~~BEAN PRODUCTION~~ SYSTEMS
PROGRAM
CENTRO INTERNACIONAL DE AGRICULTURA
TROPICAL

by

PETER H GRAHAM
Program Coordinator

I. Introduction

Dry beans (*Phaseolus vulgaris* L.) are important in the human nutrition of Latin America where middle and low income families are often unable to produce, or afford, sufficient animal protein. Traditionally beans have comprised as much as 10% by weight in diets of the region (Bressani, 1972), but per capita consumption is falling as production increases lag behind population growth rate (Sanders and Alvarez, 1978). Increased production is urgently needed, but must be realized in a predominantly subsistence crop which is rarely irrigated or adequately fertilized, which has shown limited response to changes in technology (Silva, Silva and Teixiera, 1976, J. H. Sanders and L. Alvarado, unpublished), and in which consistent research support for national research programs has been lacking (Roberts, 1970, Hernandez-Bravo, 1973, Pinchinat, 1973a).

Roberts (1970) in reviewing grain legume yields throughout the world, concluded that national and regional grain legume programs alone would be unable to achieve needed yield increases. To support them he proposed the establishment of multidisciplinary grain legume research programs undertaken through international research centers, and suggested CIAT as the center for bean research. Though some staff members worked on *Phaseolus vulgaris* prior to this time, an integrated bean research program was not initiated until the 1972-73 fiscal year.

Currently this program at CIAT has regional responsibility from the Consultative Group for International Agricultural Research (CGIAR) for research into bean production, has been requested by the Technical Advisory Committee (TAC) of the CGIAR to coordinate a regional research network for *Phaseolus vulgaris* in Latin America, and is recognized by the International Board for Plant Genetic Resources as the world center for *Phaseolus* germplasm.

This publication considers production and consumption trends for beans in Latin America and attempts to identify production and yield constraints in the region It reviews the development of the bean program over the last 5 years, and describes some achievements of the program to date Finally it outlines future research activities and realistically obtainable goals

II Production of Dry Beans in Latin America

In the period 1973-75 dry bean production in Latin America averaged 3 973 million tons/annum, approximately 32% of world output, and an increase of almost 15% over production figures for 1963-65 (Sanders and Alvarez, 1978) While 82% of this total was produced in Brazil and Mexico, countries where production increased relatively little, significant production increases were reported for Argentina, Bolivia, Colombia, El Salvador and Guatemala (see Table 1) In Argentina, production increased from 38,300 tons in 1964-65 to 108,700 tons in 1974-75 (INTA, 1977)

Yields in the region remained low, the average of 498 kg/ha being slightly less than for the 1963-65 period, and much inferior to the 1385 kg/ha obtained in the USA Yields and the rate of improvement in yields were less than those obtained with cereal grains and soybean over the same period (FAO Production Yearbooks, 1963-1975) Latin America, therefore, remained a net importer of beans, with bean prices sharply increased (Sanders and Alvarez, 1978)

These statistics occlude an extremely complex production situation In Argentina and Chile, two of the major bean exporters, bean production centers on relatively large holdings with considerable technical input possible (Hernandez-Bravo, 1973, INTA, 1977) Though other countries of

TABLE I

DRY BEAN PRODUCTION IN LATIN AMERICA 1963-65 and 1973-75[1]

ountry	Production ('000 tons)		Yield (kg/ha)		Imports (+) Exports (-) ('000 tons)		Per Capita Apparent Consumption (Kg/yr)	
	1963-65	1973-75	1963-65	1973-75	1962-64	1972-74	1962-64	1972-74
razil	2061 0	2246 0	659	561	9 8	21 7	25 4	24 2
exico	809 0	1011 3	410	646	-15 2	-47 0	22 1	21 4
rgentina	33 3	99 0	1051	907	-14 4	-50 0	2 8	2 3
hile	67 3	71 3	1047	1019	-31 8	-23 5	7 0	9 1
uatemala	49 7	70 0	585	678	1 1	2 6	13 2	12 2
olombia	42 0	71 3	555	717	2 0	- 5 8	5 6	5 7
onduras	52 7	51 7	697	669	-15 0	- 9 6	16 8	12 2
icaragua	41 3	44 3	765	760	- 2 3	0 3	22 9	18 1
aiti	40 3	43 7			0 5	0	9 6	9 6
l Salvador	17 0	36 3	623	737	15 0	0	12 4	8 5
eru	42 7	36 0	884	618	0 9	- 0 8	10 8	6 3
enezuela	39 0	34 7	457	440	31 1	35 5	8 7	6 2
cuador	26 3	33 7	503	527	0 1	0	11 8	8 6
araguay	26 3	32 3			1 1	0	13 2	17 6
ominican Rep	23 0	28 0	683	875	5 2	5 5	15 4	14 9
uba	27 3	23 7			53 9	90 7	11 5	12 9
olivia	14 0	20 3			0 2	- 0 1	5 4	6 0
osta Rica	15 7	11 7	316	474	0 4	7 7	11 8	8 8
anama	5 3	3 7			3 4	3 2	8 6	5 4
ruguay	4 0	2 0			1 4	2 0	3 2	2 3

Modified from Sanders & Alvarez, 1978

the region possess limited areas where large farms predominate, for example the Cauca Valley of Colombia (Andersen, Londoño and Infante, 1976, Londoño and Andersen, 1978), most tend toward smaller holdings, often on sloping land of limited fertility Thus, bean producing farms in El Salvador and Haiti average less than one hectare in size (Aguirre and Miranda, 1973, Scobie et al , 1974) Under such circumstances, the tendency is toward multiple cropping systems (Iunquera et al , 1972, Pinchinat, 1977) and minimal technical inputs (Bazan, 1975)

Bean color and, to a lesser extent, grain size preferences (Barrios, 1969, Moh, 1971, Flores, Bressani and Elias, 1973, Scobie et al , 1974) also complicate the production and consumption pictures Thus, though black seeded cultivars consistently outyield those of other seed color (Moh, 1971, CIAT, 1976), they would be poorly accepted in many countries (Moh, 1971, Flores et al , 1973) Since Cuba and Venezuela, the major bean importers, consume principally black beans, major swings in production occur as their needs and sources change

III Problems of Bean Production in Latin America

Under experimental conditions, *P vulgaris* can yield more than 5 0 tons/ha Pinchinat (1973) reports commercial dry bean yields of 4 0-5 0 tons/ha in the Constanza Valley, Dominican Republic, and even when associated with high densities of maize, yields close to 2 0 tons/ha have been reported (Desir and Pinchinat, 1976) Why then are regional yields so low?

Diseases and pests are undoubtedly a major factor in significantly lowering on-farm yields Wellmann and others (Wellmann, 1968, Ruppel and Idrobo, 1962, Vieira et al , 1971, Mancia and Cortez, 1975) cite more than

250 pathogens and 200-450 insects attacking this species

Gutierrez, Infante and Pinchinat (1975) reported bean common mosaic virus (BCMV), rust (Uromyces phaseoli), anthracnose (Colletotrichum lindemuthianum), angular leaf spot (Isariopsis griseola), powdery mildew (Erisyphe polygoni) and bacterial blight (Xanthomonas phaseoli) the pathogens of greatest importance in the 12 countries they surveyed (Table II) Surveys of disease incidence in individual countries (Echandi, 1966, Schieber, 1970, Costa, 1972, Belliard, 1975, Crispin and Campos, 1976) support this observation Losses to BCMV range from 53-96% (Laborde, 1967, Costa, 1972, Crispin, 1974, Hampton, 1975, Crispin and Campos, 1976) to bean rust from 18-82% (Carrijo, 1975, CIAT, 1975)), and to anthracnose as much as 97% (CIAT, 1975) Bean golden mosaic virus (BGMV) (Gamez, 1971, 1977, Costa, 1972, Costa and Cupertino, 1976), web blight (Thanetophorous cucumeris) (Crispin and Gallegos, 1963, Echandi, 1966, 1976), root rots (Shands, Vieira and Zaumeyer, 1964, Diaz-Polanco and Renaud, 1966, Costa, 1972) and halo blight (Psuedomonas phaseolicola) (Cardona and Skiles, 1954, Yerkes and Crispin, 1956, Costa, 1972, Belliard, 1975, Crispin and Campos, 1976) are also important pathogens, the threat posed by BGMV increasing in importance each year

The literature describing BCMV in Latin America is fragmentary, with few comparative studies Gamez (1977) reports BCMV common in all bean producing countries in Latin America but claims greater incidence and damage in Peru and Chile than in Central America Many regionally important varieties including Rico 23 (Costa, 1972), Alubia and Bonita Cristal (INTA, 1977) and ICA-Guali, Jalpatagua, and Pompodour (CIAT, 1976b) are susceptible to the virus

TABLE II

MAJOR DISEASES OF *PHASEOLUS VULGARIS* AND THEIR IMPORTANCE IN LATIN AMERICA

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

Source Gutierrez *et al* , 1975

+ indicates disease is of major importance

\- disease is of no particular importance

Numerous races of the pathogen have been identified in the region (Alvarez and Ziver, 1965, Guerra, Osores and Echandi, 1971, Ordosgoitty, 1972, Gamez, 1973), one unconfirmed report (Ordosgoitty, 1972) raising the possibility that necrotic strains of the virus (Drijfhout, 1975) occur in the region Two types of resistance to BCMV have been identified, tolerance and hypersensitivity (Hubbeling, 1963, Drijfhout, 1975) The former, in cultivars such as Robust or Red Mexican 35, is recessive and race specific with at least 8 races identified to date (Drijfhout, 1975, Drijfhout and Bos, 1977) The hypersensitive reaction, as occurs in Topcrop, Corbett Refugee and Amanda, is dominant, and epistatic to the individual race genes While both resistances have been used with success in breeding varieties for the USA (Horsfall et al , 1972, Silbernagel and Zaumeyer, 1973), breeders in Latin America have emphasized the Corbett Refugee resistance (Cafati and Alvarez, 1975) Neither resistance alone appears ideal for Latin American conditions This is because a) the hypersensitivity gene challenged with BCMV at temperatures around 30°C gives rise to a black root condition (Hubbeling, 1963), b) several race resistances would be needed to protect against already identified BCMV strains of the region (Alvarez and Ziver, 1965, Gamez, 1973, Ordosgoitty, 1972, Crispin and Campos, 1976) and c) with limited quarantine control in most countries, introduction of new or necrotic strains of the virus is a real possibility

Bean rust (Uromyces phaseoli) is endemic to Latin America, being most important in subtropical or mountainous regions to elevations of 2500 meters above sea level (Echandi, 1976) Many races have been identified (Echandi, 1966, Christen and Echandi, 1967, Netto, Athow and Vieira, 1969, Augustin and Costa, 1971a, Costa, 1972), with major swings in race frequency between seasons (Antunes, cited by Costa, 1972) or with the introduction of new cultivars (Augustin & Costa, 1971a) Many rust resistant cultivars exist (Costa, 1972, Horsfall *et al* , 1972, Coyne and Schuster, 1975) but few retain resistance over long periods of time or in all regions Thus Manteigao Fosco II was introduced as a rust resistant cultivar in Minas Gerais in 1960, was reported susceptible in 1968, and suffered severe damage in this state in 1969 (Vieira *et al* , 1971) Coyne and Schuster (1975) review breeding strategies for bean rust, and identify needs for effective breeding programs They emphasize the need for suitable differential varieties, identification of more resistant germplasm, and knowledge of the genetic control of rust resistance, and consider the different breeding strategies and gene deployments which could be used to overcome this pathogen

Though anthracnose (*Colletotrichum lindemuthianum*) requires temperatures around 24°C to initiate infection (Rahe and Kuc, 1970) it is a major pathogen in Argentina, Brazil and Mexico and in upland regions of most Central American and Andean zone countries (Yerkes and Crispin, 1956, Shands *et al* , 1964, Augustin and Costa, 1971b, Araujo, 1973, Oliari, Vieira and Wilkinson, 1973, Crispin and Campos, 1976, Crispin *et al* , 1976, Echandi, 1976, INTA, 1977) where 100% field infection can occur

While the differentials used remain to be standardized, 10 apparently distinct races of anthracnose have been identified in South and Central America The α race appears prevalent (Yerkes and Ortis, 1956, Kimati, 1966, Augustin and Costa, 1971b, Araujo, 1973, Oliari *et al* , 1973, Pio-Ribiero and Chaves, 1975, Echandi, 1976) but the races β (Yerkes and Ortis, 1956, CIAT, 1976), γ (Yerkes and Ortis, 1956), δ (Kimati, 1966, Pio-Ribiero and Chaves, 1975), Mexico 1, 2 and 3 (Yerkes, 1958, Kimati, 1965, Pio-Ribiero and Chaves, 1975), and Brasil 1 and 2 (Oliari *et al* , 1973, Oliviera, Antunes and Costa, 1973, Pio-Ribiero and Chaves, 1975) have also been identified The cultivar Cornell 92-242, identified by Mastenbroek (1960), has proved resistant to all currently important races of the region (Oliari *et al* , 1973, Pio-Ribiero and Chaves, 1975) and has been used increasingly in breeding for resistance Though several reviewers (i e Zaumeyer and Meiners, 1975) report undesirable linkages in this cultivar, none are cited by Mastenbroeck (1960) or evident in subsequent breeding programs Three additional and different sources of resistance identified by Bannerot, Devieux and Fouilloux (1971) and Fouilloux (1976) have not yet been evaluated in Latin America but provide reserves against the α Brasil race reported by Fouilloux (1975, 1976), the introduction of the kappa race (Hubbeling, 1975, Kruger, Hoffmann and Hubbeling, 1977) or newly emerging races

Angular leaf spot is perhaps the most underrated of the major pathogens, which despite intensive efforts at control in Colombia (Barros, Cardenosa and Skiles, 1957, Bastidas, 1977) continues to cause appreciable loss in many countries (Dias *et al* , 1965, Diaz *et al* , 1966, Crispin and Campos, 1976) Brock (1951), Olave (1958) and Santos-Filho, Ferraz and Vieira (1976) have each identified sources resistant to this disease, in the latter case demonstrating that resistance was due to a single recessive gene Strain relationships for this pathogen must still be elaborated

Coyne and Schuster (1974) reviewed studies with GN-Nebraska #1 Sel 27 and PI 207262, cultivars tolerant to *Xanthomonas phaseoli* in Nebraska, and concluded that tolerance was quantitatively inherited with different genes in each cultivar The susceptibility of these cultivars to Colombian and Ugandan isolates of the pathogen (Schuster et al , 1973, Ekpo and

Saettler, 1976, CIAT, 1976) and their poor adaption to warm, short-day conditions (D Webster, unpublished) will necessitate special methodologies to introduce tolerance into Latin American cultivars and to pyramid tolerance levels More detailed attempts at interspecific hybridization with the resistant *P acutifolius* (Horsfall *et al* , 1972) are justified

Seed transmission of pathogens such as BCMV, anthracnose, angular leaf spot and bacterial blight complicate the disease picture In the USA, grower's seed is produced in relatively dry areas with little disease, and must meet stringent quality standards (Copeland, Adams and Bell, 1975) Latin American bean producers have no such system of disease control In Brazil for example, only 0 5-3 8% of farmers use certified seed (Silva *et al* , 1972, Terra Wetzal, *et al* , 1972, Walder *et al* , 1977) In Minas Gerais, 59 1% of 338 farmers surveyed resowed harvested seed for between two and five years, while only 16% used pure line seed (Walder *et al* , 1977) Farmer's seed from Huila, Colombia averaged 40% germination and 81% internal fungal contamination (Ellis, Galvez and Sinclair, 1976) *Acrostalogmus*, *Alternaria*, *Aspergillus*, *Botrytis*, *Cladosporium*, *Colleototrichum*, *Fusarium*, *Isariopsis*, *Macrophomina*, *Monilia*, *Phomopsis*, *Rhizoctonia* and *Sclerotinia* spp were identified as seedborne contaminants in this study Sanchez and Pinchinat (1974) obtained an average germination of 68% in a similar study in Costa Rica

Empoasca species, principally *E Fabae* and *E Kraemeri*, are generally considered the insects most injurious to beans (Gonzalez, 1959, Bonnefil, 1965, Langlitz, 1966, Costa and Rosetto, 1972, Gutierrez *et al* , 1975) Gutierrez *et al* (1975) reporting significant damage by this insect in 11 of 12 countries they surveyed Yield losses of up to 96% have been reported (Chalfant, 1965, Diaz, 1971, Miranda, 1971), damage generally being greatest under relatively dry conditions with low soil moisture While intermediate levels of tolerance have been identified (Beyer, 1922, Wolfenbarger and Sleeman, 1961a) current control methods usually emphasize insecticides (Costa and Rossetto, 1972) and so can be unacceptable to small farmers

Apion godmani is a major bean pest in El Salvador, Guatemala, Mexico and Nicaragua (McKelvey, Guevara and Cortes, 1947, Enkerling, 1957, Mancia, Gracias and Cortes, 1972, Mancia, 1973a, Sommejier, 1977) with pod infestation ranging from 20-95% (Enkerling, 1957, Diaz, 1970, Mancia, 1973a) Varieties tolerant to the insect have been identified (Guevara, 1957, 1969, Mancia, 1972, 1973b) and integrated control systems proposed (Guevara, 1961), but control is mostly dependent on insecticide (Diaz, 1970, Mancia et al , 1972, Mancia, 1973a)

Epilachna varivestis, the Mexican bean beetle, is a major problem in Mexico, Guatemala, El Salvador and parts of the USA, causing yield losses of up to 75% (Paz, Reyna and Martinez, 1975) Existence of resistant cultivars is disputed (Wolfenbarger and Sleeman, 1961b, Campbell and Brett, 1966, Garcia and Sosa, 1973)

Storage insects, principally Acanthoscelides obtectus and Zabrotes subfasciatus are common throughout Latin America, but direct loss estimates are surprisingly low (Schoonhoven, 1976) Indirectly, these insects force the rapid sale of grain post-harvest and short-storage periods in granaries, and so cause post-season price collapse and marked seasonal price fluctuations (CIAT, 1977)

Nematodes have been little studied in Latin America but are reported important in Brasil, Chile, Mexico and Peru (Mellofilho and Lordello, 1970, Costa, 1972, Crispin et al , 1976, Jimenez, 1976)

Given the major disease and insect problems mentioned, one could expect extensive breeding programs aimed at introducing identified resistance genes into nationally important varieties   While genetically improved lines are available in several countries (Orosco, Cardona and Camacho, 1964, Vieira, 1970, 1974, 1977, Lopez, 1972, Cafati and Alvarez, 1975, Lopez and Andrade, 1975, Bastidas, 1977), and have improved yields (Cafati and Alvarez, 1975, Bastidas, 1977, Vieira, 1977), this is not generally the case   Instead major varieties such as Flor de Mayo and Jamapa (Mexico), Alubia and Caballero (Argentina), Tacarigua (Venezuela) and Pompadour (Dominican Republic) are mass or individual plant selections from unimproved land race cultivars (Crispin, 1968, Ortega and Barrios, 1972, INTA, 1977, F Saladin, unpublished)   Rico 23 was introduced to Brazil in 1954 (Vieira, 1959), is susceptible to BCMV, rust, anthracnose and bacterial blight (CIAT, 1976b) but remains one of the principal varieties in this country (Vieira, 1970, 1974, Vieira _et al_ , 1972) Seed color preferences presumably limit movement of improved genotypes between countries

Agronomic constraints, particularly problems of phosphorous or nitrogen deficiency, and soil acidity also contribute to poor yields Analysis of 110 Central American soils showed 20% of less than pH 6 0 (Muller _et al_ , 1968), 66% highly deficient in phosphorous (Fassbender, Muller and Balerdi, 1968) and 75% nitrogen deficient (Diaz-Romeu, Balerdi and Fassbender, 1970)   Central American bean fertilization trials, reviewed by Fassbender (1967) and Bazan (1975), show widespread response to nitrogen and phosphorous but not potassium

The situation is similar in Brazil   Malavolta (1972) reviews 232 bean fertilization trials covering 8 states, reporting responses to nitrogen (67 times), phosphorous (103), potassium (15), lime (31) and microelement combinations (17) Maximum yields of beans or maize in such soils can require more than 2 0 tons/ha P_2O_5 applied (CIAT, 1977), due to high phosphate fixation (Fox, 1974), so banding is essential for efficient fertilizer use Aluminum (Buol _et al_ , 1975) and manganese toxicities (Dobereiner, 1966) and Mo deficiency (Franco, 1977) also complicate fertilizer recommendations With the low nitrogen status of many soils it is unfortunate that _P vulgaris_ has proved weak in symbiotic nitrogen fixation Yield increases following inoculation have been reported (and are reviewed by Graham and Halliday, 1977) but inoculation failure is common Currently less than 1% of bean seed planted in Brazil receives inoculation (Araujo, 1974)

In Latin America, beans are often grown mixed or intercalated with other crops, principally maize, cassava or potatoes (Moreno, Turrent and Nunez, 1973, Andrade, Ramalho and Andrade, 1974, Londoño and Andersen, 1978) Many different systems exist, in some countries accounting for more than 80% of the bean area sown (Gutierrez _et al_ , 1975) Associated culture, the growth of two or more crop species together for much of their life cycle, does lead to lowered bean yield (Francis _et al_ , 1976, 1977, Londoño and Andersen, 1978) However, it is less risky and will normally provide better economic returns over a wide range of bean and maize prices than does monoculture (Lepiz, 1971, Moreno _et al_ , 1973, Andrade _et al_ , 1974, Soria _et al_ , 1975, Desir and Pinchinat, 1976) While yields close to 2 0 tons/ha in a 5 ton maize crop have been reported (Desir and Pinchinat, 1976), even experimental yields are often much less (Krutman, 1968, Santa Cecelia and Vieira, 1976) Common problems include relative density of maize and bean, time of planting, fertilization, and compatibility of cultivars

Intercalated cropping, the system where crops share the same soil for a part of their growth cycle, but at different stages of development, has not been studied as intensively, but is commonly less satisfactory Often the legume component is planted toward the end of the season and must battle drying conditions to flower and yield (Gomez and Sandstra, 1977, D R Laing, unpublished) Development of later maturing maize populations, as proposed for some regions of Central America, can only aggravate this problem

IV Objectives and Strategies of the CIAT Bean Program

The CIAT bean program has a single major objective, to increase the yield and productivity of field beans throughout Latin America Increases in production of at least 3% per annum are needed to match population growth rates, and even at a 6% per annum production increase, initial slight price falls would be offset by significantly increased demand among middle and low income families (Andersen, Londoño and Hoover, 1976) In contrast to the "green revolution" crops, rice and wheat, such yield increases would need to be effected in a predominantly subsistence crop which is rarely irrigated or adequately fertilized, and in which grain color preferences would affect acceptance of improved cultivars

The program would hope to achieve its goal through its active experimental program, through training and support for Latin scientists working in national programs, and through collaborative research both with Latin American and other laboratories Clearly its activities should not duplicate or compete with those of the national bean programs, but reinforce them in specific areas

Two major areas which CIAT can emphasize with comparative advantage are the maintenance, characterization and distribution of bean germplasm and the development of genetically improved materials which could be funnelled to appropriate national programs It has already been shown that a number of currently important varieties are unimproved landraces having limited disease resistance Major breeding programs are needed if yield is to be increased but several national programs have neither staff nor facilities to undertake them (Roberts, 1970, Pinchinat, 1973b) It is also duplicative and inefficient to maintain separate germplasm collections in each national program and to effect the same hybridizations in a number of locations CIAT therefore has tried to develop an innovative breeding approach which concentrates hybridization activities in only a few locations, but encourages the testing of early generation materials by appropriate national programs

What traits and breeding methodologies to emphasize? Jennings (1974) considers increase in yield potential the prime goal for any breeding program associated with static agriculture, and cites yield increases in rice following changes in plant height and grain to straw ratio The bean situation, however, appears quite different, especially in Latin America where only a small proportion of the crop is likely to be grown under high input technology Thus,

i) No traits of positive value equal to those discussed by Jennings have been identified in _P vulgaris_ Specific attributes have been proposed as breeding goals (Wallace, Ozbun and Munger, 1972, Adams, 1973) but yield gain to date has been limited

ii) The yield potential of beans is already 8-10 times, the yield obtained by most farmers (Cartree and Hanks, 1974, CIAT, 1974)

iii) Significant yield losses in beans following disease or insect attack were detailed in Section 3 The potential for rapid gain from disease breeding is evident in the 700 kg/ha yield increase achieved by Cafati and Alvarez (1975) following incorporation of BCMV resistance into the Chilean variety Tortola

iv) Resistance to multiple pathogens will be obtained most efficiently when a number of high yielding cultivars are combined with resistance sources early in the breeding process

Breeding for improved protein content and quality in beans (Milner *et al* , 1973, Wettwer *et al* , 1975) also seems unjustified at this time Though an understanding of the genetic control of seed protein biosynthesis is closer following recent research (Bliss and Hall, 1976, Yu Ma and Bliss, 1978), no major gene controlling protein biosynthesis or amino acid composition has been identified and broad sense heritability estimates for protein content are from low to medium (Bliss and Hall, 1976) Commonly, but not inevitably, percent protein is negatively correlated to yield (Evans, 1973)

Summarizing these points, it appears that the most logical approach for relatively short-term yield gains in beans is to emphasize disease and pest breeding, but simultaneously to widen available genetic diversity in characteristics such as lodging resistance, length of crop cycle, plant architecture, and the efficient translocation of energy reserves, which could increase the yield potential of the crop Protein content, quality and digestibility must be maintained near current levels

To this end the bean program has mounted a three pronged breeding program, as shown in Fig 1 "Mainstream" breeding activities emphasize resistance to BCMV, rust, anthracnose, angular leaf spot and *Empoasca* ,

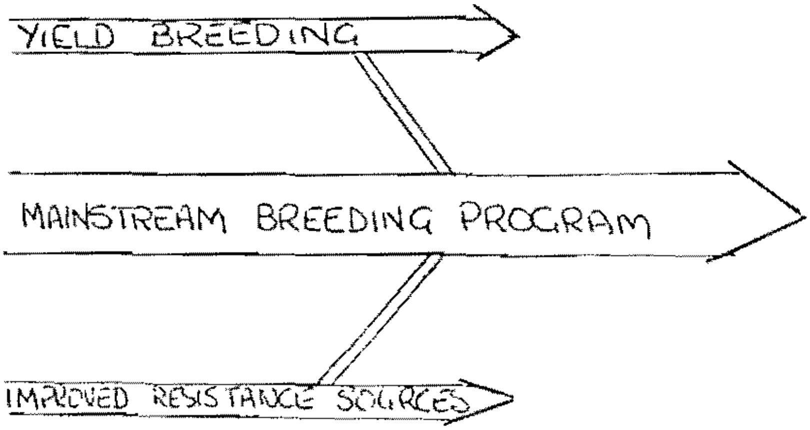


Fig 1. The CIAT bean-team uses a 3-pronged approach to the development of genetically improved materials, and emphasises transfer of promising materials to the mainstream breeding effort whenever possible

seeking to obtain multiple resistance in materials of high yield potential An early goal, to recover the superior yield potential of black seeded cultivars (Moh, 1971) in materials of other seed colors appears, already, to have been accomplished The variable growing conditions and seed color preferences of the different bean producing regions of Latin America for which hybrid materials are being developed, coupled with the need to transfer materials as rapidly as possible, have necessitated some departures from traditional breeding methodologies Thus,

i) four basic bean ideotypes corresponding to different production conditions of Latin America have been described (Table III) and are sought by program breeders

ii) early generation testing of hybrid materials at CIAT emphasizes disease resistance, permitting rapid reduction in the number of materials being handled, and the distribution of manageable populations of early generation material to national program scientists for evaluation of yield and adaptation, and for screening against local races of major pathogens Fig 2 shows the screening sequence for materials produced by the program

iii) in collaboration with the Biometry Unit, program breeders have developed a computer program (SIFFRI) to flag favourable genes likely to occur in segregating materials, and also to ensure that national programs receive only those materials which are likely to interest them

An implication of this methodology is that CIAT itself will produce few finished varieties Fig 3 outlines a possible time frame for the movement of disease resistant and higher yielding materials to national programs, and to farmer's fields

*

TABLE III

CHARACTERISTICS OF FOUR BEAN IDEOTYPES USED IN PHYSIOLOGICAL BREEDING PROGRAM

1 Common Features

2 Specific Attributes

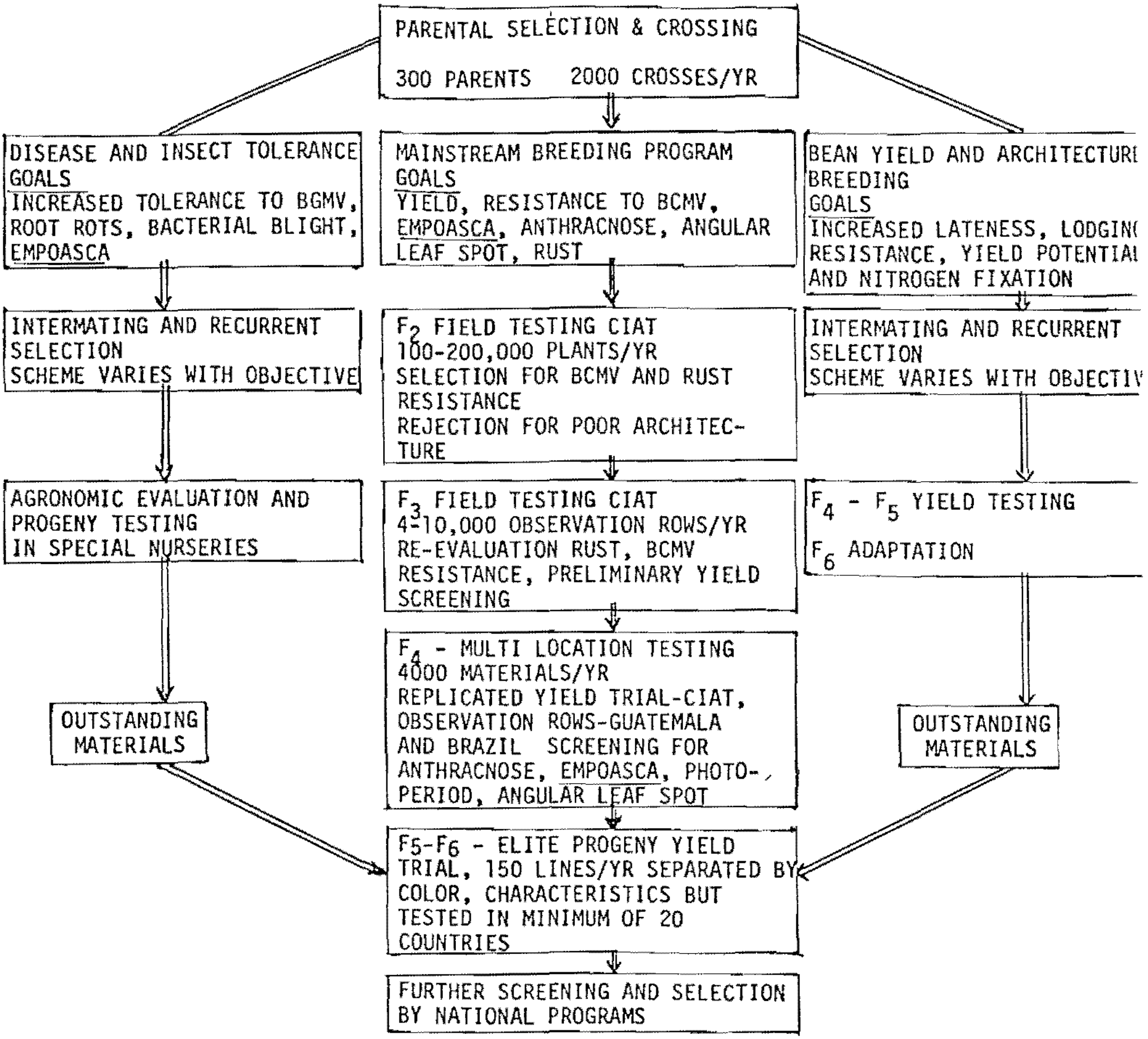
A

B

C

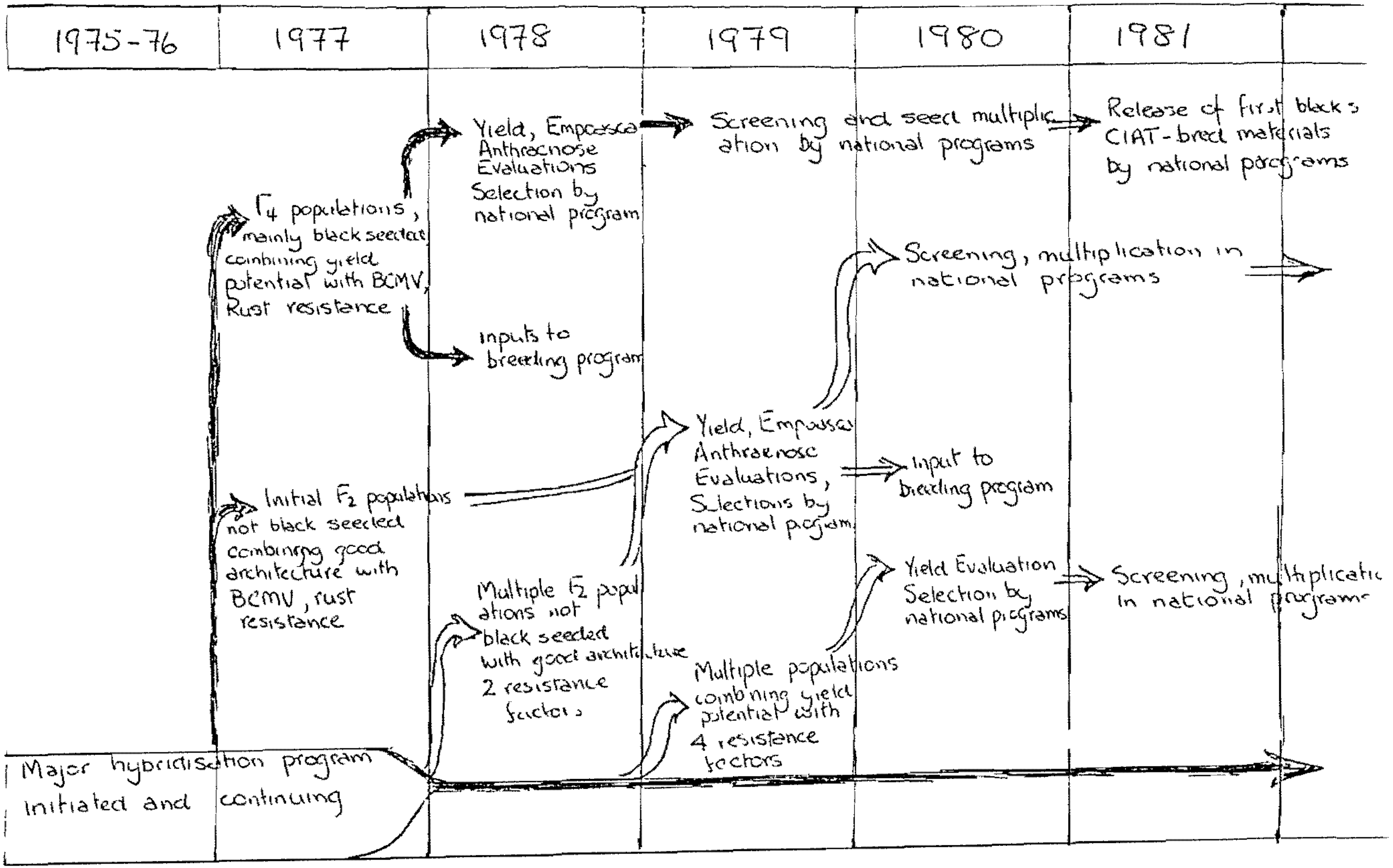
D

Figure 2. SEQUENCE OF PARENTAL SELECTION, HYBRIDIZATION AND PROGENY TESTING DISTRIBUTION AND EVALUATION, USED AT CIAT



FOOTNOTE This outline reflects the inputs of all program staff at CIAT but particularly reflects the work done by Drs S R Temple and S Singh

from CIAT to national programs and to farmers fields This was first prepar
in 1976 and currently is 6-12 months ahead of schedule



Paralleling mainstream breeding activities and feeding new materials directly to it, are programs to develop and improve specific physiological or disease resistance traits Areas under study include improvement in lodging resistance, development of lines with longer growth cycles, breeding for increased nitrogen fixation and pyramiding tolerance levels for diseases such as BGMV and bacterial blight As initial breeding goals are achieved, these activities will assume increasing importance in the breeding program

While the emphasis to the moment has tended to be with bush beans, yield increases with climbing cultivars are also important, particularly at the higher elevations Here the need to understand maize-bean interactions is a complicating factor, particularly for the low-input agriculture adopted in most mixed cropping systems Physiological, agronomic and microbiological studies of associated plantings are necessary, but would be difficult to mount within national program activities This situation is illustrative of another area where the multidisciplinary and international approach of the CIAT bean team can be highly effective

With new varieties and methodologies forthcoming, location specific agronomic and adaptation studies will be needed These will stress national programs who will need additional young scientists trained in practical field-oriented bean research Training is an integral part of bean program activities, and will be discussed in greater detail on page 26

V Staffing of the CIAT Bean Program

Current funding of the program is for a core scientific staff of 11 senior scientists, as shown in Table IV All positions reflect national

*

TABLE IV

SCIENTIFIC STAFF, BEAN PRODUCTION PROGRAM, 1978

Staff Member	Nationality	Research Field and Position	Research Assistants
P H Graham	Australian	Coordinator-Microbiologist[1]	J C Rosas & S Vitery
A v Schoonhoven	Dutch	A/Coordinator-Entomologist	L A Gomez &
J A C Davis	English	Breeder-Agronomist	S Garcia &
D R Laing	Australian	Physiologist	S Zuluaga & J Restrepo
N N ~~L Salazar~~	Peruvian	Virologist	M Castano &
J H Sanders	American	Economist	C Alvarez & N R de Londono
H F Schwartz	American	Mycologist	P Guzman & R Rivero
S P Singh	Indian	Breeder	R Campos
S Temple	American	Breeder	
M Thung	Indonesian	Agronomist-Soils	C Medina &
O Voysest	Peruvian	Agronomist	F Takegami &

---

[1] On sabbatical leave until August, 1978

programs needs, with breeding and pathology emphasized, as might be expected from previous discussion In addition a separate germplasm facility has been established at CIAT with Dr Lionel Song and Dr Robert Luze collaborating closely with bean program staff Two additional positions, for work with the ICTA bean program in Guatemala, have been provided through special fund support from USAID, and are currently filled by Dr S H Orosco (plant breeder) and Dr Kasuhiro Yoshii (Plant Pathologist) Recently Dr G E Galvez was named to the position of coordinator of bean research in Central America, stationed in San Jose, Costa Rica

VI Research Highlights of the CIAT Bean Team

It is impossible in this document to review exhaustively the various research activities of bean team staff Greater detail is available in the annual reports of the program, and in the publications of individual scientists (see Section VIII)

1) Research Locations

Experimentation in the period 1973-1977 has concentrated on 6 locations, representing a range of temperature, rainfall and soil conditions These are shown in Table V, in decreasing order of current importance Additional locations used for specific experiments or activities within Colombia, as well as sites of collaborative experiments in other countries are shown in Fig 22 Work in the extremely acid soil of the Colombian Llanos has been discontinued

2) Germplasm Evaluation

The CIAT collection of Phaseolus vulgaris is recognized by the IBPGR as the major holding of bean germplasm in the world The 16,000 plus accessions derived from more than 20 countries represent

TABLE V

CLIMATIC AND EDAPHOLOGICAL DATA FOR THE MAJOR LOCATIONS USED IN CIAT BEAN RESEARCH, 1973-1978

Location	Altitude (masl)	Mean Temp °C	Rainfall mm/year	Organic Matter (%)	pH	P content ppm Bray II	Soil Texture
1) CIAT, Palmira	1000	24.0	1000	6.80	6.9	46.3	Clay
2) Popayan[a]	1760	18.0	2500	7.56	5.0	2.4	Clay-Loam
3) CIAT, Santander							
4) Obonuco[b]							
5) Tibaitata[b]	2250	13.1	606				
6) Turipana[b]	13	28.0	1200	3.1	6.8	13.8	Clay

[a] In cooperation with the Secretaria de Agricultura de Cauca

[b] In cooperation with the Instituto Colombiano Agropecuario (ICA)

a wide genetic diversity in regard to plant type, flowering and maturity behavior, yield components, and disease and insect resistance Figures 4, 5 and 6 contrast specific characteristics of some germplasm accessions

Initial evaluation of the accessions disclosed some 800 materials with particular promise These have been intensively re-evaluated, some 50 descriptors in all, being considered Table VI gives mean values and range for some of the agronomic descriptors used, Table VII the response of accessions to long days, a factor likely to be important in moving germplasm between countries

Priority in pathology has been in screening for resistance to rust, BCMV, BGMV, web blight, anthracnose and bacterial blight, as shown in Table VIII Screening for tolerance to angular leaf spot was initiated in 1977 when economic surveys (p 25) showed appreciable loss to this pathogen in Colombian bean fields With the exception of BGMV, bacterial blight and web blight, for which only field tolerance has been identified to date, germplasm lines have been identified (or obtained from other sources) which are tolerant or resistant to each of the major pathogens of the region (see Table IX) Evaluation of the different resistance sources continues, in several cases revealing cultivars with multiple disease resistance (Table X)

Among insect pests emphasis has been on *Empoasca* species with more than 8000 cultivars evaluated since 1974 Differences in the susceptibility of cultivars to this insect are evident in Fig 7 Studies have also been initiated to confirm reports of resistance to *Hyelema*, *Apion*, and *Epilachna*

Fig 4 : Differcnees in maturity of bean cultivars grown in Popayan few really late maturing cultivars have been identified

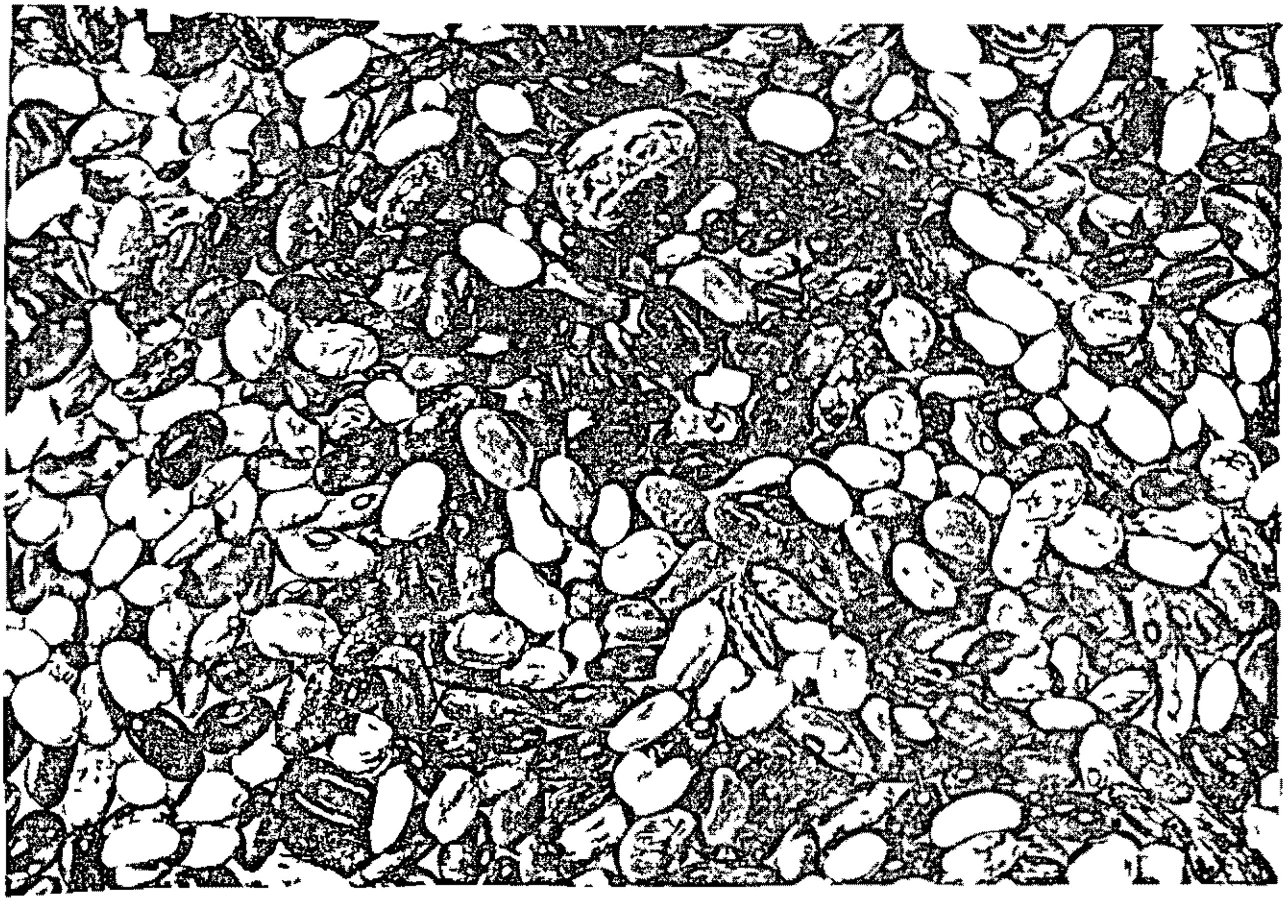


Fig 5 : Accessions of *P vulgaris* in the CIAT germplasm facility differ markedly in seed colour and size, a factor of considerable importance in satisfying different national program needs

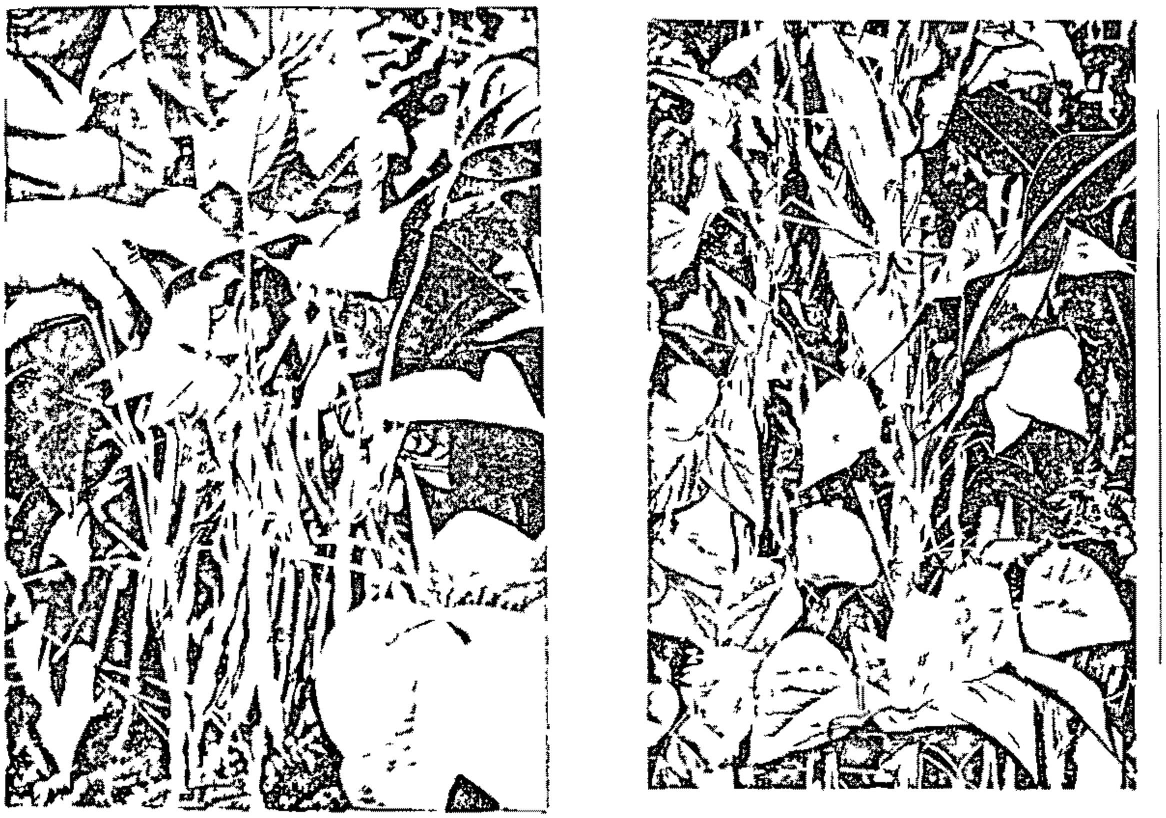


Fig 6 : Growth habit differences in *Phaseolus vulgaris*. The plant on the left is a bush cultivar which normally reaches 50-75 cms in height, on the right a climbing cultivar which can grow to heights of 2 m and which is normally grown associated with maize

TABLE VI

RANGE AND MEAN VALUES FOR SOME OF THE DESCRIPTORS USED IN DESCRIBING CIAT GERMPLASM ACCESSIONS (FROM CIAT, 1976b)

Descriptor	Unit	Accessions	Mean Value	Range
Time for emergence	Days	779	5 4	4 to 12
Hipocotyl length	mm	775	39 4	18 to 69
Canopy Height	cm	635	44 8	23 to 69
Node No at flowering	--	773	13 3	5 to 30
Time to first flower	Days	780	37 2	31 to 82
Plant Height	cm	768	79 8	13 to 257
Racemes/plant	--	753	11 5	2 to 51
Pods/plant	--	754	16 9	3 to 79
Seeds/pod	--	759	5 0	2 to 9
Yield	g/plant	754	11 0	2 to 45

TABLE VII

PHOTOPERIOD RESPONSE OF 808 ACCESSIONS OF P VULGARIS TESTED AT CIAT FROM 1975-1977[1]

	Photoperiod Response					Total Accessions Tested
Classification	1	2	3	4	5	
Days flowering delayed[2]	<4	4-10	11-20	21-30	>30	
Growth Habit						
I	97 (43)	22 (10)	59 (26)	30 (13)	18 (8)	266
II	163 (55)	40 (14)	67 (23)	17 (6)	7 (2)	294
III	61 (30)	26 (13)	41 (20)	38 (18)	40 (19)	206
IV	15 (18)	7 (9)	18 (22)	10 (12)	32 (39)	82
Accessions/response group %	336 (41)	95 (12)	185 (23)	95 (12)	97 (12)	808

[1] Figures in parentheses give % of each group showing response

[2] Flowering delay in 18 h photoperiod comapred to normal 12 h 20 min photoperiod

(Laing, pers comm , 1976)

TABLE VIII

NUMBER OF ACCESSIONS FROM THE CIAT GERMPLASM FACILITY EVALUATED FOR RESISTANCE TO SPECIFIC DISEASES IN THE PERIOD 1972-1977

Disease against which screened	Year 1972	1973	1974	1975	1976	1977	Total Screened
Rust	1320[a]	175	346	1500	1700[b]	--	5041
BCMV	--	--	1950	100	587	789[b]	3426
BGMV	--	1236	--	3700	2150	1150	8236
Anthracnose	--	--	--	100	524	600[b]	1224
Bacterial Blight	200	283	330	366	4000	--	5179
Web Blight	--	1427	2952	--	3505	--	7884
Rugose mosaic	--	--	--	--	--	190[c]	190
Oidium	1754[a]	--	--	--	--	--	1754
Root rots	--	--	--	--	150	900[b]	1050

[a] Evaluations from agronomic trials with natural epiphytotics

[b] Includes majority of promising germplasm lines

[c] Includes majority of parental materials used by breeding

TABLE IX

SOURCES OF TOLERANCE OR RESISTANCE FOR MAJOR PATHOGENS AND PESTS OF BEANS IN LATIN AMERICA[1]

Pathogen or Pest	Nature of Resistance	Source
BCMV	Hypersensitivity	Many varieties including Corbett Refugee (P690), Topcrop (P714), Widusa, and a number of black cultivars from the tropics
	Specific Strain Tolerance	Many varieties including Imuna, Red Mexican 35, G N 16
Rust	Immunity or Resistance	Compuesto Chimaltenango 3 Turrialba 1(P709) ICA-Pijao (P675) Mexico 309 (P699) Ecuador 299 (P693) Cornell 49-242 (P685)
Anthracnose	Resistance	Cornell 49-242 (P685), Kaboon Mexique 222 or 227, TO, TX
Empoasca	Tolerance	PI 310 732 (P325), P414, Miranda 5 (P466)
Common Blight	Tolerance	PI 313 343 (P662), PI 282086 (P261), PI 207 262 (P684) Jules (P698) G N Nebraska #1 Sel 27
BGMV	Field Tolerance	Miranda 5 (P466), Turrialba 1 (P709), Porrillo 1 (P757)
Angular Leaf Spot	Resistance	Caraota 260, Epicure, P713
Halo Blight	Resistance	Redkote, Great North UI 16 831
Web Blight	Field Tolerance	P17, P358, P401, P716
Powdery mildew	Resistance	Topcrop (P714), PI 306149 (P278)
Root Rots	Tolerance	PI 203958, PI 165, 435, P566, P746, PI 325, 619, PI 311991
Rugose Mosaic	Resistance	P259, P398, P694, P698, P699

---

[1] Cultivars marked (P---) are maintained as promising materials within the CIAT bean program, and are available on request

TABLE X

PROMISING LINES WITH MULTIPLE DISEASE RESISTANCE OR TOLERANCE TO FUNGAL AND BACTERIAL PATHOGENS IN VARIOUS FIELD NURSERIES IN COLOMBIA

	Disease Reaction					
Promising Nº	Rust	Anthracnose	Web Blight	Powdery Mildew	Gray Spot	Common Blight
P167	I	R	S	S	I-R	S
P168	I	R	S	S	I-R	T
P179	R	R	T	N	N	T
P189	R	R	S	S	I-R	S
P203	I	R	S	S	S	T
P204	R	I	S	S	I-R	T
P256	I	I	S	I-R	S	S
P334	I	R	T	S	I-R	S
P349	I	S	S	I-R	S	S
P507	I	R	T	S	T	T
P631	R	R	S	S	I-R	S
P670	R	R	T	S	S	S
P782	I	R	T	S	I-R	T

* R= resistant, T= tolerant, I= intermediate, S= susceptible, I-R= resistant during natural epidemics, require controlled tests to confirm resistance, N= P line not observed for reaction to specific pathogen

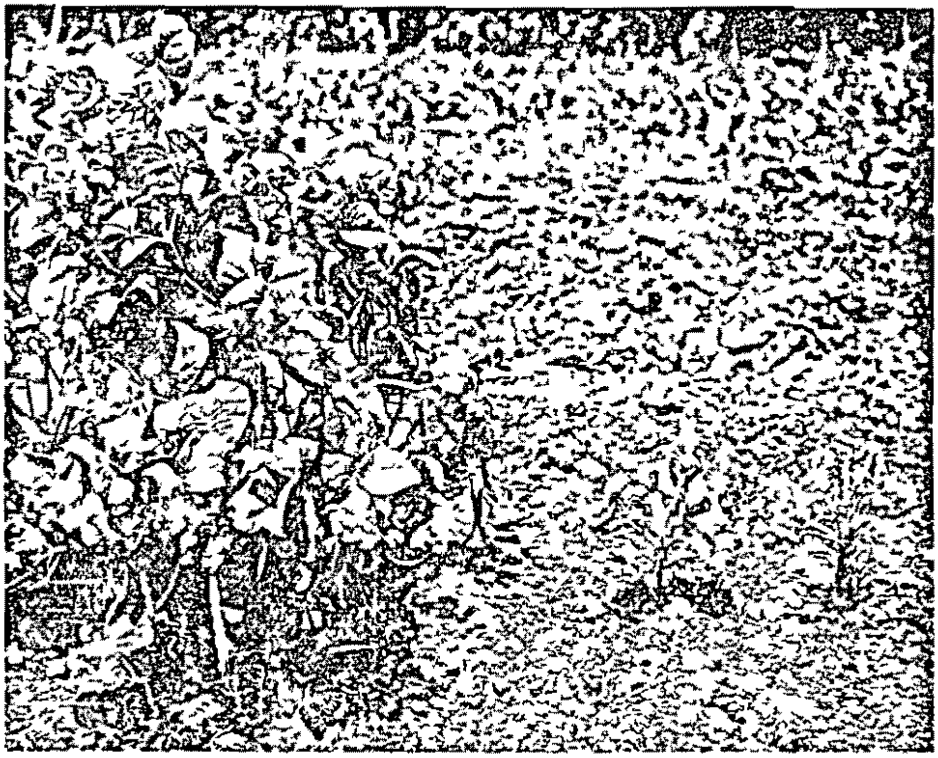


Figure ~~8~~ 7 Resistance of the variety Brazil 1087 to *Empoasca* under dry season conditions at CIAT
The variety on the right is the susceptible Calima

To ensure the availability of such germplasm to national programs all information is stored on tape and an on-line linkage maintained to a major computer in Bogota Requests for specific combinations of characters can usually be met within 24 hours For the more important "promising" materials a catalogue has been prepared and distributed listing characteristics of each cultivar (CIAT, 1976b) More than 11,000 accessions have been shipped from the germplasm facility since 1974

An essential second level of germplasm screeding is the development of international resistance nurseries Screening for rust resistance provides an obvious example Initial screening at CIAT identifies varieties resistant to local rust races but does not consider races prevalent in other areas In 1975-76, 123 bean cultivars reported as resistant to bean rust were evaluated in 32 trials (locations and seasons) No cultivar was resistant at every location, but some cultivars showed wide tolerance (Table XI) and must be considered excellent resistant sources Knowledge of resistance patterns will permit rapid identification of emerging rust races and effective deployment of resistance genes, thus minimizing genetic vulnerability International nurseries are also distributed for anthracnose, BGMV and web blight

3) Plant Breeding

Plant breeding goals and mainstream breeding operations were discussed on page 14 Plant breeding methods have evolved considerably from the modest breeding effort initiated in 1974 Currently more than 200 parents are used in the crossing program with more than 2,000 different crosses effected each year (see Fig 8) CIAT has ideal conditions for large scale, early generation, field testing of progeny, more than 200,000 F_2 plants being

TABLE XI

REACTIONS OF MOST WIDELY RESISTANT ENTRIES TO BEAN RUST (*UROMYCES PHASEOLI*) IN THE 1975 AND 1976 INTERNATIONAL BEAN RUST NURSERY (IBRN) DATA ON NUMBER OF LOCATIONS WERE THE ENTRIED RECEIVED DISEASE RATINGS[1]

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

[1] IM = Immune, R = Resistant, Int = Intermediate, S = Susceptible, ND = no data

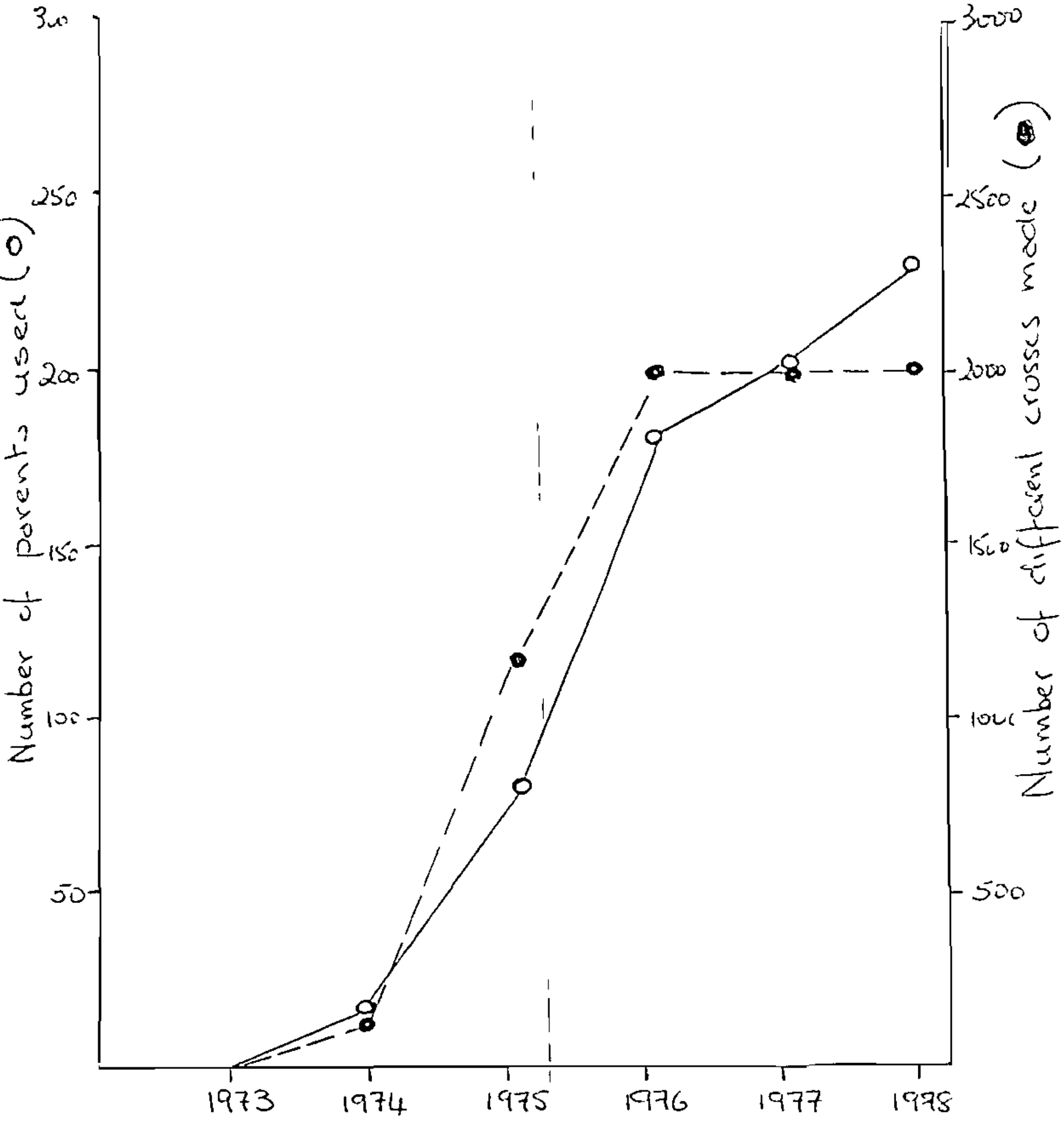


Fig 8: Development of the crossing program at CIAT in the period 1973-78 Number of hybridisations effected now remains relatively stable, though parental number continues to climb

evaluated under field conditions in 1977 alone (Fig 9) It is anticipated that more than 4,000 F_4 families, combining high yield with increasing disease resistance will be available for selection by national programs each year Multiple disease resistance has already been identified in many hybrid populations now undergoing preliminary yield tests The addition to the program of additional scientists in the areas of yield breeding and the breeding of climbing beans should also permit more rapid gains than originally anticipated

4) Physiology

While the genus Phaseolus has been studied intensively in temperate regions, especially the USA, physiological studies under tropical or semitropical conditions have been limited

Growth analysis experiments conducted during the period 1975-1977 defined yield limiting factors in 5 varieties, representative of the four growth habit groups recognized at CIAT (see Table XII) The differences in mean yield between the groups is clear, the earliness of Type 1 plants apparently limiting maximum leaf area and thus LAD For all varieties increased node structure and leaf areas are strongly related to yield

Flower and pod abscission has proved a major problem in beans, all cultivars tested showing close to 70% flower and pod abscission (Table XIII) Abscission is greatest in flowers and pods high in the canopy, on branches, or in the higher positions within a raceme, with first formed flowers more likely to mature than those produced later Growth habit groups have distinctly different patterns of flower production, a factor likely to be important in varieties grown under rainfed conditions (Fig 10)

Fig 9 · Each semester at CIAT large areas of F_2 segregating populations are planted at CIAT and evaluated for disease resistance The photo shows aspects of the inoculation of a typical nursery with BCMV

TABLE XII

YIELD PARAMETERS FOR CULTIVARS OF P VULGARIS FROM DIFFERENT GROWTH HABIT GROUPS IN GROWTH ANALYSIS EXPERIMENT AT CIAT

Cultivar	P635	P788	P566	P498	P589
Growth habit	I	I	II	III	VI
Mean yield (14% moisture), g/m^2	230	242	273	322	365
Number of experiments	3	2	9	3	3
Pod number/m^2	142	246	216	265	294
Bean per pod	2 55	3 20	5 56	4 36	5 69
Bean size, mg/bean	544	272	195	240	185
Maximum node number/m^2	363	413	587	923	864
Maximum leaf area index	3 03	3 43	3 57	4 14	5 99
Leaf area duration[a] (E-F)[b]	23	18	36	41	81
Leaf area duration (F-M)	95	96	94	123	180
Leaf area duration (E-M)	118	114	130	164	261
Days to flowering (E-F)	25	25	33	33	41
Days to maturity (E-M)	64	67	73	81	89
Yield/day (planting to maturity)	3 31	3 36	3 51	3 73	3 88
Yield/LAD (E-M)[c]	1 95	2 12	2 10	1 96	1 40

[a] LAD, m^2 days/m^2

[b] E = emergence, F = flowering, M= physiological maturity

[c] Leaf area efficiency, g/m^2 days/m^2 land area

(Laing, pers comm , 1977)

TABLE XIII

FLOWERING AND POD ABSCISSION DATA FOR 3 CULTIVARS
OF *PHASEOLUS VULGARIS*, CIAT 1975

	Cultivar	P635	P566	P326
	Growth habit	I	II	III
Total number of flowers/plant		37	39	39
Pods abscissed < 3 cm		21	20	13
Pods abscissed >3 cm		7	5	9
Pod set efficiency (%)		24	36	44
Flowering period (days)		18	19	17
Period to form 60% flowers		4	10	10
Pod set efficiency during first 60% flowers formed		36	60	70
Pod set efficiency during last 50% flowers formed		7	0	6

(Laing, pers. comm., 1976)

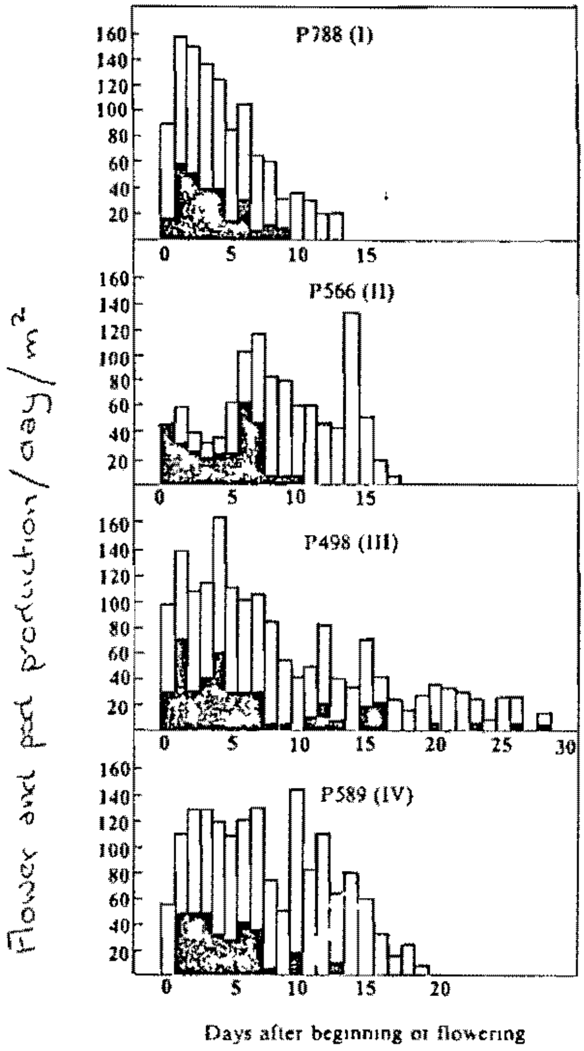


Fig 10. Number of flowers and pods produced /m²/day during flowering of cultivars belonging to the 4 different growth habit groups (□ flowers ▨ mature pods)

(Laing, pers comm, 1976)

Treatments altering source-sink relationships markedly affect yield Thus a photoperiodically induced delay in flowering permitted greater node development and leaf area accumulation, and increased yield nearly 50% (Table XIV) The yield of 4 12 tons/ha in this experiment gives an idea of the yield potential of even unimproved cultivars Increase in source capacity is not the whole solution to low yields, however, as abortion can occur even as stems accumulate carbohydrate

5) Microbiology

Microbiological studies have emphasized varietal differences in nitrogen fixation and carbohydrate supply to nodules Climbing cultivars have proved active in nitrogen fixation with seasonal rates of N_2 fixed in excess of 40 kg/ha While fixation (C_2H_2) rates in such cultivars is more than comparable with data from other grain legumes, fixation by determinate, early flowering cultivars has proved weak, as shown in Fig 11 In a number of experiments nitrogen (C_2H_2) fixation has been positively correlated with carbohydrate supply to nodules, again with major differences apparent between cultivars (Fig 12)

The effect of cultural factors such as association with maize, planting density, and phosphate fertilization on nitrogen fixation by beans has also been evaluated (Graham and Rosas, 1978a, b) Additionally CIAT maintains a collection of some 300 cultures of *R phaseoli* which are available either as cultures or peat inoculants

6) Pathology

Some major activities of the pathology program including the evaluation of germplasm accessions for disease resistance, active

TABLE XIV

INFLUENCE OF PHOTOPERIOD ON YIELD AND OTHER PARAMETERS IN THE CULTIVAR P566

Parameter	Distance from light source (m) 1-2	 19-20
Bean yield (g/m^2, 14%)	412	277
Pods/m^2	314	208
Beans/pod	5 73	5 49
Bean weight (mg/bean)	197	207
Mainstem nodes/m^2	520	370
Total dry matter (g/m^2)	778	532
Days to flowering	51	36
Maximum leaf area (m^2/m^2)	3 96	2 66

(Laing, pers comm , 1976)

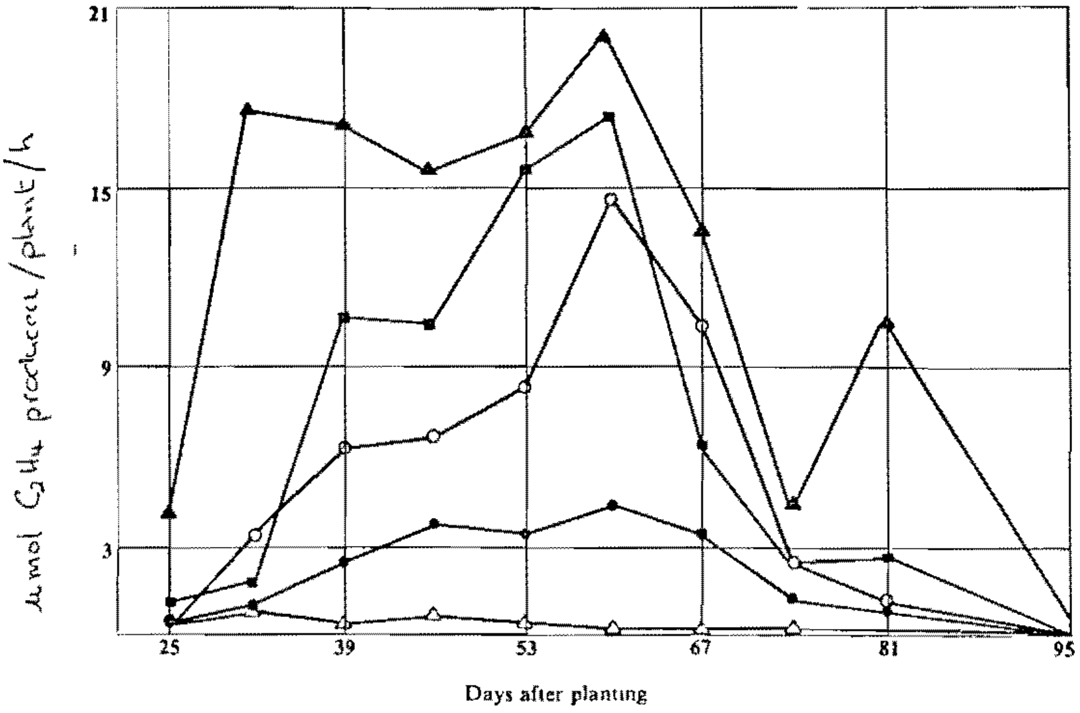


Fig 11 Seasonal profiles of nitrogen (C_2H_2) fixation for 5 cultivars of *P vulgaris* differing in growth habit (△ P635, Type I; ● P302, Type II; ○ P526, ■ P717, ▲ P590, each Type IV).

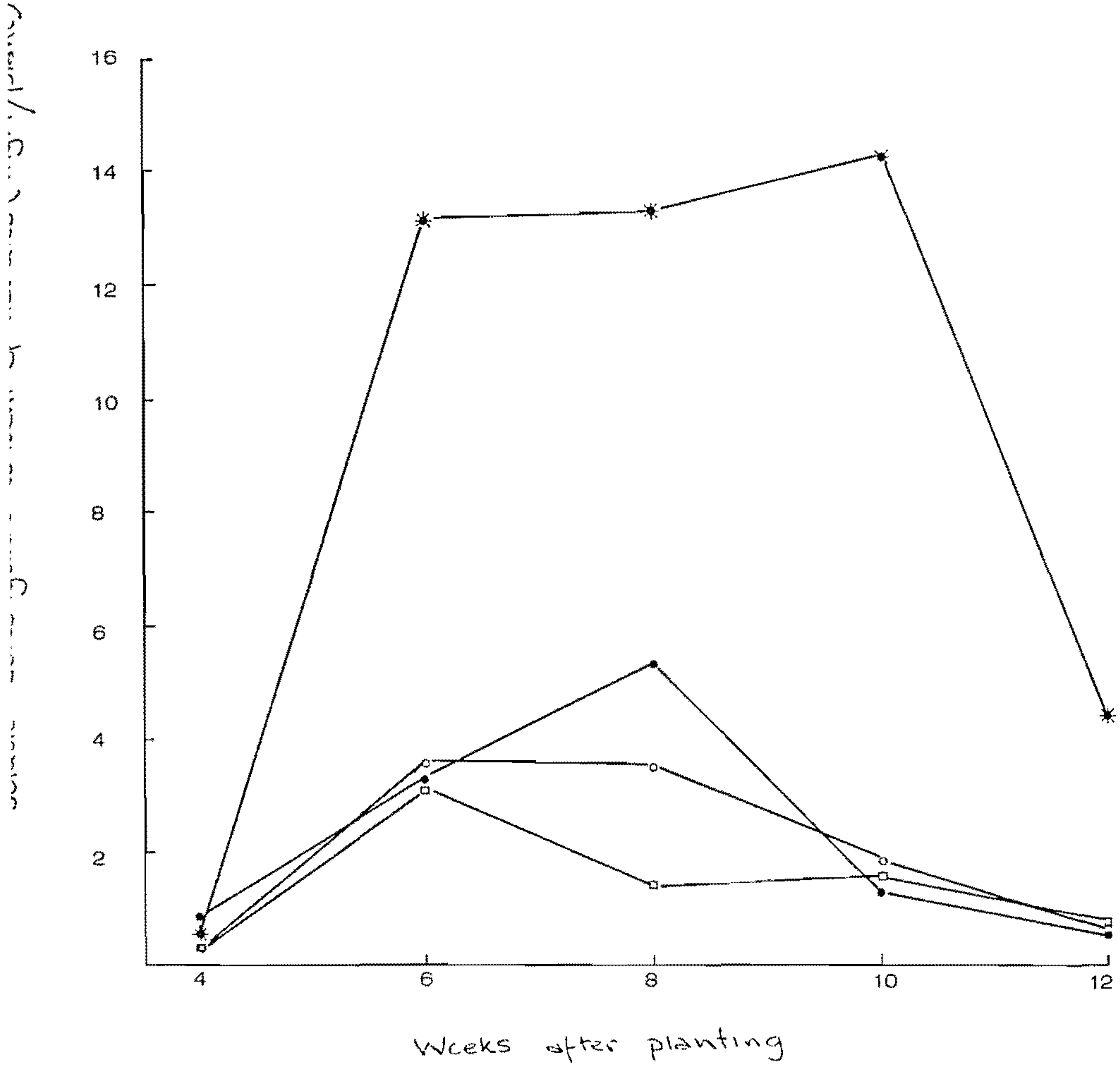


Fig 12, Cultivar differences in the soluble carbohydrate conte
of nodules at different stages in the growth cycle
(* P590, Type IV, □ P498, Type III, ● average for 6
cultivars belonging to Type I, ○ average for 4 cultivars
of Type II)

involvement in the breeding program, and the coordination of international disease nurseries have been mentioned previously

The production of disease free foundation seed has also been a priority area Studies of farmers seed from the Huila region showed low germination and great internal fungal contamination (see p8) It is a relatively simple procedure to "clean" such seed and so to eliminate or reduce foci for epiphytotics (Fig 13) Clean seed initially provided by CIAT raised yields in the Monjas and San Mateus valleys of Guatemala from 515 to 1,545 kg/ha in a single season CIAT has also collaborated in producing foundation seed for countries such as Brazil and Peru

BGMV is becoming increasingly important in Brazil and Central America Studies at CIAT have permitted for the first time the mechanical transmission and isolation of this virus, thus facilitating its study, as well as the preparation of antisera which can be used to identify and compare a number of different viruses, as shown in Fig 14

7) Entomology

Tolerance to *Empoasca*, adequate for most growing conditions and heritable, has been identified in bean accessions Unfortunately, it does not provide complete protection under hot-dry conditions as experienced at CIAT during dry season irrigated plantings Integrated systems for *Empoasca* control are being developed These combine tolerant cultivars, specific cultural practices and minimal insecticide usage, and provide the farmer a low cost system for control of this insect Thus studies relating leafhopper population, and damage with production and production costs shows optimum returns

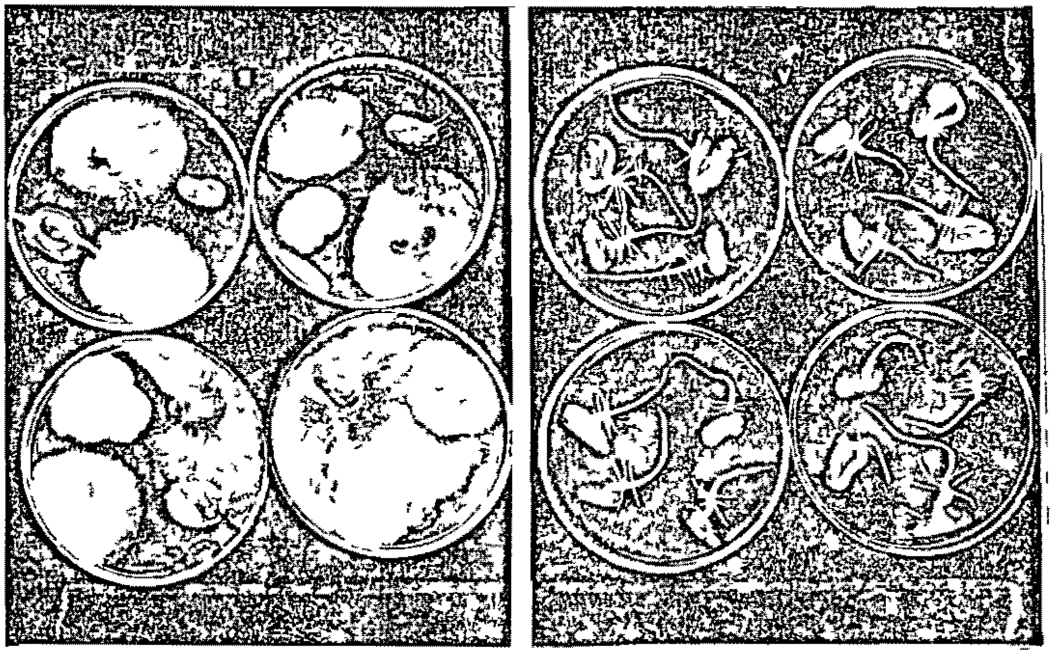


Fig 13 : Incidence of internal seed-borne fungi in farmer's seed from Huila, Colombia (left) compared to seed grown at CIAT under protected conditions. All seeds were surface sterilised before placing on H_2O - Agar medium

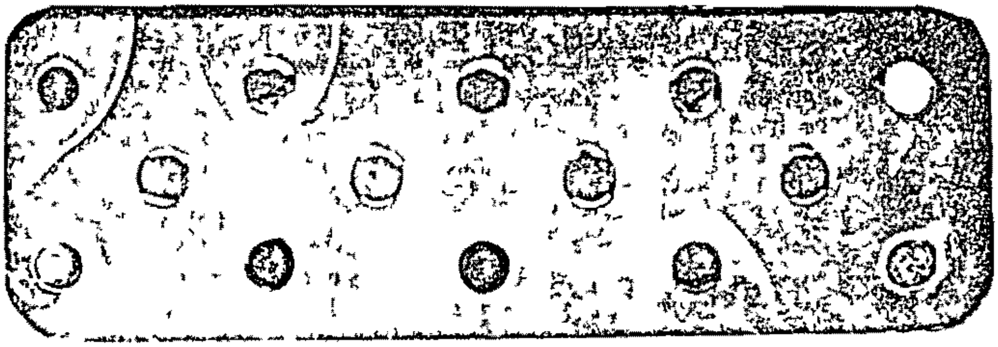


Fig 14 Serological tests can help to distinguish between virus diseases in Latin America

for the farmer when Empoasca populations are controlled at close to 1 nymph/leaf (Fig 15) This is most important during the early growth period In other studies it has also been shown that mulching or association of maize with beans will reduce insect attack

Seed treatment with small quantities of vegetable oils (a technique earlier used for cowpeas in Africa) has proved highly successful in controlling the storage pests Zabrotes and Acanthoscelides Treatment of seed with 5 ml of oil/kg eliminated insect damage but affected neither germination nor cooking quality and appearance (Table 15)

8) Agronomy and Soil Fertility

Agronomy and soil fertility studies emphasize three areas a) yield evaluation, b) phosphate fertilization and c) maize-bean associations

Since 1974, 750 accessions have undergone preliminary yield evaluation at CIAT, with 291 passed to advanced yield trials in multiple locations In each semester of testing, cultivars in these trials have achieved yields of more than 3 0 tons/ha, the highest yield being 3,659 kg/ha Advanced breeding lines were first entered in the trials in 1976, white and brown seeded lines showing appreciable yield gains relative to previous materials tested Lines from the increased hybridization activities initiated in 1975 are being yield tested now, and will be available to national programs in 1978

Details of the first international yield and adaptation nursery (IBYAN) held in 1976-77 are discussed on p 27.

Critical levels of phosphorous for bean growth have been determined in a series of experiments at Popayan, and optimum sources and means of applying phosphorous evaluated Phosphorous is clearly

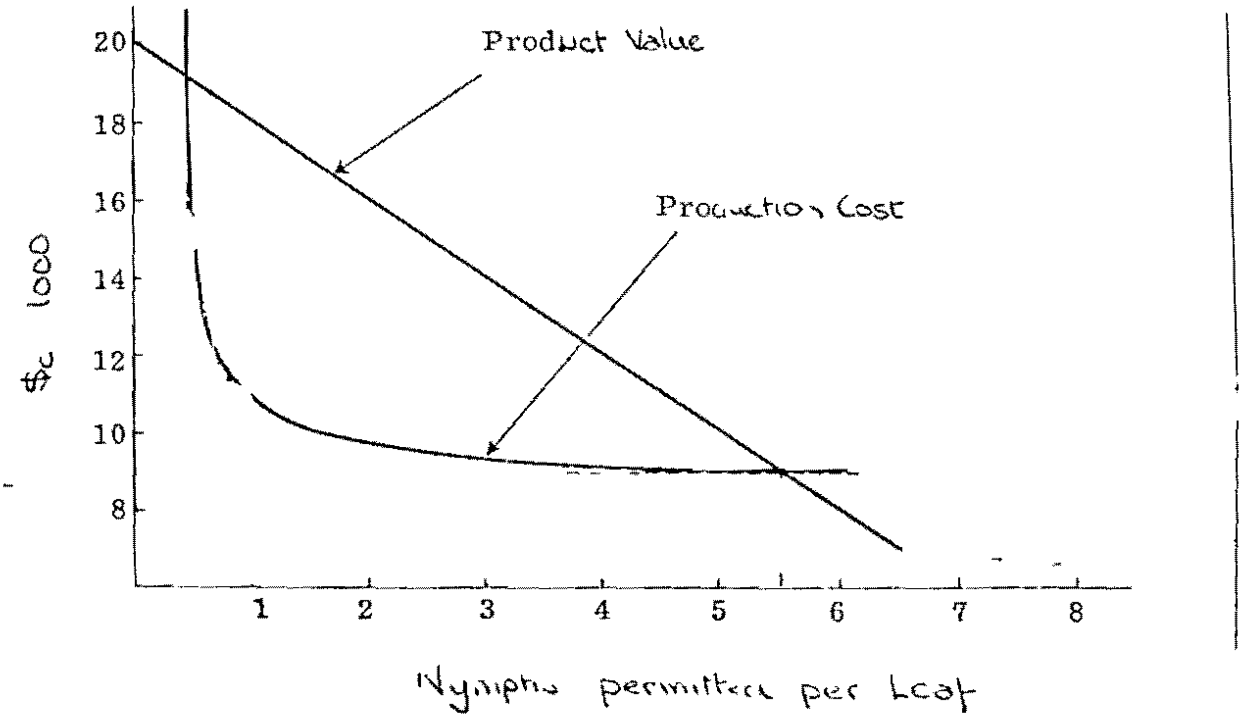


Fig 15 : Product value and production costs for beans when *Empoasca* nymphal populations are controlled at different levels of infestation

(Schoonhoven, pers comm 1977)

TABLE XV

EFFECT OF MIXING WITH MAIZE OIL ON BRUCHID ATTACK, SEED GERMINATION AND WATER UPTAKE OF STORED BEAN SEED[1]

Oil Applied ml/kg see	Adult Mortality[2] %	Eggs produced/ 100 g seed	Adults produced/ 100 g seed	Seed Germination %[3]	Weight increase following 24 h imbibition[2]
1	22.5	89.0	13.2	85.9	103.8
5	100	0	0	82.4	102.2
10	100	0	0	77.6	103.5
Control 1[4]	0	318.8	208	--	--
Control 2	--	--	--	79.6	107.7

[1] 100 g of seed/replicate, infested with 7 pairs of adults befoir oil treatment

[2] Measured 2 days after oil treatment

[3] Measured after 180 days of storage

[4] Control 1 infested as for treated seeds, Control 2 maintained at 5°C until tested

(Schoonhoven, pers. comm., 1977)

critical to bean yields in much of Latin America (Fig 16) so considerable emphasis is given to selection of cultivars tolerating low soil P, and especially to phosphorous effects on N_2 fixation

Studies with climbing beans in monoculture or associated with maize have advanced considerably since first initiated by the program in 1975, an important development being the participation of the economist in many of the experiments undertaken This is evident in Fig 17 which compares the optimum density for beans in mixed plantings with maize While the optimum bean density for yield in each case studied is 120,000 plants/ha, the density for optimum return declines with increasing maize density, with bean populations greater than 100,000 plants/ha rarely justified

Though association with maize reduced bush and climbing bean yields 58 and 64% respectively, initial observations indicated little or no decline in maize yield On this basis, and for all bean maize price ratios considered, maize-bean associations would return more to the farmer than monoculture maize Monoculture beans would become economically viable when the bean maize price ratio exceeded 4 1 (see Fig 18)

More than 300 climbing bean germplasm selections have been evaluated for yield to date, highest yield being 2 17 tons of beans in a 5 5 ton maize crop Yields in excess of 4 5 tons/ha have been achieved in Popayan using old maize stems as support, and more than 5 0 tons/ha on bamboo-wire trellices Numerous experiments have been done to evaluate genotype x system interactions for beans To the moment it appears that selection for bean yield under either system is valid, but that reduced variation permits greater precision in

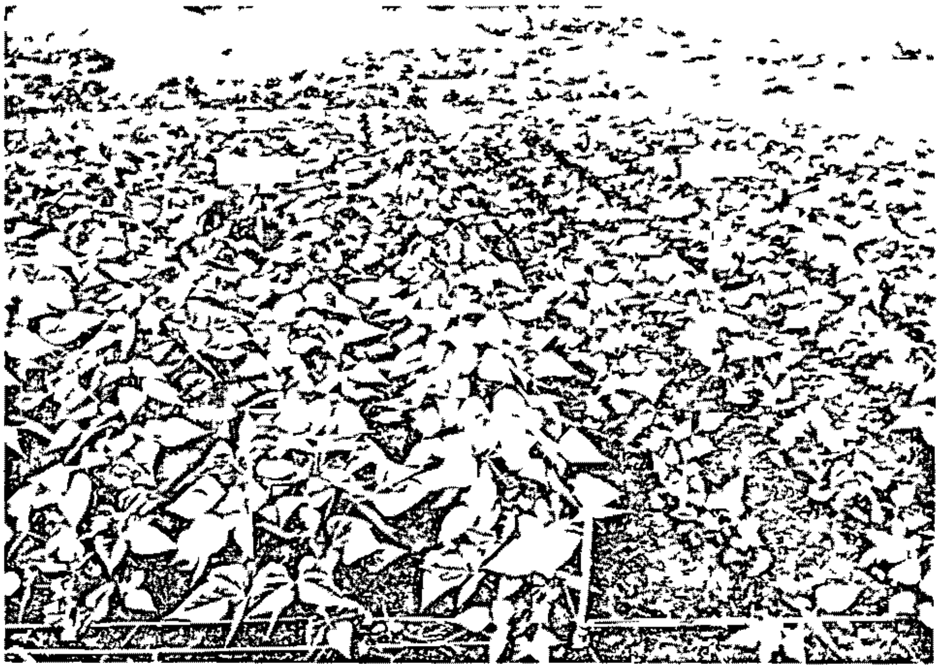


Fig 16 Response of *Phaseolus vulgaris* to levels of phosphate fertilisation at La Zapata Varietal differences in phosphate utilisation and P x N interactions are understudy at CIAT

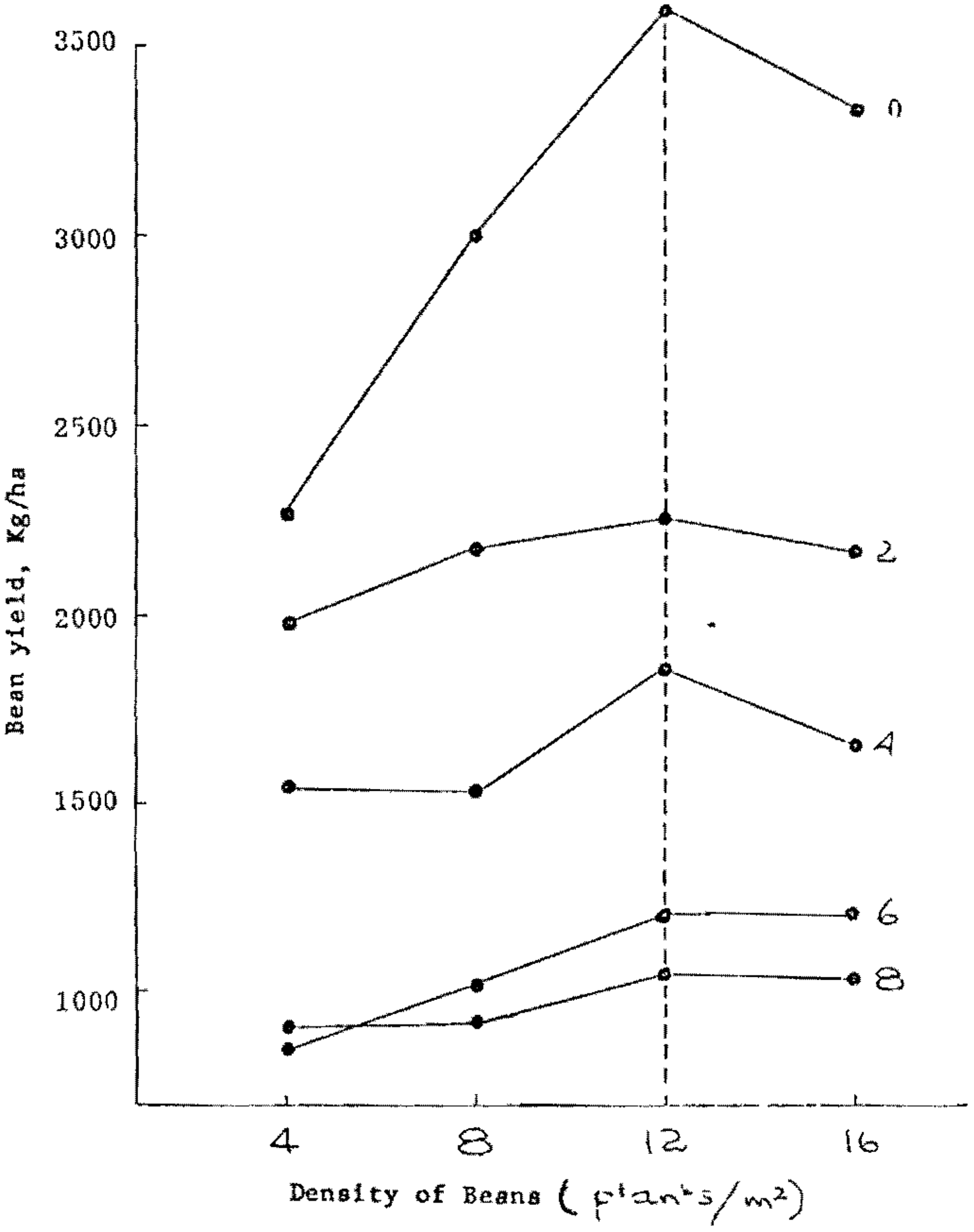


Fig 17: Yield of the climbing cultivar, P589, as influenced by planting density in monoculture or associated with different populations (2-8 plants /m²) of the maize cultivar H207

(Francis pers comm 19

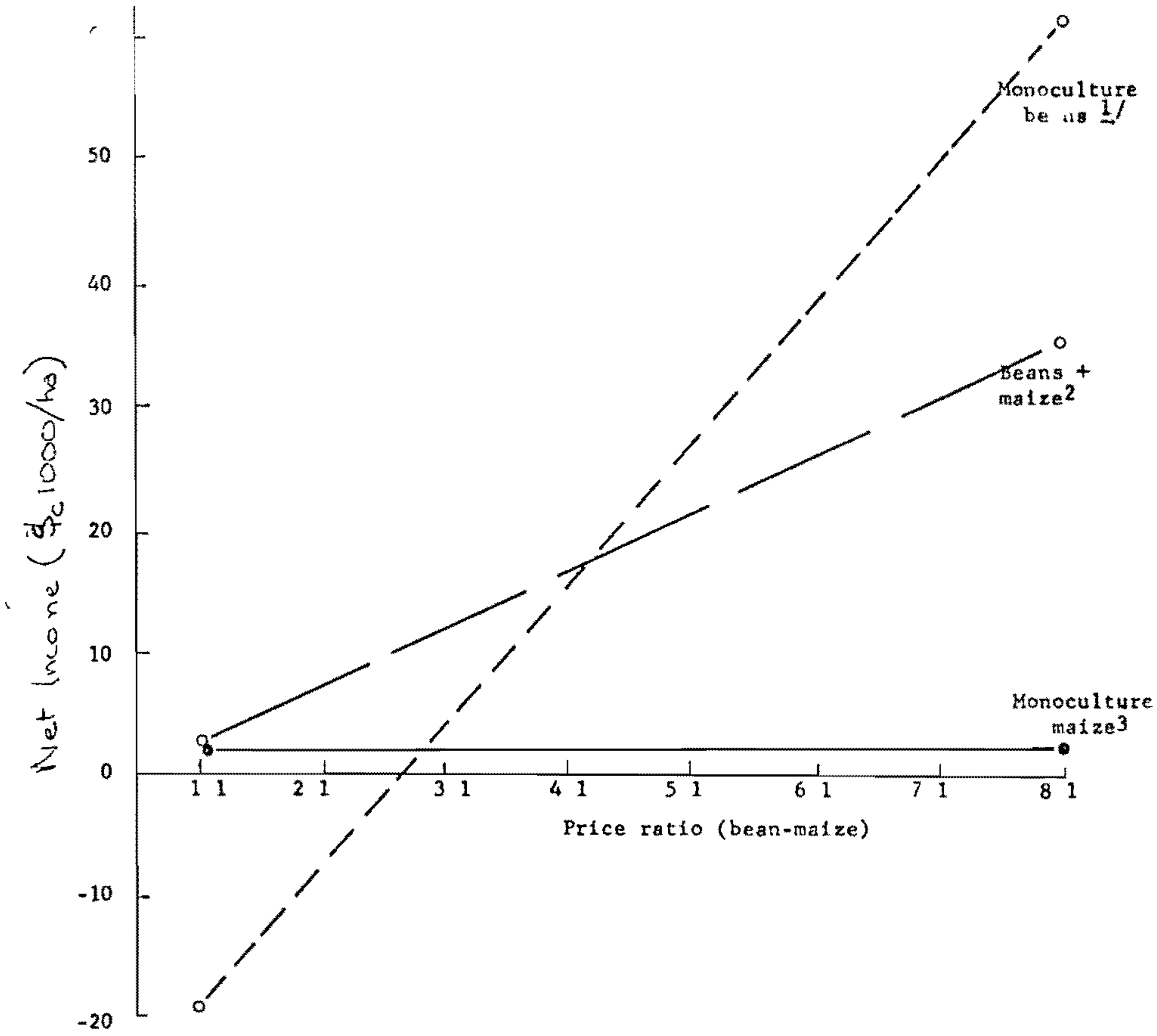


Fig 18: Relative profitability of 3 production systems at different price ratios of maize and beans
This model assumes virtually no yield loss for maize when grown with beans

(from Sanders & Francis, in press)

monoculture plantings In the future maize and bean will need to be matched

9) Economics

An economic survey of 4 major bean producing regions which differed in cropping systems and adoption of technology, has helped confirm program priorities Table XVI provides details of bean production in the 4 regions Production function analysis was used to evaluate factors contributing to lower yield in each region, as shown for 3 regions in Fig 19

VII International Collaborative Activities of the CIAT Bean Program

The bean team assumed responsibility from the CGIAR to develop and coordinate a Latin American network of bean research workers in 1975

While there is much talk of cooperative networks in international and national research programs, and even within some disciplines, few function efficiently Problems include patronizing of one group by another, duplication of activities, jealousies which cannot be resolved, and lack of sufficient communication Development must be based on respect between collaborators and on the ability of the coordinating organism to identify and satisfy needs

Though CIAT working relations with national bean programs were generally good prior to the CGIAR request, program scientists felt that each national program presented a unique situation, to be considered differently according to degree of development, local needs and priorities, and interest in collaboration with CIAT It was therefore agreed to divide the task of maintaining and improving contact with national programs, each scientist at CIAT accepting responsibility for coordinating activities

TABLE XVI

CHARACTERISTICS OF BEAN PRODUCTION IN FOUR REGIONS OF COLOMBIA[1]

	Valle	Huila	Antioquia	Narino
Average farm size (ha)	48 0	25 2	4 5	4 0
Area in beans (ha)	22 6	5 9	1 5	1 8
Percentage of farms using				
Irrigation	45	3	0	0
Certified seed	52	7	0	5
Fertilizers	94	24	100	0
Herbicides	33	0	0	0
Insecticides	87	23	64	10
Fungicides	97	10	59	0
Credit	87	53	54	58
Technical assistance	71	30	32	32
Mixed cropping	0	74	100	95
Machinery	100	44	5	0
Bean yield (kg/ha)	906	683	509	447
Bean equivalent yield (kg/ha)[2]	906	n a *	919	703

* n a = not available

[1] Translated from Londoño & Andersen (1978)

[2] The bean yield equivalent estimates and includes returns from the other components of the multiple cropping system

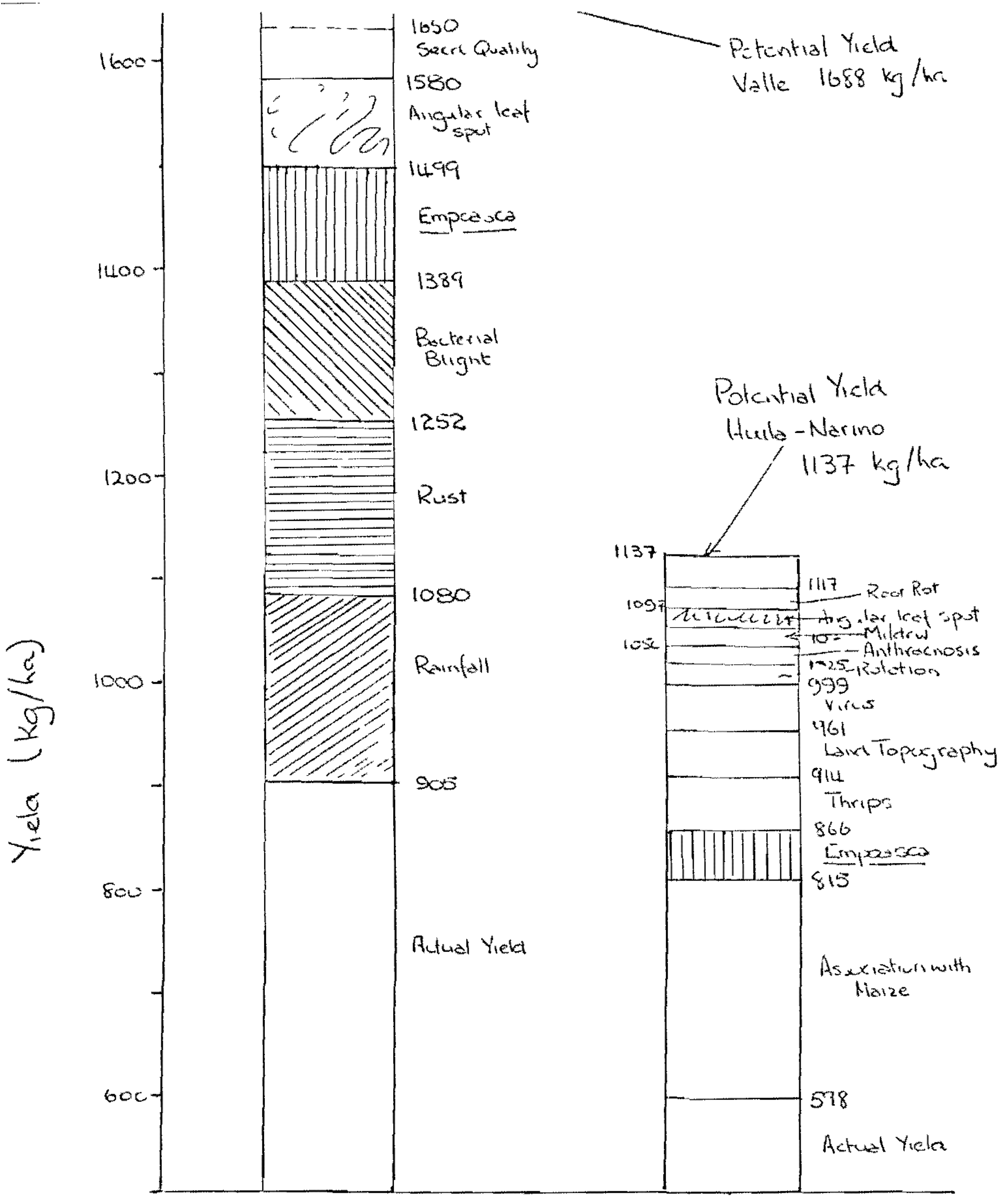


Fig 19 Actual and potential yields for P vulgaris in three bean producing areas of Colombia (Valle, left and Huila-Narino, right) showing factors which contributed to yield loss in each zone

([illegible])

with specified countries While this concept has undergone some change with the recent location of CIAT scientists in specific countries or regions, the scheme as a whole continues to function well Current country responsibilities are shown in Fig 20

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

1) Training activities of the CIAT bean program

Insufficient or inconsistent research support is a major factor in low bean yields, many countries not having or being able to train agricultural graduates in specialist fields CIAT stresses postgraduate training, receiving trainees in 3 major categories

i) post-graduate interns who spend 6-12 months at CIAT and receive discipline oriented training while working in various phases of the research program

ii) production trainees who undergo short but intensive courses equipping them better for functions in credit, extension or policy making

iii) research fellows who undertake the thesis component of their higher degree studies at CIAT

The number of people receiving training in the CIAT bean program has increased steadily since 1974 (Table 17) with most training positions currently occupied To reach a wider audience and to encourage within country training a series of more than 50 audiovisual presentations is being prepared

Fig 20 Members of the CIAT bean team have been assigned specific country responsibilities to ensure continuity in collaborative activities

TABLE XVII

NUMBER OF SCIENTISTS WHO RECEIVED POST-GRADUATE TRAINING AT CIAT IN THE PERIOD 1973-1978

Type of Training Year	Interns	Production Trainees	Research Fellows	Post Doctoral
1973	6	--	3	2
1974	11	--	3	3
1975	18	--	5	3
1976	26	--	6	4
1977	25	25	7	3
1978 (projection)	26	50	7	3

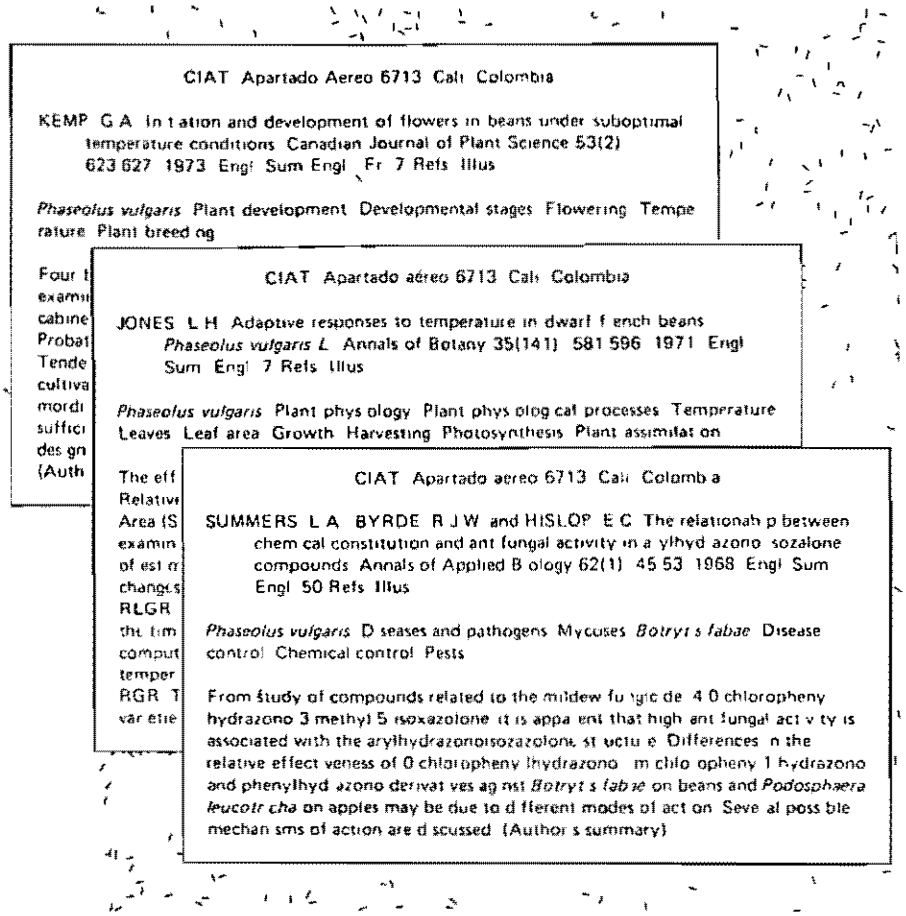
2) Information services and workshops

In 1974, and in collaboration with the CIAT Library service, a documentation and abstracting service was established to help interested institutes and scientists receive citations and abstracts of bean literature Typical abstract cards are shown in Fig 21, with more than 3,000 articles identified and distributed to the moment In 1976 the first group were compiled in book form to permit ready indexing To further promote interchange of information a series of workshops has been held with participants invited from most national programs

3) Collaborative experimentation

Fig 22 summarizes collaborative activities of the bean team in Latin America during 1977-78 In addition to those aspects already mentioned, activities included

i) International Bean Yield and Adaptation Nurseries (IBYAN), Following the breeding workshop held at CIAT in 1975, participants agreed to test the yield and adaptation of promising cultivars in a multi-location trial The format suggested was that 25 cultivars be tested, 20 supplied through CIAT and grown in all locations, the remainder locally important varieties used as controls Results are available from 49 locations ranging in latitude from 1°S (Boliche, Ecuador) to 55°N (Cambridge, England) For both tropical and temperate locations the mean yield of the best five IBYAN entries exceeded that of the local cultivars by 31% Adaptation of the 20 IBYAN entries, analyzed by standard regression procedures, varied Five black Type II cultivars (P302, P459, P675, P560, and P566) showed high average yield, but $\hat{b}$ values varied from 0 85-1 12 (Fig 23) By contrast four non-black Type 1 cultivars showed both



CIAT Apartado Aereo 6713 Cali Colombia

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

Phaseolus vulgaris Plant development Developmental stages Flowering Temperature Plant breeding

Four t
exami
cabine
Probat
Tende
cultiva
mordi
suffici
des gn
(Auth

CIAT Apartado aéreo 6713 Cali Colombia

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

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

The eff
Relative
Area (S
examin
of est m
changes
RLGR
the tim
comput
temper
RGR T
var etie

CIAT Apartado aereo 6713 Cali Colombia

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

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

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

Fig 21 , Documentation cards in English or Spanish are forwarded regularly to bean research workers

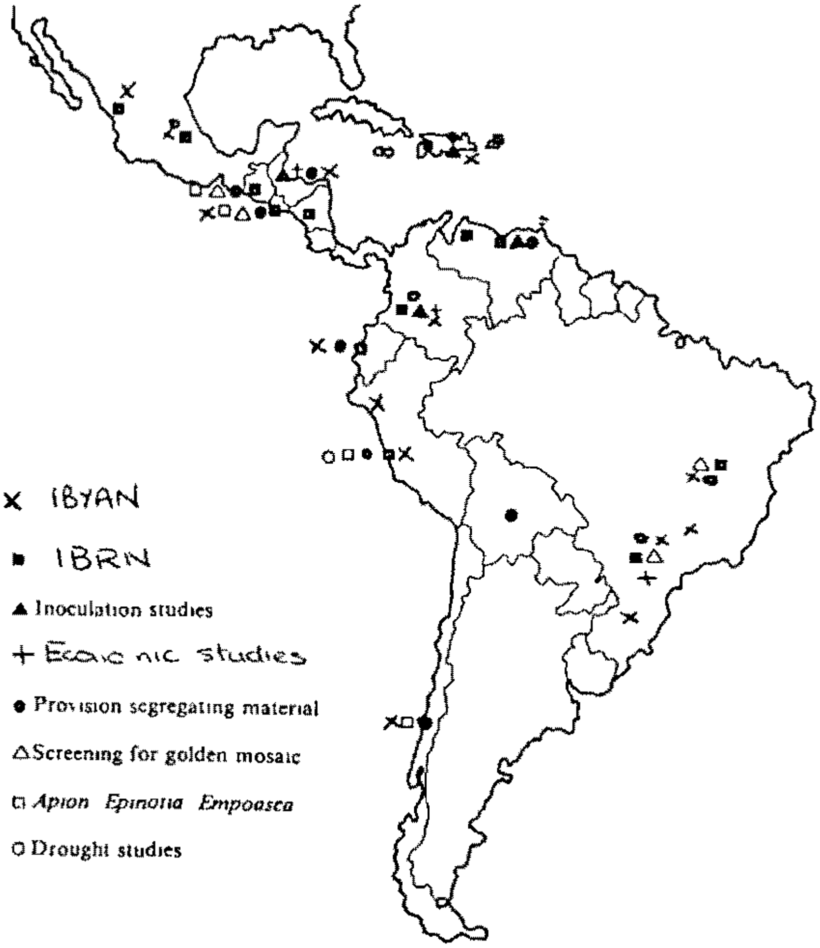


Fig 22 : Collaborative experimentation involving CIAT bean team personnel in Latin America in 1977-78

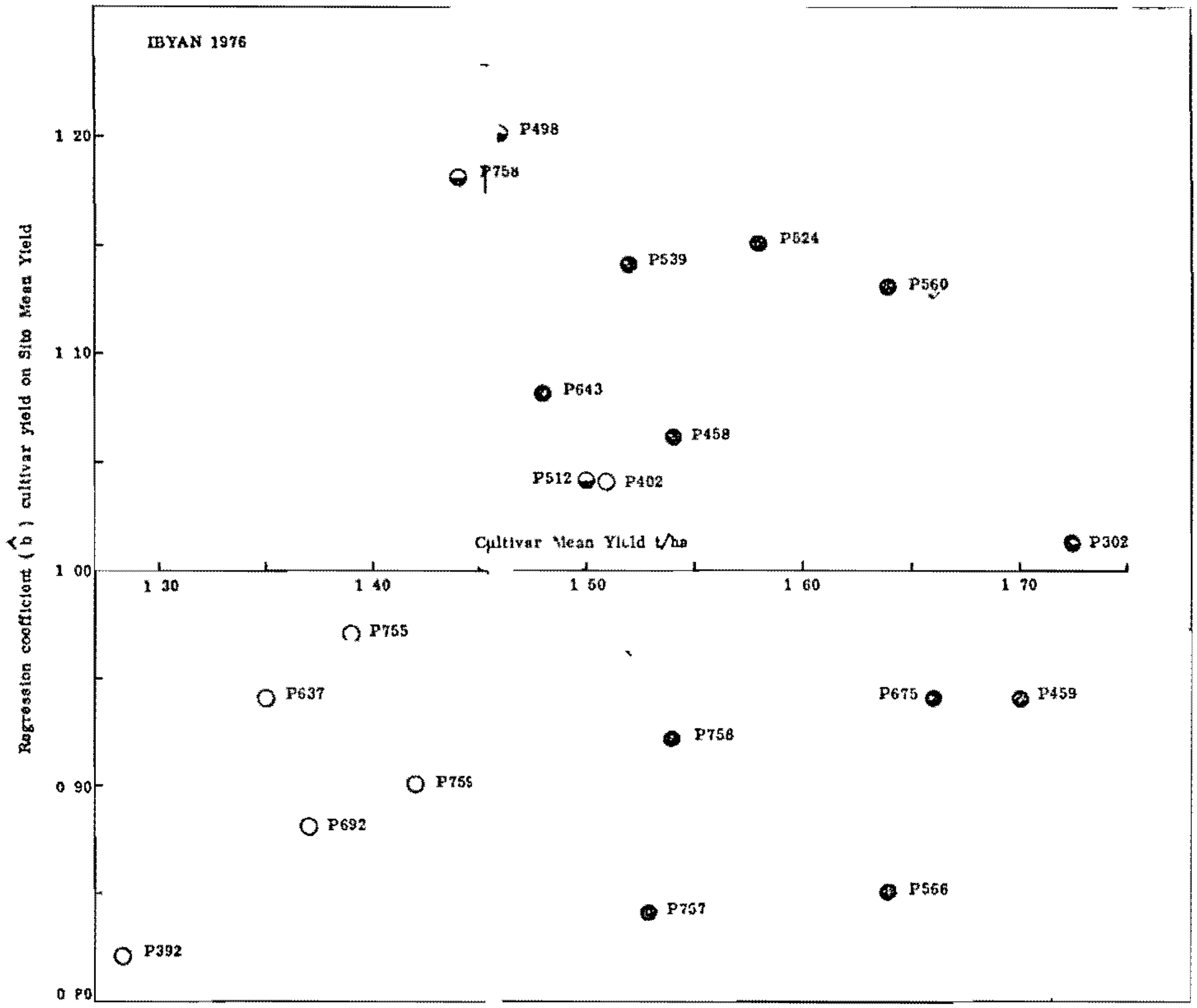


Fig 23 Cultivar mean yield and the regression coefficient of cultivar yield on site mean yield, a measure of yield potential and adaptation for the 20 cultivars in the first IBYAN (Growth habits ○ I, ● II, ◒ III)

(O Voysest & D R Laing pers com 1977)

poor yield and $\hat{b}$ values less than 1 0 This finding is consistent with results reported on pages 20 and 21, and must prejudice the continued use of such cultivars in Latin American agriculture

ii) Disease and insect screenings, Several disease organisms including BGMV, anthracnose, and bacterial blight do not occur, or are difficult to reliably reproduce epiphytotics of at CIAT This is also true of the insects Apion, Hyelema and Epilachna Collaborative studies to identify or confirm resistance sources, and/or to evaluate hybrid materials from the CIAT breeding program are underway in Brazil, Chile, Colombia, Dominican Republic, El Salvador, Guatemala, Honduras, Mexico and Peru

iii) Economic studies, Though CIAT cannot transfer technology directly to farmer's fields, it must know how farmers will accept different technologies, and what impact these are likely to have under farm conditions CIAT has collaborated with the Honduran program, Promyf, and with the Colombian coffee growers federation in studies of the impact and acceptability of varietal change, minimum fertilizer input and pest control In the Colombian example the new technologies increased net income 60-74% Currently surveys of bean production and problems are underway in Parana state, Brazil and in Honduras

Collaborative experiments outside Latin America seek assistance for problems not readily attacked at CIAT, or in national programs A number of such programs are listed in Table XVIII

4) Bean Technical Advisory Committee

When collaborative bean research network proposals were under discussion, the CGIAR stressed the need for a scientific committee to review

*

TABLE XVIII

COLLABORATIVE STUDIES INVOLVING CIAT AND NON-LATIN INSTITUTIONS

Scientist	Institution	Specific area(s) of Collaboration
M W Adams	Univ of Michigan	Carbohydrate partitioning, breeding resistance to insects
J Benepal		
F A Bliss	Univ of Wisconsin	Root rot resistance, protein quality, breeding for N_2 fixation
J Day	Rothamsted Exp Sta	Varietal differences and N_2 fixation
I Drijfhout	Dutch Plant Breeding Institute	Breeding for BCMV resistance
R Marechal & G le Marchand	Univ of Gembloux	Wide crossing, species characterization
J Meiners	USDA, Beltsville	Rust
D Mok	Oregon State Univ	Wide crossing, hormone control

regional research needs, to provide technical criticism of CIAT's research program in beans and its relevance to Latin America, and to channel technological gains to appropriate national programs The committee currently comprises,

Dr Dermot Coyne, University of Nebraska, USA, Chairman

Dr Antonio Pinchinat, IICA, Dominican Republic

Dr Rodolfo Cristales, CENTA, El Salvador

Dr Clibas Vieira, University of Vigosa, Brazil

Dr Hugh Bunting, University of Reasing, England

Dr Julio Lopez Rosa, University of Puerto Rico, Puerto Rico

Dr Alonso Bravo, University of Santiago, Chile

Dr John Nickel, Director, CIAT

Dr Ken Rachie, Associate Director, Research, CIAT

VIII CIAT Bean Program Publications 1973-1978 *

ALTIERI, M A , FRANCIS, C A , SCHOONHOVEN, A V & DOLL, J D (1978) A review of insect prevalence in maize (*Zea mays* L) and bean (*Phaseolus vulgaris* L) polycultural systems Field Crops Research *1*, in press

ALTIERI, M A , SCHOONHOVEN, A V & DOLL, J (1977) The ecological role of weeds in insect pest management systems A review illustrated by bean (Phaseolus vulgaris) cropping systems PANS *23*, 195-205

ANDERSEN, P O , LONDONO, N R de & HOOVER, E (1976) The impact of increasing food supply on human nutrition Implications for commodity priorities in agricultural research and policy American Journal of Agricultural Economics *58*, 131-142

ANDERSEN, P P , LONDONO, N R de & INFANTE, M (1976) A suggested procedure for estimating yield and production losses in crops PANS *22*, 359-365

ANON (1975) Bean production systems program CIAT Series FE No 5 (1975) 38 pp

ANON (1978) Report of the 1975 and 1976 International Bean Rust Nurseries CIAT Series (1978) in press

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (1974) Annual Report Bean Production Program pp 42

CENTRO INTERNATIONAL DE AGRICULTURA TROPICAL (1975) Annual Report Bean Production Program pp 58

CENTRO INTERNATIONAL DE AGRICULTURA TROPICAL (1976a) Annual Report Bean Production Program pp 83

CENTRO INTERNATIONAL DE AGRICULTURA TROPICAL (1976b) Descriptive list of the *Phaseolus* spp germplasm 1 Promising materials 54 pp

CENTRO INTERNATIONAL DE AGRICULTURA TROPICAL (1977a) Annual Report Bean Production Program, in press

ELLIS, M A , GALVEZ, G E & SINCLAIR, J B (1976) Hongos internamente portados por la semilla y calidad de la semila de frijol (*Phaseolus vulgaris* L) cosechado en fincas de pequenos agricultores en cuatro departamentos de Colombia Noticias Fitopatologicas 5, 79-82

ELLIS, M A , GALVEZ, G E & SINCLAIR, J B (1976) Efecto de tres fungicidas sobre la germinacion de semilla infectado de frijol (*Phaseolus vulgaris*) Turrialba 26, 399-402

ELLIS, M A , GALVEZ, G E & SINCLAIR, J B (1976) Effect of pod contact with soil on fungal infection of dry bean seeds Plant Disease Reporter 60, 974-976

ELLIS, M A , GALVEZ, G E & SINCLAIR, J B (1976) Effect of foliar applications of systemic fungicides and late harvest on seed quality of dry bean (*Phaseolus vulgaris* L) Plant Disease Reporter 60, 1073-1076

ELLIS, M A , GALVEZ, G E & SINCLAIR, J B (1977) Efecto del tratamiento de semillas de frijol (*Phaseolus vulgaris*) de buena y mala calidad sobre la germinacion en condiciones de campo Turrialba 27, 37-39

FRANCIS, C A , FLOR, C A & TEMPLE, S R (1976) Adapting varieites for intercropping in the toprics In "Multiple cropping", ASA Special Publication 27, 235-253

is →
S

GALVEZ, G E & CASTANO, M (1976) Purification of the whitefly transmitted Bean Golden Mosaic Virus Turrialba 26, 205-207

GALVEZ, G E , GALINDO, J J & ALVAREZ, G (1977) Defoliacion artificial para estimar perdidas por danos Foliares en frijol (*Phaseolus vulgaris* L) Turrialba 27, 143-146

GRAHAM, P H (1976) Identification and calssification of root-nodule bacteria In "Symbiotic nitrogen fixation in plants", P S Nutman Editor, Cambridge University Press pp 99-112

GRAHAM, P H (1978) Problems and potentials of field beans (*Phaseolus vulgaris* L) in Latin America Field Crops Res *1*, in press

GRAHAM, P H & HALLIDAY, J 1977 Inoculation and nitrogen fixation in the genus *Phaseolus* In "Exploiting the legume-*Rhizobium* symbiosis in tropical agriculture", J M Vincent Ed , University of Hawaii, College of Tropical Agriculture Mis Publ *145*, 313-334

GRAHAM, P H & HUBBELL, D H 1975 Soil plant-Rhizobium interaction in tropical agriculture In "Soil Management in Tropical America", E Bornemisza & A Alvarado Editors, North Carolina State University pp 217-230

GRAHAM, P H & HUBBELL, D H 1975 *Rhizobium*-Plant relationships in tropical agriculture Florida Agric Exp Station Journal Series 5439, 9-21

GRAHAM, P H & ROSAS, J C 1977 Growth and development of indeterminate bush and climbing cultivars of *Phaseolus vulgaris* L inoculated with *Rhizobium* J Agric Sci (Cambridge) *88*, 503-508

GRAHAM, P H & ROSAS, J C 1978a Nodule development and nitrogen fixation in cultivars of *Phaseolus vulgaris*, as influenced by planting density J Agric Sci (Cambr), in press

GRAHAM, P H & ROSAS, J C 1978b Plant and nodule development and nitrogen fixation in climbing cultivars of *Phaseolus vulgaris* L , grown in monoculture or associated with *Zea mays* L J Agric Sci (Cambr), in press

GUTIERREZ, U , INFANTE, M A & PINCHINAT, A M 91975) Descripcion de low principales aspectos del desarrollo del cultivo del frijol en America Latin CIAT Series ES 19, 1975

HERNANDEZ-BRAVO, G (1973) Potentials and problems of production of dry beans in the lowland tropics In "Potentials of field beans and other legumes in Latin America", D Wall Ed , CIAT Seminar Series 2E, pp 144-150

KITAJIMA, E W , GALVEZ, G E & TASCON, A (1977) Virus do "ampollado" do feijoeiro microscopia electronica dos tecidos de feijoeiro infetados Fitopatologia Brasiliera *2*, p 84

KRETCHMER, P J *et al* (1977) Red and far red light effects on climbing in *Phaseolus vulgaris* Crop Science *17*, 797-799

MORALES, V M , GRAHAM, P H & CAVALLO, R 1973 Influencia del metodo de inoculacion y el encalamiento del suelo de Carimagua (Llanos Orientales, Colombia) en la nodulacion de leguminosas Turrialba (1973) *23*, 52-55

SCHOONHOVEN, A V (1976) Pests of stored grains and their economic importance in Latin America XV International Congress of Entomology, Washington, in press

SCHOONHOVEN, A V , GOMEZ, L A & AVALOS, F (1978) The influence of leafhopper (*Empoasca kraemeri*) attack during various bean (*Phaseolus vulgaris*) plant growth stages on seed yield Entomologia Experimentalis et Aplicata, in press

SCHWARTZ, H F *et al* (1978) Field problems of beans in Latin America CIAT Technical Series (1978), in press

WILDE, G & SCHOONHOVEN, A V (1976) Mechanisms of resistance to *Empoasca kraemeri* in *Phaseolus vulgaris* L Environmental Entomology *5*, 151-155

WILDE, G , SCHOONHOVEN, A V & GOMEZ, L (1976) The biology of *Empoasca kraemeri* on *Phaseolus vulgaris* Annals of the American Society of Entomology *69*, 442-444