in Bean-Producing Regions of Colombia

To evaluate the importance of nematodes in bean-producing regions of Colombia, a total of 112 soil and 66 root samples were taken from eight bean production areas. These included research plots on CIAT stations at Palmira, Popayan and Santander de Quilichao; ICA stations at La Selva and Pasto; and on-farm trials in the Huila, Restrepo, (Valle) and Rio Negro (Antioquia) regions. Nematodes were extracted from soil by centrifugal-flotation in sugar solution. Washed roots were incubated 24 hours at 24°C in shaken water to extract endoparasites. Collections of *Pratylenchus* and *Meloidogyne* were identified to species. *Aphelenchus, Aphelenchoides, Ditylenchus, Tylenchus,* and *Psilenchus* were not included in the survey.

Eighteen genera of plant parasites were collected from bean soil (Table 30) and three genera from bean roots. Three genera occurred generally in soil and root samples. *Helicotylenchus, Pratylenchus* and *Meloidogyne* occurred in 66% and 18%, 37% and 62%, and 36% and 41% of soil and root samples, respectively. Since *Helicotylenchus* is primarily ectoparasitic, relatively low recovery from roots would be expected. Populations of *Meloidogyne* spp. from root samples represent egg hatch during 24 hours incubation. These populations are not necessarily indicative of relative degrees of root infestation.

*Helicotylenchus* spp., while quite generally occurring in bean soils, were usually present at frequencies less than 1000/500 ml soil. There is no literature concerning the pathogenicity of *Helicotylenchus* to beans. However, unusual population development at CIAT -Palmira (3000/500 ml), Restrepo (3800/500 ml) and Rio Negro (4800/500 ml) may indicate some damage to beans at these sites. Damage to beans in Huila could be expected because of the very large population of spiral nematode (9700/500 ml).

*Meloidogyne* spp. occurred on 9 of 10 farms sampled at Rio Negro with *Meloidogyne arenaria* the predominant species. Soil samples frequently contained large numbers of larvae (5100/500 ml). In this limited sample, cultivars P706 showed larger galls than P590. Occurrence of *Meloidogyne* spp. was favored by the coarse soil textures and long history of monocultured beans at Rio Negro.

Five of six farms visited at Restrepo were infested with root-knot nematodes, probably *Meloidogyne incognita.* Cropping practices at Restrepo favor maintenance of *Meloidogyne* spp. in bean soils. *Aracacia xanthorhiza,* an excellent host of *Meloidogyne* spp. (10,100/500 ml), is frequently interplanted with beans and tomato, another good host, may be rotated with beans. *Bidens pilosa* (Compositae), a common weed in bean fields is another good host of *Meloidogyne.*

*Meloidogyne hapla* occurred in all soil samples from Popayan. *M. hapla* is generally not as destructive as southern species. However, at Popayan, seedlings are subjected to high populations (4800/500 ml) which would increase the effect of nematodes on beans. Root rot was common at Popayan. Since *M. hapla* can increase root rot incidence, this species could be causing losses in this way in addition to direct pathogenicity. *B. pilosa* is important at Popayan in maintaining high populations throughout the plot area. Lack of crop rotation also contributes to population increase.

Table 30.

**Genera of plant parasitic nematodes extracted from 200 ml soil by centrifugal-flotation.**

| | Genera in bean soil | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Genus | La Selva | CIAT-Palmira | Pasto | Popayán | Potosí | CIAT-Quilichao | Restrepo | Río Negro |
| *Cacopaurus* | | 4/44[1](3200)[2] | | | | | | |
| *Criconema* | 1/6 (100) | | | | | | | 12/19 (2800) |
| *Diptherophora* | 4/6 (200) | | 1/7 (500) | | | | 2/10 (200) | |
| *Gracilacus* | | 2/44 (1200) | | | | | | |
| *Helicotylenchus* | 6/6 (100) | 24/44 (3000) | 1/7 (100) | 14/23 (1200) | 2/2 (9700) | 1/1 (400) | 7/10 (3800) | 19/19 (4800) |
| *Heterodera* | | | 2/7 (700) | 1/23 ( 100) | | | | |
| *Hoplolaimus* | | | | | | | 2/10 ( 300) | |
| *Longidorus* | 2/6 (200) | | | | | | | |
| *Macroposthonia* | | | 1/7 (100) | 7/23 ( 400) | | | 1/10 ( 600) | 3/19 ( 200) |
| *Meloidogyne* | 6/6 (800) | | 3/7 (600) | 19/23 (4800) | | | 6/10 ( 800) | 16/19 (5100) |
| *Paratrichodorus* | | | | 5/23 ( 300) | | | | |
| *Paratylenchus* | | 1/44 ( 100) | | | | | | |
| *Pratylenchus* | 5/6 (900) | 17/44 ( 500) | 4/7 (1000) | 2/23 ( 200) | | | 1/10 ( 200) | 12/19 ( 800) |
| *Telotylenchoides* | | 2/44 (2200) | | | | | | |
| *Tetylenchus* | | 1/44 ( 200) | | | | | | |
| *Trichodorus* | 3/6 (100) | | | 8/23 ( 400) | | | 6/10 ( 700) | 14/19 ( 700) |
| *Tylenchorhynchus* | | 4/44 ( 700) | 5/7 (2500) | | | | | |
| *Xiphinema* | 6/6 (600) | | | 2/23 ( 200) | | | | 1/19 ( 100) |

1 Numerator = number of samples in which genus occurred; denominator = total number of samples collected at site.

2 Numbers in parentheses are maximum populations/500 ml soil.

Soil from La Selva was infested with *Meloidogyne* spp. Since root samples with females were not included in these samples identification cannot be certain, yet larval measurements indicate *M. incognita* is the predominant species. *M. incognita* commonly occurs on vegetables and weeds at La Selva.

*Meloidogyne* spp. occurred in soil samples from Pasto but galled bean roots were not collected. Nematodes could have been reproducing on weeds. The species has not been identified but the cool soil environment at Pasto would favor *M. hapla*.

*Meloidogyne* spp. levels found in this survey would undoubtedly cause yield reductions in beans.

*Pratylenchus penetrans* and *Pratylenchus crenatus* were present in high numbers in both the La Selva and Rio Negro samples. Since *P. penetrans*, in growth chamber work, can stunt bush beans at populations of 1/plant, the field levels reported must have been injurious to bean growth. Associative cropping of maize and beans would favor *P. penetrans*.

## Cultural and Biological Control of Insect Pests

### Studies with Empoasca kraemeri

Studies continued on the influence of aluminum and other mulches on *Empoasca kraemeri* populations and bean yields. Covering the soil with aluminum and with rice straw reduced nymphal and adult populations of the leafhopper, compared to the control treatment without chemical protection or mulching, both for the susceptible variety Diacol Calima (Fig. 33 and 34) and for the resistant line P14 (Fig. 35).

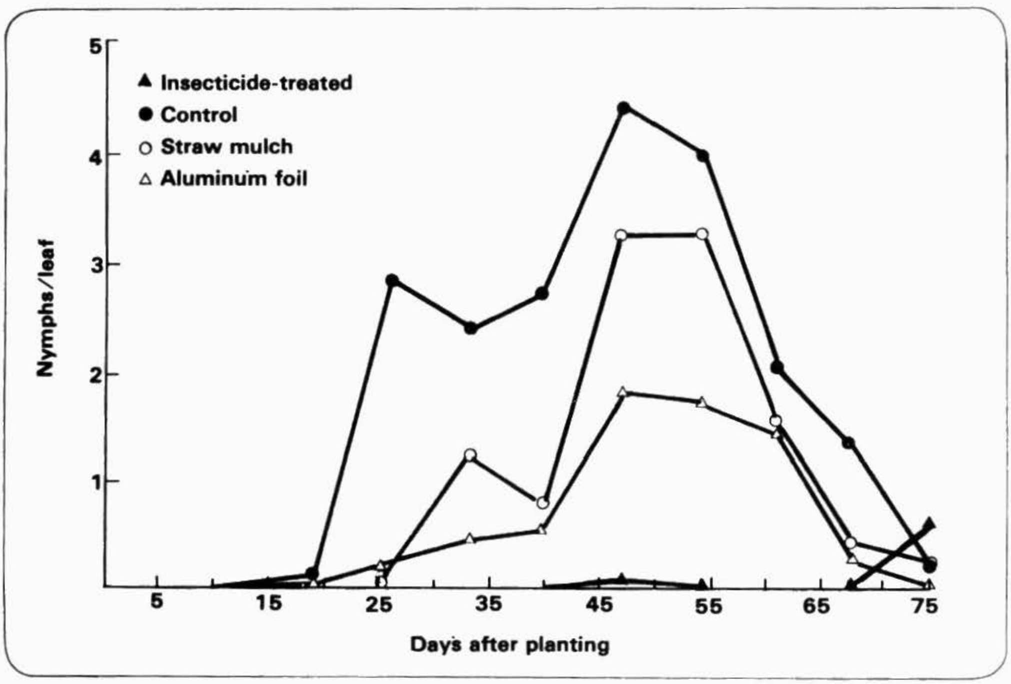



Figure 33. Effect of various soil covers on nymphal populations of *Empoasca kraemeri*, with bean variety Diacol Calima.

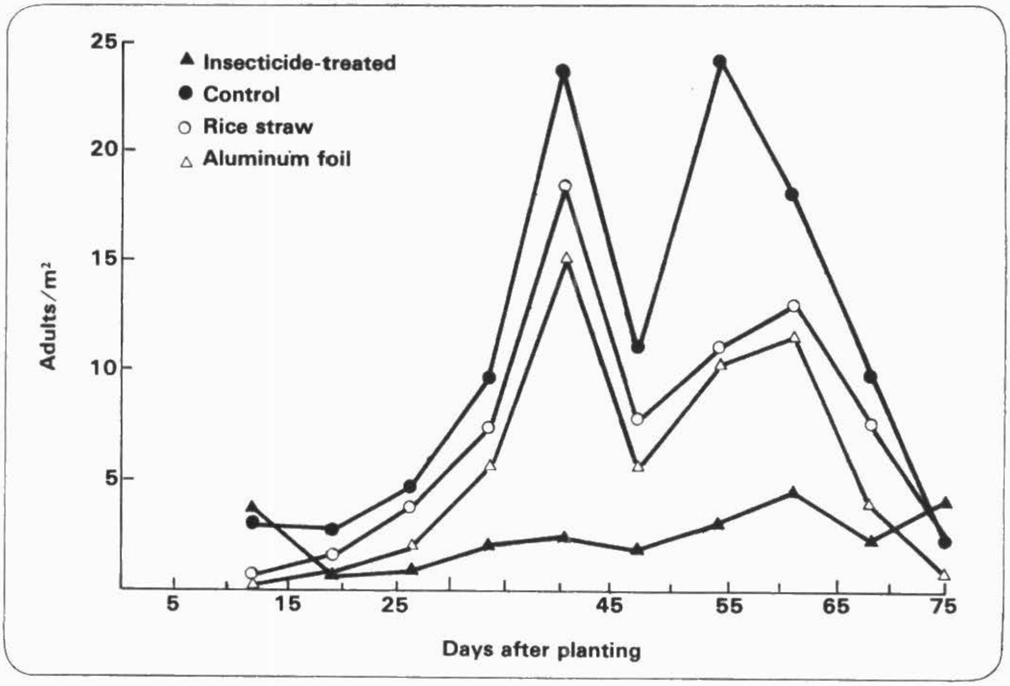



Figure 34. Effect of various soil covers on adult populations of *Empoasca kraemeri*, with bean variety Diacol Calima.

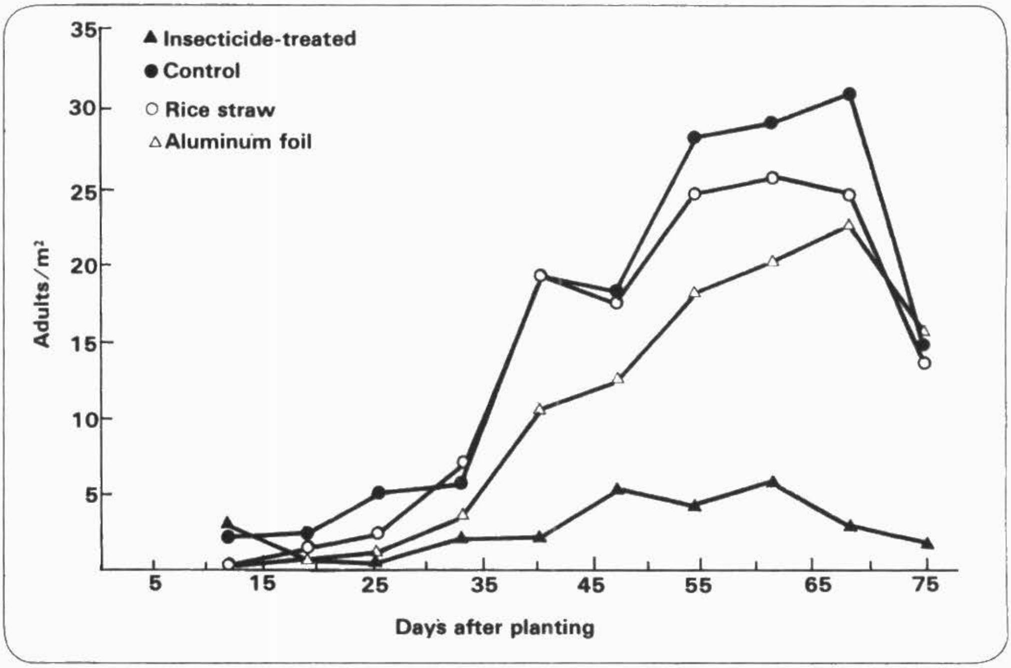



Figure 35. Effect of various soil covers on adult populations of *Empoasca kraemeri*, with bean variety P14.

Table 31.

**Yields of a susceptible variety (Diacol Calima) and a resistant variety (P14) of *Phaseolus vulgaris* under different treatments for the control of *Empoasca kraemeri*.**

| Treatment | Yield (kg/ha) Diacol Calima | P14 |
|---|---|---|
| Treated with insecticide | 1574 a[1] | 1549 a |
| Aluminum foil mulch | 1450 a | 1385 ab |
| Rice straw mulch | 1007 b | 1445 ab |
| Control | 673 c | 1101 b |

1 Values followed by the same letter are not significantly different at the 0.05 level.

With Calima, yields were significantly different between the aluminum and rice straw mulches and the control. Being resistant, P14 did not respond significantly, although it produced 400 kg/ha more with the aluminum mulch than did the unprotected control (Table 31). Differences between the controls of the varieties were significant, showing again the importance of varietal resistance on yields.

To complement the cultural practice studies and as basic essential information on the design of traps for population dynamics studies, the behavior of leafhoppers and chrysomelids was investigated with respect to the surface color surrounding the bean plant. Colors green and especially yellow, attracted the most *Empoasca* adults; black and straw colors gave a mixed or intermediate response. Aluminum and white were definitely repellent colors. Response of the chrysomelids to colors was not so marked as for leafhoppers (Table 32).

Table 32.

**Response of *Empoasca kraemeri* and chrysomelid adults to surface colors surrounding the bean plant.**

| Treatment color | Expt. 1 | Expt. 2 | Expt. 3 | Expt. 4 |
|---|---|---|---|---|
| **No. of *Empoasca* adults per plant** | | | | |
| Green | 6.2 a[1] | 4.2 a | 3.6 b | 11.8 bc |
| Control | 3.5 b | 1.7 bc | 2.2 bc | 14.4 b |
| Yellow | 3.5 b | 3.6 a | 5.6 a | 18.9 a |
| Straw | 2.6 bc | 0.8 c | 1.5 cd | 2.1 d |
| Black | 1.7 cd | 2.8 ab | 2.1 bc | 14.6 b |
| Aluminum | 0.9 cd | 0.4 c | 0.9 cd | 0.9 c |
| White | 0.2 d | 0.1 c | 0.3 d | 4.2 d |
| **No. of chrysomelid adults per plant** | | | | |
| Straw | 1.6 a | 1.6 ab | 1.6 ab | 1.4 ab |
| Yellow | 1.2 ab | 1.8 ab | 1.8 a | 1.7 ab |
| Control | 0.9 ab | 1.4 ab | 1.0 abcd | 0.7 b |
| Green | 0.8 ab | 1.2 ab | 1.3 abc | 1.5 ab |
| White | 0.8 b | 0.9 ab | 0.1 d | 2.2 a |
| Aluminum | 0.7 ab | 0.3 b | 0.3 cd | 1.4 ab |
| Black | 0.5 ab | 0.5 ab | 0.6 bcd | 0.6 b |

1 Values within columns and for each species that are followed by the same letter are not significantly different at the 0.05 level.

## Studies with Grain Storage Pests

In collaboration with ICA and CARE, and at the farm level, a study was done on controlling insect pests of stored beans. Treatments included soybean oil (3 ml/kg of beans), harvest residues (25% by weight), pyrethrins (1.7 ppm) and the unshelled pods with beans. The experiment was done at four locations, three in the Cauca Valley of Colombia (1000 masl) where conditions were adequate for *Zabrotes subfasciatus* attacks. The fourth experiment was at Popayan (1900 masl) where conditions were favorable for *Acanthoscelides obtectus*.

After four months of storage, the unshelled beans at Popayan had 34% damage from *Acanthoscelides* and 39% of the pods were perforated. Untreated beans and the treatment with harvest residues both had 2% damage. No damage was observed on seed treated either with oil or pyrethrins throughout the nine-month experimental period.

Table 33.

**Comparative survival of larvae of *Diabrotica balteata* and *Cerotoma facialis* fed with the maize hybrid ICA H-207 or the bean variety Diacol Calima.**

| Age of larvae (days) | Live *D. balteata* | | Live *C. facialis* | |
|---|---|---|---|---|
| | on maize[1] | on beans[1] | on maize[1] | on beans[1] |
| 1 | 20 | 20 | 20 | 20 |
| 4 | 20 | 10 | 0 | 19 |
| 8 | 19 | 4 | - | 13 |
| 12 | 18 | 2 | - | 12 |
| % survival | 90 | 10 | 0 | 60 |

1 Four days after germination; average of 20 replications.

Table 34.

**Number of chrysomelid larvae found in the soil of associated bean and maize crops three to six weeks after planting beans.**

| Days after bean planting | Maize planting with respect to beans | Total larvae in | | Total larvae in | |
|---|---|---|---|---|---|
| | | beans | maize | beans | maize |
| 21 | 14 days before | 0 | 7 | 0 | 0.3 |
| | simultaneously | 0 | 0 | 0 | 0 |
| | 14 days after | 0 | 0 | 0 | 0 |
| 28 | 14 days before | 0 | 11 | 0 | 0.6 |
| | simultaneously | 3 | 4 | 0.3 | 0.3 |
| | 14 days after | 1 | 0 | 0.1 | 0 |
| 35 | 14 days before | 2 | 25 | 0.2 | 1.2 |
| | simultaneously | 11 | 23 | 0.9 | 1.2 |
| | 14 days after | 4 | 0 | 0.4 | 0 |
| 42 | 14 days before | 1 | 12 | 0.1 | 0.6 |
| | simultaneously | 1 | 47 | 0.1 | 2.9 |
| | 14 days after | 2 | 7 | 0.2 | 0.5 |

Table 35.

**Foliar area, in terms of percentage foliar area of the control, after bean plants were infested with 10 larvae of *Diabrotica balteata* per plant, under greenhouse conditions.**

| Instar | Days after planting when infested: 0 | 1 | 4 | 7 | 14 | 21 | Average |
|---|---|---|---|---|---|---|---|
| First | 99.0 | 73.0 | 105.7 | 102.7 | 98.2 | 102.2 | 96.1 |
| Second | 11.0 | 12.5 | 75.7 | 73.5 | 96.0 | 89.3 | 67.7 |
| Third | 12.6 | 8.5 | 7.6 | 0 | 98.3 | 104.7 | 33.8 |

In beans stored in the Cauca Valley, the first attack by *Zabrotes* occurred at nine months into storage. All treatments greatly reduced insect attack compared with the control. On only one farm was a light attack of bruchids noted in beans treated with oil.

## Biology of *Cerotoma facialis*

To complement information reported last year (CIAT Annual Report, 1977), more studies were done on the biology of *Cerotoma facialis,* another important chrysomelid pest of beans. In the laboratory, eggs hatched within 4 to 5 days and the three larval instars lasted 4 to 5, 3 to 4 and 3 to 5 days, respectively. The prepupal stage was 3 to 4 days and the pupal period, eight days. The period from egg to appearance of the adult is thus 26 to 32 days.

Also in the laboratory, *Diabrotica balteata* survived better on maize than on beans, while *C. facialis* did not develop on maize (Table 33). In the field, in associated cropping systems, the highest incidence of chrysomelid larvae on bean roots occurred 35 days after planting and when planting was at the same time as the maize. The lightest attack occurred when maize was planted two weeks earlier than beans (Table 34).

Table 36.

**Average yields per bean plant (var. Diacol Calima) under different periods of attack at various levels of infestation by *Diabrotica balteata* adults.**

| Days after seeding when attack occurred | No. of adults per plant: 0 | 2 | 4 | 6 | Average |
|---|---|---|---|---|---|
| | Yield (g/plant) | | | | |
| 8-15 | 3.08 | 2.50 | 2.10 | 0.95 | 2.16 b[1] |
| 15-22 | 2.59 | 3.57 | 3.03 | 3.18 | 3.09 a |
| 22-29 | 2.67 | 2.98 | 2.47 | 2.25 | 2.59 ab |
| 29-36 | 2.53 | 2.46 | 2.48 | 2.28 | 2.44 ab |
| Average | 2.72 c[1] | 2.88 c | 2.52 cd | 2.17 d | |

1 Average values followed by the same letter are not significantly different at the 0.05 level.

In expanding the work on larval damage of *D. balteata* on bean plants (CIAT Annual Report, 1977), it was found that plants less than 14 days after seeding had the most severe damage from third instar larvae. Severe damage was not observed on older plants, possibly because of their tougher stems (Table 35).

In the field, high infestation levels by adults (4 to 6 per plant) did not severely reduce bean production, except when damage occurred in the first two weeks after planting, and to a lesser extent, during the flowering stage (Table 36).

# VALIDATION OF TECHNOLOGY IN ON-FARM TRIALS

Farm level activities are essential in all phases of international agricultural programs. In the initial stages farm interviews identify constraints to yield increases using current varieties and practices, and serve as an input into general research design. Combining this constraint identification with the breeder's judgements on the feasibility of obtaining desired plant characteristics permits definition of a strategy for germplasm evaluation and crossing programs. In the Bean Program this stage was essentially finished in 1978, and primary emphasis moved toward the testing of promising new varieties and agronomic practices, and of the technical barriers which could limit their success at the farm level. In 1978 the Bean Program undertook on-farm studies in Huila (Colombia) and Antioquia (Colombia).

## Huila

### Current Situation in Huila

Beans are generally planted following more valuable crops such as tomatoes, either in monoculture or intercropped with maize. In the region the average altitude is 900 to 1250 masl with an average temperature of 20°C and an annual rainfall of 1200 mm. The primary growing season for beans in this region is from March to July with a second season from September until December. Most farmers do not utilize fertilizer because the residual effect of the previous crop is still available and beans are mostly grown on soil with good fertility. Planting is still conducted principally by hand although there is some mechanized planting. In the predominant manual planting system, each hill receives two or three seeds and the distance between the holes is variable. This planting technique results in low plant population and no distinct planting pattern. Weeding, when done, is carried out three weeks after germination. Unfortunately, the planting and weeding times of bean in both semesters coincide with the coffee picking season, when very high daily wages can be earned. Hence, weeding is done irregularly or not at all.

### Effects of Different Factors in Huila On-farm Trials

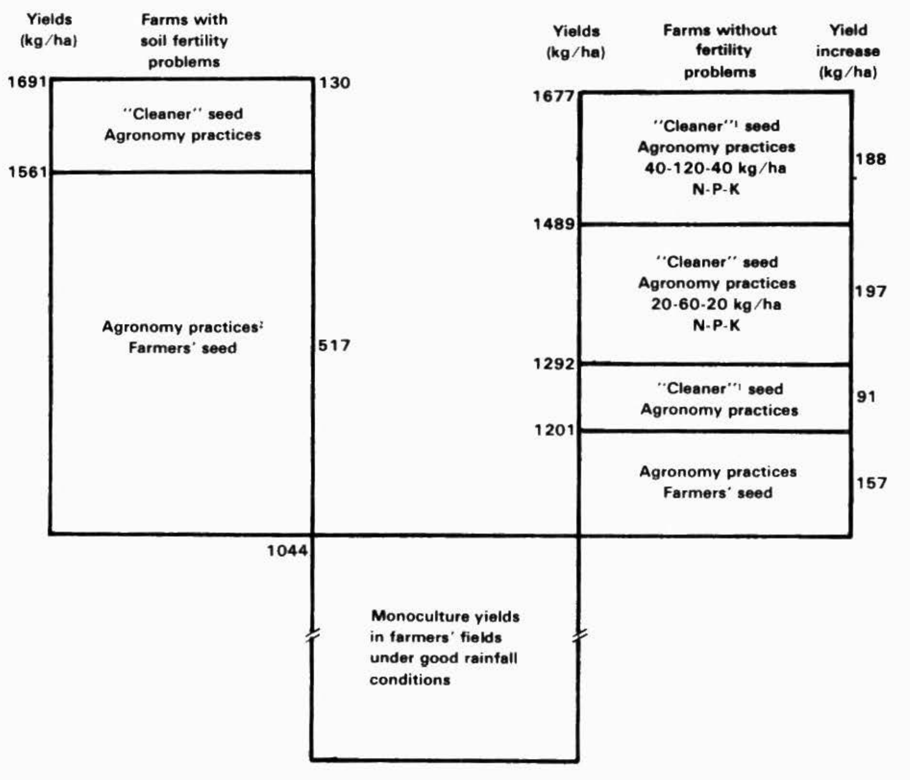
Based on experimental results and previous farm level testing (CIAT Annual Report, 1977) the technologies evaluated in 1978 were; (1) Increased density in monoculture: Population density was increased fron 9 to 18 plants/m$^2$; (2) Curative spraying; Fields were sprayed once to control anthracnose and *Empoasca;* (3) Use of Certified or "cleaner" seed (disease-free or nearly so) of the Colombian variety, Calima. Cleaner seed was produced under rainfed conditions but with intensive chemical protection. (4) Different levels (0, 200 and 400 kg/ha) of the complete fertilizer 10:30:10 were applied.

Monoculture yields under normal farmers' conditions were favored by excellent rainfall distribution and reached 1044 kg/ha (Fig. 36) when there was no soil fertility problem, the utilization of better agronomy practices with the farmer's seed increased yields to 1561 kg/ha, or 50%. These agronomy practices are low-cost ones involving curative spraying after the pest problem (anthracnose or *Empoasca)* was identified in the field and weeding at the apparent optimum time before flowering. The use of cleaner seed slightly improved yields by 130 kg/ha.

On those farms with a fertility problem (defined as below the critical level of one of the principal nutrients)[1] the combined effect of all four technologies was necessary to raise the yields to equivalent levels of the other group (Fig. 36). On these soils fertilizer use did increase yields. The simple agronomy changes with farmers' seed only increased yields 15%.

Yield increase is not a sufficient validation of new technology. Profitability and risk must also be considered. On farms

1 See Sánchez, P.A., *Properties and Management of Soils in the Tropics,* John Wiley and Sons, New York, N.Y., 1976.



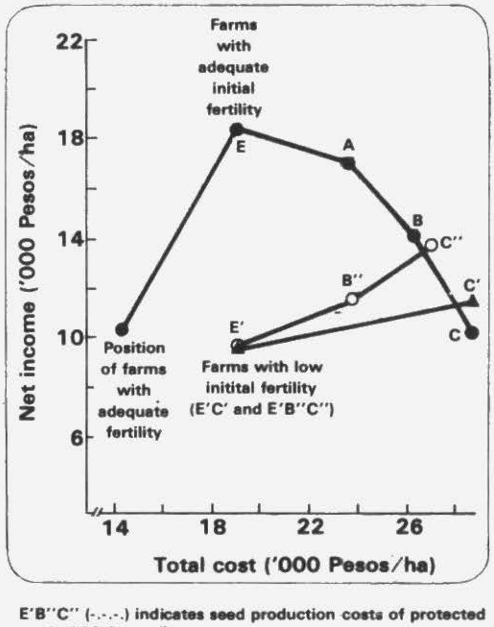

1 "Cleaner" seed refers to heavy chemical protection in Popayan. True disease-free seed will soon be available from an irrigated site. Variety is Diacol Calima.

2 Includes curative spraying and weeding at the optimal period before flowering.

Figure 36. Effects of different factors on yields in farm trials, Huila, Colombia, 1978A.

without a fertility problem the choice is simple. All other technologies besides optimum weeding with curative spraying *decrease* income. On farms with a fertility problem the high fertilizer/improved seed combination was more profitable, but also involved higher production costs than the weeding/curative spraying treatment with the farmer's seed. The farmer could choose from the low cost technology of good agronomy with his own seed (E') or the more profitable but higher cost use of fertilizer and cleaner seed (B" and C") (Fig. 37).

It was possible to determine the payoff to fertilization with soil tests and the definition of minimum initial nutrient levels. In most cases, in these alluvial soils and often following the highly fertilized tomatoes, fertilization was not profitable. Neither was seed quality very important. Certified seed from the Cauca Valley actually gave lower yields, although not significantly lower, than farmers' seed. It is important not to underestimate the farmer, who correctly preferred his own seed to certified seed. Finally, curative spraying, along with weeding at the optimum time gave a reasonable yield increment and was profitable with farmer's seed. Moreover, these yields of almost 1.7 t/ha help define the breeding requirement. A new variety with different seed type characteristics (the same color) would probably need to yield at least 2 t/ha on farmers fields in Huila to improve upon farmers' seed with good agronomy practices, and therefore be accepted by farmers.




E'B''C'' (-.-.-.) indicates seed production costs of protected seed of 50 Pesos/kg.

E'C' represents seed production cost of 70 Pesos/kg.

A: Protected seed, no fertilizer, good agronomic practices.

B: Protected seed, 20-60-20 kg/ha N-P-K, good agronomic practices.

C: Protected seed, 40-120-40 kg/ha N-P-K, good agronomic practices.

E: Farmers' seed, good agronomic practices including curative spraying and 2 weedings.

Figure 37. Net income and total costs per hectare of alternative technologies for two initial soil fertility situations, in southern Huila, Colombia, 1978A.

## Antioquia

On-farm trials in Antioquia were initiated in July 1978, and so only preliminary results are available. The technologies evaluated were: (1) Improved density and better support systems; (2) Improved anthracnose control with chemicals; and (3) Inoculation with rhizobia at several P levels.

While results of this study will be available in detail in 1979, the problems identified in the inoculation technology, evident soon after planting, have prompted detailed studies at the farm level.

### Inoculant Studies in Antioquia

Initial studies indicated two major problems in the inoculation methodology: (1) competititon for nodule sites by native soil rhizobia, and, (2) need for fungicide application to overcome root rot problems and the possible deleterious effect of this on applied inoculants.

Fifteen farms were surveyed for incidence of native soil *Rhizobium*. Most probable number counts of soil at planting showed populations of *Rhizobium* from 102 to 58,880 cells/g soil (mean 6344 rhizobia/g soil). For most soils competition between native soil rhizobia could be expected, and must be studied. A complicating factor is that more than 30% of the isolates tested reacted serologically with antiserum against CIAT 57, the normal inoculant strain. Furthermore, many of the rhizobia isolated from nodules of test plants were ineffective in $N_2$ fixation, with fixation ($C_2H_4$) levels in 10 farms surveyed at flowering varying from 0 - 31.7 μmol $C_2H_4$ produced/plant/hour (Fig. 38). More detailed studies of inoculation problems in this region are underway, as are studies on achieving compatability between inoculant and fungicide on seeds.

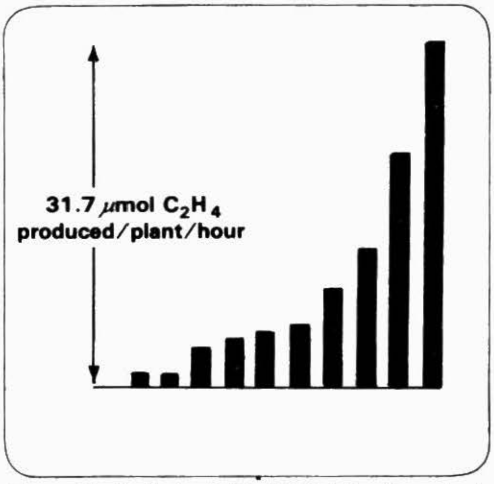



Figure 38. Variation in $N_2$ ($C_2H_2$) fixation rates in farmers' fields, in Antioquia.

# COLLABORATIVE ACTIVITIES UNDERTAKEN IN 1978 WITH NATIONAL PROGRAMS AND SPECIFIC INSTITUTIONS

Numerous collaborative activities including distribution of IBYAN experiments, rust resistance nurseries and germplasm and hybrid materials have been discussed in the previous sections.

## Collaborative Activities in Central America and the Caribbean

In late 1977, and following requests from several governments, CIAT relocated one of its bean scientists in Costa Rica, charging him with coordination within the region of the following activities:

- Supply of CIAT germplasm to national programs.
- Supply of advanced hybrid material to national programs.
- Supervision of international trials (IBYAN, IBRN et.) in the region.
- Cooperation in technical reunions, including the PCCMCA meetings.
- Selection of trainees for bean courses at CIAT and advanced degrees.

Major advances in 1978 have been in the identification of collaborators to receive IBYAN and other nurseries, and an increased efficiency in the prompt delivery, planting and supervision of CIAT trials. Numerous trainees for short courses have been identified, and four candidates suggested for MS degrees.

## Collaborative Activities with Other Institutes

### Cornell University

A collaborative study at Cornell University (U.S.A.) has studied phytochrome controlled photomorphogenic effects on stem elongation in indeterminate beans. This effect, controlled by a single gene, could be responsible for growth habit instability in particular lines and environments. The screening of CIAT germplasm material for this trait is underway.

### Oregon State University

Studies at Oregon State University (U.S.A.) and CIAT compared mulching effects on symbiotic $N_2$ fixation, and the distribution of $C^{14}$ labeled photosynthate to nodules at different stages of plant development.

Mulching lowered maximum soil temperatures, reduced temperature fluctuations, and slowed soil moisture loss. Nitrogen fixation rates were tripled, and nodule weight increased 50%. Differences in the carbohydrate content of leaves and roots were also noted.

Distribution of $C^{14}$ labeled carbohydrate in the cultivar P498 differed with leaf node treated. Leaves at node 4, treated 35 days after planting, translocated 86% of the $C^{14}$ label to roots, nodules and lower stem. At flowering 19% of the label was recovered in nodules. Photosynthate from leaves at node 8 did not pass to nodules.

### Rothamsted Experimental Station

At Rothamsted (U.K.) the photoperiodic sensitivity of the cultivar P566 (CIAT Annual Report, 1975) was used to evaluate the effect of delayed flowering on $N_2$ fixation. As in the previous study a six-day delay in flowering markedly increased yield. Nitrogen fixation was similarly increased, the yield of more than 3 t/ha in the later flowering treatment being obtained without added fertilizer N.

### Plant Breeding Institute, Wageningen

Collaborative studies at Wageningen, the Netherlands, funded through the Dutch government, emphasize breeding for resistance to necrotic strains of BCMV and to races of anthracnose not currently identified in Colombia. This permits breeding activities dangerous to undertake in Colombia.

### University of Gembloux, Belgium

Studies at Gembloux, financed through the Belgian government emphasize wide crossing between *P. vulgaris* and other *Phaseolus* spp. and the collection and characterization of additional germplasm. Two Belgian technical experts are currently at CIAT and coordinate this research.

## TRAINING

Some details of CIAT training activities are provided in the previous section on international collaboration. The Bean Program in 1978 received two Postdoctoral Fellows, two Visiting Research Associates, four Research Scholars, 28 Postgraduate Interns, two Special Trainees and 59 participants in short courses. Twenty-one countries were represented, the greatest number of trainees being from Brazil (20), Colombia (12), Honduras (9) and Costa Rica and Peru (6). Principal discipline specialities were agronomy (11), plant pathology (9) and plant breeding (7).

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# APPENDIX A

## Description of growth habits of *Phaseolus vulgaris* L. used in this Annual Report

**TYPE I:** Determinate growth habit; reproductive terminals on main stem; with no further node production on the main stem after flowering commences.

**TYPE II:** Indeterminate growth habit; vegetative terminals on main stem with node production on the main stem after flowering commences; erect branches borne on the lower nodes of the main stem; erect plant with relatively compact canopy; guide development variable depending on environmental conditions and genotype.

**TYPE IIIa:** Indeterminate growth habit; vegetative terminals on the main stem with node production on the main stem after flowering; relatively heavily branched with variable number of prostrate branches borne on the lower nodes; guide development variable but generally showing no climbing ability.

**TYPE IIIb:** Indeterminate growth habit; vegetative terminals on the main stem with node production on the main stem after flowering; relatively heavily branched with variable number of facultatively climbing branches borne on the lower nodes; main stem guide development variable but generally showing climbing ability.

**TYPE IVa:** Indeterminate growth habit; vegetative terminals on the main stem with heavy node production after flowering commences; branches not well-developed compared to main stem development; moderate climbing ability on supports and pod load carried evenly along the length of the plant.

**TYPE IVb:** Indeterminate growth habit; vegetative terminals on the main stem with heavy node production after flowering commences; branches not well-developed compared to mainstem development; strong climbing tendency with pod load mostly borne on the upper nodes of the plant.

**NOTES:** The growth habit classification has been expanded for the climbing types since the 1977 Annual Report. Type III materials with some tendency to climb are now recognized as Type IIIb and Type IV has been divided on the basis of vigor and pod distribution.

The most important distinguishing features of the growth habits are as follows: terminal raceme on main stem for Type I; indeterminate with erect branches for Type II; indeterminate with prostrate branches for Type IIIa; indeterminate with semi-climbing mainstem and branches for type IIIb; indeterminate with moderate climbing ability and pods distributed evenly up the plant for Type IVa; indeterminate with aggressive climbing ability and pods carried mainly on the upper nodes of the plant for Type IVb.

Growth habit is not necessarily a stable characteristic since changes in growth habit may occur from one location to another. The classification of growth habit for a particular genotype is only useful in a defined environment, particularly with regard to climbing ability.

# APPENDIX B

## List of Promising Lines of *Phaseolus* referred to in the 1978 Bean Program Annual Report.

| Program Promising No. | CIAT Accession No. | Identification or Registration | Source |
|---|---|---|---|
| P004 | G2115 | PI 310 878 | USA |
| P006 | 2005 | PI 310 739 | USA |
| P009 | 2959 | Pecho Amarillo | GUA |
| P014 | 2146 | PI 310 909 | USA |
| P046 | 0101 | PI 151-380 | USA |
| P083 | 0239 | PI 169 775 | USA |
| P084 | 0241 | PI 169 779 | USA |
| P085 | 0244 | PI 169 784 | USA |
| P105 | 0380 | PI 171 790 | USA |
| P166 | 0677 | PI 181 892 | USA |
| P172 | 0706 | PI 183 705 | USA |
| P179 | 0684 | PI 181 996 | USA |
| P217 | 1280 | PI 205 208 | USA |
| P225 | | | USA |
| P260 | 1098 | PI 282 074 (Ocanero) | USA |
| P271 | 1659 | PI 300 680 | USA |
| P277 | 1675 | PI 304 120 | USA |
| P300 | 1757 | PI 308 913 | USA |
| P302 | 1820 | PI 309 804 | USA |
| P326 | 2006 | PI 310 740 | USA |
| P337 | 2045 | PI 310 797 | USA |
| P353 | 2327 | PI 311 992 | USA |
| P363 | 2541 | PI 313 654 | USA |
| P382 | 3647 | Actopan | VEZ |
| P392 | G4498 | Sanilac | USA |
| P402 | 3807 | Brasil 2 (Bico de Ouro) | VEZ |
| P420 | 3607 | C.C.G.B. -44 (I-462) | VEZ |
| P423 | 3842 | Colombia I-1156 | VEZ |
| P438 | 3131 | F. negro (GUA-0325) | GUA |
| P449 | 3451 | Guanajuato 116A | MEX |
| P458 | 14454 | ICA Tui | CLB |
| P459 | 3645 | Jamapa (I-810) | VEZ |
| P472 | 3465 | Michoacan 12 | MEX |
| P476 | 4000 | Nep Bayo 22 (C-286) | CRI |
| P482 | 3994 | Olive Brown (C-236) | CRI |
| P492 | 3341 | Puebla 87 | MEX |
| P498 | 3353 | Puebla 152 | MEX |
| P499 | 3359 | Puebla 172 | MEX |
| P503 | 3371 | Puebla 298 | MEX |
| P512 | 4122 | S-166-A-N (N-555) | CRI |
| P518 | 3689 | S-315-N (I-957) | VEZ |
| P524 | 4421 | S-630-B (C-63) | CRI |
| P526 | 3872 | Trujillo 3 | VEZ |

| Program Promising No. | CIAT Accession No. | Identification or Registration | Source |
|---|---|---|---|
| P527 | 3874 | Trujillo 7 | VEZ |
| P538 | G3709 | Veranic 2 (I-980) | VEZ |
| P539 | 3776 | Venezuela 2 (I-1062) | VEZ |
| P543 | 3800 | Venezuela 72 (I-1075) | VEZ |
| P548 | 3792 | Venezuela 48 (I-1079) | VEZ |
| P560 | 3834 | 51051 (I-1138) | VEZ |
| P561 | 4152 | 50609 (N-283) | CRI |
| P566 | 4495 | Porrillo Sintético | HON |
| P567 | 5478 | Tara | PRI |
| P568 | 5479 | PR-70-15R87 (PR-5) | PRI |
| P588 | 4455 | ICA Huasaño | CLB |
| P589 | 2525 | PI 313 624 | USA |
| P590 | 5702 | Cargamanto | CLB |
| P623 | 4458 | 27R | CRI |
| P635 | 4452 | ICA Guali | CLB |
| P637 | 4523 | Línea 17 | CLB |
| P643 | 4459 | NEP - 2 | CRI |
| P654 | 4035 | S-490 B | CRI |
| P675 | 4525 | Línea 32 (ICA Pijao) | CLB |
| P684 | 1320 | PI 207 262 (Tlalnepantla 64) | USA |
| P692 | 4494 | Diacol Calima | CLB |
| P693 | 5653 | Ecuador 299 | ELS |
| P698_ | 5476 | Jules | USA |
| P699 | G5652 | Mexico 309 | ELS |
| P700 | 5706 | Jalpatagua 72 | GUA |
| P706 | 5701 | Rojo 70 | ELS |
| P708 | 4473 | Titan | CHL |
| P709 | 4485 | Turrialba 1 | GUA |
| P717 | 5711 | Comp Chimaltenango 2 | GUA |
| P720 | 0832 | PI 200 974 | USA |
| P723 | 5213 | Brasil 1096 (I-113) | BRZ |
| P730 | 2206 | PI 311 818 | USA |
| P732 | 2545 | PI 313 658 | USA |
| P738 | 4524 | Línea 29 | CLR |
| P749 | 2303 | PI 311 359 | USA |
| P750 | 4128 | Santo Tomás 8N N-595 | CRI |
| P752 | 3758 | Negro Argel | CHL |
| P755 | 4460 | Pompadour 2 | CRI |
| P756 | 4445 | Ex-rico 23 | CLB |
| P757 | 4461 | Porrillo 1 | CRI |
| P758 | 4446 | Ex-puebla 152 (Brown seeded) | MEX |
| P759 | 0076 | Red kloud | USA |
| P785 | 5141 | BRZ 805 Michoacan 75 | BRZ |
| P788 | 1540 | PI 284 703 | USA |

# APPENDIX C

## List of CIAT accessions (not classified as Promising Lines) of *Phaseolus* referred to in the 1978 Bean Program Annual Report.

| CIAT Accession No. | Identification or Registration | Source |
|---|---|---|
| *P. vulgaris* | | |
| G0124 | PI 163 372 | USA |
| 0413 | PI 173 017 (Barbunya) | USA |
| 0881 | PI 203 958 (N-203) | USA |
| 1257 | PI 201 300 | USA |
| 1813 | PI 309 796 | USA |
| 1841 | PI 309 866 | USA |
| 1873 | PI 310 531 | USA |
| 2092 | PI 310 854 | USA |
| 2227 | PI 311 861 | USA |
| 2258 | PI 311 904 | USA |
| 2325 | PI 311 990 | USA |
| 2351 | PI 312 030 | USA |
| 2540 | PI 313 653 | USA |
| 2545 | PI 313 658 | USA |
| 2546 | PI 313 659 | USA |
| 2801 | PI 319 597 (F. Almendrilla) | USA |
| 3038 | IAS (107) | Guatemala |
| 3130 | F. Negro (324) | Guatemala |
| 3134 | F. Negro (329) | Guatemala |
| 3371 | Puebla 298 | Mexico |
| G3565 | Oaxaca 39 | Mexico |
| 3716 | Snandresi | El Salvador |
| 3736 | Alabama 1 | USA |
| 3738 | Beurred' Paul Inat | France |
| 3762 | Negro de Guatemala | Venezuela |
| 3777 | Venezuela 4 | Venezuela |
| 3783 | Venezuela 24 | Venezuela |
| 3791 | Venezuela 47 | Venezuela |
| 3988 | 51054 | Costa Rica |
| 4463 | Turrialba IN | Costa Rica |
| 4721 | San Martin 8 | Peru |
| 4826 | Pintado | Brazil |
| 5508 | Rezayeh | Iran |
| 5710 | G.N UI. 31 | USA |
| 5752 | Bountiful 181 | USA |
| 5772 | Diacol Andino | Colombia |
| 5773 | ICA Pijao | Colombia |
| 5942 | PR-70-15R-55 (PR3) | Puerto Rico |
| 6636 | Cultivar de Haiti 226 | Haiti |
| 6638 | 47 | Haiti |
| 6640 | 157-A | Haiti |
| 6641 | Cultivar de Haiti 157-B | Haiti |
| 7464 | Far-lan-tou (NI-275) | China |

| CIAT Accession No. | Identification or Registration | Source |
|---|---|---|
| 8058 | 59/3 (Pop. x Nep 2) | Uganda |
| G8059 | 59/4 (Pop. x Nep 2) | Uganda |
| 8062 | 59/7 (Pop. x Nep 2) | Uganda |
| 8063 | 60/1 (Pop. x Nep 2) | Uganda |
| *P. acutifolius* | | |
| 3568 | Oaxaca 43 | Mexico |
| 4401 | Oaxaca 88 | Mexico |
| 5917 | PI 319 443 | USA |
| *P. lunatus* | | |
| 1157 | PI 299 388 | USA |