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I. SUMMARY

It is essential that genetic improvement of Phaseolus vulgaris L. for tropical conditions be based upon priorities such as those obtained from estimating yield losses and assessing alternative factors and strategies. The availability of carefully organized and properly evaluated germplasm collections increases greatly the utility of genetic resources in fulfilling crop improvement objectives. The germplasm improvement program for dry beans at the Centro Internacional de Agricultura Tropical emphasizes progressive screening in multiple, contrasting environments in which materials confront a wide range of production-limiting factors. Nurseries designed to evaluate resistance to principal diseases and insect pests are artificially inoculated, and all members of an interdisciplinary team contribute information on progeny performance. Individual projects for architecture, yield and adaptation breeding, and for specific diseases and insect resistance breeding, contribute to and compliment germplasm improvement activities.

II. INTRODUCTION

Phaseolus vulgaris L. beans are a basic component of traditional diets and highly diversified cropping systems throughout tropical Latin America. Diverse environmental challenges and highly specific local cultivar preferences make varietal improvement a difficult task. The most common feature of bean production in tropical Latin America is a low yield of harvested grain per unit area. Average yields for beans in monoculture have remained near 800 kg/ha for years (Londoño et al) a sharp contrast to the 4000 kg/ha obtained experimentally (1975 CIAT Annual Report) and 1200 kg/ha yields by progressive farmers using improved practices such as quality seed, higher plant populations, and water management (Pinstrup-Andersen et al, 1976).

III. CROP IMPROVEMENT OBJECTIVES AND PRIORITIES

We must identify those factors which account for differences of such a magnitude, and emphasize genetic improvement for characters where the largest possible gain may be realized in the shortest possible time.

A. Estimating Yield Losses

Only limited and scattered data is available for quantitative assessment of constraints to bean production in Latin America. Attempts have recently been made to economically quantify production losses according to the probable incidence, distribution, and severity of attack (Sanders and Schwartz, 1978). Farm level yield data are essential in order to validate conclusions based upon earlier surveys.

B. Weighting Alternative Factors and Strategies

After ranking bean pests according to economic losses, and before deriving a final breeding strategy, one must realistically weigh genetic improvement versus alternative means of alleviating the problem, such as disease-free seed and chemical protection. Of course it is also important to consider the existence of strains or races of the pest, mode of inheritance reported for the character, relative adaptation of prospective reported donors, and the efficiency expected in reselecting hybrid progenies for that particular trait. From all of the above criteria, the high-priority traits and stragegy to be employed must emerge. This procedure for determing breeding priorities is particularly important for tropical conditions, where such a vast array of production-limiting factors offer themselves as potential crop improvement objectives (Sanders and Schwartz, 1978).

IV. GENETIC RESOURCES AND GERMPLASM EVALUATION

A. Germplasm Collections

A world list of grain legume collections published by FAO (1973) shows 27 countries reporting a total of 48.000 *Phaseolus* samples, including a number of probable duplications. Further reports of *Phaseolus* germplasm have been made by Vieira (1973), Hernández (1973) and Winters (1973). Catalogs have been published for collections maintained in CIAT, Colombia; Cambridge, England; Pullman, USA; and CATIE, Costa Rica.

The CIAT collection (Table I) has grown rapidly since the first 3780 samples were received from USDA at Pullman in 1970. In 1976 CIAT and the IBPGR agreed that the collection, maintenance, evaluation, and distribution of *Phaseolus* germplasm would be centralized at the Palmira, Colombia site. In 1977 short- and long-term storage facilities have been completed to house the collection, which will also include other types of *Phaseolus* species.

B. Evaluation and Utilization of the Germplasm Bank

During the process of seed increase and characterization of materials from the CIAT collection, highest priority is given to agronomic characters which determine the potential utility to our P. vulgaris improvement program. More than 9,000 accessions have thus far been evaluated for one or more key agronomic/morphological characters, including anthracnose, common bacterial blight, bean common mosaic virus (BCMV), and Empoasca, and some 250 different materials have been selected for use as parents in the crossing program. With the assistance of collaborators international nurseries have facilitated the identification of promising germplasm for important factors such as rust, bean golden mosaic virus (BGMV), and the pod borer Apion godmani. The tremendous variability within P. vulgaris for characters such as growth habit, pod and seed morphology, chemical composition, and resistance to insect and diseases, has been described in part by Steimets and Army (1932), Muñoz and Cardenas (1950) and Barrios (1969).

The germplasm of P. acutifolius and P. coccineus is also of great interest, and the genetic variability within these species should be evaluated both for potential direct use in areas where they are adapted, and as a genetic resource for the improvement of more widely grown Phaseolus species. For example, high levels of resistance/tolerance to numerous disease and insect pests have already been found in P. coccineus and methods have been proposed to pyramid resistance factors (using natural cross-pollination), thereby reducing the number of undesirable associated traits accompanying the subsequent interspecific cross (Vakili, personal communication). Similarly, a cooperative program supported by CIAT and the University of Belgium, Gembloux attempts to first identify those P. acutifolius accessions with best overall agronomic value prior to attempting the interspecific hybridization.

V. GENETIC IMPROVEMENT OF *P. VULGARIS* AT CIAT, FOR THE TROPICS

A. Objectives and Organization

The CIAT bean program through local, Palmira-based activities and through collaborative activities with other national and university research programs, seeks to apply available agronomic and multidisciplinary expertise to the selection and testing of germplasm for a large group of characters. Using procedures described earlier for estimating yield losses and weighting alternative factors for genetic improvement, the program has established the priorities listed in Table II, which represents a generalization of several alternate classifications (eg. by growth habits, elevation, grain type). Germplasm improvement is the principal thrust and union of a program that has complimentary efforts in disease-insect resistance breeding, and in yield, architecture, and adaptation breeding.

B. Germplasm Improvement

From Figure 1 it is obvious that the testing procedure is open to receive promising materials from any source, including the germplasm bank. Superior entries become parents for the following cycle of crossing and the generation of new F_2 progenies, which are selected and progeny tested at the same location (Palmira or Popayán) for their reaction to inoculated diseases and insects. The 50-100 best crosses are increased for distribution to national programs requesting F_3 bulks.

F_4 families, together with selections from the germplasm bank and national and international programs (1500-2000 entries total) move to the uniform screening nursery (VEF). At this stage materials are evaluated in simultaneous but separate, non-replicated nurseries for architectural and yield characters and reaction to leafhoppers, bacterial blight, rust and common mosaic (all at Palmira), and anthracnose, angular leaf spot, adaptation, and other cool climate diseases (all at Popayán - 1800 m.a.s.l.).

Each year 500-800 selections from the VEF move forward to the preliminary trial (EP), where they are evaluated for extreme temperature reaction, photoperiod effects, drought, bean golden mosaic virus, web blight, and in replicated yield trials in two environments. The most outstanding 120-140 selections, and superior entries from national programs, pass to the international bean yield and adaptation nursery (IBYAN where they are grouped according to red, black, and other colors, into three distinct trials.

In the second semester of each year, the IBYAN is distributed to a limited number of key sites in Latin America. First semester distribution (the following year) is on a world-wide basis. The IBYAN trial represents the first stage of testing where sufficient disease-free seed is available to evaluate nitrogen fixation, tolerance to low phosphorus and high aluminum, root rots, and Apion godmani. Protein quantity and quality will also be tested at this stage.

Plans for an international bean elite trial are still in a formative stage. The objective will be to offer a small number of outstanding materials selected from the IBYAN, for a more extensive geographical distribution, and with a larger quantity of seed. The principal features of the different testing stages are summarized in Table III.

The extensive evaluations for multiple factors involve every member of the CIAT bean program in the process of crop improvement. Each successive stage is a more rigorous test in which the number of materials is progressively reduced. The bean information system (SIFRI) is designed to retain and rapidly provide an updated record of this process for materials in the germplasm improvement program. SIFRI information is integrated with the germplasm bank, through parental selection and hybridization, to the early- and advanced-generation management and testing of hybrid progenies. Data for parental characters is used to plan the management of hybrid progenies. The computerized information system, coordinated by the biometrics unit, is capable of great speed, volume and accuracy, and adapts easily to the standardized, sequential testing of selected progenies. The SIFRI output, which includes the preparation of field books, seed packing lists, and progeny managements cards, continues to be modified and improved. Our goal is that complete information will physically accompany all seed designated for planting within Colombia or internationally

C. Breeding for Architecture, Yield, and Wider Adaptation

This breeding activity, initiated during 1977, is an integral part of the genetic improvement program for dry beans. New characters and new combinations of characters are sought which would make P. vulgaris more competitive with alternative crops in good production areas, and a crop of greater confidence in more marginal production areas. Some characters, such as canopy height equal to that of soybeans, have yet to be found. Other desired components, such as later flowering and clustering of pods, exist and must be exploited more fully in combination with other agronomic traits that, as a whole, confer superior yield to genotypes destined for a heterogeneous group of cropping systems.

Specific morpho-agronomic traits that are sought for erect and prostrate bush beans are listed in Table IV. After initial screening for architectural traits, selections are evaluated for their range of temperature adaptation and particularly for yield and stability of growth habit.

D. Breeding for Specific Disease and Insect Resistance Factors

As discussed in an earlier section, diseases such as BCMV, rust, anthracnose, and angular leaf spot are routinely selected and progeny tested within the germplasm improvement program. Increased levels of resistance to production constraints, such as Empoasca, Bacterial blight, and Bean golden mosaic virus, are not easily obtained throught the mainstream procedure. All three are major limitations over substantial areas of Latin America, and evaluation of numerous materials from the germplasm bank has shown moderate levels of resistance. After identifying the best parental germplasm for each of the three problems, crosses were made within the Empoasca group in order to generate more genetic variability, with which to effect recurrent selection. Similar crosses were made within parental groups tolerant to bacterial blight and to BGMV, and selection initiated in three recurrent selection activities.

Each of the three projects presents unique difficulties. Empoasca resistance is difficult to quantify reliably on a single plant basis, and symptoms are easily confounded by the incidence of Bean chlorotic mottle virus and Bean rugose virus, whose insect vectors thrive in the midst of an unprotected Empoasca nursery. Bacterial blight evaluation is very dependent upon the physiological transition from the vegetative to the reproductive stage (Coyne and Schuster, 1974), and we have experienced difficulty to transfer resistance from poorly adapted temperate cultivars like Jules, into tropically adapted genotypes.

The incidence of BGMV within Colombia is not sufficient to screen segregating populations and conduct progeny tests locally. Therefore, it is necessary to evaluate and select early generation materials in collaboration with those national programs most interested in obtaining resistance to BGMV (Figure 2). Although Bean chlorotic mottle virus and Empoasca damage confound BGMV symptoms, resistances to both golden mosaic and Empoasca must be combined for large bean growing areas in Central America and Brazil. Black seeded selections with good levels of resistance and tolerance have been selected from the initial crosses (1977 CIAT Annual Report). As is the case for several other factors, it is anticipated that the incorporation of BGMV resistance into better-adapted acceptable non-black grain types will require more time.

The best selections from each disease and insect resistance breeding activity are utilized in subsequent intermatings, and are regularly subjected to the rigorous multiple-character test of the germplasm improvement program (Figure 1).

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Table I Cultivated PHASEOLUS species maintained in CIAT [1]

	No. of accessions	No. of accessions evaluated
P. vulgaris	12,600	9,460
P. lunatus	1,010	-
P. coccineus	165	-
P. acutifolius	45	45
Total	13,820	9,505

1 Does not include 65 accessions of non-cultivated *Phaseolus* species, such as *anisotrichus*, *filiformis*, *polystachyus*, and *ritensis*.

Table II Primary characteristics for the improvement of dry bush beans in CIAT´s germplasm improvement program.

A. Disease and Insect Resistance	B. Morpho-Agronomic
Bean common mosaic virus	Grain yield
Anthracnose	Different maturities
Bacterial blight	Plant type
Rust	Grain type
Angular leaf spot	Wide temperature adaptation
Empoasca	Variable sensitivity to photoperiod effects.

Table III Principal features of three testing stages for materials in CIAT's germplasm improvement program.

I. Uniform Screening Nursery (VEF) - Colombia

A. 1500-2000 selections and introductions.

B. Non-replicated evaluations at Palmira for Empoasca, Bacterial blight, Rust, BCMV, and Architectural characters.

C. Non-replicated evaluations at Popayán for Colletotrichum, Isariopsis, Ascochyta, Cercospora, and Architectural characters.

II. Preliminary Trials (EP) - Colombia

A. 500-800 selections and introductions from VEF.

B. Replicated yield trials at Palmira and Popayán.

C. Evaluations for extreme temperature reaction, photoperiod effects, drought.

D. Evaluation in Central America for Bean golden mosaic virus and Web blight.

III. International Bean Yield and Adaptation Nursery (IBYAN)

A. 120-140 selections from EP, separated by seed color preference.

B. August distribution to key locations in Latin America, February distribution internationally,

C. Simultaneous evaluations for Nitrogen fixation, tolerance to low P and high Al, protein quantity and quality, and resistance to Root rots and to Apion godmani.

D. Superior materials from IBYAN pass to an international bean elite trial.

Table IV Characteristics under improvement in bush bean architecture, yield, and adaptation breeding.

A. Morpho-Agronomic Characteristics

1. Erect bush (determinant and indeterminant)

   Grain yield

   Lodging resistance

   Greater effective plant height

   Early and late maturity

   Strong stem

   Small leaves, delayed senescence of foliage

2. Prostrate bush

   Grain yield

   Long flowering duration

   Response to low plant density

   Tolerance to pod rotting

B. Adaptive Characteristics

   Wide temperature adaptation

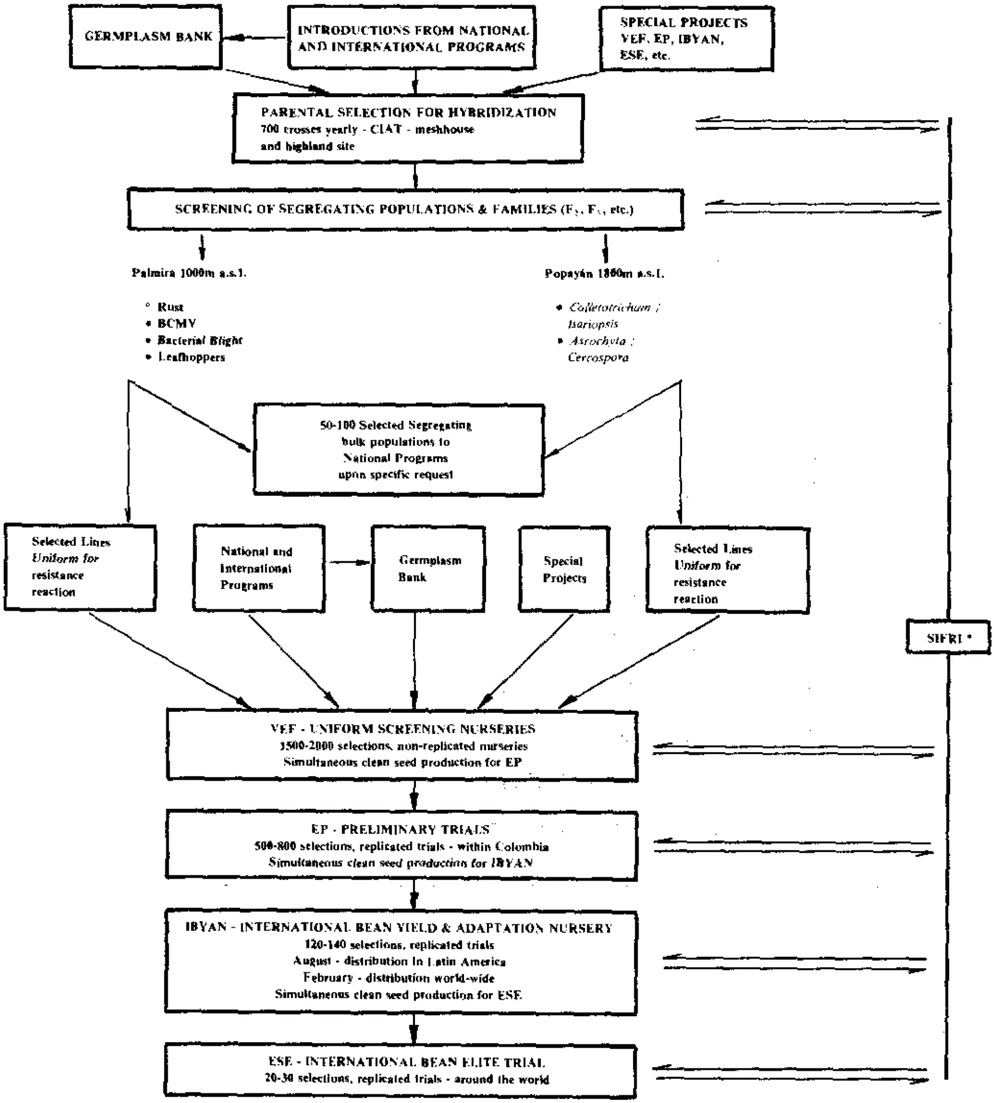
   Drought tolerance

   Tolerant to low P, and high Al and Mn soils

   Efficiency of Nitrogen fixation

Figure 1

CIAT-GENETIC IMPROVEMENT OF DRY BEANS *(Phaseolus vulgaris L.)*



* *Bean information system*

Figure 2   Genetic improvement for resistance of beans to bean golden mosaic virus.

Feb. - May	Intermatings, generation of 100-200 F_1 hybrids
June - August	Production of quality F_2 seed
Sept. - Dec.	F_2 nurseries, with spreaders, planted in Guatemala, El Salvador, Dominican Republic, and Brazil (2 locations)
Jan. - April	F_3 selections progeny-tested in same locations where selected. Remnant seed planted at CIAT in February, and reduce to selected parents on basis of family data from international test. Harvest best 8-10 plants from superior families as bulk (F_4 seed)

Generate new F_1 hybrids

Advanced progeny and yield testing varies with the national program. Selected families enter the International Bean Golden Mosaic Virus Nursery