Papers presented in SEMINAR on

Potentials of field beans and other food legumes in Latin America

SERIES SEMINARS No. 2E

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Centro Internacional de Agricultura Tropical

CONTENTS

SUMMARY REPORT OF THE SEMINAR

It was in Latin America that man first brought the common bean in from the wild and added it to the world's great food crops. In the ancient cultural patterns of Latin America's people, it is natural that beans hold a special place in traditional agriculture and accustomed foods.

Along with their edible relatives in the legume family, beans both offer promise, and pose stubborn problems, for hungry millions everywhere. This is nowhere more evident than in the developing countries of Latin America.

What is the promise? Into diets too narrowly based on cereals such as maize, or roots such as cassava, beans and other food legumes bring quantities and qualities of body-building protein lacking in the customary daily food of lower income people. Protein is vital need, particularly of the growing young. No source of the needed protein, other than food legumes, is so close to the means of, and so accepted by, the masses of people.

What are the problems? Climatic hazards and prevailing low-level technology keep bean yields low. Demands exceed supply and keep market prices beyond reach of many low-income people, even while farmers too commonly find growing bean risky and commercially unprofitable. The subsistance farming family simply hopes, too often vainly, that the little bean plot will fend off hunger. Even if we learn how to produce more beans, there are gaps in our knowledge of how best to process beans into various food products, and how best to utilize their food values.

What are the solutions? They are not simple. Both technological and socio-economic actions are needed. While the long-term problems are tackled, short-term ingenuity is needed. Plant breeders can raise yields by combining productive genes from the wide variety found in the many strains of **Phaseolus vulgaris** (the common field bean).

Agronomists, with the help of entomologists and pathologists, can devise better ways of planting, tending and protecting the crop. More effective storage methods can be developed along with ways of processing beans into new and perhaps more acceptable foods. Aided by newly built-in qualitles, nutritionists can explore how to use beans in healthful, satisfying diets compatible with traditional customs. Extension workers can carry the new "technology package" to farmers and new dietary knowledge to homemakers. Governments can provide the infrastructure of supporting institutions.

To confront this complex of promise-problems-solutions, a Seminar on The Potentials for Field Beans and Other Food Legumes in Latin America and the Caribbean was organized by CIAT—Centro Internacional de Agricultura Tropical. The seminar took place February 26-March 1, 1973, in Cali, Colombia, CIAT's base.

From more than 20 countries on five continents, from national and international, public and private, institutions, some 150 participants came to hear 32 speakers—not only to listen, but also to contribute their own experience and insights in lively inter-disciplinary discussions. They were scientists in a dozen biological and social disciplines; researchers and practical agronomists and engineers; administrators and communicators.

One result, is the gathering together of a great fund of knowledge about the potentials and the problems of food legumes. This information is being published by CIAT in English and Spanish for widespread circulation.

Out of the Seminar came no new Institute or "Program," nor was this intended. The national and international organizations represented are already, each in its own way, engaged in programs spanning research, training, communication, and action in the field.

There resulted, however, agreement to find practical means to link all these efforts together and so to focus more sharply upon recognized priority tasks.

To this end, the seminar participants asked the Seminar Steering Committe to form a small task force to draft a proposal as to how these linkages might be most effectively forged. This request came at the conclusion of a plenary session in which the reports of 12 general discussion groups were heard and consolidated.

While there was unanimous agreement about the convenience and desirability of establishing a regional cooperative network or program, suggestions varied with respect to criteria of formulation and operation. It general, it was considered convenient to review the experiences obtained in Latin American institutions such as the Central American Cooperative Program for Food Crops Improvement (PCCMCA) that could be the basis for the establishment of a wide-ranging network.

Participants agreed that an international network must not replace national activities, but must complement and provide effective liaison among them. Activities suggested for consideration included cooperative research projects, publication and documentation systems, conferences and symposia, exchange of personnel, training, and operation of germplasm banks.

Once operating, the network could also help channel research activities and technical and financial resources to member institutions.

Within one hour after adjournment of the seminar, the Steering Committee met and nominated three persons to staff the proposed task force. All had participated in the seminar and were still available. When invited to serve on the Task Force, all three agreed to do so.

Members of this group are Dr. Ricardo Bressani, Institute for Nutrition in Central America and Panama, Guatemala City, Guatemala; Dr. Luis Marcano, president, Shell Foundation, Caracas, Venezuela, and Dr. Oswaldo Voysest, Departamento de Leguminosas de Grano, Estación Experimental "La Molina," Lima, Peru.

In addition to the papers of the seminar and the specific comments which the participants were invited to send the Task Force, the group will draw upon the recommendations of the 12 discussion groups mentioned above as well as the reports of the six disciplinary work groups. These latter reports identify the major problem areas, assign priorities to the problems, propose approaches to consider and suggest the institutions and individuals which the people from that discipline attending the seminar believed might most appropriately undertake the needed work.

Specific research-oriented goals of a coordinated program were outlined as follows: To identify research areas of common interest; to establish priorities among these; to plan experimental work toward these objectives; to seek additional funds when needed to carry out the indicated experiments; to assist various cooperators to conduct the agreed upon research, and to evaluate and disseminate the results of the cooperative research effort.

While each disciplinary work group listed several areas for priority attention, some of the areas emphasized by each group were as follows:

Agronomy: Greater attention to the cultural practices of small bean producers in hilly areas who grow beans inter-planted with other crops, as well as varieties and practices for those who produce beans as a monoculture, commercial crop.

Breeding: Increased efforts to identify and to incorporate into productive genotypes resistance to a wide spectrum of insects and disease.

Plant Physiology: Intensive research on the physiological capabilities that limit yield in a continuing program to determine superior plant types.

Crop Protection: Location of sources of resistance for or means of controlling the principal diseases (rust, root rot, bacterial blight, common mosaic, golden mosaic) and the main insect pests (small harvest flies, lady bugs, cutworms, aphids, storage insects).

Economics and Nutrition: Establish nutritional and chemical composition patterns according to eating habits; study price stabilization mechanisms attractive to producers and consumers; seek improved means of taking technology to farmers; study bean processing; establish adequate storage conditions, and provide more reliable statistical information on production and prices.

Administration: Form a small task force to develop plans and criteria for an international network for bean improvement.

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Section 1.

FOOD LEGUMES AND HUMAN PROTEIN NEEDS

THE IMPROVEMENT OF FOOD LEGUMES AS A CONTRIBUTION TO IMPROVED HUMAN NUTRITION

Samuel C. Litzenberger

The FAO Food Survey estimates that on a world basis some 10 to 15 percent of the people are undernourished and up to half suffer from hunger or malnutrition or both. These nutritional deficiencies are most serious within the developing countries. According to Schertz (7) about two-thirds of the world, the poor countries, consume only half of the world's protein; and this is mostly cereal protein. If the projected population increases are realistic, that within the next generation the world's population will double, the food situation will worsen unless substantial effort is directed toward increasing food production.

Undernourishment or malnutrition may arise from inadequate caloric intake, protein deficiencies, and a shortage of vitamins and minerals. Of these deficiencies protein deficiency has aroused the greatest concern. Protein hunger may largely be overcome by an increase in availability in animal or plant proteins at price levels the affected population can afford, or through fortification. These alternative routes have often been considered as competitive; in reality they are complementary. Each alternative has special advantages and disadvantages and both have their inherent costs.

In fortification the costs include the price of the basic ingredients (soybean flour, fish concentrate, amino acids, minerals, vitamins, etc.) and the costs of transportation, dietary incorporation and distribution. The costs of materials can be calculated but the characteristics of the target population (age profile, geographic distribution, etc.) are largely unknown making transportation and distribution costs difficult to estimate.

Increased plant or animal proteins can be achieved from improved plant varieties and from better management practices. These, in turn, require increased expenditures for research. Increased levels of productivity resulting from research can be predicted almost with certainty but the costs involved are less predictable. This is true because for many crops the potential for improvement is largely unknown. Secondly, the efficient utilization of improved cultivars is somewhat dependent upon the local infrastructure (extension effort, seed production and distribution facilities, transportation and marketing facilities, etc.). Thus, any precise cost comparisons between the alleviation of protein deficiency through breeding, or through fortification are not possible at present.

Table 1. Comparative cost of major protein sources in human diets

Food Source	US$/kilo	% Protein	US$/kilo protein
Beef	1.54	15.2	10.12
Pork	1.10	11.6	9.46
Poultry	0.66	20.0	3.30
Nonfat dry milk solids	0.32	35.6	0.90
Dry beans	0.18	23.1	0.77
Soybeans	0.11	34.9	0.31
Oats	0.051	13.0	0.40
Wheat	0.062	12.2	0.51
Maize	0.057	9.5	0.59
Potatoes	0.11	2.0	5.50

Source: Dimler, R. J. Soybean protein food. Soybean Protein Foods 1966, Agr. Res. Service, USDA 71 - 35 May 1967.

This paper will be concerned only with the possible role of the food legumes in alleviating protein deficiency and opportunities for increased production. As for comparative costs of major protein sources in human diets, the cost per kilo of protein for crops is strikingly lower than that for animal protein (Table 1). Of those listed, cereals and soybeans are the least costly.

The world over, vegetable proteins account for approximately 70 percent of the protein in the human diet and animal proteins some 30 percent. In the developing countries even less of the total dietary protein comes from animal sources. Cereal proteins make up more than 70 percent, a sizeable fraction of the total vegetable protein consumed. The protein content of cereals normally ranges from about 8 to 16 percent. In each of the cereals, protein quality is below the optimum need of man; some one or more of the essential amino acids being limiting, the major ones being lysine and tryptophan. Small animal trials run on opaque-2 maize, high proly, barley, high protein wheats, and on the man-made species triticale, indicate that even within the cereals, improvements in protein quantity and quality are being achieved.

Compared with the cereals and root/tuber crops the food legumes in general present a much more favorable picture with respect to both quantity and quality of protein. Protein varies from 20 to 40 percent. Methionine and to some extent cystine, both sulfur-bearing, are usually the most limiting amino acids. Thus cereals and legumes complement each other very satisfactorily, both in terms of protein content and quality. The food legumes, when raw, contain a number of toxic factors. Most of these, however, are destroyed by normal cooking procedures. The heat stable factors which must be considered include cyanogens, alkaloids (most serious in Lupinus species), lathyrogens (**Lathyrus sativus**), favism (**Vicia faba**) and flatulence factors.

Approximately 20 species of the Leguminosae family are used for human food in some area of the world. Eight of these are most extensively grown but even within this group there are striking differences in area of adaptation and use. Roberts (5) has grouped six of these into four major classes depending primarily upon climate requirements. These are as follows:

A. Low humid tropics

(1). Pigeon peas (**Cajanus cajan**)

(2). Cowpeas (**Vigna sinensis**)

B. Semidry or seasonal tropics

(3). Groundnuts or peanuts (**Arachis hypogaea**)

C. Tropical intermediate elevations to temperate zones

(4). Soybeans (**Glycine max**)

(5). Dry beans (**Phaseolus vulgaris**)

D. Cool weather, high elevation zone

(6). Chickpeas (**Cicer arietinum**)

(7). Peas (**Pisum sativum**)

(8). Broad beans (**Vicia faba**)

We have added peas and broad beans to the Roberts' list with chickpeas in the cool weather group because of their relative importance as food legumes in these special environments. Next to soybeans and groundnuts, peas and dry beans are the most extensively grown legume crops, each occupying about 10 percent of the world's area planted to food legumes. After these in importance come the broad beans, averaging about 5 percent of the area planted.

The limitation of food legumes to the above eight species must be somewhat arbitrary. In certain geographical areas other species would equal or exceed them in importance. For example, lentils and broad beans are grown as extensively as chickpeas in the Near East and pigeon peas, although widely grown, are of little importance as a food crop in Africa. Similarly cowpeas are yet only of major consequence in Africa as a legume food crop.

Data on production and on average yield by regions, for a selected group of legumes and oilseed species, are presented in Table 2. Average yields for any given species vary greatly among regions and only soybeans and peas on a worldwide basis and to a lesser extent groundnuts and broad beans exhibit any marked yield superiority. These average yields, however, provide a poor measure of yields which might be expected under more favorable management practices.

GOALS FOR RESEARCH

If the six species listed by Roberts (5) plus certain others of regional importance, are to play an important role in alleviating protein deficiency a greatly expanded research program will be required. With a few notable exceptions, only limited research has been done on food legumes encompassing a balanced program involving both the development of improved cultivars and a careful examination of soil management and production practices. In terms of grain yield per hectare the food legumes are characteristically lower yielding than the cereals. Critical data are lacking to establish what fraction of the yield differential is inherent and what fraction a reflection of the limited research effort expended.

Table 2. Average world and region production of grain in thousands of metric tons (M /MT) and yield in hundreds of kilos for a selected group of legumes and oil seed species

Crop	World Total Production (M/MT)	World Total Yield (kg/ha)	North America Production (M/MT)	North America Yield (kg/ha)	Latin America Production (M/MT)	Latin America Yield (kg/ha)	Near East Production (M/MT)	Near East Yield (kg/ha)	Far East Production (M/MT)	Far East Yield (kg/ha)	Africa Production (M/MT)	Africa Yield (kg/ha)
Pulse Crops												
Dry beans	10708(11) 1/	4.7	833	15.3	4003 2/	5.9	195	11.0	2619	3.1	805	6.0
Dry peas	10115(10)	11.5	197	16.3	101	6.9	7	17.5	970	9.2	352	7.3
Broad beans	4636(5)	9.9	–	–	189	5.9	328	15.0	11	12.2	341	8.3
Chickpeas	7445(7)	6.9	–	–	150	7.2	206	9.1	6558	6.9	316	6.3
Lentils	996(1)	6.2	31	12.4	22	5.9	223	7.7	458	5.1	128	5.9
Pigeon peas	1829(2)	6.3	–	–	31	7.0	–	–	1760	6.4	38	3.8
Cowpeas	1083(1)	3.9	25	6.3	–	–	16	12.3	26	6.2	1004	3.7
Oil Seed Crops												
Soybeans	43613(44)	13.0	30269	18.1	903	10.5	9	11.3	1161	7.0	23	7.7
Groundnuts (in shell)	15034(15)	8.5	1153	19.8	1246	11.5	292	7.8	5869	7.0	4219	8.1
Sesame	16285 –	2.9	4	4.0	3211	6.6	2107	3.6	5930	1.9	1305	3.0
Sunflower	9944 –	12.7	102	9.5	1032	8.7	237	9.6	–	–	155	6.0

Source: 1969 FAO Production Yearbook Vol. 23.

1/ Numbers in parentheses indicate percentages of world total food legume production which totaled 101,347,000 metric tons.

2/ Values darkened indicate the current world center of production of the crop listed. For dry peas and sunflowers it is Russia with respective production of 4,818,000 and 6,685,000 M.T., and for yield of 1,540 and 1,370 kg/ha. For broad beans it is Mainland China with an average production of about 3,000,000 MT and a yield of 980 kg/ha.

For the production of protein nutrition per hectare not all of the food legumes yield less protein nutrition per hectare than the cereals (Table 3). Soybeans averaged about 150 percent more than the three most extensively grown cereals in the world; groundnuts were nearly 25 percent more productive, while peas were nearly 10 percent higher. For dry beans, one of the most extensively grown food legumes in Latin America, protein nutrition averaged about 30 percent less than the best of the cereals. The other food legumes yielded progressively less.

While climate is a major limiting factor in the ultimate yield of any crop, it is apparent from these data that past concerted effort in breeding and selection has undoubtedly played a major role in giving comparative advantages to soybeans, peas and groundnuts for yield superiority. For example, starting from a tropically-adapted plant the soybean was transformed through a concerted effort into one of the most efficient producers of grain of any of the legume crops in the temperate zone. This is not to indicate that no further improvement is possible. Quite the contrary, since the past efforts were geared mostly toward the production of a seed with the highest content of oil.

Continued orientation of research to the development of types with more and better protein and the selection of plant types particularly well adapted to the tropical and subtropical environments can develop equally superior plants not only for the soybean, but can be similarly effective in improving yields of other selected food legumes. Most species are endowed with sufficient genetic diversity to make this advancement possible, otherwise they would already have disappeared as species. Continued effort on the part of research is necessary, first to locate the needed genetic factors and then to combine them into the winning combination.

Fields in which additional research is obviously needed include the development of higher yielding cultivars having the maximum possible resistance to disease and insect pests of local importance; improvements in protein percentage, amino acid balance and other nutritional qualities; and the development of better soil management and production practices.

VARIETAL IMPROVEMENT

In tropical areas work on varietal improvement of food legumes has suffered from lack of continuity as well as limited resources. Where major advances have been realized, e.g., beans in Mexico and Colombia, cowpeas in Nigeria, pigeon peas in India, etc., the new varieties have had only limited impact due to restricted seed production and distribution programs and extension efforts.

At the Stockholm Conference on Human Environment considerable emphasis was given to the necessity for the collection and preservation of both cultivated and wild plant species. The importance of such efforts cannot be over-emphasized. One of the first requirements for effective breeding research with any crop is an adequate germ plasm reservoir of the variability characterizing the species. Some collections exist but it is questionable if these are adequate for any of the species of interest.

Major collections now available include beans, soybeans and peanuts maintained by the U.S. Department of Agriculture, beans by CIAT, cowpeas by IITA and the Nigerian Government. A program in Iran and India supported by AID and the Agricultural Research Service (ARS), U.S. Department of Agriculture, assembled a collection of some 26,000 items representing 10 species. This collection is currently

Table 3. Relative efficiency of worldwide protein production of selected food crops

Crop	Total world production	Grain yields	Protein content of seed	Nutritional value	Protein content nutritional coefficient	World avg yield protein nutrition
	(Million MT)	(MT/ha)	(%)	(% egg protein)	(%)	(kg/ha)
Legume food crops						
Soybean	43.6	1.3	38	62	23.6	306.8
Dry beans	8.7	0.8	22.1	47	10.4	83.1
Dry peas	10.1	1.2	22.5	50	11.3	130.0
Chickpeas	7.4	0.7	20.1	53	10.7	73.8
Groundnuts	15.0	0.7	25.6	69	17.7	123.9
Broad beans	4.6	1.0	23.4	41	9.6	95.0
Pigeon peas	1.8	0.6	20.9	39	8.2	51.7
Cowpeas	1.1	0.4	23.4	57	13.3	51.9
Lentils	1.0	0.6	24.2	41	9.9	61.4
Mungbeans	2.0	0.3	23.9	32	7.6	19.7
Cereal grain crops						
Wheat	332.5	1.5	12.2	68	8.3	121.2
Rice (Paddy)	284.2	2.2	7.5	76	5.7	122.6
Maize	251.1	2.4	9.5	55	5.2	123.2
Sunflowers	9.9	1.3	12.6	93	11.7	148.6
Potatoes (Irish)	315.5	13.8	2.0	53	1.1	151.8
Cassava	85.6	8.7	1.6	85	1.4	121.8
Plantain	12.7	15.0	1.1	71	0.8	120.0

Sources: 1969 Production Yearbook (FAO Vol. 23) and 1970 Amino Acid Content of Foods and Biological Data on Protein (FAO Vol. 24).

being maintained by the A11 India Coordinated Pulse Program and by the U.S. Department of Agriculture in Puerto Rico. In addition, smaller collections involving items of local interest are maintained by each active breeding program.

The assembling of germ plasm variation in world collections, however large, is of limited value unless adequate provision is made for both maintenance and evaluation. Too often, these two activities have been dependent upon the interests of a very few individuals. As a result, neither effort has been completely satisfactory.

Roberts (5) has suggested a system which should give a greater degree of stability and usefulness to collections now in existence and for their further expansion. This responsibility would be assumed by the several International Institutes. Some of his recommendations have already become a reality. For example, dry beans are currently being supported to a beginning extent by CIAT; cowpeas have been accepted by IITA as a major pulse crop for needed research and training on an international basis; pigeon peas and chickpeas are now the international responsibility of ICRISAT; soybeans were to have been assigned to CIAT or IITA and groundnuts possibly to IITA.

No priority support was indicated for dry peas or broad beans, two of the food legumes which have shown some real advantages as producers of quality protein in volume in selected environments. The Federal Station at Mayaguez and the University of Puerto Rico would continue their general interest in soybeans for the tropics and subtropics in cooperation with the University of Illinois and its large legume collection.

As for the mungbean, while the brief production and seed quality data of Table 3 show it to be a poor performer, its importance as a short-seasoned catch crop following other regular crops, especially rice, in tropical regions requires some research support. This will probably be forthcoming from the Asian Vegetable Research Development Center (AVRDC), Taiwan,which will be working very closely with IRRI.

Regardless of the final disposition of responsibilities for further collection and for maintenance, provision must also be made for a network of cooperating stations to accumulate the information needed on relative yield performance, day-length responses and disease and insect reactions.

More recently AID has been encouraged by the Consultative Group (CG) through TAC (Technical Advisory Committee on International Agricultural Research) to consider the development of an International Soybean Resource Base at the University of Illinois where advantage would be taken of the vast competence that already exists with this crop in the U. S. at the University and as supported by the Regional Soybean Laboratory located nearby. To support its immediate need for a U. S. based tropical environment Puerto Rico would become an integral part of the Resource Base.

Such a proposal would serve as the nucleus for the ultimate establishment of an international institute providing research and training services to the international soybean network much as is currently being done by the other international crops centers. Outreach and linkage activities would be handled comparably to those already worked out for the different crops by the international institutes. Soybean Resource Base activity linkages with IITA, CIAT, ICRISAT, IRRI, etc., would be envisioned to be direct and supported by multilateral funding through the CG.

In the Regional AID/ARS Pulse Improvement Project which has variously cooperated with India, Iran, and at Puerto Rico, since 1969 for special support to Latin America on bean and cowpea diseases and related insects, tremendous differences have been observed among the collections representing each species. These variations included apparent yield potential, maturity, plant type and resistance to various diseases and insect pests. It was apparent that major improvements could be achieved by selection among and within currently grown types. Even greater increases in yield potential should be possible by selection among the progeny of carefully selected parents or through population breeding where a broad genetic base is required to control limiting diseases and insects. Relatively little breeding work of this type has been undertaken and yet this is the simplest way in which desired recombinants may be produced.

Each crop poses its own peculiar problems. Extensive breeding work has been done on soybeans within the temperate regions and a large number of commercial varieties are available. Soybeans, however, are day-length sensitive and these varieties are of limited usefulness outside the region of their development. Most of these varieties would be poorly suited to the range of day-lengths prevailing in the tropics. Many other legumes exhibit similar response to variation in day-length. Similary, the major disease and insect pests vary from species to species and, possibly to a lesser extent, with ecological zones. It is thus apparent that any screening or selecting of improved types must be done in the environment in which the crop is to be ultimately grown.

Breeding and management are complementary activities; high yielding cultivars cannot express their potential if water or fertility is limiting. Similarly, good management cannot compensate for inferior germ plasm. This relationship requires that breeding and management studies be conducted simultaneously. Population densities, time of planting, pest control, water distribution and fertility regimes each may affect yield response and must therefore be incorporated into any breeding and evaluation program. Knowledge of response under an adequate or optimum regime is required to provide useful information on relative yield potential.

IMPROVED NUTRITIONAL CHARACTERS

Information on variation in protein percentage is available for several of the food legumes. Environmental effects are known to be important. Corresponding information on the effects of environment on the individual amino acids is much less extensive.

Protein content

The most extensive work on protein variation has been done in soybeans (1). Protein and yield are negatively correlated as are also protein and oil content. These correlations, while statistically significant, are not so great as to be a major barrier to genetic progress. The major emphasis in modifying composition has been directed toward increasing oil percentage. Only limited effort has been directed toward increasing protein percentage yet two varieties, Protana and Bonus, have been released having approximately 43 percent protein. If protein were to receive increased emphasis it appears that still higher types could be developed.

Silbernagel (8) has screened a large number of bean varieties and introductions and found protein values ranging from 16 to 33 percent. Protein percentage was found to be influenced by environment with considerable variation among both locations and years. Certain lines, however, were consistently high in protein under all environments tested. Rutger (6), also working with beans, found variation in protein content ranging from 19 to 31 with a mean of 24.6 percent. Within the sample of lines used yield and protein content were not significantly correlated but a positive correlation was observed between protein content and late maturity and negative correlation between protein and seed weight.

While mungbeans were not included in the select group of six listed earlier, variation in protein percentage is of some interest. Studies were conducted at the University of Missouri in 1970 and 1971 under an AID contract. Among the 313 strains tested from the world collection protein percentage ranged from 19.1 to 28.3 percent in 1970 and from 22.1 to 31.2 percent in 1971. Yield, protein percentage and seed weight were negatively correlated.

In studies conducted in India with chickpeas, pigeon peas, mungbeans, peas and cowpeas, Krober et al (3) reported significant varietal differences in protein content. No significant differences were found among the urd bean and lentil varieties tested.

From the rather limited data available, it appears that protein content is under some degree of genetic control; however, the pattern of inheritance has not yet been established. The development of higher protein types should therefore be possible in most of the species examined. An effect of environment on protein content was noted in most studies. This relation complicates the problem of breeding for increased values as the material must be evaluated under a range of environments to obtain a fair measure of real differences. The extent to which environmentally induced differences can be minimized by uniform management practices remains to be established.

Protein quality

Information on amino acid profile in the food legumes is less detailed than for protein content. Data for some of the legumes of interest are presented in Table 4. Some cereal and root/tuber crops and animal products are included for comparison.

Two points are of particular interest. First, lysine values tend to be high for the legumes. This fact is responsible for the complementarity of cereals and legumes. Second, there are rather large variations in the methionine plus cystine values among the different leguminous species. The values given serve for average comparative purposes but have the limitation that the samples tested were not necessarily grown under uniform conditions.

In breeding for improved protein quality primary emphasis must be given to methionine, as it is normally the first limiting amino acid. Cystine variation would also be of some interest as methionine and cystine exhibit a mutually sparing relation. Possibly some attention should also be given to lysine to ensure discarding strains with below normal values.

The ion exchange amino acid analyzer is not well suited to the needs of the plant breeder who is concerned with the evaluation of large numbers of samples. The microbial assay, though possibly less precise, can be more readily adapted to handle

Table 4. Comparison of amino acid content per 100 grams of food

Food	Moisture (grams)	Protein (grams)	Lysine (mg)	Sulfur-containing amino acid			Trypto-phan (mg)	Total essential amino acids (mg)	Total amino acids (mg)
				Methi-onine (mg)	Cystine (mg)	Total			
Cereal Grains									
Maize	12	9.5	254	182	147	329	67	3,820	9,262
Rice-brown	13	7.5	299	183	84	264	98	3,033	7,973
-polished	13	6.7	255	150	108	259	95	2,695	6,785
Wheat	12	12.2	374	196	332	528	142	4,280	12,607
Roots and Tubers									
Potato	78	2.0	96	26	12	38	33	667	1,572
Yam (Dioscoria)	72.4	2.4	97	38	27	65	30	821	2,009
Cassava (Manihot) meal	13.1	1.6	67	22	23	45	19	404	1,184
Legumes (pulses)									
Beans (Phaseolus)	11	22.1	1,593	234	188	422	223	8,457	20,043
Beans, Broad (Vicia)	11	23.4	1,513	172	187	359	202	8,244	20,951
Chickpea	11	20.1	1,376	209	238	447	174	7,802	19,290
Cowpeas (Vigna)	11	23.4	1,599	273	255	528	254	8,640	21,086
Peanut	5.2	25.6	1,036	338	366	704	305	9,502	27,610
Lentil	11	24.2	1,739	194	221	415	231	9,504	23,447
Lima bean	11	20.0	1,466	246	199	444	199	8,359	19,104
Mungbean	11	23.9	1,927	126	168	294	—	8,547	20,344
Peas	11	22.5	1,692	205	252	457	202	8,464	20,901
Pigeon pea	11	20.9	1,607	107	204	311	117	7,505	18,460
Soybean	8	38.0	2,653	525	552	1,077	532	16,339	40,945
Meat and Poultry									
Beef and Veal	61	17.7	1,573	478	226	704	198	7,875	17,163
Chicken	66	20.0	1,570	502	262	764	205	8,380	18,206
Egg (Hen)	74	12.4	863	416	301	717	184	6,338	12,763
Fish meal	10.1	75.0	5,808	2,052	924	2,976	720	30,360	70,308

large numbers. The modified microbiological assay developed by Kelley et al (2) has been used extensively on beans. From a study involving 3,600 strains he concluded that methionine level was under genetic control and speculated that through breeding and selection the present level of critical amino acids might be doubled. Work with mungbeans at Missouri (9, 10) indicated a three-fold range in methionine content. Unfortunately, there appeared to be an inverse relation between protein and methionine content.

Amino acid compositional studies are under way at a number of institutions in both the U.S. and India. Hopefully, information will soon be forthcoming on the inheritance patterns of the individual amino acids of interest and their interactions with both protein and environment established.

Other nutritional characters

The heat stable factors of greatest concern include the cyanogens, alkaloids, favism and flatulence factors. Fortunately, all of these factors are not common to all species and therefore routine screening of all material may not be necessary. Any new variety, however, should be carefully evaluated for all heat stable factors before release. Assay procedures are available for the factors of greatest potential importance.

Wide variations in the time required for cooking exist among the food legume species. Reduced cooking time may be an important factor in consumer acceptance of new cultivars where fuel is in limited supply.

Evaluation of each of the factors of interest (amino acid composition, heat stable factors and cooking time) can be incorporated into a laboratory screening program closely coordinated with a breeding program. Staff and funds required for such an effort will, however, be substantial. Experience will likely dictate that some priorities be established and that only a small segment of the breeding material will be subjected to all tests.

The final evaluation of any breeding product must depend upon nutrition studies with appropriate test animals, both when utilized as the major source of protein and when utilized in combination with normally available cereal and root and tuber crops that are consumed with it. Differences in amino acid nutritional availability have been demonstrated in some of the cereals and may exist more widely even in the food legumes. Unfortunately, because of the quantities of material required, nutritional evaluation must be deferred until late in the breeding and evaluation process. However, this is an early must for any new variety being considered for release. For obvious reasons this should even be a basis for selecting parent stocks in any expanded breeding program.

MANAGEMENT

The complementary relation between breeding and management has already been mentioned. Management studies on the food legumes have been limited. A partial explanation for this arises from the wide differences in cultural practices employed. Legumes may be grown in monoculture or as mixtures with corn, sorghum, cotton or other crops. When grown in mixtures, the regime of planting time and fertility is that employed for the major crop. This may or may not be optimum for the legume.

When grown in monoculture it has commonly been assumed that nitrogen requirements will be satisfied through nitrogen fixation by appropriate strains of Rhizobium. In studies with soybeans in Illinois the use of nitrogen fertilizer has given some increase in yield but the level of response was not economic. Nitrogen applications, however, did produce a higher protein percentage in the seed. The need for phosphorus and potash will be dependent upon soil characteristics and previous management and cropping practices. With the introduction of any relatively new species into a community either for testing or production, and especially in the tropics and sub-tropics, assurance of appropriate nitrogen fixation by Rhizobium is of prime importance.

Plant population must be geared to rainfall distribution patterns and stored soil moisture unless water needs are to be met through irrigation. Fertilization levels must be geared to both available water and population levels.

ECONOMIC FACTORS

Unless plant breeding and management research are successful in increasing average yield levels to the extent that they become competitive with cereals, the deserved increase in production may be difficult to achieve. Some data from India (Table 5) may serve to illustrate the problem.

Prior to the introduction of the short-statured wheats, yields of wheat were approximately 30 percent greater than for chickpeas (gram). With approximately equal prices, returns per unit area would correspond to the average yields. With the current extensive use of the new improved wheats and the accompanying improvements in management practices yields per hectare have nearly doubled while yields of chickpeas have shown little change. The effect of this example is self evident.

Thus, in 1970, per unit area returns from wheat were nearly double those from chickpeas, ignoring any differences in cost of production.

Table 5. Average yield and price for wheat and chickpeas (gram) in India for the agricultural years, 1950 to 1970

Crop	1950	1960	1965	1968	1969	1970
Wheat						
Avg. yield, lbs/acre	591	759	738	1043	1079	1159
Price RO/Quintal			97.0	97.1	1068	104.5
Chickpeas						
Avg. yield, lbs/acre	430	601	469	541	639	600
Price RO/Quintal			93.2	101.5	99.0	108.1

Source: Bulletins of Food Statistics, Ministry of Agriculture, New Delhi, India.

This comparison is not entirely valid as the two crops are not completely competitive. Wheat is grown under irrigation where this is possible, while chickpeas are more commonly grown under rain-fed conditions. The illustration, however, emphasized the point that without substantial increases in yield or without some differential pricing structure substantial increases in legume acreage may be difficult to achieve on a sustained basis.

CONCLUSIONS

In conclusion, the prospects of developing food legume types superior in yield to those in common use appear excellent. Improvements in quantity and quality of protein appear equally feasible. Either of these developments would contribute greatly to a lessening of the protein deficiency problem. The extent to which these possibilities are achieved will depend upon continued resources being allocated to needed research.

Priority support should be provided to the eight most extensively grown food legumes whose prospects appear comparatively brightest for more and better protein production on a world or regional basis. Current average protein production performances per hectare for the eight major food legumes for specific countries or regions serve as a beginning for any overall food legume improvement program (Table 6).

For the greater part of Latin America, to help alleviate the problem of protein deficiency, no national or regional program supporting research, training, and production, could exclude the bean. Beans have been and will continue to be for some time a major supplier of protein in that part of the world. It is apparent, however, that as a first priority special effort will be necessary for all concerned to concentrate on the development of improved strains and supporting cultural practices which result in economically competitive yields when compared to other crops grown, while at the same time retaining or increasing their consumer acceptability and nutritional value.

Table 6. Comparative production levels of protein nutrition in kg/ha for Latin America and centers of most extensive cultivation

Crop	Latin America	Center of most extensive cultivation
Soybeans	248	425 (USA)
Groundnuts	163	90 (India-Pakistan)
Dry beans	61	69 (Brazil)
Dry peas	78	174 (USSR)
Chickpeas	77	74 (India-Pakistan)
Broadbeans	57	94 (Mainland China)
Cowpeas	–	79 (Nigeria)
Pigeon peas	57	54 (India-Pakistan)

To accomplish this, actual protein yields per hectare of beans will have to be more than doubled in Latin America to be on a par with the cereals; more than tripled to be on a par with the groundnut; and more than quadrupled to be on a par with the soybean. Thus, where the soil and climatic environments appear appropriate for the culture of soybeans and groundnuts, the researcher-production team may find these two crops the quickest route to increased production of quality protein and deserving support accordingly.

For the more humid environments where limiting disease and insect pests also do well, special consideration may have to be given to the cowpea, pigeon pea and possibly other species. While the present farmer yield level of protein nutrition per hectare is hardly that of the other food legumes considered worthy of research support, their prospects of improvement appear to be as great as for the bean. However, as with any of the food legumes, advancements will only come with a continued and expanded research effort with central direction.

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ACCEPTABILITY AND VALUE OF FOOD LEGUMES IN THE HUMAN DIET

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INTRODUCTION

Leguminous grains have been recognized as important sources of protein in the diet of populations of many tropical areas of the world. As the production of meat, milk, eggs and fish increases slowly, legume foods offer a way to bridge the problem of an enlarging protein gap. They can easily cover the amount of protein that is needed, and what is probably more important, they may, when properly consumed, provide the quality of protein highly desirable for the feeding of vulnerable population groups - infants, children, pregnant and lactating mothers.

These foods are generally accepted and consumed by all populations, including those in areas where animal protein foods are more available. Therefore the task of supplying more protein through legume grains is in many ways easier than other approaches. In spite of these well known and accepted general facts, legume grains have been, in a way, regarded as more of a laboratory curiosity because of their protein and antiphysiological factors, than as food which can provide significant amounts of nutrients. Furthermore, the efforts of agricultural scientists to improve on them, are far behind their achievements with cereal grains, oilseeds, fruits and vegetables. Today, however, the food problems of the world, particularly the protein problem, make it mandatory to increase research in all aspects of legume grains from production to consumption.

ACCEPTABILITY

Information on the intake of legume grains is not easily obtained and available data comes mostly from production records. However, there is some reliable information from dietary surveys. Granting limitations inherent in these statistics, values reported from both sources for Latin American countries are listed in Table 1. The table also includes information on the total dietary intake of calories and protein, as well as from legume grains specifically (1).

Table 1. Legume grain intake in Latin American countries, excluding soybeans and peanuts

Country	Legume Food Intake g/day	Calories /day	Proteins /day	Total intake calories cal/day	Total intake protein g/day
Argentina	6.3	20	1.3	2,820	81.6
Bolivia	5.6	19	1.3	1,840	47.9
Brazil	64.4	220	14.8	2,780	66.3
Chile	27.1	92	5.8	2,410	77.2
Colombia	11.4	38	2.6	2,160	51.9
Costa Rica	27.3	93	6.0	2,430	53.9
Ecuador	26.3	91	6.1	1,890	48.4
El Salvador	31.6	108	7.1	2,030	56.7
Guatemala	23.3	80	5.3	2,080	55.4
Honduras	29.9	102	6.6	2,080	53.7
Mexico	54.7	208	12.0	2,610	71.9
Nicaragua	72.0	245	17.3	1,986	64.4
Panama	24.0	82	5.2	2,310	58.1
Paraguay	30.6	105	7.1	2,560	64.1
Peru	26.2	91	5.8	2,230	55.9
Uruguay	9.0	28	1.8	3,220	104.3
Venezuela	29.6	100	6.5	2,310	58.7

Source: Food Balance Sheets 1960-62. FAO, Rome, 1966.

One could conclude that except for three or four countries of the 17 listed, legume grains are a significant part of the people's diet. However, the intake is really not as high as desirable, probably for reasons other than lack of acceptance or because they do not belong to the area's food patterns. The reasons probably lie in availability.

The value reported is for the whole country; however, it has often been reported that different areas within a country show higher consumption rates. For example, in Venezuela for 1966, the national average intake was 26 g per person per day, represented by **P. vulgaris, P. sativum, C. cajan** and **V. sinensis,** while in a rural town in the Venezuelan Andes, consumption per person was close to 71 g, mainly from **P. sativum** (2). A study carried out in a coffee plantation in Guatemala showed that children aged 18-32 months consumed 24 g/day, mothers, 79 g/day, and adult men, 91 g/day (3). These figures are significantly higher than the national average shown previously (4).

KINDS

Table 2 lists the legume grains more often consumed by the population of Latin America. Although **P. vulgaris,** whether black, white or red, occupies first place in

Table 2. Legume foods consumed in Latin America

Scientific name	Common name English	Spanish
Phaseolus vulgaris	Garden beans	Fríjol, Caraota, Poroto, Habichuela
Phaseolus angularis	Adzuki	Judía
Phaseolus calcaratus	Rice bean	Judía
Phaseolus coccineus	Scarlet runner bean	Judía
Phaseolus lunatus	Sieva bean	Judía
Phaseolus limensis	Lima bean	Judía
Vigna sinensis	Cowpea	Fríjol, Caupí
Cajanus cajan	Congo pea Pigeon pea	Gandul, Guandu, Quinchoncho
Pisum sativum	Alaska pea	Arveja, Guisante
Cicer arietinum	Chick pea	Garbanzo
Lens esculenta	Lentils	Lenteja
Vicia faba	Broad bean	Haba
Dolichos lablab	Field bean	Gallinazo
Lathyrus sativus	--	Almorta
Lupinus mutabilis	Lupin	Lupino

most countries, there is color preference between countries, black coated grains are preferred in most. Other legumes consumed, but in lower amounts, probably because of acceptance, are **Vigna sinensis, Cajanus cajan** and **Vicia faba.** Also consumed in lower amounts, but for reason of price are **Lens esculenta, Cicer arietinum** and **Pisum sativum.**

RELATIONSHIPS TO AGE AND INCOME

Food habits or acceptance patterns are formed early in childhood and like other fundamental habits tend to resist change. The acceptance pattern for legume grain consumption is clearly shown in Figure 1 (5). The values represent the average of dietary surveys in three towns in Guatemala. They show that legume intake in one form or another begins early in childhood. Consumption of **P. vulgaris** broth, relatively high at first, decreases with age, while the intake of the cooked grain increases.

This pattern, which from the nutritional point of view is highly desirable, is not necessarily stable, and it is changing mainly due to the low availability and consequent high price of **P. vulgaris** The relatively low intake of beans by children is not peculiar to Guatemala, but is a practice of mothers almost everywhere where beans are consumed. For example, Martínez and Chávez (6), indicated that in a very poor

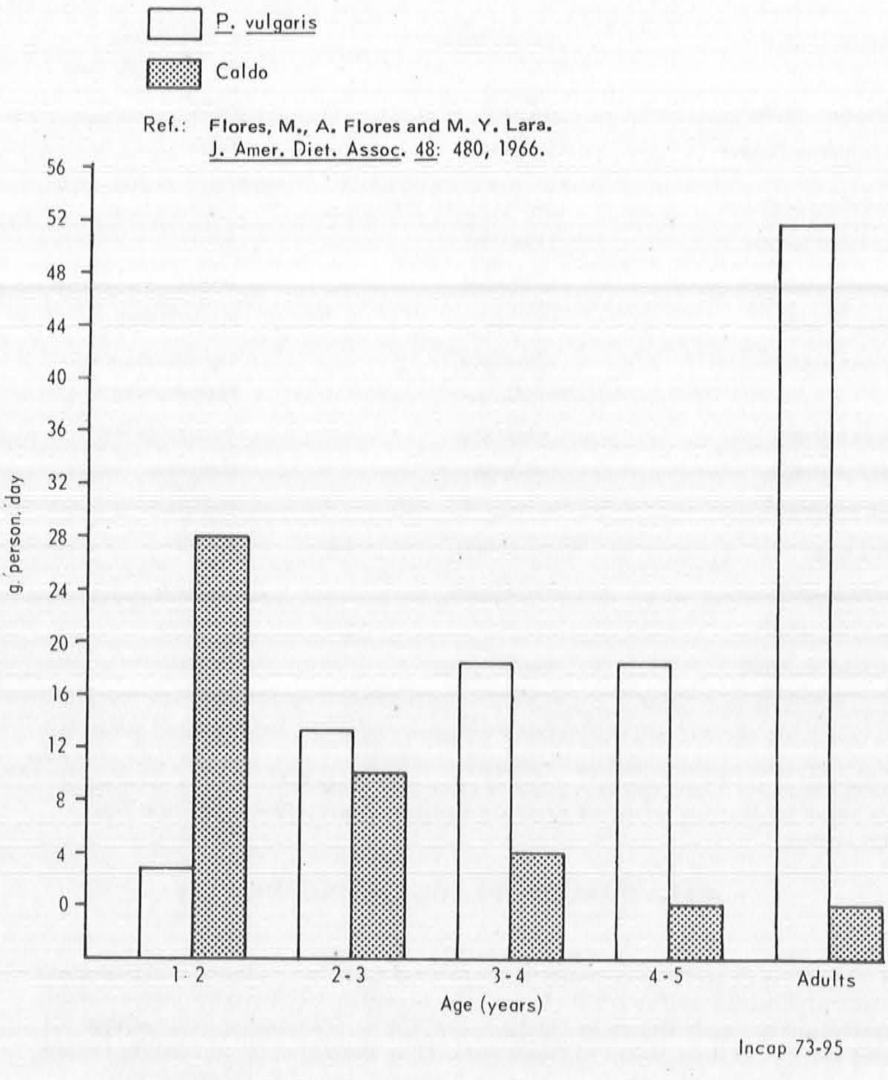

Figure 1. Relationships between the intake of some P. vulgaris food preparations and age.

Mexican rural community, mothers did not feed any beans to children aged 3 to 24 months. However, when an educational program was initiated, at least 50 percent of the mothers accepted beans as a food for their children. Similar observations have been reported from other countries, for example in Jamaica, where children one to six years of age consume from 2.6 to 5.3 g of legume grains per day (7).

Because of their low availability, the frequency with which legumes are consumed is far less than daily, particularly in very poor communities, as shown in Table 3. The data in the table come from continous dietary surveys performed in Santa María Cauqué, in the highlands of Guatemala (8). About 37.0 and 49.0 percent is consumed by the mother and father, respectively, and the difference by the other four family members. On this basis, the four young members, who need more protein of better quality, would get only 8 to 10 g per serving, the two adults, 85 to 113 g per serving.

Frequency of intake is important for most nutrient sources if they are to make a nutritional impact on the quality of the diet. An example is shown in Table 4. In this study, carried out with young rats, fed a maize diet, soybean protein was fed daily, every two and every three days. The results show a favorable relationship between frequency of intake and weight gain of the animals, and between frequency of intake and the protein quality of the diet, and utilizable protein.

Obviously, a daily intake of **Phaseolus** represents a higher intake of protein, therefore more utilizable protein, than when intake is less frequent (9). The same effect is observed in children. Table 5 presents results of a study in which **Phaseolus** was fed every 3,6 and 12 hours as a supplement in a constant ratio of one part **Phaseolus** to three parts maize. The effects were measured using the nitrogen balance method. These results suggest a lack of complementation between maize and **Phaseolus** protein. They suggest also the need to make **Phaseolus** more available if expected to improve protein nutrition (10).

The acceptance pattern indicated by the amount of legume food consumed is quite constant during the year for the family unit. Table 6 shows figures published by Flores **et al** (11) on legume intake over a 12-year period. Intake per family varied

Table 3. Frequency of **Phaseolus** intake per family in Santa Maria Cauque, Guatemala[1/]

Frequency days/week	Number of families	Distribution %
2	10	12.7
3	20	25.3
4	36	45.5
5	10	12.7
6	3	3.8

Source: INCAP. Unpublished data. García, B. **et al.** 1972.

1/ Average of 690 g **Phaseolus**, served in 3 meals to a 6 - member family

Table 4. Effect of frequency of intake of a soybean protein supplement on the protein quality of a maize diet [1/]

Frequency of supplementation	Avg. weight gain, g 28 days	PER	Utilizable protein, %
Daily	74	2.26	6.71
Every 2 days	61	1.98	5.83
Every 3 days	60	1.84	5.42
None	35	1.49	3.47

Source: Bressani, R., L. G. Elías and M. Flores (1971).

1/ 8% soybean flour added to basal diet when supplemented.

from 48 to 54 g per person per day, while intake for 3 to 5 year old children, varied from 10 to 14 g. During the same period, production increased about 25 percent while prices increased from $0.07 to $0.10 per pound. The relatively low production increase, together with the higher price and population in the country, may explain the constancy of intake.

METHODS OF PREPARATION

Since **P. vulgaris** is the most accepted legume grain in Latin America, more discussion will be given to its preparation than to other legume foods. Figure 2 represents schematically the process of cooking and food preparations obtained.

Table 5. Effect of frequency of **Phaseolus** intake on nitrogen balance in children [1,2/]

Frequency	Nitrogen balance: Intake	Absorbed	Retained	Absorption	Retention
	mg/kg/day			% intake	
Every 3 hrs	326	209	74	64.1	22.7
Every 6 hrs	340	211	61	62.0	17.9
Every 12 hrs	310	202	50	65.2	16.1
Milk	322	260	55	80.7	17.1

Source: INCAP. Unpublished data. Wilson, D. et al. 1964.

1/ Nine children, aged 2-6 years, weight 9.30-23.20 kg.

2/ Ratio of maize/Phaseolus intake: 3 parts maize to 1 part **Phaseolus**.

Table 6. **Phaseolus vulgaris** consumption in rural Guatemala

g/person/day

Year	Family	Child
1953	54	–
1956	54	–
1959	51	10
1960	52	14
1961	48	10
1962	53	11
1965	50	13

Sources: Flores et al. 1955, 1957, 1964, 1966.

For **P. vulgaris** the grains are placed in sufficient water to cover them, with additional water to allow for absorption and evaporation. Onions and other flavoring ingredients are usually added and cooked at atmospheric pressure for four to five hours until soft. The bean broth, if available, is consumed as a soup with rice, cubes of toasted bread or other such food. The cooked beans may then be consumed as such, usually with plantains, rice or maize in the form of tortillas, or by crushing and straining, strained beans are prepared. These are then mixed with fat to make fried beans. The changes in chemical composition and nutritional value are shown in Table 7. Some crude fiber is lost during straining and fat content increases as expected in fried beans. Cooking improves protein quality through destruction of antinutritional factors, but fried beans show a slightly lower value, probably due to destruction of some essential amino acids, such as lysine and/or methionine (12). There are variations to the above cooking process, particularly addition of salts, sodium chloride and sodium bicarbonate. In most countries, fried beans are more popular with the consumer.

Table 7. Protein quality of bean preparations in Guatemala

Processing product	Avg. weight gain, g	PER	Available lysine g/16 g N	Protein	Fat	Crude fiber
Raw beans	0	–	5.83	24.6	1.9	4.6
Cooked beans	34	1.24	6.30	24.9	0.7	2.8
Bean broth	–	–	–	1.9	0.1	0
Strained beans	37	1.43	6.35	24.0	0.6	1.6
Fried beans	10	0.87	5.17	17.8	13.3	1.6
Casein	130	2.73	–	–	–	–

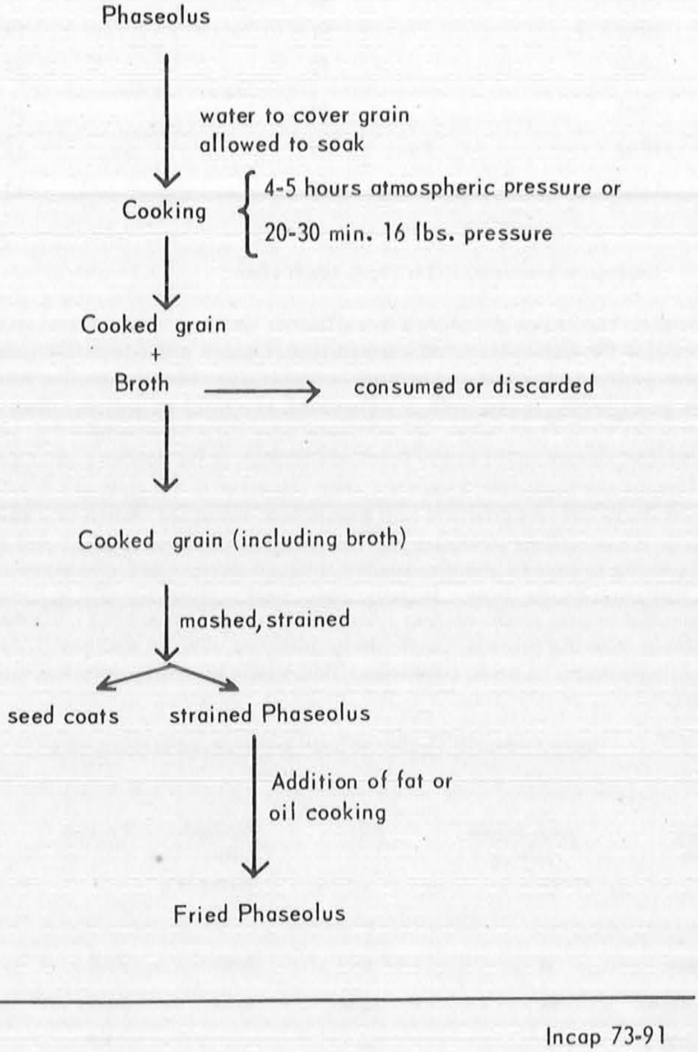

Figure 2. Home cooking process and food preparations of **Phaseolus vulgaris** in Guatemala.

Other legume grains are similarly prepared, but some are eaten differently. For example, Vicia faba may be consumed immature but is often allowed to mature and then toasted. The toasted seed is ground into a fine powder and used to prepare cold drinks. C. cajan, also consumed when dry, in areas where it is consumed is also prepared in the immature form as garden peas (13).

IMPORTANT FACTORS IN LEGUME FOOD ACCEPTABILITY

Legume grains known to contain antiphysiological factors have received the attention of many investigators. Table 8 lists such factors which, it should be clear, are not universally found in all legume grains (14, 15). Furthermore, the concentration of such substances is not the same for all edible legume grains.

The most common of such factors are the trypsin inhibitors. These antiphysiological factors are important chiefly in raw legume grains, since heat processing destroys them in most cases. These substances are rich sources of cystine, a semi-essential amino acid which may replace part of the methionine needs of monogastric animals. Since legume grain protein is methionine deficient, the presence of cystine may be of nutritional benefit. Therefore, it has been suggested that selection of legume grains for higher trypsin inhibitor content might be useful in increasing the protein quality of legume grain protein (16). However, Jaffé and others, have indicated a negative relationship (17, 18). Most, if not all, of the studies of trypsin inhibitor activity in legume grains have concerned monogastric animals, particularly rats; however, some species such as poultry are not as sensitive and it has been indicated that such an antiphysiological effect is not detectable in humans (19). This point, however, should be studied.

Hemaglutinin compounds are also present in most legume grains, characterized by causing blood clotting. As these are assumed to be destroyed by heating, their importance is only in raw grains. Recent results show, however, that in some situations cooking does not destroy all hemaglutinin activity (20).

The goitrogenic factors and cyanogenic glucosides are less well known antiphysiological factors in legume grains and as is the case for trypsin inhibitors and hemaglutinin compounds they are destroyed during heat processing (15).

Lathyric factors present in L. sativus constitute a serious problem in areas where such a legume is consumed. Much work has been done on the identification of the

Table 8. Antiphysiological factors in legume grains

Trypsin inhibitors
Hemaglutinin
Amylase inhibitors
Cyanogenic glycoside
Goitrogenic factors
Flatulence factors
Lathyric factors
Favism

responsible compounds and mode of action. The same is also true for favism, a toxic compound present in **Vicia faba**, a legume grain produced and consumed in Central America, and for toxic alkaloids of bitter taste found in **Lupinus mutabilis**, a legume grain consumed in Ecuador (21, 22).

Flatulence factors have received much attention in recent years, particularly in soybeans. These compounds are not destroyed by heat processing, and for many people, they probably limit the intake of beans. Consumption of beans in some cases has increased flatulence from 16 cc/hr to about 190 cc/hr. Along with the volume increase, CO_2 content rises from a normal value of 10 to 12 percent to above 50 percent.

Evidence suggests that the primary cause of flatulence may be the production of gas by gram-positive, anaerobic bacteria present in the intestinal tract, after stimulation by unknown factors in dry beans. The microorganism **Clostridium perfringens** has been shown to be the primary source of gas, and it is the main intestinal anaerobe. The unknown factors utilized by the bacteria may very well be low molecular weight carbohydrate fractions present in legume grains, including sucrose, stackyose and raffinose (23, 24, 25). Recently, it has been reported that processing may decrease to variable degrees the flatulence factors in some legume grains (26).

Up to now, mention has been made of the antiphysiological factors in legume grains. However, some relatively recent reports show that they have a hypocholesterolemic property; that is, they decrease blood cholesterol levels. Studies in the United States and in India have shown that individuals consuming cooked beans, such as **P. vulgaris**, or **Cicer arietinum**, had lower serum cholesterol levels than those who did not. The factors responsible are not known. Some workers have suggested legume grains have a carbohydrate fraction which causes such a decrease in cholesterol (27). However, it should be pointed out that the lipid content of beans is highly unsaturated, although present in low amounts (28).

Legume grain contain other factors not yet even well classified, which may cause pathological effects when consumed raw. For example, it has been noticed in pregnant ewes, rats and chicks that feeding of raw beans causes muscular dystrophy, increasing vitamin E requirements. These compounds however, are sensitive to heat, therefore are destroyed during processing (29, 30).

THE PROBLEM OF LEGUME-PROTEIN DIGESTIBILITY

Most people recognize that beans are difficult to digest and may give rise to stomach upsets. Nutritionists are aware that they have a low protein digestibility. Information on this particular problem is limited. It is not known whether these effects are caused by a more rapid movement of the cooked legume through the intestinal tract or by resistance to protein hydrolysis by the gastrointestinal enzymes. In any case, significant losses of nitrogen occur in feces when beans are consumed.

Table 9 summarizes the results of studies on human adults fed Alaska split pea (**Pisum sativum**) (31). Similar observations have been made in children. Table 10 shows results of various studies of children fed **Phaseolus vulgaris** in combination with other foods. Fecal nitrogen increased as milk-protein nitrogen intake decreased. Not all the effect can be attributed to bean protein, since it was given in

Table 9. Fecal nitrogen and apparent protein digestibility of human adults fed egg protein and split peas with and without methionine addition

Protein source	Nitrogen, g Intake	Urine	Fecal	Absorbed	Retained	App. prot. dig. %
Egg	5.60	4.90	0.81	4.79	−0.11	85.6
Split pea	5.47	4.62	1.16	4.31	−0.31	78.8
Split pea + met	5.95	4.21	1.19	4.76	+0.55	80.0

Source: Esselbaugh et al. 1952.

combination with maize. However, nitrogen losses increased, and beans may be responsible to some degree (32).

Results in the lower section of Table 10 were obtained from young dogs. The intake of beans equalled 32 percent of total nitrogen, and with these relatively small amounts of beans, fecal nitrogen increased from 36 percent to 40 percent of the nitrogen intake (32).

Additional information for children summarized as nitrogen balance data is shown in Table 11. In these results (33), fecal nitrogen for milk was equivalent to 19 percent of milk nitrogen intake. On the other hand, for beans, fecal nitrogen was equivalent to 36 percent of nitrogen intake. Nitrogen loss in urine is quite similar for both protein sources. Therefore it may be concluded that the lower retention of

Table 10. Fecal nitrogen from children and young dogs fed various protein containing cooked beans

Diet	Nitrogen Intake (mg/kg/day)	Fecal (mg/kg/day)	% Fecal N of N intake
	Children		
Milk	387	70	18.1
25% Milk + 75 % (maize + beans)	358	98	27.4
10% Milk + 90% (maize + beans)	353	134	38.0
100 % (maize + beans)	347	107	30.8
	Dogs		
Maize	520	189	36.3
Maize + black beans	635	254	40.0

nitrogen is due mainly to the significant losses of nitrogen in feces, rather than to a poorly balanced absorbed protein. The author indicated that in comparison with the number of bowel movements from milk, used as reference, bean consumption increased bowel movements by six. There was also an increase in the weight of feces when beans were ingested (33).

These findings indicate again some of the reasons for the lower digestibility of beans. However, the fundamental factors are not known. Studies with rats have shown accelerated food passage when beans are consumed. Furthermore, the cotyledons and not the seed coat were responsible (24).

The low protein digestibility of legume grains has been observed not only as among species, but also among varieties of the same species; see Table 12, Jaffé (34).

No experimental results permit us to estimate with precision the variability of protein digestibility of the various bean cultivars, which would allow us to select varieties with higher values. It is possible that grain size has a significant influence, since small seeds have heavier cotyledons.

Recently, Seidl **et al** (18) obtained a protein fraction from black beans that was resistant to **in vitro** digestion by 10 proteolytic enzymes, even after protein denaturation, and that was inhibitory to trypsin and papain. It is not known if such a protein is present in all legume grains. The classical trypsin inhibitor is thermolabile, so it follows that it cannot be responsible for the low digestibility of protein observed in some species and varieties of beans.

PROTEIN CONTENT AND QUALITY OF LEGUME GRAINS

Because legumes are nutritionally important among vegetable foods for their relatively high protein content, attention is given here only to that nutrient.

Protein content of edible species of legume grains, excepting soybeans and groundnuts, varies between 18 to 32 percent. The cotyledons contain about 27 percent protein, while the embryonic axes and seed coat contain 48 percent and 5 percent, respectively. Cotyledons contribute the largest amount of protein because of their greater weight. Salt-soluble globulins are the predominant class of proteins in seeds of **Phaseolus** and some of these have been shown to be resistant to hydrolysis by proteolytic enzymes. The presence of such proteins in legume grains may explain the low digestibility of legume grain protein (18).

Table 11. Fecal nitrogen losses from milk and **P. vulgaris** fed to children

Protein source	Nitrogen balance				
	Intake	Fecal	Urine	Absorbed	Retained
	mg/kg/day				
Milk	236	46	116	190	74
Cooked black beans	227	81	109	146	37

Source: Data from Rosales Arzú, A. M. INCAP (1972).

Table 12. True protein digestibility of legume grain species and varieties

Legume grain	True protein digestibility, %
Phaseolus vulgaris (black)	76.8
Phaseolus vulgaris (white)	84.1
Phaseolus vulgaris (pink)	79.5
Vigna sinensis (black)	90.0
Vigna sinensis (beige)	86.4
Pisum sativum (green)	90.7
Pisum sativum (yellow)	93.9
Cajanus indicus	90.5
Cajanus indicus	59.5
Lens esculenta	92.6
Cicer arietinum	90.5

Source: Jaffé, W. G. (15).

In addition to species differences, other factors have been shown to affect the content of protein as well as other nutrients, including essential amino acids. Table 13 summarizes the results of one study carried out with 25 varieties of **Phaseolus vulgaris.** The protein content ranged from 20.1 percent, to 27.9 percent, and was influenced significantly by both variety and location. Methionine varied from 0.17 percent to 0.33 percent, lysine from 1.69 percent to 2.42 percent, and tryptophan from 0.14 percent to 0.22 percent. This variation was the result of both, varietal and location factors, except in the case of methionine, where varietal differences were not significant.

This particular study found that the intervariety coefficients of correlation between pairs of these nutrients were all positive and that a majority of them were highly significant. This implies that genetic factors that cause one nutrient to increase effect an increase in other nutrients as well (35).

The essential amino acid content of legume grains has been studied many times. Representative values indicating the variations reported are shown in Table 14. For comparative purposes, the table also shows values for beef, since beans have been called "the meat of the poor." This table shows that legume grain protein is high in lysine content, a factor of much nutritional significance when beans are considered as supplements to cereal grains. A second factor of interest is that they are low in total sulfur-amino acid content, which also is important when considered in terms of diets based primarily on such roots as cassava. The next amino acid of special interest is tryptophan with relatively low values.

Amino acid content of legume grains depends on species, varieties, localities, and management practices. Of particular significance are the results of application of minor element fertilizers. For example, it has been shown that the uptake of zinc

Table 13. Analysis of variance of nutrient content of bean varieties grown in two localities

Source of variation	D. F.	Mean square			
		Nitrogen	Methionine	Lysine	Tryptophan
Varieties	24	0.560**	0.009	0.193*	0.003**
Localities	1	2.869**	0.189**	0.998**	0.041**
Var x loc	24	0.090**	0.006**	0.091**	0.001**
Reps within loc	4	0.016	0.0002	0.021	0.0002
Exptl error	96	0.024	0.001	0.019	0.0002

Source: Tandon et al. (35).

* Statistically significant differences at the 5 % level of probability.

** Highly significant differences at the 1 % level of probability.

by the pea bean causes increases in methionine. In another study, **Pisum sativum** fertilized with sulfur, increased methionine content from 1.29 to 2.18 g per 100 g of protein (11).

The nutritive value of legume grains also has been studied extensively. Biological value, representing the amount of absorbed nitrogen retained in the body, has been found to be variable and low in most legume grains. Some representative results are

Table 14. Range in essential amino acid content in species and varieties of legume grains

Amino acid	Range g/ g N	Beef g/ g N
Arginine	0.36 – 0.57	0.40
Histidine	0.08 – 0.21	0.22
Isoleucine	0.32 – 0.62	0.33
Leucine	0.20 – 0.68	0.51
Lysine	0.34 – 0.71	0.55
Methionine	0.03 – 0.11	0.15
Cystine	0.01 – 0.07	0.08
Phenylalanine	0.15 – 0.49	0.26
Threonine	0.16 – 0.31	0.28
Tyrosine	0.06 – 0.24	0.21
Tryptophan	0.01 – 0.07	0.07
Valine	0.24 – 0.49	0.35

Table 15. Biologic value of some species and varieties of legume grains

Legume grain	Biologic value %
Cajanus cajan	46 – 74
Phaseolus vulgaris (black)	62 – 68
Vigna sinensis	45 – 72
Cicer arietinum	52 – 78
Lens esculenta	32 – 58
Phaseolus aureus	39 – 66
Phaseolus mungo	60 – 64
Pisum sativum	48 – 49

shown in Table 15. Values range from 32 percent to 78 percent, and large variations are also observed for varieties of the same species (34, 36). It is difficult to explain such high variability because many factors are involved. However, it is highly probable that the main factor is the relatively low concentration of sulfur-amino acids in legume grains.

The beneficial effect of the addition of methionine to beans has been shown many times (11). Table 16 summarizes some results. Addition of 0.3 percent methionine increased the protein efficiency ratio in every case, but not equally among all species. This small effect of methionine addition in some cases may be explained on the basis that methionine is not the most or the only limiting amino acid in some legume species.

Table 16. Effect of methionine addition to various species and varieties of legume grains

Legume grain	Protein efficiency ratio	
	–Methionine	+Methionine
Phaseolus vulgaris (black)	0.0 – 0.9	3.5 – 3.8
Phaseolus vulgaris (red)	0.0	1.7
Phaseolus vulgaris (white)	1.2	2.7
Vigna sinensis (black)	1.0	1.6
Vigna sinensis (beige)	1.0	1.8
Pisum sativum (green)	0.3	2.7
Pisum sativum (yellow)	0.0	1.2
Lens esculenta	0.0	0.9
Cicer arietinum	1.7	2.8

Source: Jaffé, W. G. (17).

Table 17. Amino acid supplementation to **Cajanus indicus**

Amino acid	Amount added	Avg. wt. gain, g	PER
None	–	48	1.82
DL-methionine	0.1	35	1.52
DL-methionine	0.3	30	1.32
DL-tryptophan	0.1	58	1.81
DL-methionine	0.2	118	2.65
DL-tryptophan	0.1		

Source: Braham **et al.** (37).

The results in Table 17, obtained with **Cajanus cajan**, show that methionine addition has no effect on improving protein quality. The same is true if only tryptophan is added. However, when both amino acids were added, protein quality increased, which indicates that, at least in **Cajanus**, both amino acids are about equally limiting (37). The same sort of situation may exist with other legume grains, particularly with those that do not respond significantly in protein quality improvement when supplemented with methionine.

The protein quality of legume grains can also be affected by other factors, such as storage, and processing. These two post-harvest factors may have played important roles in the nutritive value reported by various workers. Legume grains contain antinutritional factors which are destroyed by cooking, and cooking may decrease protein quality. So it is possible that if processing is not carried out under equal and standardized conditions, it may contribute to the variability in the biological value reported in the literature.

Storage affects cooking quality, because it is common to find hardshell beans in stored beans. Hardshells require longer cooking, which may decrease protein quality. Therefore, it is suggested that optimum cooking conditions should be established for each legume grain species, in order to reduce the variability in nutritive value as determined biologically. This will be of value for agronomic and nutritional improvement programs. Furthermore, care should be taken to compare bean species and varieties that have been under equal storage conditions.

NUTRITIONAL VALUE

Among vegetable crops, legume grains contain the highest amounts of protein, in general well above twice the level in cereal grains, and significantly more than in root crops. The protein of the legume grains is considered to be a rich source of lysine. Sulfur-containing amino acids are the major amino acid deficiency. Cereal grain proteins are low in lysine but have adequate amounts of the sulfur-amino acids. It is evident that legume grain protein is the natural supplement to cereal grain proteins. If this is accepted, any nutritional improvement to be done in legume foods must consider the nutritional role they play in diets, based on cereal grains and starchy foods. In the specific case of edible roots such as cassava and other starchy foods such as plantain, legume grain protein may constitute the only source of protein.

The supplementary effect of legume protein to cereal grains is well documented. On a dry-weight basis, the level of beans usually represents about 10 percent of the dry weight in diets, at least those eaten in Central America (4, 5). Therefore, in the results presented in Tables 18 and 19, the diets fed to rats were prepared with 90 percent cereal and 10 percent black beans (**P. vulgaris**). The resulting performance was compared with that from diets which contained 100 percent cereal grain protein.

The effect of beans in increasing utilizable protein in cereal-legume mixtures is due to an increase in protein quality as well as to a higher protein content. This is shown in Table 18, in which protein content is equalized to about 7.5 percent among dietary treatments. Even though the presence of 10 percent beans in diets increased the protein quality of the cereal, the increases were larger for those cereal grains poorer in protein quality, such as maize and sorghum, followed by wheat, rice and oats.

The results when protein content of the diet was not adjusted to a fixed level are shown in Table 19.

Table 18. Percent utilizable protein from cereal fed alone and from 90 percent cereal + 10 percent bean mixtures

Protein source	Protein in diet, %	Utilizable protein, %
100 % Rice	6.9	4.01
90 % Rice + 10 % Beans	7.9	4.96
100 % Maize	8.5	2.41
90 % Maize + 10 % Beans	10.3	4.10
100 % Sorghum	7.7	2.23
90 % Sorghum + 10% Beans	8.6	3.93
100 % Whole Wheat	11.0	4.26
90% Wheat + 10 % Beans	12.0	5.94
100 % Oats	13.8	8.22
90 % Oats + 10 % Beans	14.6	8.73
Casein	10.7	8.02

Table 19. Protein quality of cereal grain and of cereal grain–bean diets fed at equal levels of dietary protein

Protein source	Avg. wt. gain, g	PER
100 % Rice	43	2.15
90 % Rice + 10 % Beans	56	2.32
100 % Maize	13	0.87
90 % Maize + 10 % Beans	32	1.40
100 % sorghum	12	0.88
90 % Sorghum + 10 % Beans	30	1.39
100 % Wheat	19	1.05
90 % Wheat + 10 % Beans	41	1.73
100 % Oats	34	1.60
90 % Oats + 10 % Beans	75	2.37
Casein	75	2.71

Table 18 shows two results of interest. One is the increased protein content of the diets when they contained 10 percent bean. This is a significant increase, particularly for children, who require relatively higher protein intakes than do adults but have a smaller stomach capacity. The second point of interest can be seen under the utilizable protein column, which is higher for diets made with cereal and beans. It is also of interest to see that higher increases in utilizable protein are obtained from the cereal-bean mixtures when the cereal is of a low protein quality-as for example, maize, sorghum, wheat, rice and oats, in that order.

The term "utilizable protein" means the product of protein quality and protein content relative to a reference protein, which in the present case was casein.

The evidence presented serves to propose at least two factors that should be considered in bean quality improvement programs. First is the desirability for higher protein concentration in legume grains, which becomes more significant in terms of child feeding. Second, such protein should be higher in lysine content, as this amino acid is limiting in all cereal proteins tested. Even though lysine is not the only limiting amino acid in cereal proteins, increased protein content in beans will carry

Table 20. Amino acid supplementation of maize–bean diets.

Dietary treatment	Avg. wt. gain g/28 days	PER
Maize + Beans 1/	69	2.11
Maize + Lys + Try + Beans 2/	103	2.64
Maize + Beans + Met 3/	66	1.93
Maize + Lys + Try 2/ + Beans + Met 3/	108	2.69
Maize	32	1.21
Maize + Lys + Try 4/	100	2.68

1/ 72.4% maize + 8.1% beans.
2/ 0.30% L-lys HCl + 0.10 DL-try.
3/ 0.30% DL-met.
4/ 0.40% L-lys HCl + 0.10% DL-try.

with it more tryptophan, threonine, and methionine-amino acids that are somewhat deficient in the cereal grain protein.

Even though the presence of 10 percent beans increases the protein quality of the cereal, such mixtures are still deficient in the same amino acids as the particular cereal under consideration. However, the amounts needed are lower. The information in Table 20 supports these statements. Maize alone shows a significant response to the addition of lysine and tryptophan; these two amino acids also improve the quality of the mixture of maize and bean under consideration (38). Addition of methionine to beans, whether or not maize is supplemented with lysine and tryptophan, does not improve the quality of the protein. Similar results have been observed with rice-bean mixtures, in which bean contributes about 10 to 12 percent of the dry weight of the diet.

The above information is presented to indicate that any consideration given to improving the nutritive quality of beans must be based on the fact that they are eaten together with other foods, cereal grains in particular. In this respect, it is of interest to ánalyze the results in Table 21. This study seeks information on what changes should be introduced into beans to obtain cereal-based diets with higher protein quality.

The results were obtained by changing those nutritional characteristics in beans that would be reflected in better quality protein diets. Adding beans to a maize diet improves protein content and protein quality.

Table 21: Effect of various dietary treatments of beans on the protein quality of corn - bean diets

Dietary treatment	Protein in diet, %	Protein Maize %	Protein Beans %	Avg. Wt. gain g/28 days	Utilizable protein %
100 % maize	8.7	100	0	25	2.93
87 % maize + 13 % beans	10.6	71	29	48	4.54
74 % maize + 26% beans	12.3	51	49	86	6.26
87 % maize + 13 % beans 1/	12.3	62	38	72	5.87
87 % maize + 13 % beans 2/	12.8	59	41	94	7.09
87% maize + 13% beans 3/	10.5	71	29	71	5.45

1/ Bean with a protein content 1.5 times the protein content of common beans.
2/ Bean with a protein content 2.0 times the protein content of common beans.
3/ Bean with a higher lysine content than common bean.

In treatment 6, bean intake and protein content were maintained as found in nutritional surveys. However, the bean protein simulated in this case represented one with a lysine content higher than normal. The results indicated that this was as adequate a change in bean protein composition as were the other modifications studied.

For practical purposes, the data shown in this and other tables suggest that the protein quality of cereal-based diets could be much improved if the intake of beans could be increased through increasing their availability and reduced prices - provided of course, that there are no physiological factors limiting the intake. Likewise, the data suggest that beans containing higher protein or those containing normal protein with higher lysine levels could be nutritionally beneficial to populations who consume cereal-based diets. This applies particularly to preschool populations, where nutrition problems seem to be concentrated. Any alternative should be as good, and it is up to the agronomist to concentrate on one of the possibilities. Let me emphasize, however, that it is not advisable to generalize, because the situation recommended is (a) for populations consuming maize, (b) when beans contribute about 13 percent of the dry weight of the diet, and (c) when the legume food is **Phaseolus vulgaris.**

Some information is also available for cassava-based diets. Results are shown in Table 22. Beans with or without methionine addition improve growth performance, as indicated by lower weight loss in a 28-day experimental period. The results were expected, because dietary protein is about 4.6 percent, a level too low for growing weanling rats. The solution would be to increase the intake of beans, and the beans utilized should have a higher menthionine content.

Table 22. Effect of small amounts of legume grain on the nutritive value of cassava–based diets

Dietary treatment	Protein %	Avg. wt. gain, g
Cassava (100)	1.8	−13
Cassava + beans (87/13)	4.6	− 7
Cassava + beans + met (87/13/0.3)	4.6	- 6

As shown in Table 23, manioc flour diets with and without methionine were tested in the presence of three levels of beans in the diet. Protein intake was higher as the percentage of bean in the diet increases. Best performance was obtained in every case in which methionine was present, also expected in view of the well known

Table 23. Protein quality of manioc flour with and without methionine addition mixed with various levels of beans

Dietary treatment	Protein % in diet	Avg. wt. gain, g	PER
65 % manioc flour + 35 % bean flour	8.04	7.7	0.78
65 % manioc flour + 0.6 % methionine + 35 % bean flour	8.85	68.2	2.70
55 % manioc flour + 45 % bean flour	9.97	14.2	0.96
55 % manioc flour + 0.6 % methionine + 45 % bean flour	10.09	66.8	2.68
45 % manioc flour + 55 % bean flour	12.17	31.7	1.28
45 % manioc flour + 0.6 % methionine + 55 % bean flour	12.23	71.0	2.27

Source: Dutra de Oliveira et al. (39)

sulfur-amino acid deficiency in bean protein. Even though protein efficiency appears to decrease as common beans increased in the diet, the percentage of utilizable protein was essentially the same.

It must be pointed out that a recommendation for bean with a high methionine content to complement manioc diets will depend on the actual amount of bean consumed by these particular populations. Although methionine addition to beans fed to humans has resulted in improved quality (31), the levels needed are smaller than those commonly utilized in rat studies.

NUTRITIONAL CONSIDERATIONS OF LEGUME-CEREAL AND LEGUME-CASSAVA MIXTURES

It has been shown that small amounts of legume protein added to cereal grains improve the amount of utilizable protein in the mixture. It also has been shown that higher intake of beans with a higher protein content and beans with a higher lysine content also could result in better quality diets. Assuming that bean production could be easily increased and that this increased production would stimulate higher intakes, the question would be: How much is recommendable in terms of protein quality?

Figure 3 presents results when diets for growing rats contained equal amounts of protein, derived in different proportions from maize and **Phaseolus**. Maximum protein value was obtained when 50 percent of the protein in the diet was derived from beans and 50 percent from maize (40), corresponding to 72 g of maize and 28 g of beans. The ratio of maize to beans is 2.6 to 1.

It is interesting that a mixture of the two components in the ratio shown has a protein quality greater than each component fed alone. From the amino acid content of the two components and comparison to amino acid patterns, lysine appears to be the main limiting amino acid when maize provides from 50 percent to 100 percent of the protein of the diet. On the other hand, methionine becomes the deficient amino acid as greater proportions of protein are provided by beans.

Some evidence to this is shown in Table 24. The addition of small amounts of the three limiting amino acids to maize increased protein utilization from a protein efficiency ratio (PER) value of 1.05 to 2.47. The 50/50 mixture was improved from 2.10 to 2.42 by the addition of small amounts of lysine and methionine. The addition of methionine, tryptophan and leucine improved the quality of bean protein, an effect probably due mainly to methionine.

Additional results are shown in Table 25. This shows the effect of amino acid supplementation to optimum protein quality mixtures of cereal and legume grains. The effect of methionine supplementation is dependent on the cereal grain as well as on the legume. For example, the mixtures of maize and sorghum with **Phaseolus vulgaris** are improved when methionine is added, but this is not true in the case of rice. On the other hand the cereals with **Phaseolus lunatus** are not improved in quality when supplemented with methionine.

Similar studies have been carried out with opaque-2 maize and black beans, with the results shown in Figure 4 (42). In this example, bean protein is still deficient in methionine; however, though opaque-2 maize has essentially the same methionine content as common maize, it has significantly higher levels of lysine and tryptophan.

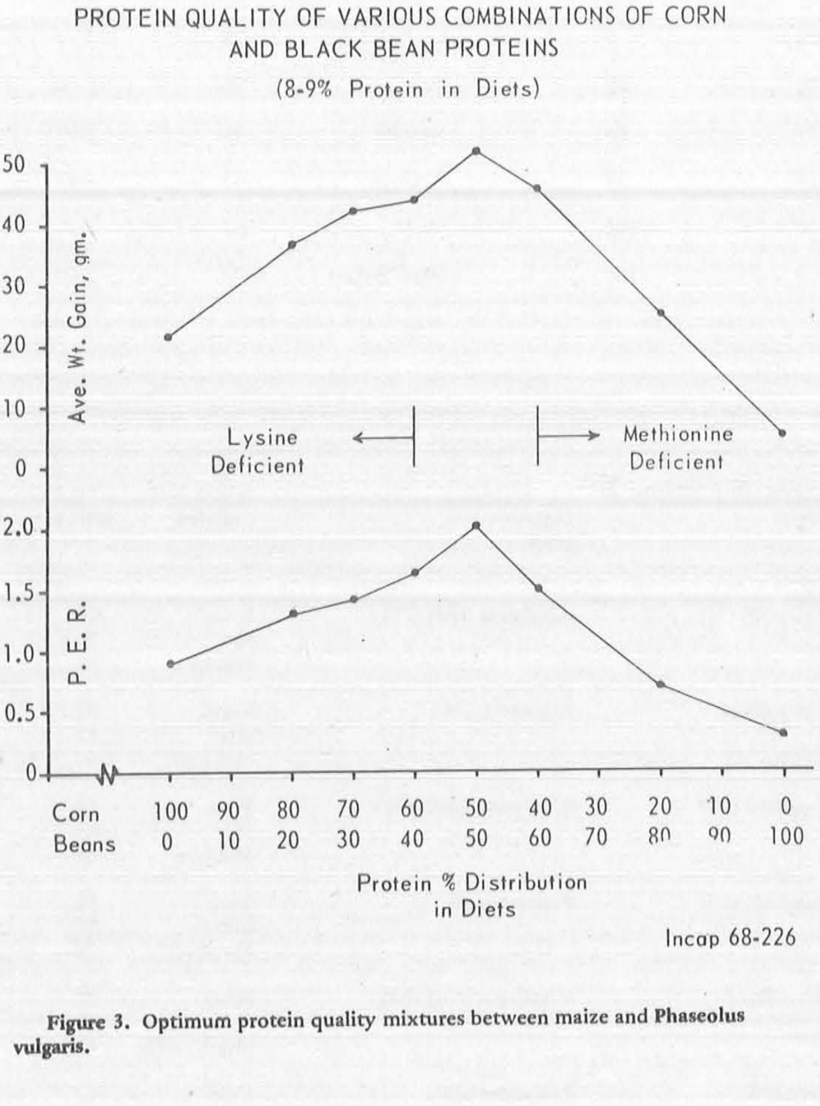

Figure 3. Optimum protein quality mixtures between maize and Phaseolus vulgaris.

Table 24. Amino acid supplementation of 72 percent maize and 28 percent bean mixtures

Weight distribution, % Maize	Beans	Amino Acids added	Avg. wt. gain, g	PER
100	0	None	29	1.05
100	0	Lys-Try-Leu	74	2.47
72	28	None	51	2.10
72	28	Met-Try	59	2.03
72	28	Met-Lys	75	2.42
0	100	None	−3	—
0	100	Met-Try-Leu	23	1.04

Table 25. Amino acid supplementation of cereal legume grain combinations

Weight distribution, % Cereal	Legume grain	Amino acid added	Avg. wt. gain, g	PER
Maize (70)	P. vulgaris (red) (30)	None	47	2.41
		Met	58	2.60
		Met-Lys	42	2.35
Maize (80)	P. lunatus (20)	None	52	2.50
		Met	51	2.56
		Met-Lys	46	2.49
Sorghum (70)	P. vulgaris (black) (30)	None	56	2.54
		Met	58	2.61
		Met-Lys	64	3.05
Sorghum (70)	P. lunatus (30)	None	50	2.44
		Met	50	2.47
		Met-Lys	77	3.27
Rice (80)	P. vulgaris (red) (20)	None	57	2.85
		Met	62	2.98
		Met-Lys-Thr	67	3.20
Rice (80)	P. lunatus (20)	None	62	3.08
		Met	63	3.13
		Met-Lys-Thr	73	3.66

Source: Sirinit et al. (41).

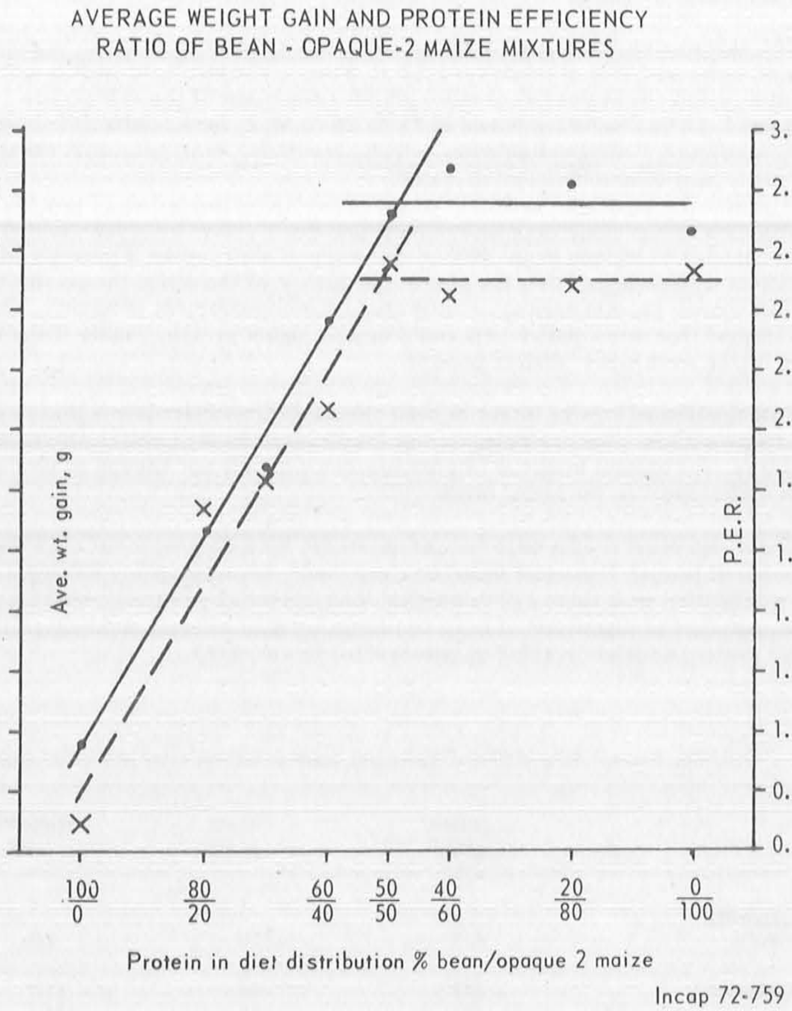

Figure 4. Optimum protein quality mixtures between opaque – 2 maize and **Phaseolus vulgaris.**

Highest performance occurred when 50 percent of the dietary protein was derived from each component. However, similar values were observed when maize contributed greater levels of protein. On the other hand, greater levels of bean protein in the mixture resulted in lower performance, because of an increasing methionine deficiency. The 50/50 mixture of maize and **Phaseolus vulgaris** gave a PER value of 2.1 and a weight gain of 52 g. In contrast, the 50/50 protein mixture of opaque-2 maize and **Phaseolus vulgaris** gave a PER value of 2.6 with a weight gain in 28 days of 108 g.

The experimental results show the optimum proportion of maize to beans to be 78 g of maize and 28 g of beans for a 2.6 to 1 ratio. The results of various nutritional surveys carried out in Central America permit calculation of the actual ratio consumed. These results are shown in Table 26 (4,5). In both adults and children, consumption of maize predominates, which permits the conclusion that the diets are low in protein and deficient in lysine.

Mixtures that provide the maximum protein quality have been determined for other cereals and legume grains (43). A summary of such results is presented in Table 27. These results suggest that the poorer the quality of the cereal the greater the level of legume protein needed to bring about the improvement in quality. They also suggest that cereal-based diets could be of a higher protein quality if the legume grain intake were higher than at present.

Examination of legume intake in bean-consuming countries shows that in general, it is relatively low -- for example, average intake levels in the Central American countries. The highest intake is 72 g/person/day which is not enough to give a 2.6 ratio with respect to the cereal intake (5).

These and other results raise various questions. Why do people eat only these amounts of beans? Can more beans be consumed? Is consumption limited by their low availability, or is there a physiological limit induced by unrecognized factors, or by a resistance to digestion? If bean consumption is to increase and help solve the world protein deficiency, these questions must be answered.

Table 26. Average daily intake of maize and beans in various areas of Central America

	Maize g/day	Beans g/day	Maize/Bean ratio
Guatemala			
Adults	423	58	7.3
Children	281	24	11.7
	295	26	11.3
	277	15	18.5
Honduras			
Adults	398	56	7.1
El Salvador			
Adults	374	60	6.2
Best ratio	72	28	2.6

Table 27. Protein value of optimum combinations between cereals and leguminous seeds

Distribution of Protein in diet, % From cereal	From beans	PER	Increase, %
100 rice	0 beans	2.25	
80 rice	20 beans	2.62	16.4
100 maize	0 beans	0.90	
50 maize	50 beans	2.00	122.2
100 maize	0 cowpea	1.22	
50 maize	50 cowpea	1.84	50.8
100 wheat	0 beans	47*	
73 wheat	27 beans	70*	48.9
100 maize	0 soybean	1.50	
40 maize	60 soybean	2.85	90.0

Net Protein Utilization (NPU).

An attempt to answer some of them is shown in Table 28. In this study, young rats were allowed to eat as they wished from two feeder cups placed in the cage. One contained maize, the other **Phaseolus.** The maize and bean diets were modified (second column) to permit the rat to choose the food that was made more suitable nutritionally. Intake from each cup was recorded (third column) and used to calculate the maize-to-bean ratio. From the protein ingested and the protein efficiency ratio, the percentage of utilizable protein was calculated.

The first group was fed on maize and beans without any other dietary treatment. The ratio of maize to beans was 3.58 with a utilizable protein of 3.11 percent.

Results indicate that the animal tried to balance the quality of the protein ingested, because the ratio of 3.6 is closer to the best ratio-2.6- found in other experiments. When both maize and beans were supplemented individually with vitamins, minerals and additional calories, the animals consumed higher amounts of maize and beans to give a ratio of 3.87, similar to that of the previous case. Utilizable protein increased - to be expected because other needed nutrients were provided.

The third treatment stimulated the free intake of beans and also of maize. The increased intake of beans can be explained on the basis that the animal consumed more to meet its needs for other nutrients. There was also an increase in maize intake, probably needed by the rat as a source of calories to balance the increased intake of protein from an increased intake of beans. These results also indicate that beans do not impose a physiological limit of intake.

Table 28. Effect of various dietary treatments on the free intake of maize and bean by young rats

Foods	Dietary treatment	Intake g /rat / 28 days	Intake Ratio	Utilizable protein %
Maize	None	188	3.58	3.11
Beans	None	53		
Maize	Vit-Min-Cal	238	3.87	5.15
Beans	Vit-Min-Cal	61		
Maize	None	257	2.08	6.24
Beans	Vit-Min-Cal	124		
Maize	Vit-Min-Cal	250	2.65	6.19
Beans	None	94		
Maize	Lys-Try	184	3.86	3.81
Beans	Met	47		
Maize	Lys-Try-Vit Min-Cal	272	2.26	6.68
	Met-Vit-Min-Cal	120		
Maize	Lys-Try-Vit Min-Cal	291	2.94	6.10
Beans	Vit-Min-Cal	59		

Factors more directly related to protein quality were tested in treatments 5 to 8. Adding lysine and tryptophan to maize and methionine to beans did not significantly alter the ratio of maize to beans observed in the first group. Utilizable protein increased slightly. When all three amino acids and other nutrients are added to the two foods there is a high intake of both to give a 2.3 ratio with 6.7 percent of utilizable protein. Treatment 7 improved the protein quality of maize, but not of beans, with other nutrients present in both. This stimulated maize intake, but not that of beans, contrary to what is seen in treatment 8, in which beans, but not maize, were supplemented with methionine to improve protein quality. This resulted in an increase in bean intake, but it did not differ greatly from the intakes observed in the third treatment.

The results indicate clearly that when the rat was allowed to choose its food, it did so by nutrient supplementation, but not by amino acids alone. Many observations are difficult to explain, and no attempt is made to do so now. However, the results show clearly that the animals tend to consume more beans when they are available and that this higher intake causes no damage to the animal. Therefore, efforts should be made to increase production of legume grains to permit cost reductions and thus a greater intake.

On the basis of the results presented regarding the supplementary and complementary effect of bean protein to cereal grain protein, as well as the effect of amino acid addition to bean-cereal mixtures, calculations were made on the best levels of certain essential amino acids and other nutrients which beans should have. Consideration in these calculations was also given to the possibility of attaining them now or in the near future according to the variability in the nutrients normally found in a relatively large number of samples analyzed.

The calculations based on these facts suggested that bean protein should contain 6.4 g of lysine/16 g of nitrogen, 1.2 g of tryptophan/16 g of nitrogen and 2.3 g of total sulfur-containing amino acids per 16 g of nitrogen.

These values in bean protein will complement cereal protein efficiently. The protein level in beans should be not less than 25 percent. The reasons behind this figure have been outlined. Furthermore, present cereal-bean diets are low in protein content, which makes it difficult for a child to meet his protein needs from such diets, because they tend to be bulky. The protein digestibility of beans should be about 85 percent. Finally, maize-bean diets have a low calorie density, and populations consuming them also have a calorie deficiency. Therefore, it would be ideal if bean lipid concentration was around 6 to 8 percent. An advantage of soybeans as a food over other legume foods is their higher fat content. The lipids in beans should be of great nutritional benefit not only as sources of calories, but as sources of essential fatty acids.

CONCLUSIONS

It would appear that the most important effort to be made in bean research is to increase the yield, which, it is hoped, would increase their availability and decrease their cost. Significant advances have already been made in this respect in some countries, for example, El Salvador. However, the higher yield effort may be short-lived because of improper storage conditions, which cause hardshell in the grain, so reducing cooking quality.

Once the above is achieved, bean research should concentrate on increasing total protein content. Results indicate that higher levels of lysine, tryptophan and methionine, in that order, result from higher protein-containing beans. Higher protein content is of benefit to situations in which beans are consumed together with cereal grain and manioc-based diets.

Attempts should also be directed toward increasing protein digestibility of some legume grain species. The factors responsible for protein indigestibility are not known. Trypsin inhibitors could not be totally responsible, because they are destroyed during heating. However, it is possible that presently available techniques do not permit assays for other heat-stable factors.

Beans with a higher lysine content might prove to be very effective in improving the quality of the cereal diet. However, if digestibility of the protein is improved, it is probable that the amounts now present are enough to balance the low lysine content in cereal grains.

The flatulence factor is another characteristic of beans that should be eliminated. It may be possible that it might be destroyed by certain processing techniques.

High methionine-containing beans also should receive attention, particularly for those populations on manioc diets, which contribute little protein.

Higher intakes of bean protein probably could be achieved through the preparation of stable pre-cooked products, which offer the advantages of improved stability, lower costs of preparation, and possible additional nutrients.

Finally, it should be emphasized that for nutritive quality screening purposes, it is essential to standardize all procedures, starting with storage, through processing and drying to the biological assay technique. The optimum cooking procedure to inactivate trypsin inhibitors and other heat-sensitive toxic substances probably is not the same for all legume species or varieties, because they contain different concentrations of those compounds. Similarly, some species have a greater tendency than others to hardshell. Standardization and definition of the screening procedures will speed up the nutrition role of legume grains for human populations.

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Commentary upon:

ACCEPTABILITY AND VALUE OF FOOD LEGUMES IN THE HUMAN DIET

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and Nelson de Souza

NUTRITIVE VALUE OF BEANS

We would like to make a few comments on the basis of our past work, mainly with common beans (**Phaseolus vulgaris**). Brazil is the largest common bean producer of the world and we have one of the largest per capita consumptions. It can be said that it is the staple food in Brazil. In the northeast area of the country it is consumed mainly with manioc flour and in the south with rice.

The ICNND survey in northeast Brazil found that common beans were used at least once daily by almost 100 percent of the families and are the most important single source of protein in the local diet (1).

The intake of beans varies from one place to another within the northeast; a few results of dietary surveys in that area appear in Table 1. Because beans are eaten along with manioc flour in that area, we thought it would be advantageous to utilize manioc as a methionine carrier to balançe the local diet. Our initial results have been shown by Dr. Bressani, and further studies on the same subject, including different ratios of beans to manioc and variable amounts of methionine, have been published (2).

Table 1. Food consumption in some areas in northeast Brazil

Food	Recife	Urban area	Rural area A	Rural area B
		g/day		
Beans	80	130	215	70
Rice	100	155	125	15
Manioc flour	65	125	200	330
Meat	235	105	40	70

In south Brazil, where beans are commonly used along with rice, we have intensively studied this combination. The most common bean is the brown variety. We have been finding in rats that the mixture with the best nutritive value is the one with 80 to 90 percent of the protein from rice and 10 to 20 percent from beans.

We did a series of studies on amino acid supplementation of the rice and beans mixtures. We think it of interest to report a study on self-selection of dietary protein from rice and beans by rats (3). We confirmed that on the **ad libitum** intake the animals chose a mixture of 80 percent of the protein from rice and 20 percent from beans. It was also shown that methionine supplementation of the beans is responsible for a three-fold increase in the total intake with a better PER. When both rice and beans are amino acid fortified the animals gain more weight, the PER is greater but the bean consumption is not so large as when only the bean is supplemented (Table 2).

We have done a few metabolic studies on children, giving them a rice and bean diet in the same proportions as they eat at home. The nitrogen retention is not so high and the nutritive value of the mixture can be improved when part of it is replaced by milk or corn and soya mixture (4).

Acceptance of beans as a daily food in the south is quite good and we do not expect a problem in this respect. Current food habits in Brazil make it unlikely that a large intake of beans by infants and small children will occur. We believe that in this region a bean flour or a formulated well-balanced bean mixture could be of value.

The price of beans in Brazil (Table 3), is not higher than other usual foods; in terms of protein it is even cheaper.

A better contribution of beans to the human diet can be achieved by new varieties with more methionine, or with pre-cooked products. Methionine can be infused in beans in the pre-cooking process, as we have reported earlier (5).

Using common bean protein concentrates is another approach through which, we thought, beans could supply protein for human consumption (6).

Also new varieties, or bean processing, that would save the three to five hours cooking and the fuel used, could enhance bean consumption.

Table 2. Food intake and utilization of rats by self-selected diets

Food intake, g	Diet 1	Diet 2	Diet 3	Diet 4
Rice	166	137	233	234
Beans	41	129	50	75
Amino acid Supplementation				
Rice	-	-	+	+
Beans	-	+	-	+
Weight gain, g	40	67	70	95
PER	2.71	3.51	3.39	4.28

Table 3. Price of beans as compared to other foods in Brazil (1972) *

	Belem	Recife	Rio	S.Paulo	Protein content
					g/100 g
Beans, kg	2.13	1.46	1.31	1.89	20-25
Rice, kg	1.50	-	1.73	1.89	7-8
Manioc flour, kg	0.75	1.06	1.01	1.11	0.8-1.8
Meat, kg	7.33	5.89	5.91	6.32	18-22
Milk liters	1.30	0.70	0.67	0.71	3.4-3.6

* Cruzeiros (1 dollar = 6 cruzeiros)

In summary, we conclude that beans can have a real impact on the quantity and quality of the protein intake and diet of several areas, if interest and support can be brought to thoroughly investigate different aspects of their utilization.

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PROBLEMS AND POTENTIALS IN STORAGE AND PROCESSING OF FOOD LEGUMES IN LATIN AMERICA

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INTRODUCTION

The leguminosae comprise approximately 600 genera with around 13,000 species; however, out of this number only a few, about 20, are of economic importance as legume foods, and they are consumed either immature or dried by humans. In Latin America the varieties recognized and accepted as edible food are fewer. In Central America and Mexico, as well as Argentina, the most widely consumed is **Phaseolus vulgaris**, in all of its variety of forms and colors. Although in lower amounts other legume foods such as **Phaseolus lunatus, Vigna sinensis, Cicer arietinum, Lens esculenta** and **Cajanus cajan** are also eaten in specific regions of this continent.

Preference for one type of legume over the other is probably related to availability in the area; in turn, availability is determined by environmental conditions which favor higher yields of one over other legume foods. It is also possible that factors not related to agronomic aspects are responsible for preferences, such as dietary habits and cultural practices. Apart from these problems, it must be recognized that a great part of this potential source of protein, which could help improve the nutritional value of the diet consumed by the Latin American population, has not been fully utilized. This is due not only to the low production of this food, but as well to lack of adequate storage conditions, which further limit its availability.

The purpose of this paper is to analyze some present and potential aspects related to the storage and processing of legume foods in Latin America.

PRODUCTION

Obviously, it is necessary to know the availability of the raw material if recommendations are to be made in order to improve storage conditions and increase the possibilities for processing. Unfortunately, due to extensive gaps in crop production statistics, no accurate statement can be made as to the production of legume foods in Latin America. One of the reasons is that in most of the area legume foods are grown in small plots, usually around the homestead, to supply the needs of the family. Only that part of the production calculated as a surplus is sold in the market, or when the need for money arises. Even though the figures have their limitations, it is possible to draw some interesting observations from them.

The data published in the 1966 FAO Production Yearbook for the six continents are shown in Table 1. As can be observed, the production of dry beans in Latin America is only surpassed by the Far East. Yield per hectare is quite variable for the same species, not only between regions, but also between species in the same region, suggesting that some species are better adapted to environmental conditions than others. Therefore, an increased production would be achieved through the selection of species which are best adapted to prevailing environmental conditions in the region.

On the other hand, the variability of production and yield indicates also that there is a definite potential in the developing countries for a substantial increase in legume food production. It is also of interest to note that yields vary with the type of pulse and with respect to region, being lower for Latin America, Africa and the Far East. Such a situation could well be due to slow development of improved varieties, poor agricultural practices and adverse environment. It is feasible to think that the use of an appropriate technology would permit an increase in the production of legume foods in Latin America. However, higher production requires the availabilit of adequate facilities to handle the crop in terms of storage and processing.

Postharvest problems

The chemical and physical characteristics of the leguminous seeds suggest they are one of the more stable foods. However, long periods of storage require some technical measures to avoid detrimental effects on their quality for processing, on their organoleptic and culinary characteristics and on their nutritive value.

Dry bean quality includes the characteristic of softening during reasonable cooking time, uniformity in color and size of the seeds, absence of fissures, and normal sanitary conditions (1).

STORAGE

Lack of adequate storage conditions appears to be one of the most important technological problems, affecting indirectly the production and more directly the availability of leguminous seeds. The problem can influence these aspects mainly in two ways:

(1). The farmer has to sell the crop to intermediaries at a lower price, before demand for the product arises, thus reducing economic incentive.

(2). The total availability is affected by the physical and organoleptic changes which occur in the seeds, due to inadequate conditions of storage, hardening of the shells being the effect most often observed.

Table 1. Production of dried pulses, by continent, in 1966

1965		Dry beans	Dry peas	Dry broad bean	Chick peas	Lentils	Pigeon peas	Cow-peas	Vetch	Lupines	Other pulses
Europe	Area	4009	484	715	391	109	---	13	314	225	357
	Prod.	863	722	841	162	67	---	12	250	257	204
	Yield	2.2	14.9	11.8	4.1	6.1	---	9.2	8.0	11.4	5.7
North America	Area	645	112	---	---	---	---	41	---	---	---
	Prod.	805	219	---	---	---	---	24	---	---	---
	Yield	12.5	19.6	---	---	---	---	5.9	---	---	---
Latin America	Area	6293	151	297	132	64	23	---	---	4	31
	Prod.	3776	120	188	120	40	15	---	---	6	25
	Yield	6.0	7.9	6.3	9.1	6.3	6.5	---	---	15.0	8.1
Near East	Area	190	13	248	247	307	---	13	325	7	209
	Prod.	207	12	432	209	281	---	13	298	12	227
	Yield	10.9	9.2	17.4	8.5	9.2	---	10.0	9.2	17.1	10.4
Far East	Area	7560	1146	16	10256	973	2584	47	---	---	4199
	Prod.	2315	946	17	6546	473	1915	27	---	---	1995
	Yield	3.1	8.3	10.6	6.4	4.9	7.4	5.7	---	---	4.8
Africa	Area	1233	463	333	400	207	127	2504	21	226	1654
	Prod.	607	345	295	240	122	49	1083	11	56	822
	Yield	4.9	7.5	8.9	6.0	5.9	3.9	4.3	5.2	2.5	5.0

Area: 1,000 hectares.
Production: 1,000 metric tons.
Yield: 100 kg/hectare.
Ref. Taken from: FAO Production Yearbook (1966 b).

According to results of several studies carried out to establish optimum conditions to maintain dry bean quality, the main factors involved are moisture content of the seeds, environmental temperature, relative humidity and period of storage (2, 3, 4, 5). Although there are no specific investigations studying these four variables simultaneously, the results so far obtained indicate that these conditions are closely interrelated.

Physical changes.

The most evident physical deterioration in quality through inadequate storage conditions is the hardening of the shells. This effect is generally evaluated by the time required for the beans to soften during cooking. Figure 1 shows the effect of temperature, moisture content of seeds and period of storage on the cooking time of a variety of **Phaseolus vulgaris.** By increasing the moisture, temperature and period of storage, the cooking time required was increased significantly. These results also indicate that a moisture content in the seeds of less than 13 percent does not affect the cooking time, regardless of the temperature and period of storage. Other studies have confirmed the importance of the moisture content in keeping the quality of dry beans during storage (3), indicating a high positive correlation between moisture content in the seeds and cooking time.

It is also known that these conditions depend not only on temperature but also on the relative humidity of the environment. Studies on the hygroscopic equilibria of beans stored at different relative humidities (6) are of interest. Figure 2 shows the results obtained with a variety of beans with an initial moisture content of 11.4 percent, stored at 25°C in relative humidities ranging from 11 to 75 percent.

It was not possible to obtain equilibrium moisture values for relative humidities between 80 and 98 percent, due to the development of mold growth on the seed. Using this same procedure, different varieties were studied, and it was found that there were no significant varietal differences in equilibrium moisture values. However, differences were found in the change of moisture content when beans were stored at high humidities. From these results it was possible to establish a relationship between the equilibrium moisture values and the environmental relative humidity, as shown in Figure 3.

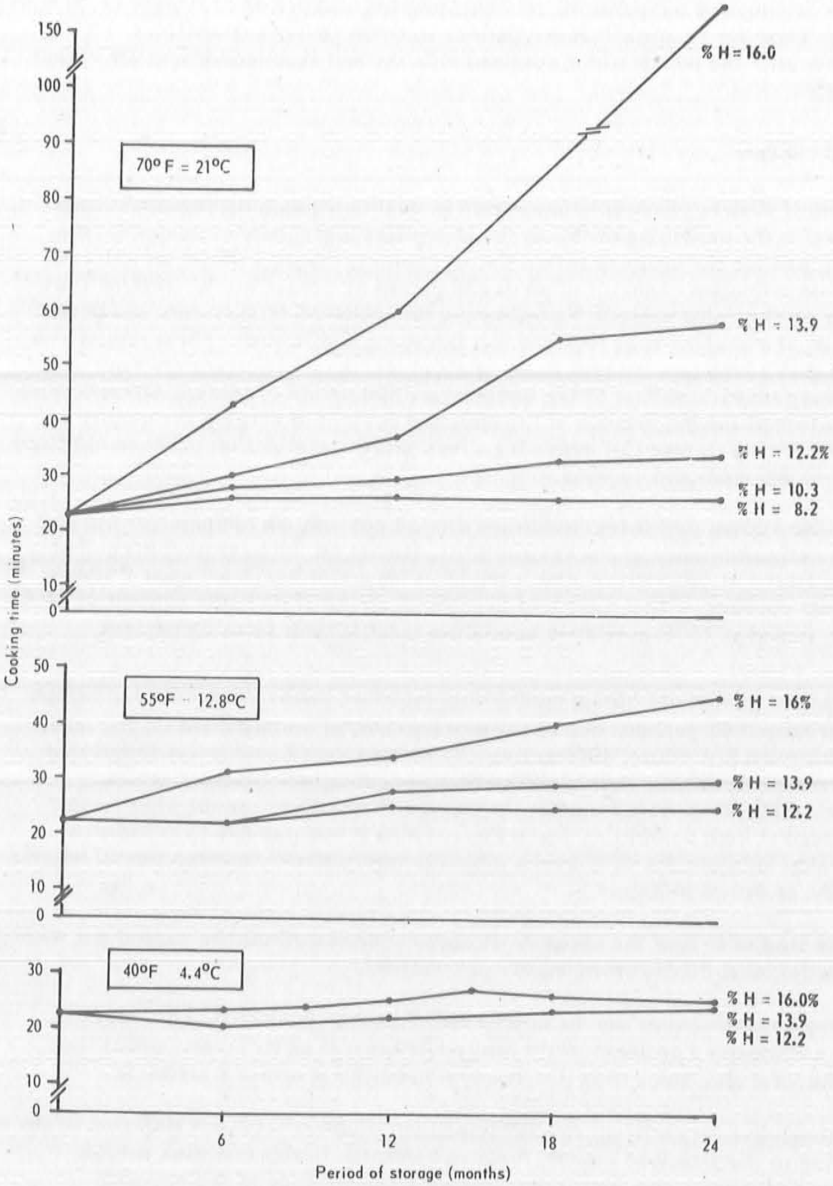
These studies to find the adequate storage conditions should be carried out with the varieties most often consumed in our countries.

A longer cooking time due to varietal differences or inadequate conditions of storage constitutes a problem to the housewife because of fuel costs, and at the industrial level also, since food processors standardize processing methods.

Although less appreciated, another important problem is biodeterioration of the seeds, due to the attack of insects, fungi and rodents. In this case also, proper conditions of storage and appropriate handling and cleaning of the material contribute to decrease serious wastage of a food which is at present in shortage.

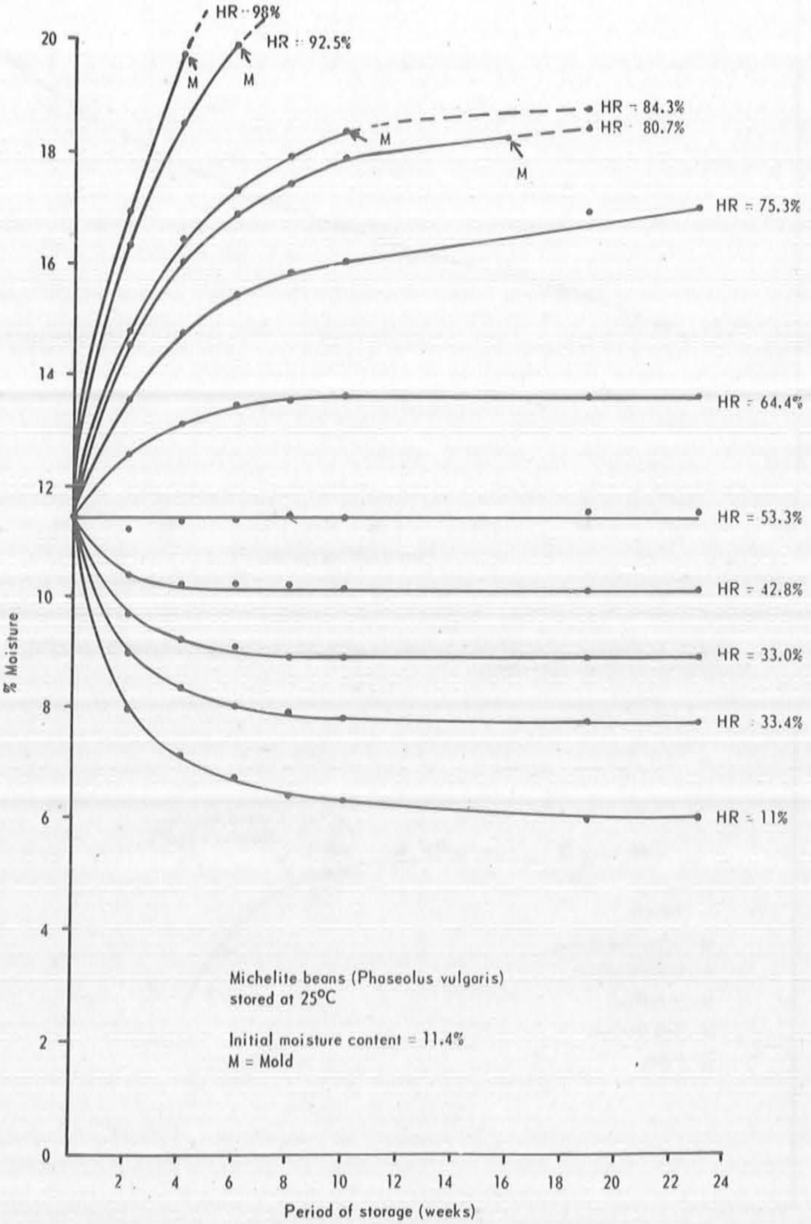
Changes in the chemical and organoleptic properties

Besides the observed changes in texture, beans can also be affected during storage in their organoleptic properties.



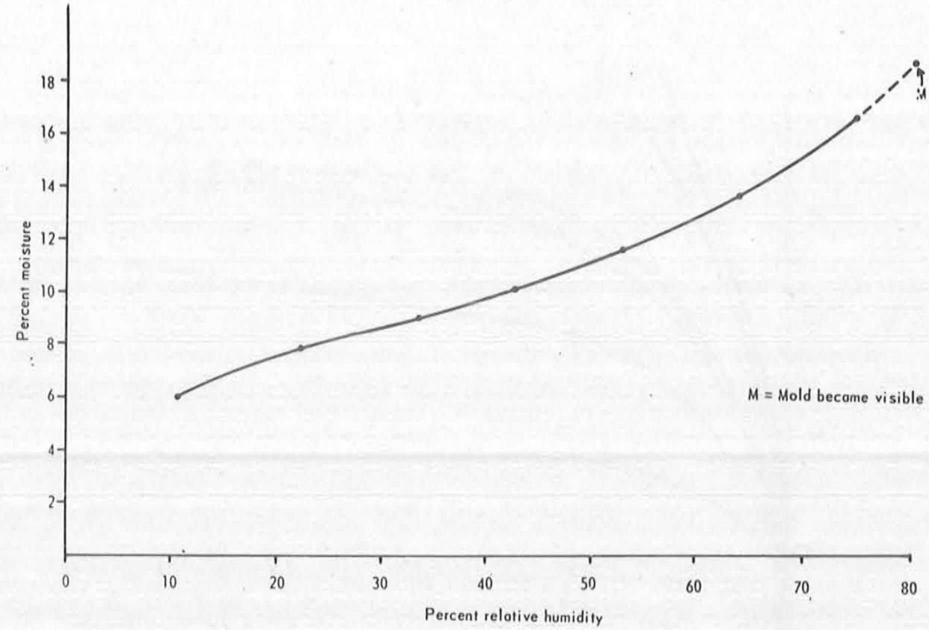
Taken from: Burr, H. K., Samuel Kon and H. J. Morris. Food Tech. 22: 336, 1968. Incap 73-98

Figure 1. Cooking time of Pinto Beans stored at different humidities and temperatures.



Taken from: Weston, W. J. and J. H. Morris. Food Tech. 8: 353, 1954. Incap 73-99

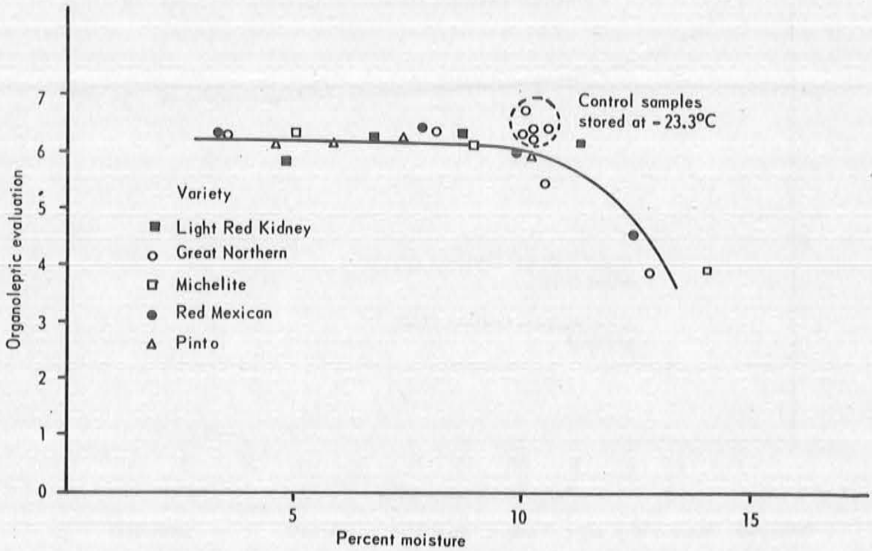
Figure 2. Rates of approach to moisture equilibrium at various relative humidities.



Taken from: Weston, W. J. and J. H. Morris. Food Tech., 8: 353, 1954.

Incap 73-96

Figure 3. Relation of equilibrium moisture content to storage relative humidity at 25°C. Michelite beans (Phaseolus vulgaris).



Taken from: Morris, H. J. and Wood, E. R. Food Tech. 10: 225, 1956.

Incap 73-101

Figure 4. Organoleptic evaluation vs. moisture content of dry beans stored 2 years at 25°C.

Figure 4 shows the results when six varieties of beans with different moisture contents were stored for two years at 25°C. These data indicate that beans with a moisture content higher than 10 percent, developed off-flavor, whereas beans stored with a moisture content below 10 percent kept their quality for two years. These organoleptic changes are due to the deterioration of the lipidic fraction of the seeds, as is illustrated in Figure 5, which shows an increment in the acid value of this fraction for beans with a moisture content higher than 10 percent. It is also of interest that the fat content of pulses represents a relatively small percentage of their overall composition, varying from 1 to 6 percent depending on the species (7).

However, it has been found that a high percentage of the lipid content is of unsaturated fatty acids, consisting mainly of palmitic, linoleic and linolenic acids, together with smaller amounts of stearic and oleic acids (8, 9, 10, 11, 12). Development of a rancid off-flavor during storage, therefore could well be due to the action of the enzyme lipoxidase present in beans on the unsaturated fatty acids (9). It is also possible that oxidation and polymerization of the lipids cause changes in water permeability which in turn affect cooking time (9). The main factor affecting the texture of the seeds, that is, the moisture content, is also responsible for the deterioration observed in their organoleptic properties. Figure 6 illustrates the effect of moisture content on the lipid acid values of a variety of **Phaseolus vulgaris.** The sample with 16 percent moisture, at six months of storage, gave a relatively high acid value as compared to the initial values, and increased significantly with the storage period. On the other hand, the sample with a moisture content of 5 percent was stable during 24 months of storage. Panel testing carried out on the same material showed a positive correlation between the lipid acid values and acceptability

Changes in nutritional value

There is little information in the literature related to the effect of storage on the nutritive value of bean protein. Some investigators (1), however, have suggested that the factors affecting the physical-chemical, organoleptic and culinary characteristics of legume foods could also alter its nutritional quality due to the longer time required for cooking (3, 13).

Specific studies related to the nutritive value of soybean during storage have been reported by some investigators (14, 15) using **in vitro** techniques. These results indicated that protein solubility in salt solutions, as well as the enzymatic digestibility, decreased during storage. Table 2 shows the effect of storage on the biological value and the digestibility of soybean protein. Biological value decreased during the period of storage for the raw whole beans as well as for ground autoclaved seeds. It is also of interest that the reduction in protein quality was not observed until 12 months of storage for autoclaved beans. Storage decreased protein digestibility only for raw whole beans.

Further work on this problem carried out by Mitchell and Beadles (16), indicates that the higher stability of autoclaved beans as compared to the raw is probably due to the lack in the processed beans of conditions which permit enzymatic reactions to take place. These enzymes are involved in respiration processes in the embryo, which accounts for 92 percent of the total weight of the seed. According to the authors this factor could also explain that the nutritive value of cereal grains stored under these conditions is not appreciably altered by seed respiration since the embryo or germ in these seeds represents only 9 to 10 percent of their total weight.

Table 2. The effect of storage on the true digestibility and B. V. of whole soybean and soybean ground and autoclaved

Treatment	True digestibility	Biological value
Raw soybean	84	72
Stored for 8.5 months at 26^{o} - $27^{o}C$ (78-$80^{o}F$)	78	63
Stored for 12 months at 26^{o} - $27^{o}C$ (78-80^{o} F)	79	66
Ground, autoclaved and stored for 8.5 months	85	73
Ground, autoclaved and stored for 12 months	84	68

Taken from: Mitchell, H. H. (quoted in Adv. Food Res. 4:269, 1953)
Ind. Enq. Chem. Anal. Ed., 16: 696, 1944.

Adverse conditions of storage can also affect the nutritive quality of bean proteins, through a reduction of the availability of some amino acids, as reported for other foods (17, 18, 19, 20, 21, 22).

PROCESSING

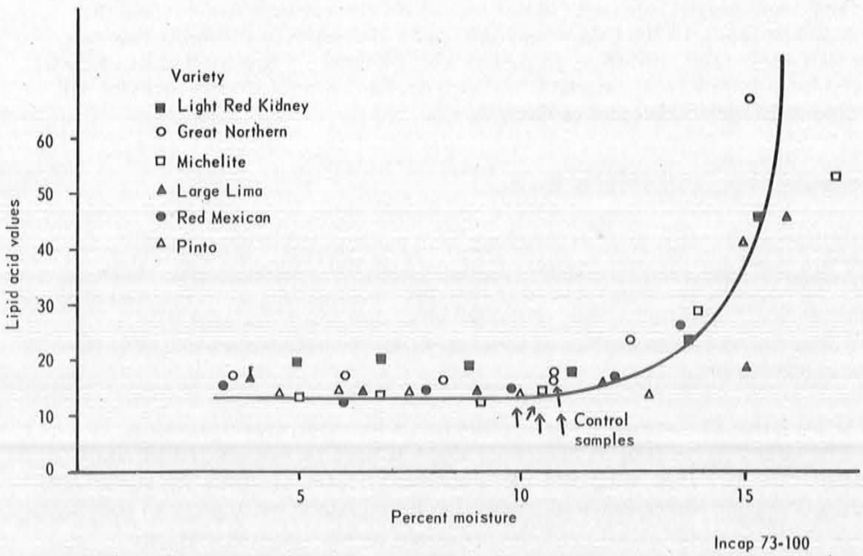
Measures to increase the production as well as to improve storage conditions of legume seeds are one of the most important aspects for the solution of the problems faced by this crop. An additional aspect is that technological processes are required to take care of increased availability. It is also very important to find new ways of utilizing the product.

Industrialization of beans could, in fact, be an indirect way to increase their cultivation through a more stable economic incentive, and could be a guarantee in the utilization of the crop. In addition it would permit selection of varieties needed by the industry and consequently stimulate the use of improved agricultural practices.

The processed product would have, furthermore, the advantages of a higher stability, constant availability through the year, more uniformity, and easier preparation, and could also be used as a vehicle for other nutrients. From the industrial point of view, the main problem is economic, since processing involves an increase in the final cost of the product. This aspect becomes more important in the case of beans, since this food is a basic ingredient in the diet of most Latin American countries.

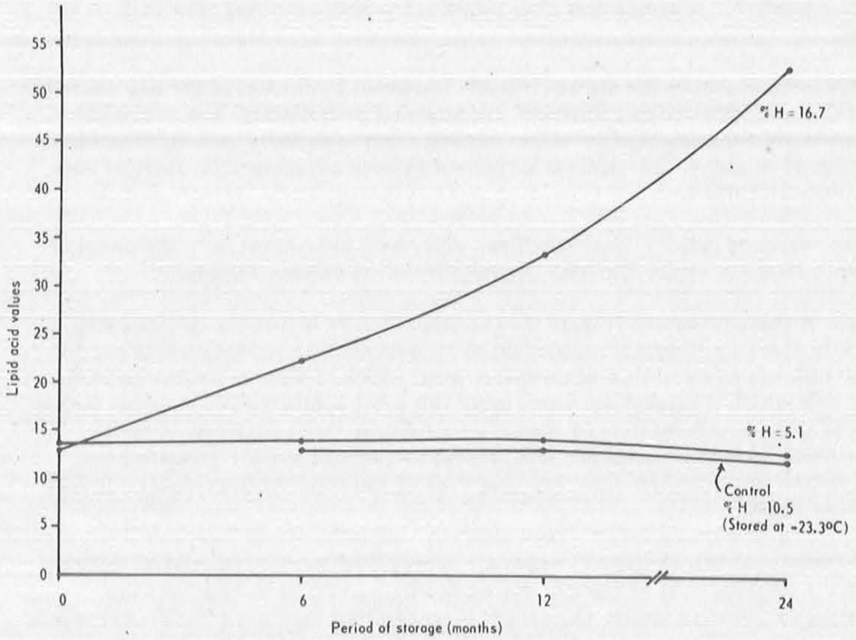
Types of processing

The types of processing must be developed according to the dietary habits of the population and also to the forms in which the food is consumed. This does not mean that other types of products could not be processed, but in the beginning it would be easier to introduce preparations that are part of the normal diet.



Taken from: Morris, H. J. and Wood, E, R., Food Tech., 10: 225, 1956

Figure 5. Acid values of lipid fraction in 6 varieties of dry beans of different moisture content stored 2 years at 25ºC.



Taken from: Morris, H. J. and Wood, F. R. Food Tech. 10: 225, 1956. Incap 73-97

Figure 6. Effect of moisture content on the lipid acid values of a variety of Michelite beans (Phaseolus vulgaris) stored at 25ºC.

The food technologist must also have in mind the housewife's convenience in preparing the product. In the case of legume foods, the types of products that can be processed are (1) pre-cooked, dehydrated whole beans; (2) pre-cooked bean flour; (3) canned bean (whole); (4) canned beans (fried). Each one of these processes will be analyzed as to advantages and problems.

Pre-cooked, Dehydrated Whole Beans

Continuous advances in food technology have made possible development of different processes for the preparation of pre-cooked, dehydrated whole beans. A great deal of research has been done to reduce the cooking time of beans, and at the same time to avoid adverse changes in the physical characteristics of the final product. Figure 7 shows an outline of some methods proposed and utilized in the preparation of this product.

In general terms, it consists of soaking the beans in water, steam-cooking, followed by dehydration (23). A blanching step has been recommended by some investigators (24, 25), indicating that this additional treatment offers the advantages of ensuring complete hydration, and destroying lipoxidase activity prior to soaking, improving in this way the stability of the processed product during storage.

Freezing before or after cooking as well as dipping in a sugar solution is carried out to avoid "butterflying", a characteristic represented by the development of fissures which appear during drying of cooked beans. The cooking time required to soften the final product varies according to the process employed and the variety of beans utilized, as well as the previous conditions of storage. In this case, the final product is ready for consumption after rehydration and a cooking time of 5 to 10 minutes.

The process shown at the right of Figure 7 involves hydration of the dry beans by soaking in water, pre-cooking in steam, cooking and dehydrating. The processed beans are ready for consumption after covering them with hot water, followed by boiling for 30 minutes. This process is claimed to have advantages in terms of cost and of product quality.

Other processes (26, 27) that have been described, ensure not only the physical appearance of the product, but also the stability of its nutritional quality.

In one of these processes (Figure 8), the main feature is that the cooking step is omitted. In this case, beans are subjected to an intermittent vacuum treatment for 30 to 60 minutes in a solution of inorganic salts, which facilitates hydration in the soaking step which is carried out later, using this same solution. The material is then rinsed and dried. Cooking time of the processed beans varies between 25 to 30 minutes. With little modifications, this process can also be used to prepare pre-cooked frozen beans. In this case, cooking time of the final product varies between 10 to 20 minutes.

In the other process (Figure 9) beans are coated with sucrose instead of dextrose to avoid the development of fissures during drying, as well as to maintain the nutritive value. This is possible since there is no Maillard reaction (29, 30, 31) which occurs when a reducing sugar, as for example dextrose, is used (32). This reaction is known to decrease the nutritive value of foods, due to the interaction of carbohydrates with amino acids, giving as result a decrease in the physiological availability of these nutrients.

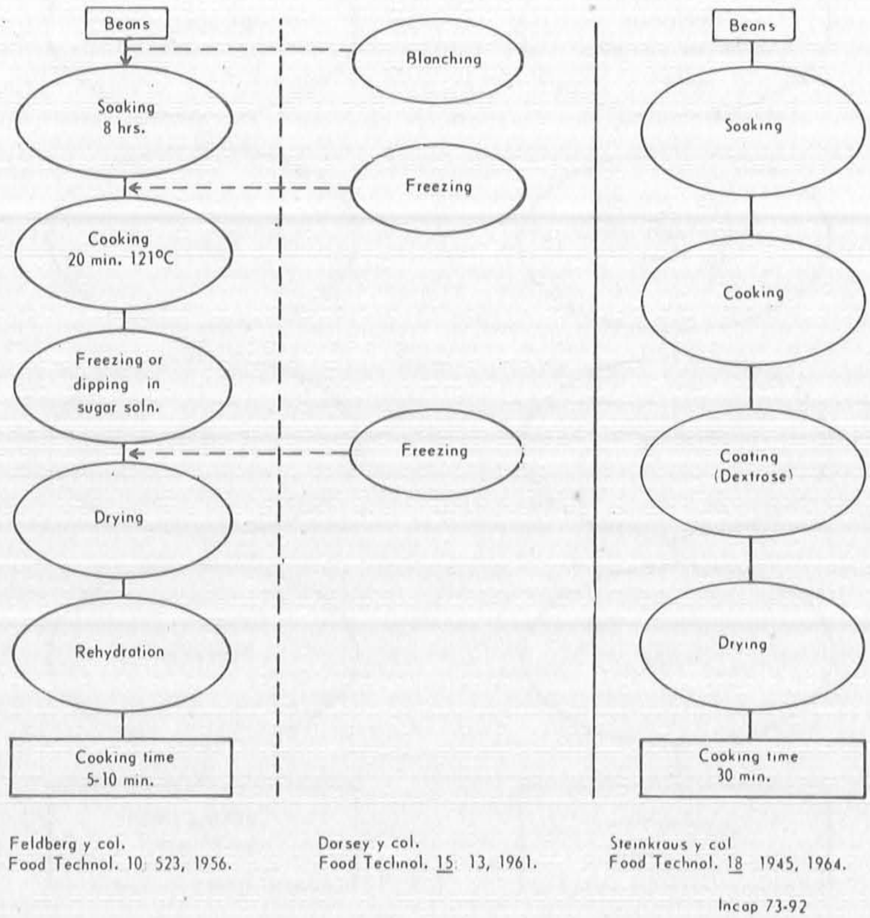


Figure 7. Processes used in the preparation of pre-cooked, dehydrated whole beans.

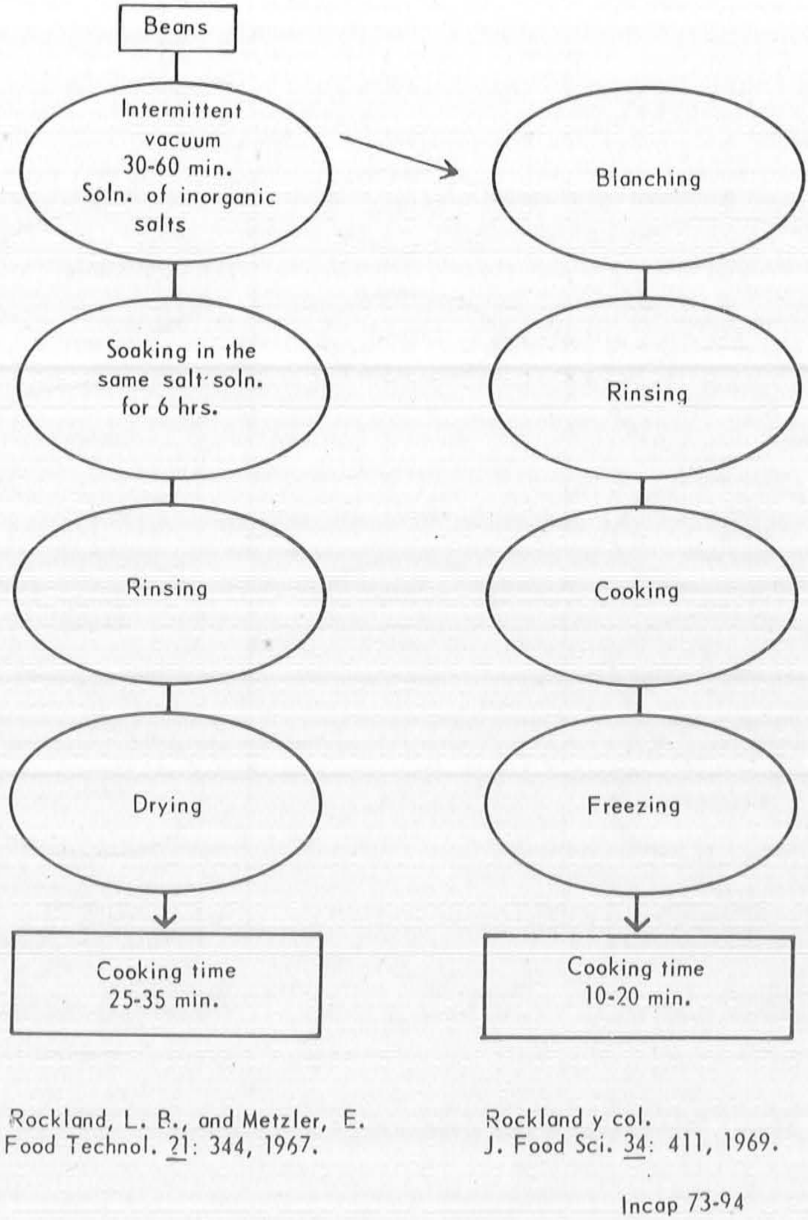
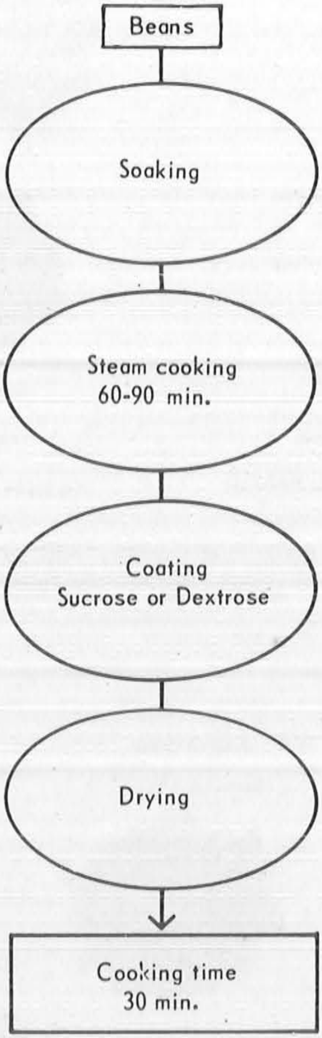


Figure 8. Processes used in the preparation of pre-cooked, dehydrated whole beans.



La Belle y col. (1969). Ninth Dry Bean Research. Conference at Forth Collins, Colorado, August 13-15, 1968. (ARS 74-50).

Incap 73-93

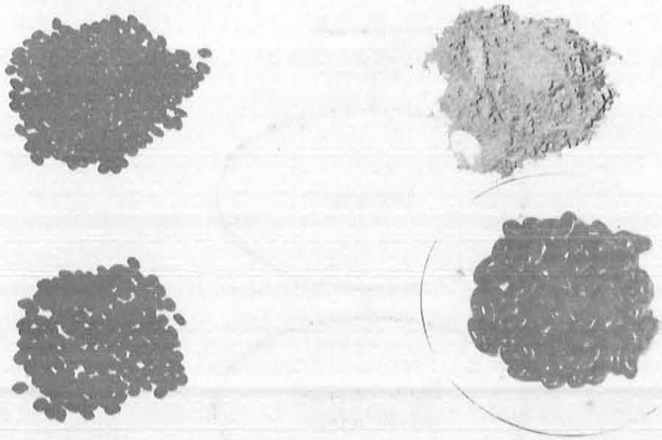
Figure 9. Processes used in the preparation of pre-cooked, dehydrated whole beans.

RAW BEANS

FRIJOLES CRUDOS

PRE-COOKED BEAN FLOUR

HARINA DE FRIJOL PRE-COCIDA



PRE-COOKED, DEHYDRATED BEANS

FRIJOL ENTERO PRE-COCIDO Y DESHIDRATADO

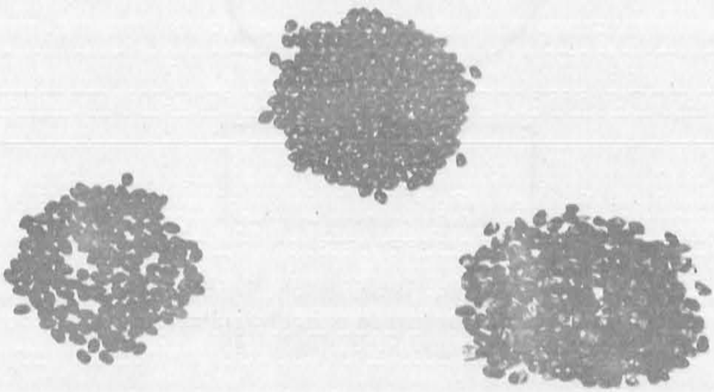
CANNED BEANS

FRIJOLES ENTEROS ENLATADOS

For the housewife's convenience, industry is manufacturing different types of food products from legume grains.

RAW BEANS

FRIJOLES CRUDOS



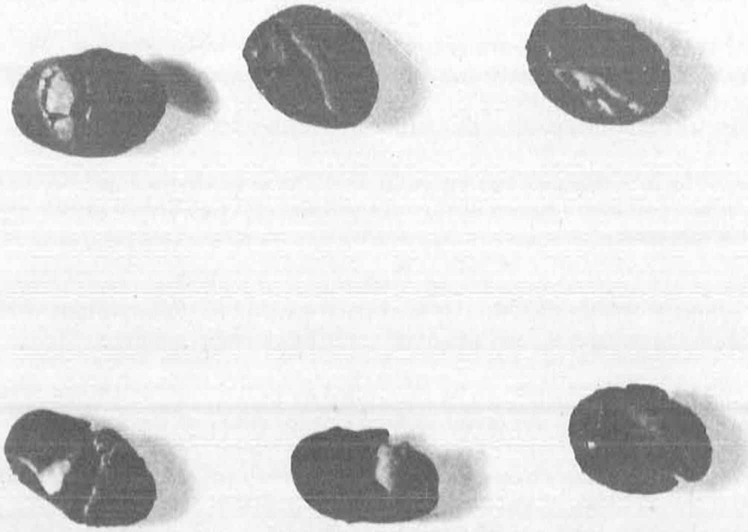
PRE-COOKED, DEHYDRATED BEANS

FRIJOL ENTERO PRE-COCIDO Y DESHIDRATADO

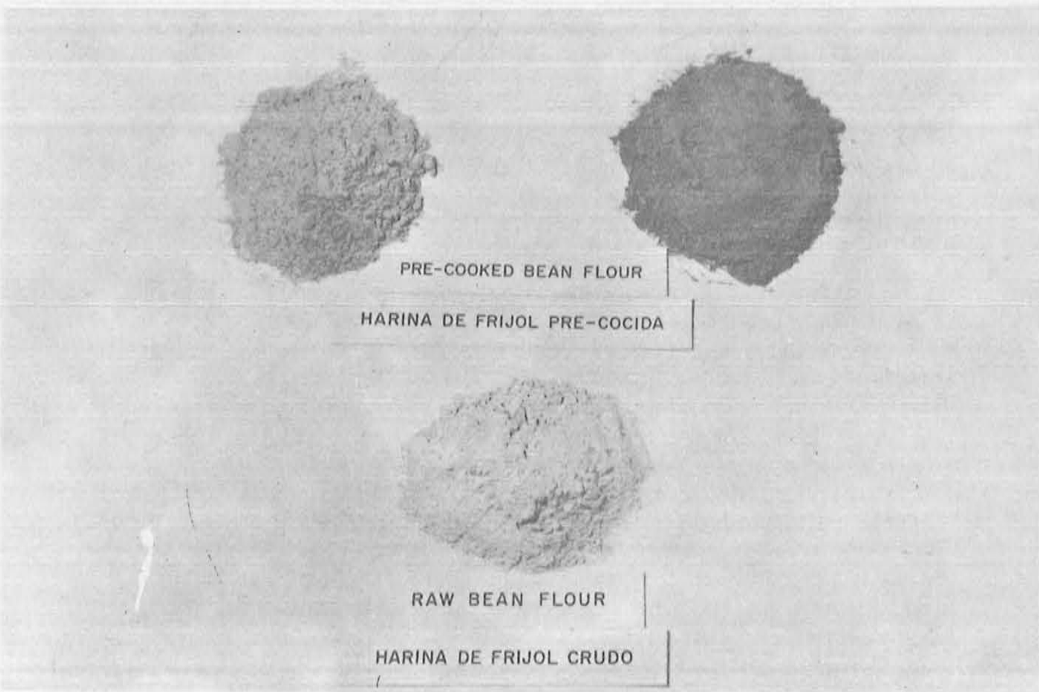
PRE-COOKED DEHYDRATED BEANS, DAMAGED

FRIJOL ENTERO PRE-COCIDO Y DESHIDRATADO DAÑADO

Damage of beans (right) ocurred during drying in comparison with pre-cooked beans, processed adequately (left).



Close-up of damaged pre-cooked beans.



Partial loss in color in bean flour occurs generally when black beans are used.

Pre-cooked Bean Flour

The technology used in the preparation of pre-cooked bean flour (33, 34) is very similar to the processes previously described (See Figure 10). The material is subjected to soaking, cooking and dehydration, followed by grinding. The final product is ready for consumption after cooking for 10 to 15 minutes.

As in the previous process, the main objective is to obtain a quick-cooking product with minimum deterioration of the organoleptic and nutritional properties of the original material.

Two problems have been found in relation to the physical characteristics of the final product: the final texture of the preparation and a discoloration of the flour. Partial loss in color is mainly observed when black beans are used.

Apparently this change can be controlled by processing conditions during cooking. Cooking in water seems to facilitate solubility of the pigments located in the seed coat, which further penetrates the cotyledons, resulting in a darker flour color. A discoloration of the flour is observed when the cooking step is carried out without the addition of water. This is a very important aspect from the viewpoint of the consumer, since a good quality of black bean soup is associated with its darker color. Coarse texture of the flour is due to the presence of dried particles of the seed coat, which is not completely pulverized. Care should be taken in the grinding step to obtain a more homogeneous product, since eliminating the seed coat makes the process more expensive.

Several studies have been made of the effect of this process on the nutritive value of the bean proteins (13, 34, 35, 36). The results shown in Table 3 demonstrate that a cooking time beyond 30 minutes at 121°C under 16 lbs pressure, without a previous soaking, decreases the nutritive value of the proteins. This reduction is due, in part, to a lower availability of lysine, one of the essential amino acids (13). The combined effect of different periods of soaking and cooking time on protein quality is illustrated in Figure 11. The data show that optimum cooking time for the samples without soaking varies from 20 to 30 minutes. On the other hand, the soaked samples showed a reduction in the nutritive value when the cooking time was higher than 10 minutes.

Statistical analysis showed significant differences between the samples subjected to 16 and 24 hours of soaking and those cooked for 20 and 30 minutes (37). Furthermore, the conditions of soaking, cooking and grinding must be controlled in order to obtain an acceptable product, from the organoleptic and nutritional point of view.

Pre-cooked Canned Beans

The preparation of pre-cooked canned beans differs from the process previously discussed in at least two aspects. First, beans are generally cooked in the can, and second, in some products the legume food is mixed with other ingredients, such as meat, tomato sauce, and other condiments. The simplest product is prepared with beans in brine.

To obtain an acceptable texture in the final product, it is important to use beans with a normal cooking time, since it has been reported that sometimes canners find that the heat process required to sterilize canned beans is not sufficient to make them tender (38).

Table 3. The effect of cooking on the protein quality of beans

Cooking time minutes[b]	Weight gain g/28/days	Protein efficiency ratio
0	0[a]	0
10	75	1.31
20	72	1.35
30	76	1.29
40	59	1.20
60	35	0.89
90	37	0.92
120	37	0.88
150	29	0.78
180	24	0.63

a. All animals died.

b. Cooked in autoclave at 121°C and 16 lbs pressure.

In some cases canning has been found to affect protein quality significantly (39). For example, in the preparation of canned beans with sauces, sugars are generally added, which can react with bean proteins under the high temperature processing conditions, causing non-enzymatic browning reaction to take place (29). This reaction is desirable from the organoleptic point of view, giving a product with a characteristic flavor, known as "baked beans". However, the nutritive value is drastically affected (39, 40, 41, 42) if a reducing sugar, like glucose, is used.

Table 4 shows the effect of adding glucose and sucrose on the protein quality of canned beans. Canned beans, cooked in water for 70 minutes, showed a decrease in weight gain and in protein efficiency ratio, indicating a reduction of nutritive value. The addition of sucrose to the input solution, resulted in a slight decrease of these two parameters, whereas the presence of glucose alone in the canned product reduced significantly the weight gain as well as the protein efficiency ratio. The simultaneous addition of sucrose and dextrose to the input solution, did not significantly affect the protein quality as compared with the addition of glucose alone.

Excessive cooking time affects not only the protein quality, but also the vitamin content of the product. Lantz et al (43) have shown an increased destruction of thiamine in prolonged cooking.

Stability of the processed products

The processes to which beans are subjected no doubt help increase the chemical stability and the organoleptic, cooking and nutritional characteristics of the raw

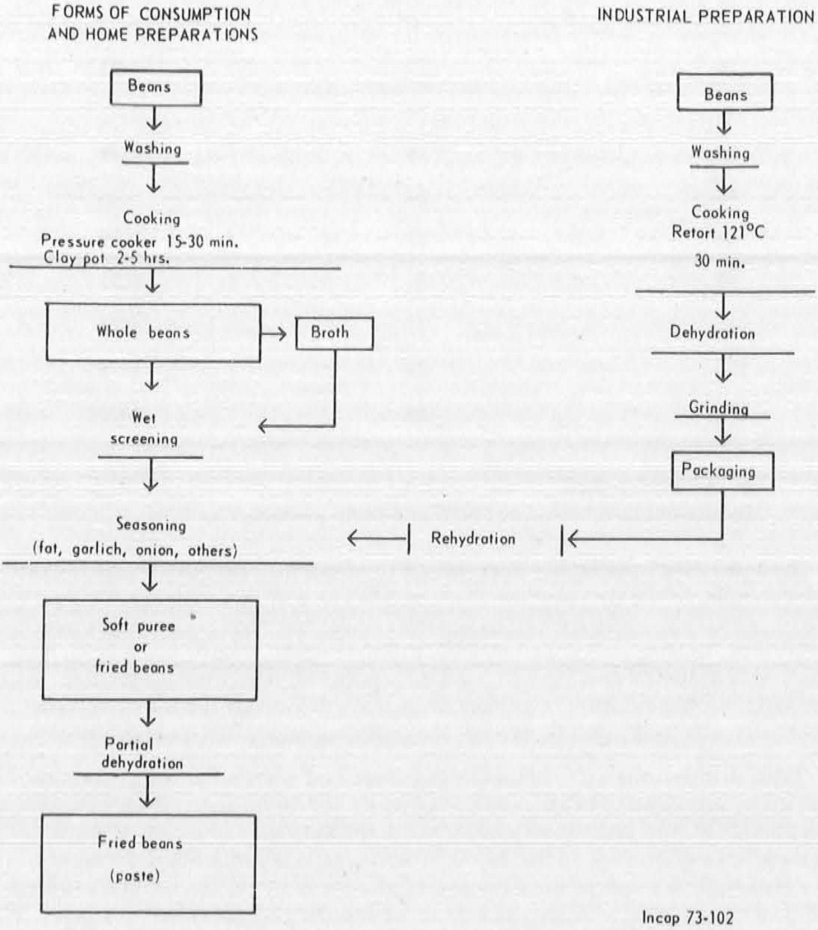


Figure 10. Process for the preparation of pre-cooked bean flour.

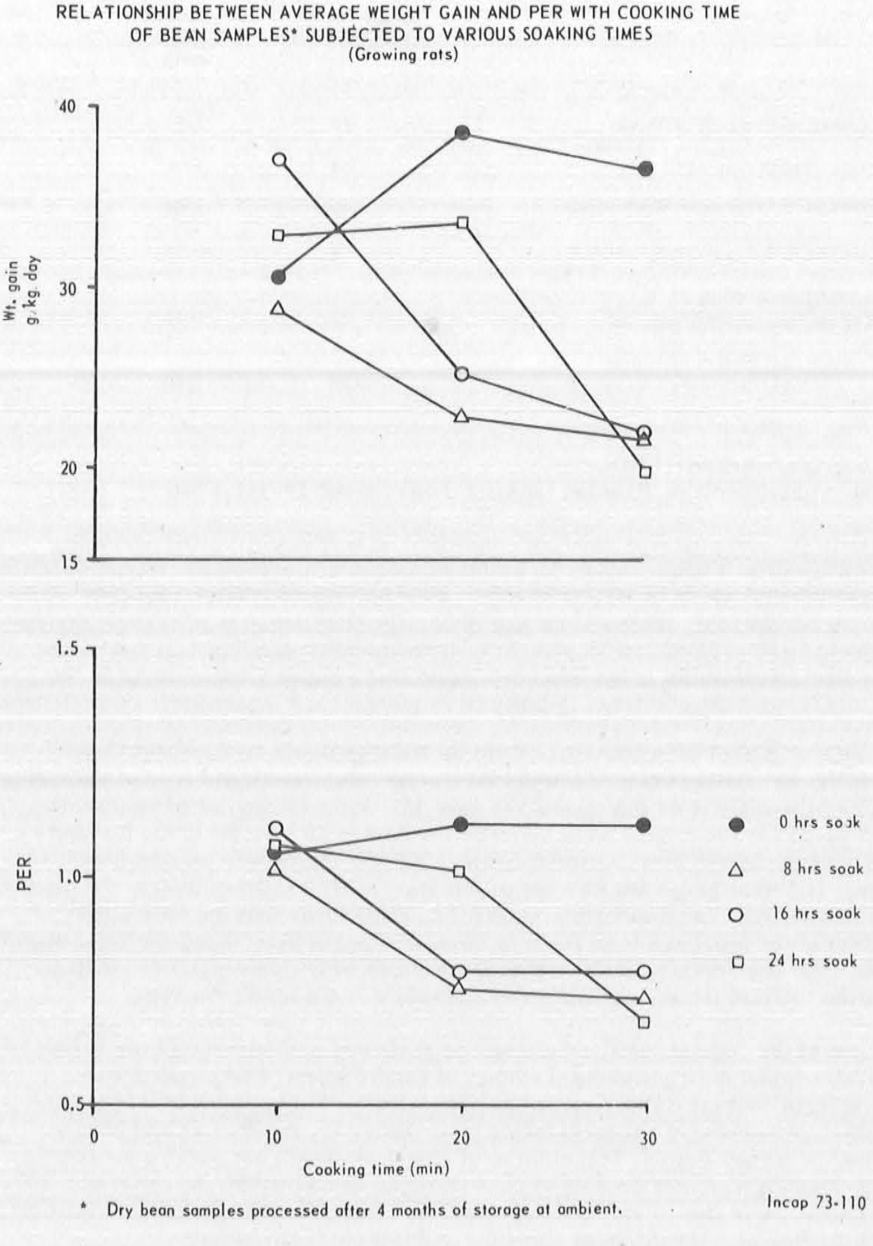


Figure 11. Relationship between average weight gain and PER with cooking time of bean samples (dry bean samples processed after 4 months of storage at ambient) subjected to various soaking times (Growing rats).

Table 4. Protein quality of canned beans

Samples of canned beans	Average weight gain, g/53 days	Protein efficiency ratio
1. Cooked with water* (20 min)	72	1.53
2. Cooked with water (70 min)	44	1.06
3. Cooked in 10% sucrose solution	40	1.09
4. Cooked in 10% glucose solution	4	0.16
5. Cooked in solution of 8% sucrose and 2% glucose	26	0.78
6. Control: casein-lactoalbumin (5:1)	158	3.64

* Cooking temperature: 121°C.
Taken from: Powrie, W. D. and E. Lamberts. **Food Technol. 18**: 111, 1964.

material. However, storage time and conditions, as well as the type of packaging will influence to a larger extent the keeping qualities of the product. When pre-cooked and dehydrated whole beans, for example, were packaged in plastic bags (25) at room temperature, there was no sign of damage after one year of storage. Similar samples stored at 50°C and 50 percent relative humidity developed an unpleasant odor after two months. It has also been found that a higher water content in the product is conductive to lesser stability of its physical and organoleptic characteristics.

Similar studies have been carried out on stability of pre-cooked bean flour. Recently, Del Busto et al (50) found that storage temperature and type of packaging affected the stability of this product (Figure 12). After 15 months of storage, the flour packed in paper or in polyethylene bags showed an increase in the free fatty acid content, as well as in the water content. Similar results were obtained with storage at 5°C although the increase of free fatty acids was lower than in the previous case (Figure 13). These and other results (51, 52) indicate that the final water content in the processed food is a very important factor in retaining the organoleptic qualities of the product. In this regard the addition of antioxidants is an adequate solution to avoid the damage due to deterioration of the lipidic fraction.

Loss of the original color and alterations in texture and odor have been the main problems found during prolonged storage of canned beans. This physical and organoleptic damage is due to an interaction between traces of minerals with the organic constituents of the seed, taking place during the autoclaving and later on during the storage period. The addition of chemicals during the soaking process often contributes to the keeping of characteristics demanded by the consumer (53). Obviously, these aspects are very important and should be taken into consideration when dealing with the different climatic conditions in Latin America.

Technical and nutritional problems

The technological and nutritional problems inherent to each of the products described can, in general, be solved by means of adequate processing techniques.

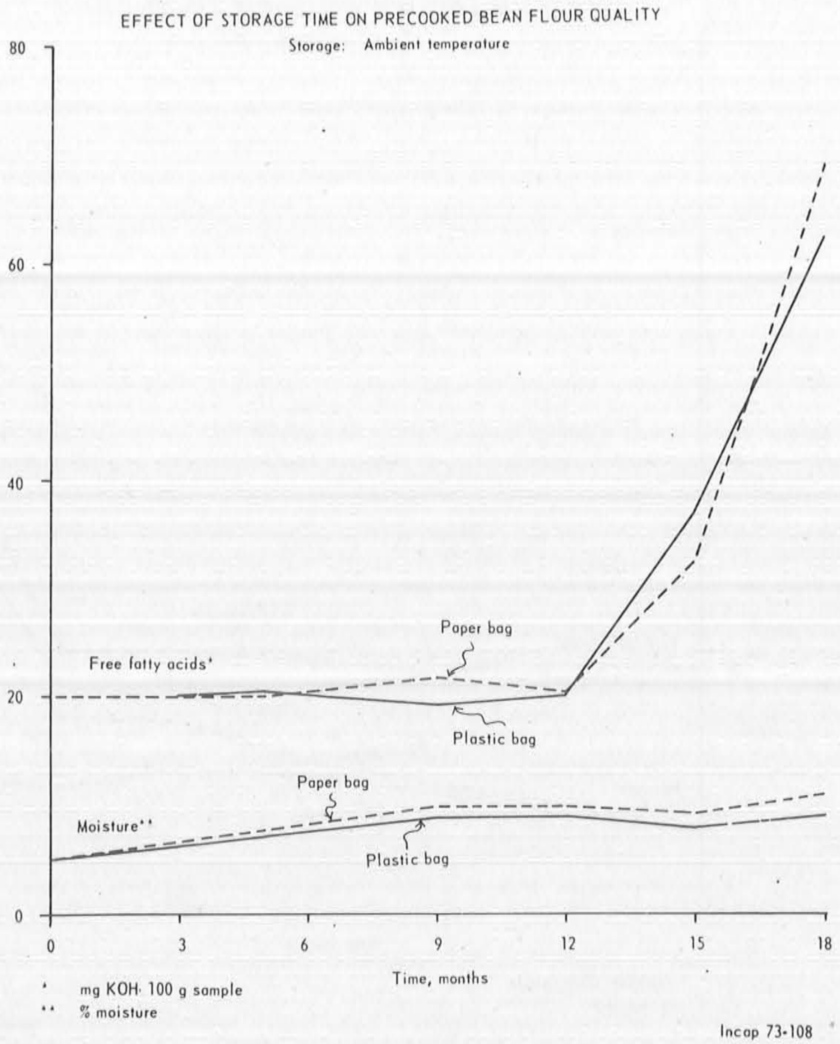


Figure 12. Effect of storage on precooked bean flour quality.

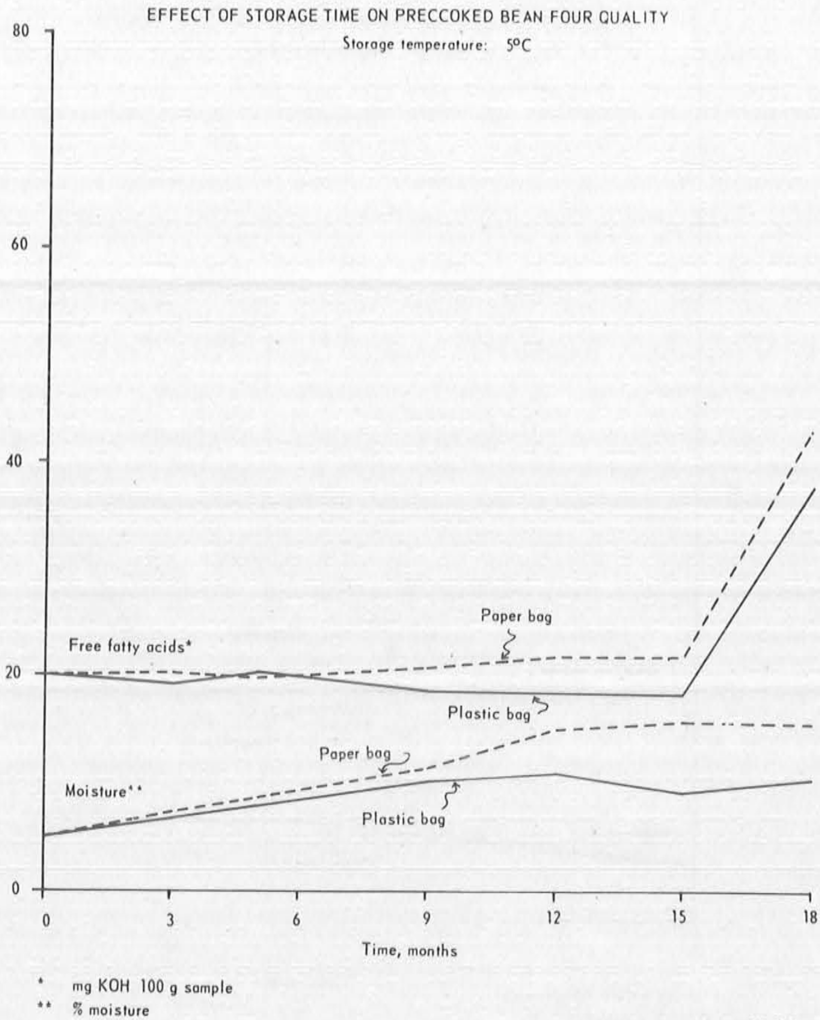


Figure 13. Effect of storage on precooked bean flour quality.

PRE-COOKED BEAN FLOUR (Pigeon pea)

HARINA DE GANDUL PRECOCIDA

PRE-COOKED BEAN FLOUR (Black beans)

HARINA DE FRIJOL NEGRO PRECOCIDO

PRE-COOKED BEAN FLOUR (Cow pea)

HARINA DE CAUPI PRECOCIDA

BLACK BEANS + COW PEA

FRIJOL NEGRO + CAUPI

Pre-cooked gandul flour, pre-cooked cowpea flour, pre-cooked black bean flour and mixture of black bean and cowpea flours. Note similar appearance of products.

PRE-COOKED BEAN FLOUR

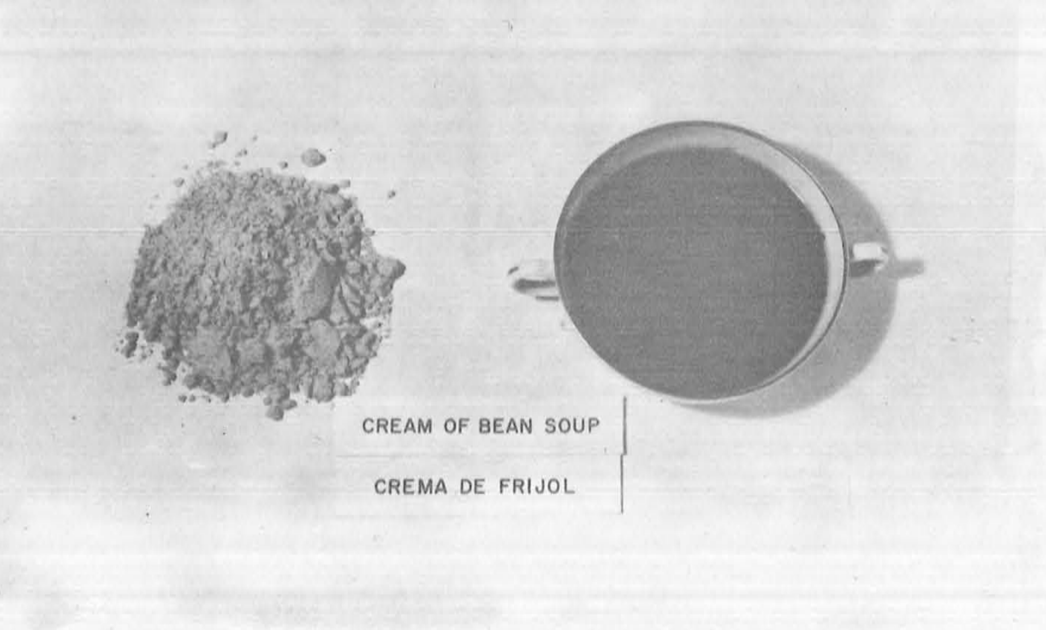
HARINA DE FRIJOL PRE-COCIDA

CANNED BEANS (Fried)

FRIJOLES FRITOS ENLATADOS

Pre-cooked bean flour and canned fried beans are two products that have been in the market of Guatemala since 1971.

Whole cooked beans with rice is a typical dish in several Latin American countries.



Pre-cooked flour of legumes can be used to prepare soups of different type and flavor.

This technology, however, is used to a limited extent by the food industry, in the Latin American countries, mainly because of the unavailability of the raw material, and the lack of acceptability of the product by the consumer for economic reasons.

The food industry needs perforce a constant availability of raw materials. In the case of beans, the problem is more complicated since beans are a basic food in most Latin American countries, and thus the direct demand of the population competes with industrial demands.

The problem could be obviated, at least in part, by increasing production or by using other legume grains less consumed than beans but capable of being used in processed foods. As an example, it is possible to partially replace beans (**P. vulgaris**) by other legumes in the production of pre-cooked black bean flour, without affecting the nutritional or organoleptic characteristics of the product. Table 5 summarizes results obtained in biological trials when black bean flour was substituted by cowpea (**Vigna sinensis**). Substitution did not significantly alter protein quality as measured by weight gain of experimental animals and protein efficiency ratios.

Another interesting aspect shown in this table is that as cowpea replaced black beans, no increase in the weight of the pancreas was observed. The increase of pancreas weight, according to previous studies (44, 45, 46), is a reflection of the presence or residues of heat-stable trypsin inhibitors present in some legumes. Cowpea thus presents the added advantage of being free of trypsin inhibitors, and some varieties have a superior protein quality to that of beans (**Phaseolus vulgaris**) (47, 48)

Combinations of black beans with other legumes such as pigeon pea (**Cajanus cajan**) could also be used in order to make black beans more available, possibly reducing the price of the product and developing interest in the production of new legumes in Latin America.

As concerns acceptability of these products by our population, it has been said that for several reasons, it would not be successful at present. We believe that the industrial and economic change that has been taking place in our countries will allow the consumption of these products by the majority of the population. In Guatemala, for example, at least two of these products pre-cooked bean flour and canned fried beans have been in the market for the last two years, thus showing the feasibility of processing and consumption of these products.

Advantages and uses

Advantages of a processed product, mentioned previously, are greater stability, uniformity, and availability. Regarding beans, shorter cooking time is an obvious practical advantage to the housewife. The use of these products will, of course, depend on the culinary preparations in each country. Pre-cooked and dehydrated beans can be used in several cooking preparations, such as whole cooked beans, beans and rice, salads and so forth.

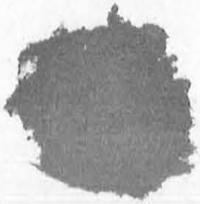
Pre-cooked flour of legumes can be used mainly as soups of different type and flavor and other home preparations as shown in Figure 10. Besides, it can be combined with other foods in the preparation of thick soups of a high nutritive value (49). Table 6 shows the composition and nutritive value of one of these products developed by INCAP. The quality of the protein of the basal formula, as evaluated by protein efficiency ratio, is quite high.

Table 5. Protein quality of different combinations between black beans (*Phaseolus vulgaris*) and cowpea (*Vigna sinensis*)

Ingredientes	1	2	3	4	5	6	7	8
Precooked cowpea flour, %	33.00	26.40	23.10	19.80	16.50	13.20	6.60	–
Precooked black bean flour, %	–	8.30	12.50	16.70	20.80	25.00	33.40	–
Percentage distribution of protein in the diet from cowpea	100	80	70	60	50	40	20	0
From black beans	0	20	30	40	50	60	80	100
Average weight gain, g	56	46	50	53	48	55	55	57
Protein Efficiency Ratio	1.69	1.53	1.40	1.61	1.50	1.54	1.57	1.62
Weight of pancreas, g	0.445	0.368	0.326	0.995	0.923	1.038	0.9657	1.090

Table 6. Composition and protein quality of soup base formula of high nutritive value

Ingredients in the basal formula	g	Soup Base formula	g
Precooked beans flour	45.00	Base formula	90.00
Cereal flour (corn, rice)	25.00	Seasonings and other ingredients	10.00
		Total	100.00
Cottonseed flour	27.00		
Torula yeast	3.00		
Total	100.00		
Percentage of protein in the diet,	12.5		
Weight gain, g	97		
Protein Efficiency Ratio	2.19		

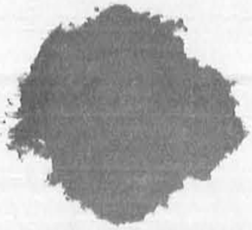


1

2

SOUP BASE FORMULA
OF HIGH NUTRITIVE VALUE

FORMULAS BASE PARA SOPAS
DE ALTO VALOR NUTRITIVO



3

4

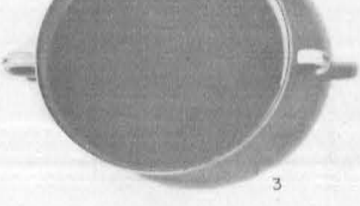
Above and below: physical appearance of pre-cooked flours of legumes and home made soups prepared with these products.

1

2

LEGUME SOUPS OF HIGH NUTRITIVE VALUE

SOPAS DE ALTO VALOR NUTRITIVO
A BASE DE LEGUMINOSAS



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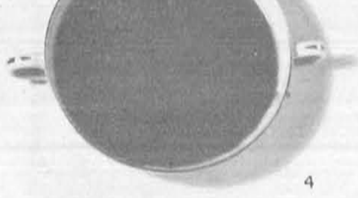

4

INTERRELATIONSHIP BETWEEN STORAGE AND PROCESSING

The quality of the raw material determines to a very large extent the quality of the final product. Adequate storage conditions are of primary importance in retaining bean quality for processing. The phenomenon known as hardening of the seed is one of the most serious problems confronting the food industry, since "hard" beans are not properly cooked during the time normally used in this step of processing.

With the purpose of separating normal beans from "hard" ones, Bourne (54) developed an interesting practical method based on the fact that seed size in a given lot of beans follows a normal pattern of distribution, while "hard" beans are usually found in the fraction comprising the smaller size. Rejection of 20 percent of beans prior to soaking discards about 70 percent of "hard" beans. Likewise, during the soaking process, normal beans absorb water and swell, while "hard" beans do not swell and are, consequently, discarded with the smaller-size seeds. Selecting again for size after soaking, "hard" beans can be practically eliminated, obtaining a better final quality of raw material.

Storage conditions can also determine the processing to which beans should be subjected. It has been found, for example, that when recently harvested beans are processed by the same technology used for beans that have been under storage, results on the nutritive value are different (37), as can be observed in Figure 14.

In this case, protein quality was damaged by cooking times longer than 10 minutes, including those samples that were not previously soaked, which suggests a greater swelling capacity of the recently harvested beans. This hypothesis was confirmed (Figure 15), when the hydration coefficients of recently harvested beans, and beans stored for four months under laboratory conditions, were compared. Beans that had been stored did not, in 24 hours, reach the hydration level reached by the recently harvested beans in 8 hours (37). These results could explain the greater sensitivity of the fresh bean protein to the thermal treatment used during processing, especially that of samples which were not subjected to soaking.

In some cases, bean quality can also determine the kind of processing which will be more adequate from the practical and economic points of view. The seeds that require a longer cooking time, for example, can preferentially be used for the manufacture of precooked flours, thus utilizing a raw material which is unfit for ordinary consumption or for other preparations.

CONCLUSIONS

The most pressing nutritional problem facing Latin America seems to be the unavailability of legume seeds for human consumption, due mainly to agronomic, economic, and technological factors.

Inadequate storage conditions contribute also to decreased human consumption of these products, due to a deterioration of the cooking and organoleptic characteristics of the seeds.

Industrialization of beans could help to partially solve the production problem, through an incentive for increased agricultural technology, price stabilization,

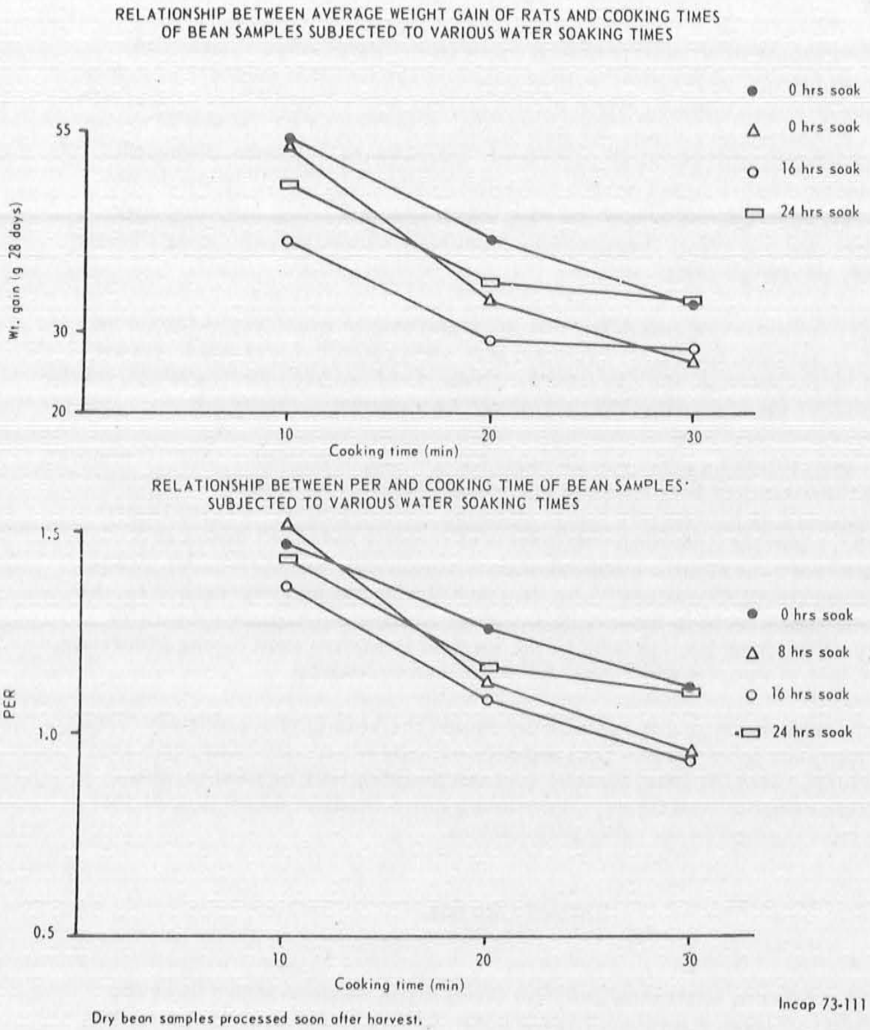

Figure 14. Relationship between average weight gain of rats and cooking times of bean samples subjected to various water soaking times.

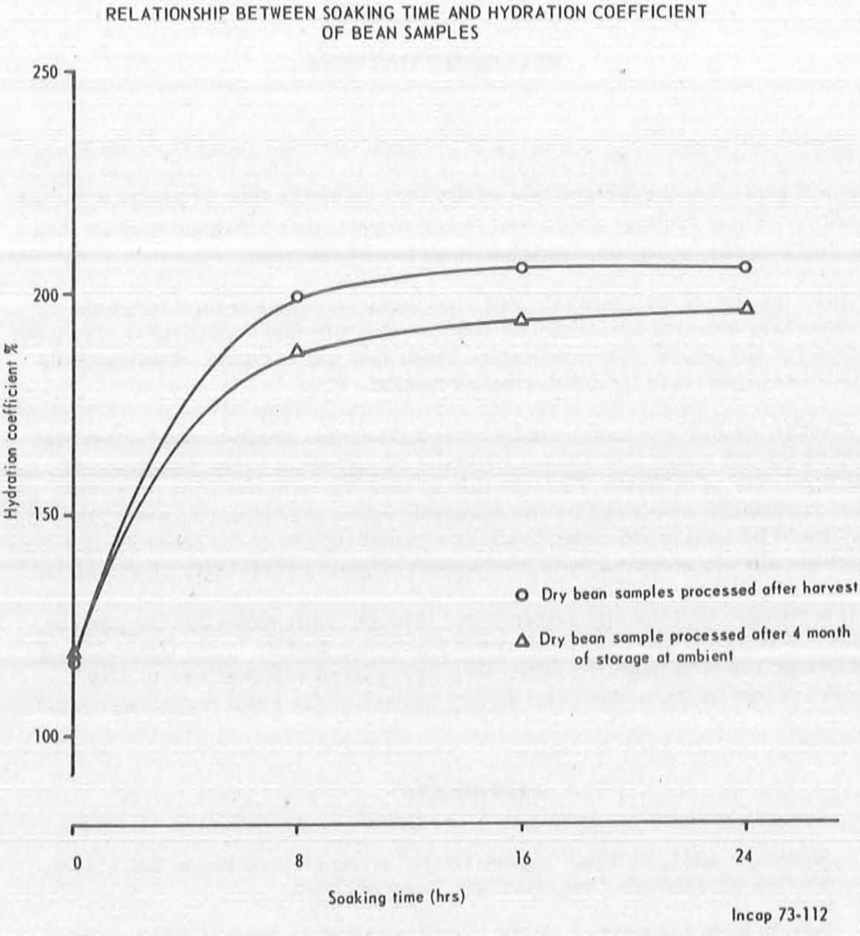

Figure 15. Relationship between soaking time and hydration coefficient of bean samples.

greater availability throughout the year of these products, and production of a variety of processed foods aimed at the convenience of the housewife.

Since beans are a basic food in most Latin American countries and considering their potential as a protein source, their increased consumption would contribute to the improvement of the nutritional status of these populations.

RECOMMENDATIONS

Studies are needed on the storage of the most common varieties of beans consumed in Latin American countries, in order to establish the adequate conditions that will guarantee the preservation of the crop up to the time of purchase by the consumer. These findings would lead to the construction of adequate silos, thus guaranteeing the farmer the economic incentive of his crop.

Since quality of raw materials is of vital importance to the food industry, improved legume varieties should be selected that will fulfill the quality standards needed for the production of processed foods that can compete advantageously with other products in the food industry market.

Another desirable measure would be to increase the production of other high-yielding legume grains that are not normally consumed in these countries and which are easy to cultivate. The selection of varieties with the same seed shape and color as normally consumed by the different regions should not be overlooked since they could be used in processed foods as a partial substitute for those legume grains which are already accepted, with consequent increased availability of the latter.

It is possible that through research and through conferences like the present, beans will finally achieve the preeminent place they deserve in the field of food technology since, through the years, they have played and continue to play a significant role in the cultural and dietary pattern of the Latin American countries.

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FACTORS AND TACTICS INFLUENCING CONSUMER FOOD HABITS AND PATTERNS

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INTRODUCTION

Anthropologists and sociologists have been the first investigators to provide information on food habits from regions of historical interest in civilizations that have disappeared, or native groups living in primitive conditions. Little is known about food habits elsewhere because research studies have been very scarce.

On the other hand, nutritionists have been studying the quantitative consumption or availability of food in each country without paying too much attention to food habits. Nevertheless, the developing countries are those in need of such information. In some, customs and food habits are known but unfortunately sociologists and anthropologists do not give the origin but only the prevalence of these customs without data on the reasons behind them. Therefore, some nutritionists, as they gather data on quantitative intake also take the opportunity to collect information to explain food habits. This is the case in Central America (1-8) where the characteristics of the diets are well known in the different population groups, and the reasons for the dietary habits in those food patterns.

These studies were first carried out through dietary surveys which covered seven days of almost living with the family (9) to observe the handling, preparation and distribution of foods within the family. In Guatemala, unique in this regard, the anthropologist Antonio Goubaud Carrera (10) studied extensively all social aspects and especially food habits among rural communities.

Later, the dietary studies in Central America have continued in a more specialized way, as measuring the food consumption of preschool children (11, 12). Small children represent one of the most vulnerable groups in regard to nutritional status of the population of Central America and Panama.

FOOD HABITS

Nature offers human beings an enormous variety of foodstuffs. Men usually select them according to the quantity in which they are produced and give preference to those that satisfy their basic needs. The main cultures and civilizations have flourished in areas where man's efforts were rewarded by abundance of a certain indigenous cereal.

Rice, wheat and maize have represented the source of life for the civilizations of the Far East, the Mediterranean (Egypt and Rome) and America, respectively, during the development of their societies. The opening of routes across the world brought those grains to the rest of the world, where they combined with other products and formed special dietary designs called food patterns.

In some areas of the world, the majority of people enjoy plentiful food sources, while in others low production limits food availability drastically, and only a minority satisfies its needs. The amounts in which different items are consumed by people in each area, and the customary treatment given to them, determine the levels reached by calorie and nutrient intake in every population group.

FACTORS INVOLVED IN FOOD SELECTION

Differences in types of foods and combinations in which they are consumed have been determined by several ecological factors, defined below.

Geographical Location

The territory where man happens to live will lead him to select the staple, as well as other food products, with which to build his diet. In the highlands or near the sea, close to the rivers or lakes, in the tropical or temperate zones, land and water will offer him different foods.

In general, most cereals such as wheat and maize, and legume grains, such as beans or chickpeas, grow better in the highlands and temperate climates, while some root crops, such as sweet potatoes or yam, and oily seeds, as sesame or cotton, are native to warm lowlands. Sea shores shaded by palm trees provide foods rich in protein and fats; in addition, a variety of marine products may be available.

Extensive grassy plains where cattle or other domesticated animals can be fed provide their inhabitants with meat and milk. Thus, great differences in food patterns may exist not only between countries, but also within each country.

Cultural Factors

Throughout the centuries, cultures have developed around an area's principal indigenous foods. Man learned to cultivate and domesticate the necessary plants and animals. After many generations, he inherited special technologies for preparing those products. Each society disseminated its own culture, so foods which originated in one place appeared in different areas also, following the expanding civilization. Optimum climatic and soil conditions found in differing areas have favored the adoption of foreign items. Thus, with human migration there has been a real exchange of foods between continents. Cacao, used to prepare chocolate, regarded as the beverage of the gods in the Middle American civilization, emigrated to other lands, while coffee from Ethiopia came here to replace it (13). India has been the motherland of many products now cultivated in African, European, and tropical American countries.

How well introduced foods were accepted by the people has been a matter of time, prestige, production, and the essential needs of the people. If local conditions were suitable they became a part of the food patterns. If the new food was unadaptable to local conditions, it was not considered an important item, even though its prestige may have been great. Experience of previous generations with new food products resulted in favorable or unfavorable social attitudes toward them. Important roles are played by ease of preparation and good preservation, as well as flavor, appearance, and other qualities, in adoption of the new product into food patterns.

If the introduction of the new food was associated with an unhappy event, like disease or a change in the social organization, it is considered taboo and is avoided at least by certain groups. In other instances, religious or related beliefs force the people to avoid important foods. Foods with high nutritive value, but with associated religious meaning, may be consumed only during local festivities, but for the rest of the year may not be considered appropriate in customary diets (14).

There are recent examples of misleading beliefs or unfortunate experiences with new products. When powdered skim milk was introduced in different parts of the world, and prepared with contaminated water, people deduced that children became ill from the new kind of milk. In several impoverished areas, where fruits are abundant, residents prevent their children from eating them because previous experience has convinced them that some fruits produce worms. Meat and eggs may be considered as luxury items, or as very strong foods, to be avoided for the duration of certain physiological conditions.

In many instances, flavor is the quality that has guided people's attitudes toward a certain food, and on this basis they attribute ill effects or medical properties to it.

FACTORS WHICH MODIFY FOOD HABITS

Although geographical location and culture are factors responsible for establishing food patterns, other factors will modify diets while keeping the basic food pattern but introducing changes with the new products. Factors that may modify the food patterns are the following ones.

Economic Factors

Food availability and traditional food patterns lead groups of people to eat the same type of diet through the generations. However, new foods with more prestige may gradually replace indigenous products partially or totally if economic conditions permit. Every dietary survey carried out in any country, and even among small towns with the same culture and more or less homogenous social status, has always revealed differences in consumption closely related to the economic status of the families.

The common picture in a poor locality shows a large proportion of families with diets in which the staple food constitutes almost the total daily consumption. At the same time, a smaller proportion with larger incomes are consuming new products and less of the staple food, which improves the quality of the diet. While differences within a town are not great, differences between towns in a given country are remarkable when there are economic differences.

Since calories constitute the primary necessity, poor families will be satisfied with a sufficient amount of calorie sources, as cereals or tubers, and very small quantities of other food products, while families in higher income brackets will be able to obtain a more varied diet and greater quantities of more expensive foods. Differences between poor and rich are painful to perceive, especially in regard to expensive foods of animal origin.

In certain impoverished countries of Africa (15) or Central America (16), where the sole occupation in the rural area is farming, the comparison between rural and urban areas in food consumption is paradoxical. The main farming products of the rural areas daily reach the city markets. Urban families with regular cash income are able to buy a great variety of products. The families in the rural area have to be satisfied with a monotonous diet, combining a basic cereal with beans or peas and some wild green leaves.

In those countries, food supplies, especially animal products, are insufficient to feed the entire population. Only better-off city families, a small segment of the population, enjoy the privilege of good diets. In any dietary survey of these cities, a long list of tropical fruits or fresh vegetables and meat, milk and eggs will be part of the usual food pattern. Sugar and fats will complete the list. The diets enjoyed by a privileged few are rich in vitamins and animal protein, and are more comparable to the diets of families living in rich or well developed countries.

In high income countries where the economy no longer relies primarily on agriculture, where industry and technology are sufficiently developed to offer the people a high standard of living, rural and urban areas do not show those great dietary limitations.

Education

The level of education has influenced the dietary patterns in a significant way in all those highly developed countries. Studies on undeveloped countries have not been carried out, or at least have not been planned for this purpose, and consequently, information is very limited.

In the studies of Hollingsworth (17), it is clear that the educational level modifies the diets of English families since several products appear in the diets with greater frequency and in greater amounts, according to the number of school years of the parents. Other studies present similar results, as in the United States (18). Not only have food patterns changed but also the schedule of the meals and working methods.

The same studies mention that family size may also modify diets. But the findings do not show clearly if the effects result primarily from the size of the family, or from the economic level.

Urbanization and Industrialization

The degree of urbanization that is taking place in some areas also influences the food intake, producing changes in the diets of the people. Sometimes a more varied diet is produced and in other instances a negative change can take place, as when some local highly nutritive products are abandoned. As mentioned, differences between the rural and urban area, in the poor countries, are disappearing with the degree of urbanization. Rural communities change significatively when a new road is opened, or with the installation of factories, or with the improvement of public services in the community.

Industrialization of the countries has visibly increased the income level of the families. That change has modified the type of diets of families in low socio-economic levels when they improve their income. In these countries, the seasonal changes that once produced modifications in the diets have disappeared with the help of industrialization and technology. Advances of food technology in preservation, storage, and transportation have made it possible for people to have all kinds of products at their disposal during the entire year.

THE STATIC AND DYNAMIC ASPECTS OF FOOD PATTERNS

The degree of change or modifications of the diets will depend on the intensity with which societies succeed in following their plans for economic advancement, urbanization, agricultural development, and industrialization.

The more static area in food patterns corresponds to staple foods consumed by the people, mainly in low income countries where farming systems are strongly traditional (19). The tendency of staples to survive through different conditions increases with the risk of changing farming systems. The urgency of basic needs makes it essential to secure the production of the main local food. It is easier to change the systems for products not essential to the diets, through such means as the introduction of new seeds, new implements or new methods of cultivation.

The main difficulty in changing staple foods resides in the fact that they are deeply embedded in the system of cultural values of a society. In the rural areas of Central America, for instance, the same staple food - maize - has persisted for centuries and has always been the principal farming product. For the cultivation of maize, people are still using the same implements and following the same methods employed by their ancestors. Furthermore, the process for converting maize into food has not changed since the ancient time of the Mayan civilization, and this is true not only for Central America but also for Mexico.

A good illustration of the static mechanism of the staple food in a society may be found in a relatively recent project launched in New Mexico, U. S. A., to help the Navaho Indians. The basic diet of this group was maize, beans, squash, and potatoes (20). The agent paid great attention to the relationships between agricultural technology and the environmental condition of farming practices, as well as social organization. With excellent field demonstration methods, the hybrid maize was planted and successful yields drew enthusiastic response. A good percentage of families planted the new seeds instead of the indigenous maize, and the desired improvement of production was obtained.

However, the program collapsed when families failed to use the maize for their daily bread. The agent forgot to investigate food habits among the women, who discovered that the qualities of the new maize differed from those of common maize when tortillas were prepared, changing the original flavor and texture.

On the other hand, economic changes have such an impact on the behavior and social attitudes of people as even to produce changes in staple foods. The proximity of large urban centers to small rural groups and the opening of new roads often promote acculturation in developing countries. As families gradually derive better incomes, they start changing their food habits and introducing new products or replacing some of the local ones.

For instance in Central America it is frequently observed that rural families begin to use lard according to rising income, mainly for the preparation of beans and rice, while rice replaces maize partially or totally in spite of its higher price. In this case it is not only the economic level producing the change, but also the prestige that rice and fat have, since they are considered as Spanish foods (16).

Changes due to social status or prestige may bring beneficial effects, but this is not always the case. Main sources of carotene in the Indian diets of Central America are yellow maize and wild green leaves. With acculturation, these foods, lacking prestige, are dropping from the diets of this population group, and being replaced by white maize and other cereals and vegetables of low vitamin content.

The most dynamic areas in food patterns comprise items generally utilized to complement the main calorie source, like new cereals, fats, and sugars. These are easily incorporated into the diets to improve flavor, and may gradually replace the basic food or give it more variety. If the new products can be prepared with less work, and if their flavor is accepted, adoption is more rapid. Thus, sugar sweets, and pancakes or biscuits made from wheat flour, for example, all have a high degree of acceptability among such people as the inhabitants of the Polynesian Islands (21), the Eskimo in Canada (22) or the Indians of the reservations in the United States (23). The products are brought by white people, missionaries or other visitors belonging to what is regarded as an upper class group, so that articles used by them are accepted because of their prestige value.

Prestige clearly provides a definite guideline for changes in food patterns promoted by socio-economic factors. The use of wheat bread in the rural communities of Latin America makes the people feel that they are eating like city people. The use of sugared water by some rich families in the Polynesian Islands, instead of the unfashionable but more nutritious coconut sap, is another example. Cultural or religious beliefs no longer count in some groups of India and Africa when money is available to obtain expensive milk or meat products, because they are eaten by Europeans (24).

FOOD PATTERNS IN CENTRAL AMERICA AND PANAMA

The economy of the countries of Central America as well as others in Latin

America relies on agriculture. About 50 percent of the population is occupied in farming where the main products are maize, beans, rice, bananas and coffee, in addition to such export crops as cotton. The basic diet in Central America and Mexico consists mainly of maize consumed as tortillas, beans, fresh vegetables especially tomatoes and green leaves, bananas, tropical fruits and coffee. Sporadically, the diets include also meat, milk, eggs in small amounts, and also sugar and fats.

In Guatemala, El Salvador, Honduras and Nicaragua the staple food is maize tortilla. For its preparation maize is treated with lime water or with ashes dissolved in water and placed in the water where the grain is boiled. Later the maize is made into "masa" by a fine grinding, and shaped in round cakes of different thickness according to the area. While in Costa Rica and Panama rice replaces maize as a staple food, in the areas where the population is of Negro or Caribbean extraction, they prepare the wheat flour pancakes fried with fat as the daily bread.

The second important food item in Mexico and Central America and also in some countries of South America is common beans of different color varieties, mainly the black and red. The Indians prefer to prepare beans by boiling them with some herbs for flavor, while the "mestizos" boil the beans and add lard. For more sophisticated preparations, the boiled beans are mashed, strained, and fried, the resulting paste having a very soft texture and special flavor.

Fresh vegetables constitute the third item of the diets in Central America, mainly in Guatemala where green leaves and tomatoes appear very frequently in the rural areas, while in the urban area cultivated vegetables, carrots and lettuce appear. The Negro-Carib groups consume more starchy roots and tubers-cassava, yam or potatoes. Fruits are not important in Central America, except for the city families and even in this group only citrus fruits and bananas are eaten with some degree of frequency.

In all these countries meat is consumed in very small amounts, except in Panama, where consumption is about twice that of any of the other Central American countries. The meat most commonly used is beef, but fish also appears in some population groups of Panama, Nicaragua and Costa Rica. In the highlands there is some consumption of goat meat or pork, but these do not count as an important contribution to daily diets.

Availability of sugar is high in all these countries, since sugar cane is one of the main crops; therefore, the consumption level is sufficient. Raw sugar is still more popular in the rural areas, while in urban areas refined white sugar has higher acceptability. Fat consumption in Guatemala is extremely low, especially among the Indian population where the only source of fat is the oil content in maize used for tortillas. On the Atlantic Coast and in Panama, however, large quantities of vegetable oil or fat are consumed, or coconut milk which is used for special preparations (25).

In Mexico and Central America some traditional dishes appear on feast days or Sundays, such as maize dishes or sometimes beans with maize and pork, prepared with the addition of sauce, the whole covered with banana or maize leaves. One of the most typical dishes in Guatemala is the preparation of mashed plantain filled with black beans which have been boiled, strained and fried.

Another characteristic of the diets of Central America and Panama is the low consumption of milk and milk products. The Indian population consumes products such as cheese but in very small amounts. In Nicaragua and Costa Rica, where there is a greater availability of dairy products, dietary surveys show a greater consumption. In the three countries, Nicaragua, Honduras and Costa Rica, one of the typical breads called "rosquillas" is prepared with maize flour and cheese, and is very popular among children and adults.

Most Indian and "mestizo" families in the rural areas rear small animals such as chickens, but consumption of that kind of meat is very small, though consumption of eggs is frequently observed. The Indians prefer boiling the eggs while the "mestizos" prefer eggs fried or in Spanish preparations, where beaten whole egg is used to coat some vegetables which sometimes are stuffed with meat. A typical dish is "chiles rellenos" (stuffed peppers).

Those food patterns do not correspond strictly to each of the population groups, but may change through cultural interrelations or urbanization as well as by a better socio-economic status or social changes. The introduction of fats in the diets of the Indians is observed when there is a certain degree of urbanization, or great Spanish influence, while fish, green bananas, rice or starchy roots enter the diets of the "mestizos" when they live in the coastal areas.

Table 1 shows the average consumption of the different foods which are consumed in Central America and Panama in both rural and urban areas. Marked differences between the rural and urban areas reveal the limitation that exists in the rural area, in regard to the more important foods especially those of animal origin.

Sources of protein in the diets

The roles played by different products in the food patterns of Central America and Panama are presented in Table 2, where the figures correspond to the percentage contribution of the different items to total protein intake. The more important contribution corresponds to cereals, essentially maize and rice, which provide 30 to 50 percent of the total protein. The second most important item in all cases is the group of beans, especially in Nicaragua where 32 percent of the total protein comes from this group. The other foods, with the exception of meat and milk from which around 15 percent of the total protein is derived, do not have great importance as far as the nutritive value of the diets is concerned.

Bean consumption in Central America and Panama

We see in Table 1 no differences in the consumption of beans among the population groups in Central America when rural and urban areas are compared. Also there is no difference between the different socio-economic groups, which indicates that beans are one of the most important items in the food pattern, which has not been modified by introduction of new products. To illustrate this aspect, Table 3 presents the results of bean consumption according to the socio-economic status of families in rural areas of Costa Rica. The consumption of the low-level group is 51 grams per person per day; the middle group 50 grams, in other words equal; and the high-level 43 grams, which is a very small decrease.

The striking differences that may be observed among the countries in regard to bean consumption is that each country has preference for one color of beans, but of the same kind. Table 4 shows the consumption of beans in the rural and

Table 1. Food consumption at family level in Central America and Panama: 1965-67

Quantities expressed in grams per person per day

Method: 24—Hour Recall

Foods	Guatemala		El Salvador		Honduras		Nicaragua		Costa Rica		Panamá	
	R[1/]	U[1/]	R	U	R	U	R	U	R	U	R	U
Dairy products[2/]	84	246	190	237	194	289	243	377	193	350	73	163
Eggs	13	31	10	31	13	21	12	21	15	23	11	19
Meats	44	85	37	77	41	87	58	90	40	74	90	134
Leguminous seeds	54	49	59	52	56	47	72	50	57	48	20	19
Vegetables	66	150	53	90	51	56	27	74	66	126	25	68
Fruits	14	58	17	71	40	54	41	52	7	60	50	99
Bananas and plantains	20	64	16	49	43	49	72	75	47	57	99	75
Starchy roots and tubers	14	34	13	12	22	24	33	24	46	55	82	70
Cereals:												
Corn tortilla and tamal	544	228	533	249	340	203	190	84	62	21	6	0
Pinol (toasted corn)	0	0	0	0	0	0	14	26	0	0	0	0
Rice	16	34	27	55	29	50	54	80	100	103	186	150
Wheat bread	36	167	26	66	12	74	28	51	54	80	37	65
Wheat flour and pastes	4	5	0	0	8	9	7	0	12	16	10	9
Other cereals	2	5	6	5	5	7	16	7	0	4	29	13
Sugars	52	74	41	38	39	45	58	63	89	77	51	42
Fats	4	24	15	37	16	21	19	29	19	41	26	35

1/ R = rural U = urban

2/ Expressed in terms of liquid milk

Table 2. Percent contribution of foods to protein intake among families of the rural area in Central America and Panama: 1965-67

Method: Three-day Daily Record

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama
Dairy products	6.8	13.7	13.2	15.2	17.1	6.0
Eggs	3.2	1.9	2.6	1.8	3.5	1.6
Meats	13.5	10.2	16.8	13.6	16.6	34.5
Leguminous seeds	18.7	18.8	21.9	32.2	23.4	9.3
Vegetables	1.7	1.3	1.6	0.5	1.7	1.4
Fruits	0.2	0.2	0.7	0.6	0.2	1.6
Bananas and plantains	0.4	0.2	0.8	1.8	1.4	2.0
Starchy roots and tubers	0.4	0.3	0.5	0.4	1.5	2.0
Cereals	52.6	52.0	39.7	32.3	31.6	39.3
Sugars	0.1	0.1	0.1	0.0	0.3	0.1
Fats	0.0	0.0	0.0	0.0	0.0	0.0
Miscellaneous	2.3	1.3	2.0	1.8	2.7	2.1

Table 3. Consumption of leguminous seeds per person per day among families of the rural area in Costa Rica: 1966

Quantities expressed in grams

Method: Three–day Daily Record

	Socioeconomic groups		
	Low	Median	High
Red beans	33	25	21
Black beans	17	22	20
White beans	–	1	1
(Phaseolus coccineous)	–	1	1
Other kinds of beans	1	1	–
Total	51	50	43

urban area for each country, where consumption of guandú (**Cajanus cajan**) and lentils is observed only in Panama. The totals for Guatemala, El Salvador, Honduras, Costa Rica and Panama do not show much difference between rural and urban areas, except in Nicaragua where the rural consumption is very high, because of the great availability of beans there.

Diet of preschool children in Central America and Panama

In the diets of preschool children, who constitute one of the most vulnerable groups in Central America, beans take also an important place in the dietary pattern of the child. Table 5 presents the average food consumption among preschool children in the rural area of Central America and Panama. The same situation which was found among the families, but in smaller amounts of food, is seen in this table.

When the figures are analyzed, especially those for bean consumption among preschool children, by age groups, one sees that beans are part of the diet among the small children from 1 to 2 years, but their importance increases for children of 3 and 4 or older. Table 6 shows bean consumption by preschool children according to age, for rural areas in Central America and Panama. During the first years of life the family, even with their limitation, offers to the small child the only milk available. Therefore, the figures for bean consumption increase for the following years since milk intake decreases drastically. Figure 1 illustrates the average consumption of beans in each age group in the different countries, where Nicaragua stands out with the higher amounts (Fig. 1 appears on page 102).

Table 4. Consumption of leguminous seeds per person per day in the families of Central America and Panama: 1965-67

Quantities expressed in grams

Method: 24-Hour recall

Countries	Beans				Guandú (cajanus cajan)	Lentil	Total
	black	red	white	others			
Guatemala							
rural area	54	–	–	–	–	–	54
urban area	48	–	1	–	–	–	49
El Salvador							
rural area	38	21	–	–	–	–	59
urban area	5	46	1	–	–	–	52
Honduras							
rural area	15	41	–	–	–	–	56
urban area	1	46	–	–	–	–	47
Nicaragua							
rural area	–	66	2	4	–	–	72
urban area	–	48	–	1	–	–	49
Costa Rica							
rural area	23	34	–	–	–	–	57
urban area	30	17	1	–	–	–	48
Panama							
rural area	–	6	–	10	1	3	20
urban area	–	13	–	–	–	6	19

Table 5. Diet of preschool children in the rural area of Central America and Panama: 1965-67

Quantities expressed in grams per child per day

Method: Three-day Daily Record

Foods	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama
Dairy products *	127	300	255	336	403	154
Eggs	13	6	10	7	13	6
Meats	10	6	11	14	11	40
Leguminous seeds	13	14	14	34	9	7
Vegetables	17	20	20	9	19	7
Fruits	16	18	29	23	12	41
Bananas and plantains	17	10	22	45	33	62
Starchy roots and tubers	7	5	8	8	20	40
Cereals:						
Rice	8	11	13	28	41	66
Oatmeal	1	—	—	—	1	3
Wheat bread	28	28	20	27	31	29
Pastes	1	—	1	—	4	2
Corn tortilla	140	164	128	58	12	6
Other cereals	1	6	5	26	5	20
Sugar	32	31	26	43	52	43
Fats	3	6	7	7	9	13

Expressed in terms of liquid milk.

Table 6. Consumption of leguminous seeds among preschool children in the rural area of Central America and Panama: 1965-67

Quantities expressed in grams per child per day

Method: Three-day Daily Record

	Age groups			
	1 year	2 years	3 years	4 and 5 years
Guatemala	6	14	23	14
El Salvador	4	11	18	23
Honduras	4	12	17	28
Nicaragua	17	17	48	74
Costa Rica	6	8	9	20
Panama	5	9	11	4

Sources of Protein in Diets of Preschool Children

The important role of beans in the diets of children is better appreciated in Figure 2 where the contribution of different foods to the total protein intake is shown. For illustrative purposes, only El Salvador and Nicaragua are shown. During the first years of life the intake is small but for the following three and four years beans contribute with around 50 percent of the total protein intake, particularly in Nicaragua.

EFFECT OF DIET ON NUTRITIONAL STATUS OF POPULATION GROUPS

The high incidence of diets deficient in calories, protein and other nutrients is a consequence of the limitations in food availability in Central America. The average overall nutrient intake levels for the whole country in each case are more or less sufficient to cover the nutritional requirements, but uneven food distribution brings about inadequate consumption by a great segment of the population.

The dietary findings of the nutritional evaluation performed in each of the countries during 1965-1967 (25) revealed that in a significant number of families in all the countries the intakes of calories and protein do not reach a sufficient level to cover nutritional needs.

Limitation in the calorie and protein intake is one of the principal causes of

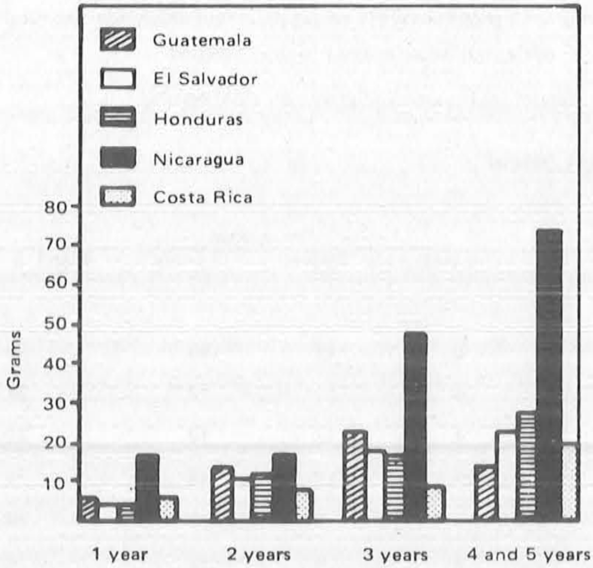

Fig. 1. Consumption of beans per child/day in Central America

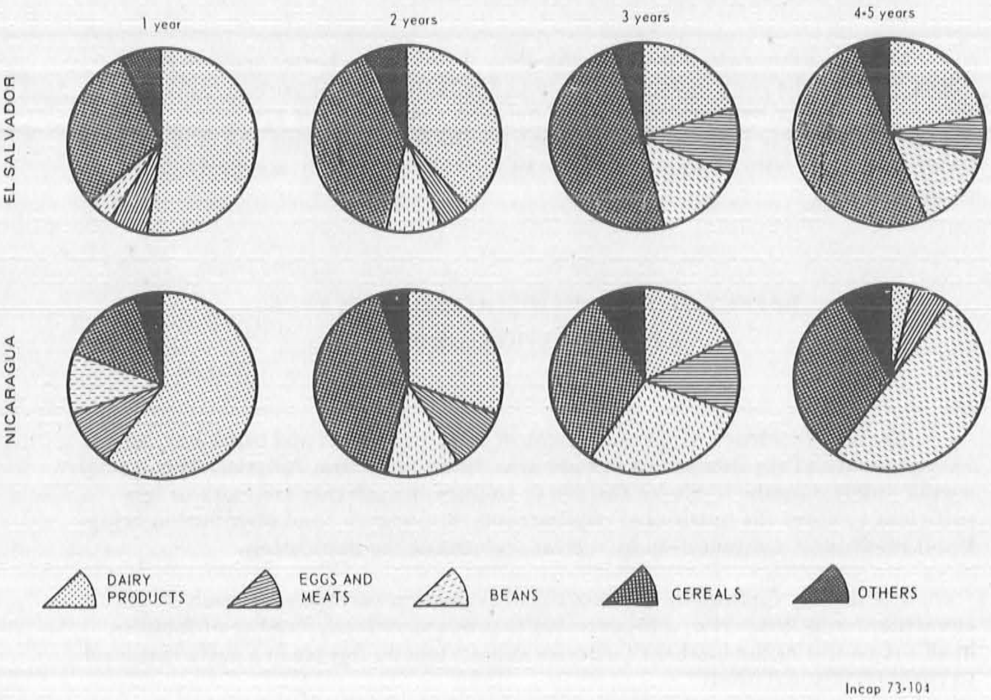

Fig. 2. Percent distribution of the protein intake in children's diets

growth retardation in countries with the socio-economic, agricultural and dietary characteristics of underdevelopment typical of the Central American countries.

The small child gets the smallest share in the distribution of food within the family, and consequently, the protein intake is very low. The anthropometrical measurements and clinical findings give more evidence on the prevalence of protein-calorie malnutrition in these population groups. Epidemiological evidence indicates that protein intake is drastically reduced as the supply of breast milk diminishes and the growing child begins to receive foods rich in carbohydrates and very poor in protein, as in the case of cereals (26). In addition, the preschool age is the period of most rapid growth and once retardation is established there is little likelihood of catch-up. Therefore, the preschool age is the most critical one.

Adequacy Levels of Preschool Children's Diets

The percentage of adequacy of the average diets of the children for each country of Central America and Panama is given in Table 7. In spite of the fact that the average figures do not indicate the real situation, it can be observed that the diets of the children in all cases are deficient in calories. In these diets more or less adequate in protein and low in calories, the protein has to be utilized primarly to cover the caloric needs. The results are diets deficient in calories and protein, as well as in other nutrients.

PRESENT AND FUTURE AVAILABILITY OF BEANS IN CENTRAL AMERICA

Using the food balance sheets to determine the availability of food in the countries of Central America, it is found that the average consumption of calories and protein in 1970 reaches levels that cover only 80 or 90 percent of the caloric needs in Guatemala and El Salvador. If the same information is given, not by average figures for the whole country, but by social strata, it is found that 50 percent of the population in the low group in Guatemala, El Salvador and Honduras reach only two-thirds of the needs for calories and protein. If these countries were able to increase the availability of beans, as in the case of Nicaragua and Costa Rica, such low socio-economic strata could have diets that would cover adequate values, provided the price of beans were sufficiently low to be afforded by all.

Bean consumption and demand, projections for 1990

The consumption figures for beans obtained through food balance sheets for 1970 are given in Table 8, and also the demand projections estimated on the basis of the increments in production and population growth. Only Nicaragua reached an adequate average figure of 57 grams daily per person in 1970, in the low strata. For the median and high strata, in 1970, for all countries the consumption was quite sufficient, between two or three ounces per person per day, which constitutes an adequate proportion in their food patterns. For the highest strata in the countries, where the consumption of beans is also important, by 1970 the figures were already more than adequate.

Table 7. Percent adequacy of the average diets among preschool children in the rural area of Central America and Panamá: 1965-67

Method: Three-day Daily Record

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama
Calories	64	74	65	87	76	82
Protein	94	117	104	138	116	117
Calcium	97	138	122	143	148	64
Iron	47	34	42	65	48	45
Vitamin A (Retinol)	66	47	50	69	77	77
Thiamine	90	90	68	98	82	79
Riboflavin	64	89	82	118	129	70
Niacin	50	52	44	60	45	57
Vitamin C	50	52	73	78	62	93

Table 8. Availability of beans at present and in the future in Central America *

Grams per person per day

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica
1970					
Low strata	19	16	28	57	29
Median strata	31	24	46	70	39
High strata	41	33	60	82	46
Highest strata	55	41	79	94	58
1980					
Low strata	25	21	30	59	32
Median strata	41	31	49	72	41
High strata	52	40	65	85	49
Highest strata	55	41	79	93	58
1990					
Low strata	28	21	33	61	36
Median strata	46	33	53	75	45
High strata	55	41	70	88	52
Highest strata	55	41	79	93	58

* Data from GAFICA (Grupo Asesor de la FAO para la Integración Centroamericana).

Table 9. Daily consumption per person in terms of calories and percent adequacy by population strata according to income level. Year: 1970

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica
Low strata					
Consumption	1326.1	1345.4	1464.6	1767.2	1990.0
Adequacy (%)	61	65	68	84	92
Median strata					
Consumption	2362.1	2128.0	2661.0	2703.5	2631.6
Adequacy (%)	109	102	123	128	122
High strata					
Consumption	2918.8	2696.7	3267.8	3255.1	3107.3
Adequacy (%)	134	129	152	154	144
Highest strata					
Consumption	4234.0	3694.8	4589.6	3931.2	4112.3
Adequacy (%)	195	177	213	186	191
Total population					
Consumption	2021.3	1901.0	2250.1	2379.7	2456.5
Adequacy (%)	93	91	104	113	114

Table 10. Daily consumption per person in terms of proteins and percent adequacy by population strata according to income level. Year: 1970

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica
Low strata					
Consumption (grams)	30.7	30.0	33.3	46.6	47.2
Adequacy (%)	56	55	61	85	87
Median strata					
Consumption (grams)	56.9	50.1	65.0	72.5	69.6
Adequacy (%)	103	93	119	132	128
High strata					
Consumption (grams)	75.5	67.8	85.8	90.3	86.9
Adequacy (%)	171	156	196	206	200
Highest strata					
Consumption (grams)	129.7	101.4	136.8	111.9	122.9
Adequacy (%)	294	234	312	255	283
Total population					
Consumption (grams)	50.3	45.1	55.8	64.2	63.6
Adequacy (%)	91	83	102	117	117

Table 11. Daily consumption per person in terms of calories and percent adequacy by population strata according to income level. Projection 1990 – no change

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica
Low strata					
Consumption	1535.8	1477.4	1708.2	1928.8	2354.5
Adequacy (%)	70	71	79	91	110
Median strata					
Consumption	2742.3	2379.9	3127.3	2991.4	2964.2
Adequacy (%)	125	114	145	141	138
High strata					
Consumption	3485.4	3117.0	4052.4	3643.2	3497.9
Adequacy (%)	159	150	188	172	163
Highest strata					
Consumption	4243.3	3705.6	4573.6	3294.2	4110.4
Adequacy (%)	194	178	212	185	191
Total population					
Consumption	2325.1	2112.4	2628.7	2596.3	2787.6
Adequacy (%)	106	101	122	123	130

Table 12. Daily consumption per person in terms of proteins and percent adequacy by population strata according to income level. Projection 1990 – no change

	Guatema	El Salvador	Honduras	Nicaragua	Costa Rica
Low strata					
Consumption (grams)	36.9	33.1	40.4	51.6	60.4
Adequacy (%)	61	56	74	108	149
Median strata					
Consumption (grams)	67.7	55.5	77.6	81.1	81.9
Adequacy (%)	111	103	142	170	202
High strata					
Consumption (grams)	91.1	77.7	107.7	102.1	101.1
Adequacy (%)	190	180	246	245	249
Highest strata					
Consumption (grams)	130.2	101.5	136.4	112.2	123.5
Adequacy (%)	311	251	332	269	304
Total population					
Consumption (grams)	58.8	50.7	66.5	70.8	76.1
Adequacy (%)	105	94	142	148	187

Undoubtedly, to reach these projections in future years agricultural programs as well as socio-economic changes must follow an accelerated rate to parallel rapid population growth, as the report of the "Grupo Asesor de la FAO para la Integracion Centroamericana" (GAFICA) suggests.

Levels of calories and protein 1970-1990 by social strata

To illustrate more clearly the food situation in these countries, Tables 9, 10, 11 and 12 show the analysis made by the Institute of Nutrition of Central America and Panama (INCAP) of the figures obtained by GAFICA. For the years 1970 and 1990 the figures reveal that there exists and will exist a segment of the population in each country that will still be affected by deficiencies in their food consumption. In other words, by 1990 if those countries continue with the same rate of production, the low strata will continue with deficiencies in calories and protein consumption in Guatemala, El Salvador and Honduras.

Therefore, it is necessary to plan a more ambitious strategy to reach a better production and consumption, and again the group of GAFICA has proposed higher figures. These are called "projections for 1990 high tendency or with change", where a great increment of production has to take placc to attain higher increments in the consumption of all the foods, but mainly beans, proposing that the low strata in each of the countries will reach the following figures per person per day:

Country	1970 (grams)	1990 High tendency (grams)	Increment (%)
Guatemala	19	40	111
El Salvador	16	31	94
Honduras	28	50	79
Nicaragua	57	70	23
Costa Rica	29	39	34

Such a proposition means that extraordinary efforts will be necessary in development of agricultural programs, utilizing all kinds of mechanisms that may exist in the countries to apply the most efficient methods of farming, and putting to use all advances in food technology and marketing.

THE IMPORTANCE OF INDUSTRY AND TECHNOLOGY IN NUTRITIONAL STATUS

The role of agricultural extension in the improvement of food patterns is unquestionable. In some areas, advances in food science and technology have run parallel with advances in socio-economic research. There are countries where population groups are more susceptible to changing patterns, not only because they are more receptive but because they are upholding no ancient tradition left behind by great civilizations. If some remnant traits of old cultures happen to exist, they are easily changed if the people are offered a proper substitute and the means of smooth adjustment to it. This is the reason why several African communities are undergoing rapid social, economic and political changes as a result of successful educational programs.

Food technology and industrialization have been extremely influential in changing food patterns, not only in the well developed countries but also in countries where a certain progress has been achieved in different disciplines. For instance, canned foods like fruit juice or ready-to-eat breakfast cereals, where no labor is needed and preservation is easy, also acquire certain prestige because they have been used first by the rich families.

These products are replacing indigenous seasonal fruits or whole grain cereals which have to be cooked. The same thing could happen with other processed food products such as the leguminous seeds. In some Caribbean areas and in Panama, the daily main dish at noon was always prepared with meat bone and some fresh vegetables. Now this typical preparation is disappearing because the dehydrated soups, which can be obtained at low prices and need only the addition of some water and a short time for boiling, are becoming more popular (27). Of course, their nutritive value is very low compared to that of the traditional meat soup. Nevertheless, this type of soup may yet achieve an adequate process to preserve the nutritive value of the basic products.

There are cases in which industrialization or advances in food technology have brought profoundly beneficial effects to prevailing food patterns, even when the early introduction of changes in processing may have had opposite results. Machines now substitute the domestic implements originally used to prepare the flours from cereals that must be milled. In the beginning, nutrients were lost because the product did not retain them in its refined form. Subsequently, however, enrichment of those cereals or the improvement of the machines has yielded products with more B-Complex vitamin.

Usually, one of the ultimate goals of industrialization is to improve the national economy. At the same time, large-scale production causes lower-priced goods to reach more homes. Under certain other circumstances, industrialization means definite changes in life patterns for the population. These affect not only working-hour schedules, but also food habits; those pertaining to meal times, for instance.

In many developing countries, where the noon meal is most important, housewives have always had the entire morning to cook a whole meal for the family. However, industrialization eventually makes it necessary for them to change their cooking hours from morning to afternoon, because the men must work a continuous eight-hour shift. Some industries install their own cafeterias, but only the most sophisticated societies are able to adopt them successfully because it is difficult to provide an attractive atmosphere and palatable and hygienic meals.

It is ironical that improved living standards have been accompanied in some societies by an increase in the employment of women. This in turn, brings about changes in food patterns, which are due not only to an increase in the family income, but also to the fact that fresh food and home-cooked meals must be substituted by manufactured food which can be preserved and prepared easily.

Advances in food science and technology tend to improve not only the quality of food products but to make them uniform in nutrient content. Large-scale manufacturing and good preservation methods significantly decrease the price of foods, making them available everywhere at all times of the year and abolishing seasonal food shortage. In the countries of Central America and Panama, when availability of food decreases, prices rise and consumption decreases drastically. If the processed beans were accepted, prices and availability might remain constant in all seasons.

Another aspect of development that influences food patterns in any community is an improved system of communications. New roads and new transportation facilities gradually do away with cultural isolation. Food exchange and distribution are encouraged by numerous new facilities and greater variety is incorporated into the diets. At present, highly developed countries can consume different products from remote places. Furthermore, they are eaten not as an infrequent treat, but sometimes appear daily on the table.

Finally, unexpected social events have also made the breakdown of food patterns possible, introducing new foods and even rendering those with no prestige acceptable. In the history of food patterns, changes have been precipitated by natural disasters or wars. New products rejected under normal circumstances were immediately accepted. Thus, through unexpected chains of events, new and modified food patterns may suddenly appear in the most unlikely places.

GENERAL RECOMMENDATIONS TO IMPROVE DIETS

In all developing countries it is necessary not only to increase quantities in consumption of the different products, but also to keep an adequate equilibrium of calories and protein. It is necessary to consume sufficient calories to meet the energy needs according to the different activities of the people, and the protein must suffice in quantity and quality for the building, maintenance and normal function of the body.

The improvement of protein quality must depend mainly on beans and other legumes, since it is almost impossible to increase significantly the consumption of proteins of animal origin in the developing countries. It is essential to think about how to increase these or other products to improve the diets, and as well how they can be successfully introduced to give them an important place in the food patterns. A processed food is easier to accept and incorporate as a new product. To accomplish this, the new products have to reach certain standards and characteristics as outlined below.

(1). The preparation of food should be easy, with the least time and effort. There are many limitations in the developing countries in regard to fuel and if the housekeeper can use products that diminish fuel expenditure, one of the great problems facing the rural areas will be solved. With the present socio-economic changes, the mother needs to spend less time in the kitchen and looks for more convenient ways to accomplish the kitchen tasks.

(2). The new food must have some similar characteristics with the main food products of the diet, in order not to deviate greatly from the food patterns.

(3). The new product has to keep all the qualities under different circumstances, preserving flavor, odor and texture to protect it from deterioration that will waste the family budget.

(4). The new product has to gain a certain degree of prestige. It should never be identified as food for the poor. This prestige could be obtained only with an excellent advertising campaign, good packaging or an attractive container.

(5). Low purchasing power of the families is a problem. Therefore, the price of the product will be of the greatest importance for its quick acceptability. The cost of the product should be low enough to reach all the homes.

(6). Even though staple foods are the most static aspects of the food pattern, it could be possible to change them rapidly if low price, easy preparation, flavor and other qualities could be reached in the new product. A wise and intensive educational campaign to accomplish such changes is also necessary.

(7). For the introduction of the new product, the collaboration of the social sciences is required in order to learn of the people's concepts and attitudes toward the new product. Concepts or ideas can be positive or negative in regard to the information or advertising that the producers will release on the new product. It is not sufficient to know that the product is accepted because it has a new flavor or a nice color.

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Commentary upon:

FACTORS AND TACTICS INFLUENCING CONSUMER FOOD HABITS AND PATTERNS

Francis C. Byrnes

First, it is important to recognize the significance of the material which Miss Flores has presented. For too long, the bulk of the literature, scientific and popular, has concentrated on a wide variety of anecdotal vignettes relating to the eating habits and food likes and dislikes of exotic and sometimes not so exotic peoples. While interesting, such information had limited utility for research or action programs.

This information as well as other factors about which I will comment should help us make more productive plans. Instead of attributing food likes and dislikes to a variety of elusive cultural factors, we can accept the premise that this facet of human behavior is the result of certain interacting processes and influences that link culture, man and nature, into a meaningful system. The challenge to us, as scientists and educators, is to study the situation so as to provide ourselves and others with insight and understanding.

Second, the basic concerns here are not limited to beans. The issue of acceptability arises whenever a new variety of any crop is introduced or an old variety is moved into a new market. The problem appears more quickly when the new product differs significantly from the traditional commodity in one or more characteristics, such as size, color, shape, taste, texture, or cooking qualities. In addition, anything new runs the risk of being unfavorably associated with something of value to the people involved. That the associations or perceptions have no basis in fact or logic is immaterial so long as they are circulated and believed.

Third, because of the pervasive nature of the problem, CIAT has undertaken a limited effort to bring together in cooperation with others, significant research data related to food preferences and diet patterns as well as information about educational and promotional efforts designed to change these. My remarks draw upon the information we have gleaned to date and in this sense they supplement and complement the excellent material made available by Miss Flores.

RESEARCH: what do we need to know?

Unfortunately, not all of the countries have the kind of consumption data which Miss Flores and others have gathered about Central America and Panama. We encourage such studies in other countries.

What do we know about the human biological bases of food preferences and avoidances, particularly as far as beans are concerned? For instance, do some people avoid certain beans because of an inability to digest them, or because of other physiological reactions?

Some recent studies suggest why vast numbers of people in East Asia, Africa and South America regard milk as a food unfit for consumption by adult human beings. Most adult mammals do not drink milk, and when they do, they have trouble digesting it because proper digestion requires the presence of lactase, an enzyme produced by the lining of the small intestine. The principal known exceptions to the rule that adult mammals are lactase deficient appear to be the lactophilic populations of Europe and America and the domesticated cat. More than 90 percent of adult Thais, Taiwanese, Andean Indians and Eskimos have clinically established lactase deficiencies. Similar deficiencies appear to occur in less than 20 percent of Europeans, between 10 and 20 percent of the United States population of European ancestry, and 70 percent among adults of African descent (1, 2).

Consumption of fresh or powdered milk by lactase deficient populations often is associated with such problems as stomach pains and diarrhea. What might be the parallel problems with respect to matching people with specific species of beans?

Are we able to express in definite physical-chemical terms the characteristics associated with the beans which people in a given area prefer?

An example from the International Rice Research Institute will illustrate this point. While many people not too familiar with rice believe that "rice is rice," this is not the case among the predominantly rice-eating populations of the Far East. There are sharp country and regional preferences. Early in its history, IRRI scientists obtained samples of the rices commanding the highest prices in the various countries and submitted these to a wide range of physical and chemical tests (3).

Amylose content, they found, was the principal factor affecting the textural characteristics of cooked rice, being directly associated with how dry or how sticky it was after cooking. The amylose contents of the rices examined ranged from 12 to nearly 35 percent, with those preferred in Ceylon averaging more than 30 percent, and those in Taiwan less than 20 percent. Thus, you would not expect a Ceylonese to like Taiwanese rice, and vice versa.

Other properties also found associated with consumer choice included differences in gelatinization temperatures, in the length and breadth of the grain, in the presence or absence of opaque spots, in whether the grain elongated on cooking, in whether the cooked rice remained soft after cooling, and in the absence or presence of an aroma.

Later, the institute established taste panels and through much study, evolved reliable and valid techniques for selecting persons able to discriminate sharply differences in consumer acceptability of rices.

These research efforts and the resulting objective data and measures provided IRRI and subsequently CIAT with both tools and components by which to design new high-yielding rice varieties for specific market situations.

Research of a similar nature is more urgently needed with field beans because of the extremely wide product variabilities and pronounced acceptance - rejection patterns. Given such information, the bean breeders could establish definite objectives rather than pursuing elusive goals.

For instance, when studies in Colombia documented a strong consumer resistance to the newly introduced opaque-2 maize, the maize breeders renewed their efforts to introduce the high lysine gene into traditional flint type maize (4).

Do we have an adequate code for describing a diet pattern? We need to cooperate with others directly concerned with such matters to make possible a formal description of a people's dietary pattern. Such a code would allow for the description of food in all its different aspects: Physiological, sensory, chemical, nutritional and cultural. The latter would involve agricultural, economic, socio-cultural, educational, food handling and related factors (5).

The following quotation illustrates the present fragmentary state of the science of food habits:

"While some attention has been given to the physical components and the psychophysical attributes of foods, additional attention needs to be given to the social-psychological aspects. For example, we know that foods vary in their desirability (an aspect which the food preference ratings measure so well). It may well be that there are other dimensions of considerable importance: For example, foods may vary in their centrality —the extent to which they are considered essential to a diet; in their perceived nutritional value; and in their prestige." (6).

In a specific area, what socio-cultural factors are associated positively or negatively with beans, generally, and a variety specifically? This would include serious consideration of sematics: What you call something may be extremely important.

In a specific area, what economic factors operate that significantly influence availability and acceptability of beans, generally, and a variety, specifically?

ACTION: what can we Do and How do we Do it?

Given the goal of increasing the consumption of beans within a population, the following steps seem logical:

(1) Begin with an investigation of the situation. Document existing food habits, and to the extent possible.

(a) Determine their basis and strength, and their relationships with other behavior patterns, attitudes, beliefs, etc.

(b) Determine how the commodity is obtained, prepared and consumed, and by whom.

(c) Determine the characteristics associated with the preferred varieties in physical-chemical terms.

(2) Introduce, if possible, the desirable characteristics into the varieties you are trying to promote.

(3) If this is not possible, consider the various routes through which the new variety may gain acceptance:

(a) Replace totally the present varieties; the people then will have no choice.

(b) Produce and distribute the new variety at prices significantly less than current varieties.

(c) Introduce the new variety into mass-feeding situations and/or through processing channels which de-emphasize the differences.

(d) Mount nutrition educational and promotional programs which combine status factors with sound education.

(4) Accomplishing the steps just described will require development of an educational philosophy which recognizes that one does not change food habits as much as one attempts to improve existing dietary patterns with modifications and additions which involve as little dislocation and disturbance of the situation as possible. This would require, among other things, attention to cultural and religious beliefs, attitudes and practices, and cost, prestige, time of preparation, and culinary feasibility factors. The success of the effort will lie in augmenting and supplementing an existing local dietary pattern, not in replacing it. And, as Margaret Mead has advised, it is better to ask: "How do food habits change? " than to ask "How do we change food habits? ". But it is encouraging to know that, over time, and sometimes quickly, they do change.

(5) Identify and use local resources, people and institutions concerned with these matters. We need to include and work with people of several disciplines. As basic reading material, I suggest two documents:

Margaret Mead. **Food Habits Research: Problems of the 1960's.** Publication 1225. National Academy of Science-National Research Council. Washington, D. C. 1964.

Jean A. S. Ritchie. **Learning Better Nutrition.** FAO Nutritional Studies No. 20. Food and Agriculture Organization of the United Nations, Rome 1967.

SUMMARY

In summary, it appears that those who aspire to increase the yields and consumption of field beans, or other food legumes, have these alternatives:

(1) Increase the yields of the beans the people now eat. With increased yields, prices should drop and consumption increase. You avoid the acceptance problem entirely.

(2) If it is not possible to increase significantly yields of the varieties people now eat, then transfer, if possible, the desirable physical-chemical properties of these to the new strains with high yield potential.

(3) If this is not possible, then it will be necessary to mount well-designed educational and promotional programs. These efforts, while possible, may be

expensive, take years to achieve effects of significant magnitude, and, in the meantime, the depressed prices on the new variety may drive it out of production. But if its yields are sufficiently greater than previous varieties, farmers may continue to grow it and, quite likely, it will gain some degree of acceptance.

But clearly, the challenge is to the bean breeder to design a high yielding product to fit the already well established market.

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Section 2.

PRODUCTION OF FOOD LEGUMES

Relative agronomic merits of various food legumes for the lowland tropics
Ken O. Rachie

Discussants: 1) H. Doggett; 2) A. M. Pinchinat

Potentials and problems of production of dry beans in the lowland tropics
Guillermo Hernandez-Bravo

Discussants: 1) Luis H. Camacho; 2) Colin Leakey

Bean production systems
Juan Antonio Aguirre and Heliodoro Miranda M.

Discussants: 1) Fernando Fernandez and David L. Franklin

Agronomic practices for food legume production in Latin America
George F. Freytag

Goals and means for protecting *Phaseolus vulgaris* in the tropics
W. J. Zaumeyer

Discussants: 1) Leonce Bonnefil; 2) Rodrigo Gamez

RELATIVE AGRONOMIC MERITS OF VARIOUS FOOD LEGUMES FOR THE LOWLAND TROPICS

Ken O. Rachie

Discussants: H. Doggett; A. M. Pinchinat

Several species of food legumes have exceptional potential for alleviating malnutrition in both humans and domestic animals, and by constituting a vital component of both indigenous and intensive cropping systems in the lowland tropics. The universal ability to grow vigorously under a wide range of environments and on poor soils without supplemental nitrogen is particularly advantageous in subsistence agriculture in remote areas. The quick growth of some annuals like cowpeas and dry beans as well as the extended fruiting habit of long-duration viny species (yam, Lima beans and horseeye beans) and woody perennials (pigeon pea, jack bean and locust bean) are complementary advantages in complex bush-fallow farming systems. Moreover, they provide the only non-processed proteinaceous food concentrate for both rural and urban utilization.

Food legumes often have a distinct advantage over other crops in simplicity of preparation and in multiplicity of edible forms, such as tender green shoots and leaves, unripe whole pods, green peas or beans and dry seeds. Some species, notably the yam bean (new world) and winged bean produce edible tubers in addition to the fruit. The excellent nutritional value of most food legumes in terms of proteins, calories, vitamins and minerals are highly complementary in tropical diets comprised of roots and tubers, plantain, cereals, indigenous vegetables, fruits and minimal animal proteins. Pulse proteins are also the least expensive proteinaceous food source.

THE PROBLEM

The nutrition situation frequently appears to deteriorate proportionately with the decline in elevation and increase in mean annual rainfall in the tropics. In Nigeria, the largest and richest nation in tropical Africa, both per caput calorie and protein availabilities decline from north to west and southeast. In a survey carried out in 1963-64 by FAO (1966), it was found that both calories (2,719 per caput) and proteins (80 g per caput) were adequate in the semiarid Northern Region; but declined to 1,909 calories and 40 g of protein per caput in the subhumid Western Region and 1,774 calories and 33 g of protein per caput in the humid Eastern Region. Whereas cereals comprised 64 percent of the calories in the north, roots and tubers made up 53 and 68 percent of the energy sources in the west and east, respectively.

Conversely, the overt results of unbalanced nutrition may be even more acute in some humid and subhumid intermediate elevations like Uganda (1,000 - 1,200 m) where carbohydrate sources are more than adequate (3,000-4,000 calories per caput), but proteins are inadequate, resulting in an estimated five malnourishment deaths per 1,000 population, primarily in post-weaning children. Superficially then, it would appear that semi-arid lowlands and higher elevations with lower population pressures and where cereals and pulses are more easily grown and stored, are better off nutritionally - except for the fact that statistics seldom reflect that these regions are much more subject to vagaries of the climate with resulting famines which have tended to hold populations down in the first place.

Tropical food legumes are frequently subjected to many natural hazards or are not genetically capable of responding to favorable growing conditions; and frequently will not attain reasonable productivity levels nor good product quality under high temperatures and humidities. Problems include susceptibility to pest and diseases, unavailability of efficient plant types with high yielding potential and rapid deterioration in storage. These problems are often exacerbated by fertility-depleted soils with poor physical structure, low soil moisture holding capacity, poorly distributed rainfall, high humidities, low insolations, and large numbers of pests and diseases. Moreover, some legumes have specific nutrient deficiencies, or certain undesirable off-flavors, flatus factors, metabolic inhibitors or other toxic substances. On the other hand, some otherwise well-adapted, high-yielding and nutritious species are not utilized as a consequence of ignorance or unfamiliarity with their culture and methods of preparation.

PRODUCTION AND POPULATION

The tropical food legume situation is complex owing to the distribution of populations, climatic/environmental considerations, large numbers of species involved and inadequacy of available information. Since it is important to gain perspective on the problems involved and establish priorities in pulse improvement programs, a cursory analysis was made of populations and grain legume production in tropical regions based on information available in Volumes 24 and 25 of the FAO Agricultural Production Yearbook and other sources. In this analysis the tropics are defined as countries with the majority of their territories lying between the Tropics of Cancer and Capricorn. Thus, in the Americas, Mexico is included on the north, but Argentina, Chile and Uruguay are omitted. In Africa, countries lying north of the Sahara with South Africa, are omitted. In southern Asia, India is included but Pakistan, Bangladesh, Taiwan, and Australia are omitted.

In 1969 approximately 1.36 billion people or 38 percent of the World's population lived in the tropics. The vast majority, or about 24 percent, are in Southern Asia with India making up nearly two-thirds of the 852 million people in that region. Tropical Africa and Latin America contribute almost equally to the remainder - 260 millions (7.2 percent) and 240 millions (6.7 percent), respectively.

PRODUCTION TRENDS

The worldwide production of all grain legumes increased by 49.1 percent in area and 103.5 percent in production between 1948-52 and 1971. This represents a proportionately greater increase than for cereals and roots and tubers during the same period. Further, the 111.6 million metric tons of grain produced on 117.5 million hectares in 1971 was almost one-fourth higher than the production for 1961-65. However, a considerable proportion of this increase is attributable to the rapid expansion of soybean cultivation in North America.

Among tropical regions (all elevations) in 1970, southern Asia contributed 20.8 million tons on 33.1 m ha or 51.8 percent, while tropical Africa produced 8.0 million tons on 12.6 m ha or 20.1 percent, and Latin America harvested 7.9 million tons on 9.8 m ha or 28.1 percent and together totalling 36.5 million metric tons on 55.5 million hectares.

Increases in estimated grain legume production in the intermediate/high versus lowland tropics were analyzed for three separate periods over a 22-year period starting in 1948/52. There was an increase for all pulses grown in the tropics of 47.3 percent in area and 84.3 percent in production between 1948/52 and 1970. Lowland tropical legumes increased by about two-thirds between 1948/52 and 1961/65; and to 89.2 percent of 1948/52 by 1970 when they totalled 21.2 million metric tons on 33.8 million hectares; or 58 and 61 percent of production and area of all tropical grain legumes, respectively.

Chickpeas (5.97 million tons) and dry beans (5.02 million tons) constituted two-thirds of total pulse production at intermediate and high elevations; whereas peanuts (13.3 million tons in shell; or 8.85 million tons kernels) comprised 53 percent of all lowland tropical grain legumes in 1970. Pigeon peas were probably the most important lowland pulse with nearly 2 million metric tons of estimated production; although the Asian grams collectively were higher (2.7 million tons) in 1970. Proportionately, soybeans increased more rapidly at intermediate/high elevations, recording a five-fold increased production between 1961/65 and 1970. At low elevations, cowpeas more than doubled in production between 1948/52 and 1961/65 and by 2.6 times by 1970. The Asian grams increased similarly in the lowland tropics by reaching 2.5 times their 1948/52 production in 1970.

More than a dozen species contributed to the recorded production of grain legumes in tropical regions. Of these, dry beans (**Phaseolus vulgaris**), chickpeas (**Cicer arietinum**), some of the soybeans (**Glycine max**), dry peas (**Pisum spp.**), lentils (**Lens esculenta**) and broad beans (**Vicia faba**) are clearly cool-weather and, hence, intermediate to high elevation species. Similarly, pigeon peas (**Cajanus cajan** Millsp.), cowpeas (**Vigna unguiculata** Walp.), peanuts (**Arachis hypogaea**) and the Asian grams (mungbeans, black gram, moth and others included in the "dry beans" category for southern Asia) are usually grown at lower elevations; and soybeans do occur in both ecologies - at least in southern Asia. However, it is becoming increasingly evident that several less familiar species other than those mentioned above are utilized in the lowland tropics, but are not accounted for in production statistics (see Table 1).

SOME COMPARATIVE FEATURES OF TROPICAL GRAIN LEGUMES

Some botanical and adaptive characters of tropical lowland grain legumes can be summarized in tabular form to facilitate direct comparisons of their potential for specific situations. See Tables 2-1, 2-2, 2-3 and 2-4. Species are grouped according to their presumed ecological use patterns; but considerable overlap occurs in adaptation and in macro-climates of particular locales within a region.

Table 1. Regional production of lowland tropical grain legumes in 1970

(Adapted from FAO, 1971/1972)

Crop/Species		Southern Asia		Tropical Africa		Tropical Americas		World Total	
		Actual	Percent[1/]	Actual	Percent[1/]	Actual	Percent[1/]	Actual	Percent[2/]
1. Groundnuts[3/]	Area	9.32	59.7	5.43	34.8	.85	5.5	15.59	46.1
	Prod	7.73	58.2	4.42	33.2	1.14	8.6	13.28	62.6
2. Pigeon peas	Area	2.75	94.2	.13	4.3	.05	1.5	2.92	8.6
	Prod	1.87	95.5	.05	2.8	.04	1.8	1.96	9.2
3. Cowpeas	Area	.03	1.1	3.00	98.9	–	–	3.04	8.9
	Prod	.02	1.6	1.10	98.3	–	–	1.12	5.2
4. Asian grams[4/]	Area	8.13	100	–	–	–	–	8.13	24.0
	Prod	2.69	100	–	–	–	–	2.69	12.7
5. Soybeans[5/]	Area	.77	100	–	–	–	–	.77	2.2
	Prod	.52	100	–	–	–	–	.52	2.4
6. Unspecified other pulses	Area	1.91	57.6	1.36	40.8	.05	1.5	3.32	9.8
	Prod	.91	55.2	.71	43.2	.03	1.5	1.64	7.7
All lowland[6/] pulses	Area	22.92	67.8	9.91	29.3	0.95	2.8	33.77	60.9
	Prod	13.73	64.7	6.28	29.5	1.20	5.6	21.21	57.9

1/ Percent of total production of that species grown in the lowland tropics.

2/ Percent of all grain legumes (all species) grown in the lowland tropics.

3/ Since peanuts are one-third shell, net kernel production is estimated at 8.9 million metric tons or 52.8 percent of all lowland grain legumes.

4/ "Dry bean" production in southern Asia is assumed to be predominantly Asian grams (mungbeans, black gram, rice bean and others).

5/ Soybeans in tropical Africa and South America are presumed to be grown mainly at intermediate/ high elevations.

6/ Proportion of all tropical legumes including intermediate/ high elevations.

Table 2 - 1. Some important adaptive features and botanical characteristics of selected lowland tropical grain legumes.

I. Semi-arid regions (less than 500 - 600 mm annual rainfall):

(After Purseglove, 1968; Hutchinson and Dalziel, 1958; Stanton, 1966)

Region and name (Presumed origin)	Scientific name	Chromosomes (2n =)	Perenniality 1/	Duration days	Plant type/size	Soil and climate preference / tolerance	Pest/diseases susceptibility 2/	Dry Seed Productivity levels: Average kg/ha	Dry Seed Productivity levels: Maximum kg/ha	Purpose and utilization
1. Bambara groundnut (Africa)	**Voandzeia subterranea**	22	A	90 to 150	Small, bunchy herb; prostrate, rooting branches; underground fruiting.	Dry, poor soils; high temperatures.	VL	750	2600	Unripe seeds eaten fresh; and ripe seeds used as a pulse.
2. Kersting's groundnut (Africa)	**Kerstingiella geocarpa**	22	A	90 to 120	– do –	Dry, poor sandy sois; high temps. and sunshine.	VL	500	–	Unripe and mature seeds used as a pulse.
3. Moth bean (India/Burma)	**Vigna acontifolia**	22	A	65 to 90	Slender, trailing hairy herb 10-30 cm tall.	Dry, light sandy soils.	M	300 to 400	1600	Green pods as vegetable; ripe seeds whole or split as pulse. Forage, hay and green manure.
4. Tepary bean (India/Burma)	**Phaseolus acutifolius var. latifolius**	22	A	60 to 90	Suberect herb, bushy or recumbent, 25 cm high.	Dry soils; does not tolerate waterlogging.	M	400 to 700	1500	Dry seeds for pulse; forage: 5 to 10 tons of dry hay.
5. Cluster bean (India)	**Cyamopsis tetragonolobus**	14	A	90 to 120	Robust bushy herb.	Alluvial/sandy soils; high temperatures.	VL	400 to 600	1600	Green beans as vegetable; leaves and stems for forage; dry seeds for mucilage.

1/ A = annual; P = perennial; SP = short term perennial.

2/ VL = very low; L = low; M = medium; MH = medium high; VH = very high.

Table 2- 2. Some important adaptive features and botanical characteristics of selected lowland tropical grain legumes.

II. Semi-arid to subhumid regions (600 - 900 mm annual rainfall)

(After Purseglove, 1968; RPIP, 1967; Sellschop, 1962; Verdcourt, 1970; Yohe et al, 1972)

Region and name (Presumed origin)	Scientific name	Chromosomes (2n =)	Perenniality 1/	Duration days	Plant type/size	Soil and climate preference / tolerance	Pest/diseases susceptibility 2/	Dry seeds productivity levels: Average kg/ha	Dry seeds productivity levels: Maximum kg/ha	Purpose and utilization
1. Peanut (Brazil)	Arachis hypogaea	40	A	100 to 150	Low bunchy herb; underground fruiting.	Friable sandy loams.	MH	600 to 800	3000	Industrial: oil, seed cake; dry seeds for cooking and condiments.
2. Pigeon peas (Africa)	Cajanus cajan	22 (44)	P	100 to 300	Semi-woody shrub 1.5 to 5 m tall.	Well-drained sandy/clayey loams.	L	400 to 500	3000 to 5000	Dry seeds for pulse; unripe seeds as vegetable. Forage crop and cover.
3. Cowpeas (Nigeria)	Vigna unguiculata	22 44	A or SP	65 to 200	Twining, climbing or procumbent herb; or erect bush: 20 to 120 cm tall.	Well-drained sandy loams; high temperatures.	H	300 to 400	2800	Dry seeds as pulse; tender green seedlings, leaves, pods and seeds as vegetables. Forage and green manure crop.
4. Mungbeans/ Black gram (India/Burma)	Vigna radiata and var. mungo	22 (24)	A	80 to 120	Erect-suberect, hairy herb; 50 to 130 cm tall.	Well-tilled loams to clays; black cotton soils.	M	400 to 500	2700	Dry seeds as pulse - split or sprouted; green pods as vegetable; forage.
5. Horsegram (South Asia)	Dolichos uniflorus	24	A	120 to 180	Low, slender, semi-erect herb.	Tolerates very poor soils.	M	200 to 300	800 to 1200	Dry seeds as pulse and animal feed; dry forage and green manure.
6. Hyacinth bean (South Asia)	Lablab niger	22 (24)	SP	75 to 300	Herbaceous twining and bush forms.	Well-drained; Tolerates poor soils and low fertility.	M	400 to 500	1500	Young pods and green beans as vegetables; dry seeds for pulse and feed for livestock; forage.
7. African locust bean (Africa)	Parkia spp.	–	P	–	Tree: 10-30 m.	Wide range-alluvial soils.	VL	350 to 500	–	Dry seeds fermented as flavoring. Fruit pulp also cooked.

1/ A = annual; P = perennial; SP = short term perennial.

2/ VL = very low; L = low; M = medium; MH = medium high; VH = very high.

Table 2 - 3. Some important adaptive features and botanical characteristics of selected lowland tropical grain legumes.

III. Subhumid regions (900 - 1200 mm annual rainfall)

(After Purseglove, 1968; Stanton, 1966; Hutchinson and Dalziel, 1958)

Region and name (Presumed origin)	Scientific name	Chromosomes (2n =)	Perenniality 1/	Duration days	Plant type/size	Soil and climate preference/ tolerance	Pest/diseases susceptibility 2/	Dry seed productivity levels: Average kg/ha	Dry seed productivity levels: Maximum kg/ha	Purpose and utilization
1. Phaseolus beans (Central America)	Phaseolus vulgaris	22	A	60 to 100	Dwarf bush to twining/climbing.	Light sands to clayey soils.	VH	500 to 700	2500	Dry seeds as a pulse; green pods and beans as vegetable; also for forage.
2. Soybeans (S.E. Asia/ China)	Glycine max	40	A	80 to 200	Erect bush; also twining 20-180 cm.	Tolerates some waterlogging.	M	600 to 1000	5000 to 6000	Industrial-protein and oil. Green seeds as vegetable; dry seeds as a pulse. Forage from leaves, stems.
3. Rice beans (S. E. Asia)	Vigna umbellata	22	SP	60 to 90	Erect-suberect/ twining 150-300 cm.	Light to heavy soils (after rice).	L	200 to 300	1200	Dry seeds as pulse; green seeds and pods as a vegetable. Fodder.
4. Jack/sword beans (Central America and Africa)	Canavalia spp. C. ensiformis C. gladiata	22 (44)	P	180 to 300	Bushy, erect 1-2 m; Large climber.	Tolerates some waterlogging.	VL	800 to 1000	4600	Green pods, vegetable. Ripe seeds, pulse. Medicinal, urease and lectin. Vegetation for forage and cover.

1/ A = annual; P = perennial; SP = short term perennial.

2/ VL = very low; L = low; M = medium; MH = medium high; VH = very high.

Table 2 - 4. Some important adaptive features and botanical characteristics of selected lowland tropical grain legumes.

IV. Humid and very humid regions (above 1200 mm annual rainfall)

(After FAO/CCTA, 1958; Hutchinson and Dalziel, 1958; Purseglove, 1968)

Region and name (Presumed origin)	Scientific name	Chromosomes (2n =)	Perenniality 1/	Duration Days	Plant type/size	Soil and climate preference/ tolerance	Pest/diseases susceptibility 2/	Dry seeds productivity levels: Average kg/ha	Dry seeds productivity levels: Maximum kg/ha	Purpose and utilization
1. Lima beans (Central America)	Phaseolus lunatus	22	P	100 to 270	Twining climbers; or bush types.	Humid; well-drained; aerated soils.	VL	500 to 600	2800	Dried beans as pulse; green beans, young pods and leaves as vegetable (Seeds may have HCN)
2. Winged bean (Tropical Asia)	Psophocarpus tetragonolobus	–	P	180 to 270	Twining, glabrous herb 2-4 m long.	Humid climate; loamy soils.	VL	400 to 500	2500	Fresh green pods, leaves as vegetable; tubers; dry seeds as pulse; also green manure and forage.
3. African yam bean (West Africa)	Sphenostylis stenocarpa	–	P	150 to 300	Twining, climbing or procumbent herb; 3-6 m.	Humid, well-drained loams.	L	300 to 500	1200	Dry seeds as a pulse; tubers fresh or cooked.
4. American yam bean (Mexico & Central America)	Pachyrrhizus erosus	22	P	–	Herbaceous climber 2 to 5 m.	Humid; well-tilled, sandy loams.	VL	–	–	Tubers: raw or cooked. Green pods: vegetable.
5. Velvet bean (Africa)	Mucuna pruriens var. utilis	–	P	240 to 300	Herbaceous climber 3 to 8 m.	Humid, poor, sandy loams; high temperatures.	VL	700 to 1000	–	Seeds used as pulse; crop also grown for green manure, cover and forage.
6. Horseye bean	Mucuna sloanet	–	P	240 to 360	Herbaceous climber 3 to 10 m.	Humid, well drained; high temperatures.	VL	–	–	Ripe seeds are used as a pulse in thickening soups.

1/ A = annual; P = perennial; SP = short term perennial.

2/ VL = very low; L = low; M = medium; MH = medium high; VH = very high.

CLASSIFYING SPECIES

Twenty-four species (green/black grams; and jack/sword beans are described together) have been allocated to four adaptive lowland tropical regions based primarily on annual precipitation and soil types as follows: (1) Semi-arid - less than 600 mm rainfall - Table 2-1; (2) Semi-arid to subhumid - 600 to 900 mm rainfall - Table 2-2; (3) Subhumid - 900 to 1,200 mm rainfall - Table 2-3; and (4) Humid-above 1,200 mm rainfall - Table 2-4.

Five species are adapted to semi-arid conditions, eight species are classified in the semi-arid to subhumid zone, five species are allocated to the subhumid zone, and seven species are assigned to the humid region. However, only six of these crops are grown very extensively: (1) soybeans, (2) peanuts, (3) **Phaseolus** beans, (4) pigeon peas, (5) cowpeas and (6) green/black grams. Species secondary in importance or potential include: Bambarra groundnuts, guar and moth bean in the semi-arid region; horsegram and hyacinth bean in semi-arid to subhumid areas; and Lima beans in humid regions. Other species which are comparatively obscure or confined to localized regions include: Kersting's groundnut, tepary bean, locust bean, rice bean, jack/sword bean, winged bean, African yam bean, Mexican yam bean, velvet bean and horseeye bean.

Plant types

Most grain legumes are twining semi-prostrate or climbing in their unimproved state. However, several species do have erect, self-supporting structures, including locust bean - a tree, pigeon peas - a semiwoody shrub, and jack beans. There are three small bunchy herbs with underground fruiting: peanuts, Bambarra and Kesting's groundnuts. Several others have erect or semi-erect bushy forms with implications of greater photosynthetic efficiency, high yielding potential, convenience in growing and adaptation for mechanization: soybeans, mungbeans, beans, cowpeas, horsegram, **Phaseolus** beans, jack beans, Lima beans, moth beans and tepary beans. Twelve species are classified as annuals and twelve are more or less perennial, although both forms frequently occur in the same species.

Lodging occurs frequently in the erect and semi-erect **Vigna** and **Phaseolus** species and in soybeans, but is much less of a problem in pigeon peas and jack beans. Shattering is also a major problem in grain legumes, particularly in the more primitive and wild species, and where frequent wetting and drying out occurs. Shattering is most serious in soybeans, and also in the tepary bean, rice bean and wild/weedy **Vigna** species. Less susceptible are pigeon peas (except the long-podded Philippine cvs), cultivated cowpeas and mungbeans.

Soil and climate preferences

Most species require well-drained sandy to sandy loam soils. However, a few like jack beans, soybeans, black grams and rice beans tolerate heavy soils and even waterlogging to some extent. Black gram, mungbeans and rice beans are frequently grown after rice on heavier soils. Jack/sword beans also have some tolerance of salinity and certain species of **Canavalia** are used in coastal regions, for binding sand and sand dunes as they grow quickly and tolerate salt spray and brackish water. The semi-arid species are usually more sensitive to waterlogging, but also perform better under low humidities and bright sunshine. If grown under more humid conditions they are often subject to heavy disease infection and insect attack. Some of the long duration climbers like yam, velvet and horseeye beans may be tolerant of shade and very moist soils, as they are usually grown in the humid forested zones with high amounts of cloud cover.

DISEASES AND INSECTS

A subjective and somewhat arbitrary assessment of susceptibility to pests and diseases suggests that several species, including **Voandzeia, Kerstingiella, Cyamopsis, Parkia, Canavalia, Vigna umbellata; Phaseolus lunatus, Psophocarpus, Sphenostylis, Pachyrrhizus** and **Mucuna** have comparatively fewer pest and disease problems when grown in their regions of adaptation. However, peanuts, cowpeas and **Phaseolus** beans are frequently highly susceptible to various diseases and pests even in their optimal ecologies. In these situations, plant protection is often the major management input. For example, in the subhumid region of Nigeria, an effective insect control program can increase yields of cowpea on the order of 5-10 times or more.

YIELDING ABILITY

It is interesting to consider authentic yield records as one indication of a species' potential, since "average" yields may indicate that the crop was grown outside of its adaptive ecology, it was intermixed with other species, used for other purposes (leaves, green pods, or tubers), or planted as a catch crop. However, there is good evidence to confirm that soybeans, on both an average and maximum record basis, have the greatest yielding potential at present, both in terms of quantity and quality (high protein and oil content).

Nevertheless, it is very interesting that some hitherto relatively unimproved species like pigeon peas (3,000-5,000 kg/ha of dried beans) and jack beans (up to 4,600 kg/ha dry seeds) can produce high yields under certain circumstances. Even short-term crops like Bambarra groundnuts (2,600 to 3,000 kg/ha); cowpeas (2,800 kg/ha); mungbeans (2,600 kg/ha) and **Phaseolus** beans (2,500 kg/ha), have high yielding potentials for the periods they occupy lands. At Ibadan, where it is comparatively easy to obtain 2,800 kg/ha of soybeans or about 32 kg of dry seed per ha/day, short duration cowpeas will normally produce 1,500 kg or up to 25 kg dry seeds per ha/day.

FORAGE AND COVER CROPPING

The importance of grain legumes on succeeding crops or their use for forage and cover cropping is frequently ignored. Some of the best forage and grazing comes from several tropical species like the procumbent or semi-erect cultivars of cowpeas, tepary beans, horsegram, mungbeans, rice beans, velvet beans, guar, soybeans and others.

It is not unusual to obtain more than 20 to 40 tons of high protein green matter or 5 to 10 tons of dry hay per hectare within a comparatively short time (60 to 90 days) from thickly-planted grain legumes. Similarly, these and other species are valuable for their soil fertility restorative abilities and as cover crops to protect erodible soils. Spreading types of cowpeas have shown excellent cover in erosive situations, and the winged bean has such excellent nodulation and nitrogen-fixing abilities that sugar cane is reported to give 50 percent higher yields following **Psophocarpus** than in ordinary rotations in Burma. In southern Georgia (U.S.A.), seed cotton yields were increased from 918 lbs/acre following cotton to 1,578 lbs/acre following velvet beans plowed down as green manure (Martin and Leonard, 1967).

UTILIZATION FOR FOOD

The many uses of grain legumes and the broad array of dishes that can be prepared from dried pulses or tender green pods and seeds are reasonably familiar. However, it is not so widely recognized that extensive use is made of young seedlings and tender green leaves as pot herbs. As such they contribute excellent quality protein (up to 40 percent C.P.) to the diet. Moreover, the use of tubers from winged and yam beans is hardly known, nor are there any definitive reports on productivity and nutritive values of leguminous tubers, although Burkill (1967) states that winged bean tubers had 24 percent protein on a dry weight basis.

Many grain legumes have special features of utilization and of nutritional value (Harvey, 1970). Others contain toxic properties, metabolic inhibitors, off-flavor enzymes, or flatulence factors. Fortunately, the most important of these undesirable constituents are dissipated in the cooking process (except the flatulents – stachyose and raffinose).

RECENT PERFORMANCE IN SOUTHERN NIGERIA

Several grain legume species have been studied in preliminary observations and trials at the International Institute of Tropical Agriculture at Ibadan, Nigeria, to ascertain their adaptation, susceptibility to pests and diseases and to measure yielding potential if possible. Experiments and observation plots have been carried out in three seasons - long rains, short rains and irrigated dry season - with the following species: cowpeas, soybeans, pigeon peas, Lima beans, mungbeans, hyacinth bean, African yam beans (**Sphenostylis stenocarpa**), Mexican yam beans (**Pachyrrhizus erosus**), kidney beans, winged beans, jack beans, peanuts, Bambarra groundnuts, rice beans and moth beans. It has been possible to obtain some quantitative information on some of these species which is briefly summarized in Table 3.

Potential for soybeans

The potential productivity of soybeans exceeds that of all other species studied and is a tribute to the excellent work done on this species in spite of the almost insurmountable handicap of the narrow genetic base from which improvements have been made. This is particularly evident when quality and quantity of protein are considered - in addition to 20 percent oil. Moreover, pest and disease problems on soybeans are substantially less than for cowpeas and **Phaseolus** beans - at least in Africa. The most important management input in tropical soils is controlling weeds

Table 3. Some preliminary observations and yield trial results on six lowland tropical grain legumes grown at IITA (Ibadan) and Bende, Nigeria and Kpong, Ghana, in 1971 and 1972.

	Crop: Trial and Season 1/	No. of entries	Pest control 2/	Plant height (cm)	Days to first flower	Days to lst/4th harvest	Grain yields kg/ha	Mean max. yields kg/ha 3/	Remarks
		Trial Mean Values							
I.	**Cowpeas**								
	1. Advanced - 1971F	24	H	–	39.5	62.7	1,660	2,205	Excellent early growth
	2. Advanced - 1971S	24	H	–	42.0	65.4	713	998	Late season drouth
	3. Observation plots - 1972F	245	H	–	46.3	57.3	1,773	2,928 2/	Excellent: 41 exceed 2,300 kg/ha
	4. Advanced trial - 1972S	66	H	–	45.2	66.1	1,118	1,535	Late season drouth
II.	**Soybeans**								
	1. Illinois trial - 1971F	15	L	51.2	29.4	88.7	2,289	3,087	Poor stand in some plots
	2. Advanced trial - 1971F	25	L	68.9	31.2	85.9	1,948	2,820	– do –
	3. Advanced trial - 1971S	25	L	67.3	32.6	74.2	1,956	2,785	Drouth affected late cultivars
	4. Advanced - Ibadan 1972F	16	L	61.0	33.2	86.1	1,902	2,901	Maximum: 3,001 kg/ha
	5. Advanced - Bende 1972F	16	L	53.7	26.9	97.5	2,005	3,525	Conducted Bende, Nigeria (ECS)
	6. Advanced - Ghana 1972F	16	L	67.0	36.8	103.1	2,359	3,125	Conducted at Kpong, Ghana
	7. Preliminary trial - 1972F	20	L	74.0	34.0	85.0	2,588	3,080	Excellent growth
	8. Advanced trial - 1972S	16 4/	L	62.1	35.0	90.0	1,878	2,049	Affected by drouth
III.	**Mungbeans**								
	1. Advanced trial - 1972F	22	M	84.8	37.4	81-94	1,300	1,992	Good growth/development
	2. Advanced trial - 1972S	21	M	40.3	37.2	57-71	521	813	Late planting - severe drouth
IV.	**Lima and jack beans 1972**								
	1. Lima bean nursery	196	N	Viney	60	96-122	1,200	2,563	Excellent; maximum = 3,291 kg/ha
	2. Jack bean growth analysis	1	N	120	66	166	2,696	4,580	Bearing even after 166 days
V.	**Trellis Experiment 1971/72 5/**								
	1. Cowpeas: Iran Grey	1	H	S. viney	43	71-118	2,217	5/	Advantage over no trellis = 1.9X
	2. Cowpeas: Sitao Pole	1	H	Viney	44	71-128	2,182	–	– do – = 3.6X
	3. Limas: Large White	1	N	Viney	69	128-180	577	–	– do – = 19.2X
	4. Winged Bean: Large Pod	1	L	Viney	63	108-137	692	–	– do – = 2.5X

1/ Year followed by "F" indicates First or Long Rains (April-May plantings); "S" indicates Second or Short Rains (August-September plantings).
2/ Pest control measures required: H = heavy applications; M = medium schedule; L = low requirements; N = no controls necessary.
3/ Highest 10 percent averaged; except cowpea observation where mean from highest 13 (5.3 percent) were averaged.
4/ Only seven entries analyzed for yield on account of severe drouth; late cultivars received irrigation.
5/ Experiment conducted twice in 1971 and 1972; results are means from both years; highest yields of cowpeas obtained in 1972; best yields of Limas and winged beans occurred in 1971.

and producing adequate quantities of the proper Rhizobium (**R. japonicum**), and the basic elements - phosphorus and potash.

Soybeans are most tolerant of high moisture soils, but are not generally acceptable for direct consumption outside Southeast Asia. Moreover, it is frequently difficult to obtain satisfactory stands under high temperatures and slow germination (five days compared with two to three days for cowpeas and jack beans). More recent studies at IITA show that soybeans (cv Kent) have productivity levels of up to 32 kg of dry grain per ha/day compared with about 25 for cowpeas (cv Prima) when moisture is not limiting (Moormann and Nangju, 1973). However, these comparative productivity efficiencies were reversed under condition of increased moisture stress, when the shorter duration, more drouth resistant cowpeas demonstrated a distinct advantage. One of the factors contributing to greater efficiency of grain productivity in soybeans is the longer period between first flowering and maturity averaging 42 to 60 days, compared with about 23 days in cowpeas.

Pigeon peas

Although quantitative data are not available from investigations at the IITA, this is a species with exceptional potential in terms of present use (probably second in importance after cowpeas in West Africa). Advantages are a broad range of adaptability - spanning the semi-arid to humid tropics from lowland to intermediate elevations; wide range of uses both as perennial and annual forms; lower incidence of pests and diseases compared with cowpeas; excellent nutritive quality of the fresh and dried beans; and genetic potential encompassing a very broad range of genetic diversity and comparatively high outcrossing - about 20 percent.

Lima beans

This must be an overlooked possibility for the low subhumid to humid tropics. At Ibadan, this species is comparatively pest free, producing exceptional dry grain yields (up to 3,291 kg/ha within four months) under limited moisture. Moreover, it is widely consumed in the low humid African tropics both in dry and vegetable form, in spite of requiring a long cooking time. Native varieties tend to be climbing forms, but recent introductions of dwarf bush cultivars show considerable potential and elicit much local interest in Nigeria.

Other species

Mungbeans and black gram demonstrate considerable potential both in terms of quantity and quality (high protein digestibility), and for somewhat greater tolerance of pests and diseases under Ibadan conditions. In terms of yield per se the potential for jack bean (**Canavalia ensiformis**) is extraordinary. It produced very high yields (to 4,580 kg/ha) without pest control, and demonstrates very high tolerance to both high humidities and drouth. However, it is not particularly popular owing to its long cooking time, toxic principles (lectins) contained in the seeds, and general lack of palatability.

The winged bean has been highly touted for its broad range of usefulness, excellent quality, freedom from pests, and high contents of protein —37.3 percent, and oil— 18.1 percent (Posposil, et al, 1971). However, productivity at Ibadan has been rather disappointing and growth has been slow, owing to a slight chlorotic (very light green) condition of its foliage in spite of heavy fertilizer applications. Lack of moisture, the appropriate **Rhizobium** or undetermined minor nutrients are suspected as contributory causes. Masefield (1967) suggests this species will not be very successful in regions with less than six months growing season and 1,500 mm of well distributed moisture on well drained soils.

CONCLUSION AND SUMMARY

About 24 species of food legumes are cultivated to some extent in the World's lowland tropics for food, industrial products (protein, oil and mucilage), concentrates for livestock, forage, green manure and soil cover. Two of these species soybeans and peanuts, have received a modicum of effort towards improvement and progress has been remarkable, at least in soybeans. There have also been some comparatively limited investigations on cowpeas, pigeon peas, mungbeans and Lima beans; but other species have been almost totally neglected. Nevertheless, it is both surprising and encouraging that some of the more obscure species occasionally demonstrate exceptional productivity potential and often without many problems, or substantial management inputs. This suggests that comparatively modest investments on improvement could pay off handsomely and quickly.

Although several food legumes show potential for specific conditions in the lowland tropics, it would probably be unrealistic to activate major improvement thrusts on more than three or four at the present time - at least at the international level. However, as demand increases, more marginal lands are brought under cultivation and resources become available, it may become expedient over the longer term to mount programs on some of the more promising of these "secondary" species. Moreover, localized interests may well decide that emphasis on some presently obscure species lies within the realm of their national goals. For this reason and because secondary species are quickly lost with the expansion of more sophisticated farming systems, there is an urgent, immediate need to thoroughly and systematically collect and maintain indigenous germplasm. It should also be observed that the large seeded legumes may be more closely related than heretofore suspected (the majority have $2n = 22$ chromosomes). Therefore, even obscure species could have important breeding potential when techniques are developed to readily recombine quite diverse genetic materials.

It is highly important at this time to carefully choose species worthy of in-depth improvement efforts. This paper has attempted to present evidence for making rational choices for the lowland tropics. Factors considered are: present importance, preference for food, nutritional qualities, availability of genetic diversity and ease of genetic manipulation. It is further assumed that major programs on soybeans and peanuts, supported in part by their industrial potential, will be continued and expanded separately as justified by commercial demand. Therefore, both additional species are proposed as having exceptional potential for the lowland tropics. These are listed together with their important attributes in the following order:

A. **Cowpeas** - for the low semi-arid to subhumid tropics:

Present importance - about 1.2 to 1.35 million tons produced annually.

High preference for food in many forms: dried seeds as a pulse; green pods, green seeds, leaves and seedlings for vegetables.

High nutritional value, low in metabolic inhibitors and flatulents.

Exceptionally wide range of genetic diversity and broad range of adaptation.

Ease of genetic manipulation - quick and easy to emasculate and cross; outcrossing mechanisms also available for gene pools.

Quick emergence, fast early growth, short duration (many cvs), and high photosynthetic efficiency - may be partially non-photorespiring.

B. Pigeon peas for the low to intermediate elevations, semi-arid to humid tropics:

Present importance - about 2.0 to 2.3 million tons produced annually.

Excellent nutritional quality, low content of metabolic inhibitors, and preference both as a pulse and vegetable.

Potential use in both short or long term cropping systems - annual and perennial forms.

Broad range of genetic diversity available; and very wide adaptation in the tropics from semi-arid to humid and low to intermediate elevations.

Low incidences of disease and insect pests (compared with cowpeas).

High rate of outcrossing (ca. 20 percent) facilitating natural recombination and using population improvement breeding methods.

C. **Lima beans** - for the low humid tropics:

Excellent adaptation and low incidence of diseases and pests.

Wide acceptability of both dry seed and vegetable forms.

High yielding potential in both twining and bush forms.

Broad range of genetic diversity available both in short-term bush and perennial twining types.

High natural outcrossing (up to 18 percent); and availability of genetic male sterility to facilitate recombination.

D. Mung bean/black gram - for the lowland semi-arid to subhumid tropics:

Present importance - particularly in India (0.75 million tons annually).

Well adapted - high yield potential.

Somewhat fewer pests and disease problems than cowpeas.

Excellent grain quality, very high protein digestibility; used for vegetable, dry seed pulse and sprouting.

Short duration, quick germination, easy to grow.

Wide range of genetic diversity available, and ease of genetic manipulation.

Other species with exceptional adaptation to lowland tropical conditions include: Bambarra groundnut and hyacinth bean for semi-arid regions; jack/sword beans for semi-arid to humid conditions; and winged beans, yam beans (**Sphenostylis stenocarpa**), rice beans, and velvet beans for the humid tropics. However, major thrusts on these species should be deferred until their real potential is better assessed and adequate support become available.

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I. Commentary upon:

RELATIVE AGRONOMIC MERITS OF VARIOUS FOOD LEGUMES FOR THE LOWLAND TROPICS

H. Doggett

I believe that before planning large scale development of the minor legumes, careful attention should be paid to the cooking systems in the areas where they are to be used, unless the intention is to market them as beans for export, or as oilseeds for crushing.

In many parts of Africa, and I suspect that this could also be true of parts of India, fuel is a limiting factor. The women walk miles to collect water: they walk miles to collect wood, bases of sorghum and millet plants, and dried cow dung. These bulky materials must all be lugged back to the homestead.

Adequate cooking corrects many of the antinutritional and flatulence factors in grain legumes, but under circumstances of a limiting fuel supply, anything that requires lengthy cooking will be ousted by those legumes which can be prepared quickly, without making excessive demands on the housewife's labor.

I suspect that this has been an important factor in determining which legumes have been extensively developed by man. It is also a factor working against the adoption of soybeans as a food for local consumption, as opposed to an export crop or as an oilseed for crushing.

A striking fact is the complete difference between the grain legume component of West Africa and India, with East Africa occupying a rather intermediate position. With the notable exception of the ubiquitous groundnut, the legume history of West Africa and India must have been very different, and there may well be more room for exchange both of the legumes, and the food preparation systems associated with them, between the two continents.

This leads on to stressing the importance of virus diseases. These plague many of the food legumes. There are numerous viruses involved, and it is not unusual for two or three to be present in the same plant, as in the case of the rosette disease of groundnuts, where the three viruses on the East African coast are not the same as the three viruses causing similar symptoms in groundnuts on the shores of Lake Victoria.

Viruses represent the most serious hazard when we are planning regional or international programs for the improvement of the grain legumes. I understand that the grain legumes project of the U. S. Department of Agriculture, Agricultural

Research Service, which operated in the Middle East and in India, ran in to the most serious difficulties through problems with virus diseases. The history of this particular project needs to be reviewed very carefully when planning how grain legume improvement for the world is to be handled.

It is also clear that it will be folly to make such plans without consultation with virologists experienced with the virus diseases of these particular crops. It is for this reason that free interchange between India and West Africa of legume material is unlikely to be feasible or desirable, and the proper quarantine regulations would need to be rigorously observed.

Even within Africa, there is room for caution in the movement of the grain legumes, and it is for this reason that IITA would seem to be so admirably located for the improvement of the cowpea crop. Within Nigeria the whole range from humid tropics to savannah zones can be covered without quarantine problems, and if some suitable arrangements could be negotiated with Niger, the work could be carried right up to the edge of the desert. Evidently cooperating centers will be needed through this extensive region, but few places can be so well situated as IITA for cowpea improvement.

The situation in South and Central America may also need watching from the point of view of virus diseases. Free interchange with other continents would clearly be out of the question, and even within South America, the great natural barriers which exist in the form of forests and mountain ranges will have undoubtedly confined certain diseases to certain areas. Workers there are already conscious of the problems which viruses present.

In a lot of the developing world, legumes are interplanted with a cereal. This practice is not invariable,but it is very frequent. I would like to see more attention paid to this type of agriculture. Dr. Andrews, at the Ahmadu Bello University, has demonstrated that mixtures of sorghum, millet and cowpea give a substantially better return per unit of land and per unit of labour than do these crops when grown singularly. The surveys conducted by Dr.David Norman in Northern Nigeria confirm these results.

Perhaps we should be thinking more often of developing cereals and legumes which mesh in well together, and in terms of maximizing production from such an inter-planting system, rather than looking for the highest yielding sorghum, the highest yielding groundnut, or he highest yielding cowpea on its own.

Men breed cereals for high lysine in the protein of their grain. Perhaps we should be paying more attention to the actual diet of the people. Is it corn or is it corn with beans? Is it sorghum or is it sorghum with groundnuts and cowpeas ? Looked at in this light, we may find that breeding for a better amino acid balance in the whole diet presents different problems. Lysine may not matter at all. A better yield of protein from the legume, with an increase in the methionine content, may prove to be a more nearly correct answer.

II. Commentary upon:

RELATIVE AGRONOMIC MERITS OF VARIOUS FOOD LEGUMES FOR THE LOWLAND TROPICS

A. M. Pinchinat

Dr. Rachie has stressed the remarkable potential of food legumes (pulses) for alleviating human malnutrition in the world. He has also singled out the disadvantages of the low-elevation humid and subhumid regions compared with the semi-arid lowlands and higher elevation regions in supplying a balanced diet to their inhabitants. Large areas of Latin America, the Far East, and Africa, among the least developed parts of the world, are lowland tropics.

Compared with that of other food crops, the productivity of commonly cultivated pulses has been generally low, due mainly to their putative low genetic endowment and high susceptibility to environmental factors. However, according to a U. S. Department of Agriculture report released in 1970 (2), the maximum known commercial yield of dry beans (**Phaseolus vulgaris**) in the United States was 4,035 kg/ha (3,600 lb/acre) under irrigation in Colorado. That of soybeans (**Glycine max**) was 7,371 kg/ha (109.6 bushels per acre) in Missouri.

In 1970, I learned from farmers in the Constanza Valley of the Dominican Republic, that commercial dry bean yields of 4,000 to 5,000 kg/ha were not uncommon there. Such high yields were again mentioned to me by other sources while I was visiting that country in 1971 and early this year. The 1971 world mean yield for dry beans was, according to FAO estimates (1), about 510 kg/ha; that is, about one-eighth or less of the reported potential yields from commercial plantings (two hectares or more).

Excluding soybeans and peanuts (**Arachis hypogaea**), that have been used mainly as industrial or export oil crops, particularly in Latin America, the 1971 world pulse production was 53 percent higher and pulse yield 26 percent higher than those of the 1948-1952 period (1). Such increases, especially the yield increase, although modest, are very encouraging.

In Latin America (1), the most important pulse is dry beans (36.1 percent of the 1971 world production); in the Far East (especially India), it is pigeon peas (94.7 percent of the 1971 world production); and in Africa, it is cowpeas (94.2 percent of the 1971 world production). The Far East also leads in the production of grams (mungbeans and their close relatives).

But, as Dr. Rachie has indicated, in the tropics dry beans grow better at intermediate to high elevations; pigeon peas, cowpeas, and the Asian grams are mostly low elevation crops. It thus seems fitting to suggest that more attention be paid to the raising of pigeon peas, cowpeas, and possibly the Asian grams (principally mungbeans) at the lower elevations in Latin America.

Cowpeas, pigeon peas, and the Asian grams do have their share of agronomic and socio-economic problems. Yet, compared to the **Phaseolus** beans (including Lima beans, at least in the Caribbean area), agronomically they seem to be more reliable and productive crops for the lowland tropics, from semi-arid to humid, making it easier to tackle the socio-economic problems.

Since 1971, the Central American countries, including Panama, have already been working on cowpeas and pigeon peas on a regional basis through the Central American Cooperative Program for the Improvement of Food Crops (PCCMCA, in Spanish). A common interest in these crops and possibly the Asian grams, would cause and justify a closer cooperation between the institutions in Latin America on one side and those in Africa and Asia on the other, that are concerned with improvement of pulse production and productivity in the tropics.

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POTENTIALS AND PROBLEMS OF PRODUCTION OF DRY BEANS IN THE LOWLAND TROPICS

Guillermo Hernandez-Bravo

Discussants: Luis H. Camacho; Colin Leakey

INTRODUCTION

The tropical areas of production are located from 25° latitude south to 25° latitude north. These areas are characterized by high temperatures, generally fluctuating between 22° to 28°C as average temperatures per year, and by high rainfall, though the variation might be from 400 mm to 4,000 mm per year, occasionally reaching higher figures, thus justifying a division into two categories – dry tropical areas and wet tropical areas.

Dry beans (**Phaseolus vulgaris**) have a high nutritive value (23 percent protein) and a high protein price (US$ 0.35 per pound), which corresponds to 10 percent of the meat protein price. Consumption is high. Why, then, is the production of this crop rather marginal?

The fact is that the production of this legume in the tropics is subject to significant problems. Thus the production of dry beans is considered unprofitable, highly risky, and disadvantaged in competition with other crops.

Collateral factors restraining extensive dry bean production are: traditional cultural and management systems; size of production areas, and the need to develop cultural practices or a "technology package," with specific research and experimental data, and training of experts in dry bean production systems.

Based on the information and experiences obtained in research trips in countries such as the United States, Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Ecuador, Peru, and Brazil, I would like to present for discussion the problems or factors that in my opinion are limiting dry bean production in tropical areas.

DRY BEAN PRODUCTION IN THE TROPICS IS UNPROFITABLE

In countries such as Canada, the United States, Chile, Peru, and others, there are good climatic conditions during the dry bean production period and this influences the national average yield, placing it above those obtained in other countries. On the other hand, in countries having a high proportion of cultivation of dry beans under tropical conditions, as in Central America, their production is generally, low, and this is reflected also in the national average yield, as seen below in data from the FAO Production Yearbook, Vol. 23, 1969. Average yields are given in kilograms per hectare of **Phaseolus vulgaris.**

Country	Yield	Country	Yield
Canada	1,600	El Salvador	690
U. S. A.	1,550	Guatemala	640
Chile	1,220	Honduras	450
Peru	1,170	Costa Rica	410
Nicaragua	720	Panama	330

Brazil, the largest dry bean producer in the world, (2.5 million tons) with a production average of 660 kg/ha, has areas of production with very good climatic conditions where yields of 1.2 ton/ha have been obtained, as in the region of Parana, the southern part of Sao Paulo, Santa Catalina and Rio Grande do Sul.

There are countries, or rather, dry bean producing areas, with high levels of technology where outstanding production levels are obtained. A representative case is that of the U.S.A. which in the period 1959-1969 reached an average yield of 1.4 ton/ha. This figure is well above that reported for Latin America, which was 525 kg/ha. These significant results have been made possible due to breeding with different dry bean varieties. It is also true that U. S. A. has kept a high average yield because this crop is cultivated under irrigation in the states of Michigan, Nebraska, Montana, Idaho, Wyoming and Washington.

In Mexico there is a dry bean producing region highly technified (production areas of the state of Sinaloa), and in this area there are irrigation facilities. This region has an area of approximately 40,000 hectares with an average yield of 1.3 ton/ha, compared with the national average in Mexico of 460 kg/ha; the national level being affected by the production of the dry land areas or of temporary crops where yields are very low.

DRY BEAN PRODUCTION IN THE TROPICS IS HIGHLY RISKY

If we assume that 75 percent of the dry bean producing areas in the tropics depend on rainfall, then in principle, dry bean cultivation will always be subject to significant production decreases. El Salvador is an example where 90 percent of the dry beans grown are either dry land crops or temporary crops.

Heavy rainfall may destroy crops either by drowning the plants in flooded areas or by encouraging root-rot; likewise, constant rainfall, even though slight, may establish conditions conducive to diseases. On the other hand, when the rainfall frequency fluctuates markedly, which very often happens, the drought periods cause considerable decreases in yield. Strong differences in water availability in the soil also lead to the appearance of leaf diseases, and to sharp increases in insect populations, reproducing at a high rate.

Weeds are another factor that can significantly affect dry bean production in the tropics. Weeds develop rapidly due to the prevailing high temperatures, and affect dry bean production when they are not eradicated at the proper time, before critical competition for nutrients, water, and light.

DRY BEANS CULTIVATION IN THE TROPICS IS UNDER COMPETITIVE DISADVANTAGE

Since dry bean production is considered unprofitable in many instances, besides being subject to high risks, this explains why dry bean farming does not so far compete with other crops considered more profitable and less subject to risks.

For instance, in Nicaragua there is a preference for the production of cotton, coffee, corn, and rice, and cattle enterprises. In Costa Rica, coffee plantations as well as those of sugar cane, banana, and cattle raising, are more important than the cultivation of dry beans. In Panama there is a preference for the production of cattle, rice, corn, sugar cane, and cowpeas rather than dry beans. Similar situations prevail in the rest of the tropical countries where dry bean production is restricted to small areas.

The aforementioned crops, as opposed to dry beans, have the advantage of being under "agricultural insurance" and their price is guaranteed.

TRADITIONAL CULTURAL SYSTEMS IN DRY BEAN PRODUCTION

The fact that dry beans are a less profitable crop than coffee, cotton, bananas, rice, and perhaps others, would explain why the areas of dry bean production are limited.

I would venture that the largest part of dry beans produced in Latin America are planted not on flat land but on hillsides and perhaps the proportion amounts to 80 percent. It is unnecessary to point out what are the obstacles restraining yields of a crop planted on hillsides.

Since dry beans are a marginal crop, it is logical that the production areas are dispersed and consist of small farms in the hands of low income farmers. In Nicaragua, the average arable land surface per farm in beans, is 1 to 2 hectares. A similar situation occurs in El Salvador (see 2nd Agricultural Census, 1961). In Costa Rica the situation is worse, because the average arable land surface is below 1 hectare.

In the small plots dry bean yields are not necessarily lower than on larger areas. The fact is, however, that a small farm is comparatively less profitable, due to less efficient management, which results in higher production costs, hence smaller returns.

In regard to the traditional culture systems, it is important to note that a high percentage (at least 75 percent) of dry beans produced in Latin America are grown in association with maize. Brazil produces 70 percent of its dry beans under this kind of farming with maize or with other crops. In Colombia, the figure is higher, 92 percent.

Unfortunately, this system of associated crops used for dry beans has commercial disadvantages, and therefore the production is low, fluctuating between 300 and 350 kilos per hectare.

PROBLEMS INVOLVED IN MANAGEMENT OF THE "TECHNOLOGY PACKAGE"

In the application of the "technology package" in dry bean farming, that is, the use of advanced dry bean production techniques regarding management in general, one can point out highly important factors that might directly affect yields.

Sowing Systems

In the tropical production regions heavy accumulation of water from rainfall can be found in the soils at any time, which may severely damage the crops unless there is proper drainage of the excess. If the planting is on beds or hills, excess water can be channeled to drainage systems. Dry bean cultivation on flat land without furrows leads to wilting of much of the plant population by drowning, root-rot, or by high incidence of leaf diseases.

Seed Quality

It is probable that the dry bean producing countries, at least in Latin America, are not producing certified seeds that guarantee breeding quality and healthy seeds in regard to virus, fungi and bacterial diseases transmissible through seed.

In countries such as Nicaragua, Honduras, Guatemala, Peru, El Salvador, Brazil and others, improved dry bean seeds are being produced, yet the necessary conditions have not been attained for seed to be considered "certified." In principle this problem could be solved by establishing a national law on product and on seed certification that includes dry beans.

Another problem would be to find the reasons why farmers make such small use of improved seeds. Studies in El Salvador indicate that there only 10 percent improved dry bean seed is used. In the symposium on dry beans in Brazil in 1971, it was reported that during 1968 only 0.2 percent of improved seed varieties were used in the important dry bean producing regions of the central and southern parts of the country. This seems to indicate that most farmers prefer to produce their own seed because it is less expensive. It is important to demonstrate to them that in the long run cheap things are dear. Seed produced without the watchful eye of the agricultural expert may produce infected seed that will reduce production up to 50 percent.

Protection of the Seed

Prevailing environmental conditions in the tropics during germination in the field make the period critical. Seedlings may be destroyed by root diseases or insects. If during this period a minimum plant population of 90 percent is not assured, there is an initial disadvantage for obtaining good yields. It is advisable to disinfect the seed with fungicides and to incorporate insecticides in the soil before sowing.

Population Density

This without doubt is an important factor in yield which should always be considered in sowing, regardless of the sowing system. For each particular place there will always be a maximum number of plants per hectare that will produce maximum yields.

Plant Protection

Under prevailing conditions in the lowland tropics, plant diseases, pests directly damaging the plant, and insects that are vectors of viruses, toxins and other phytotoxic particles, are main factors threatening success of dry bean production. The only solution to guarantee a reasonable plant health is to use disease resistant varieties or seeds having genetic tolerance to the organisms mentioned. Unfortunately, we do not yet have commercial dry bean varieties with these genetic characteristics.

Plant Nutrition

Continuous land exploitation results in continuing soil nutrient deficiencies. Dry bean producers who have economic resources can foresee fertilization needs precisely through chemical analysis of the soil. But the low income farmers cannot pay for services such as soil analysis, and if they wish to use fertilizers (N-P-K) they do so at the risk of making an unnecessary investment; or, if the soil is rich in nitrogen, for instance, an excess of it would produce heavy foliage with a minimum of pods.

EXPERIMENTS, RESEARCH AND ECONOMIC STUDIES

Information is lacking in the production areas regarding experiments to try the "technology package" to significantly increase production. The experiments must be done in the same production areas or in selected areas representative of the climate and soils of the producing regions.

Research must be promoted and intensified on specific technical aspects of dry bean production which are of economic importance. This is urgent. To be able to conduct experiments and research on the most important economic aspects of this legume, and to establish priorities, economic studies to establish the real importance of the problem are first necessary.

DRY BEAN PRODUCTION SYSTEMS SPECIALISTS

National dry bean programs are subject to a serious problem of discontinuity of projects due mainly to changes or rotation of trained staff. The immediate solution to this problem would be to continue training new people with the collaboration of the universities and institutions that have facilities.

In agreement with the interested parties, staff should be trained in the various disciplines of dry bean production in Ecuador, Guatemala, Honduras, Nicaragua, Panama, El Salvador, and perhaps other countries.

DRY BEAN POTENTIAL IN THE TROPICS

As has been pointed out, for various reasons dry bean production is not now an economically attractive agricultural enterprise. However, the fact remains that there is opportunity for improvement to make this crop a thoroughly profitable investment.

MAKE THE DRY BEAN CROP ATTRACTIVE TO THE FARMER

In principle, to make dry beans an attractive crop to the farmer, it is necessary for it to attain a high yield potential, to produce good harvests under tropical conditions.

To analyze the bean plant potential in the tropics, detailed investigation will be necessary, of the factors of genetic and physiological processes that determine yield. These include the main components of yield as well as factors connected with plant efficiency. The plant structure –aerial as well as root– will occupy a preponderant role in the search for genotypes with high yield potential. Before any breeding program is started, it is important to be sure that the selected genotypes are desirable as parents.

MAKE DRY BEAN CULTIVATION A PROFITABLE INVESTMENT

If the improved varieties intrinsically have a high yield potential, dry beans might become profitable if the "technology package" is adequately applied. This has been demonstrated in El Salvador by increases in yield up to 100 percent.

Inoculation of seeds with nitrogen-producing bacteria specifically for commercial varieties of dry beans, is regarded as having potential to decrease fertilizer costs and also to improve the plants' ability to use nitrogen.

Establishing a national seed inspection and certification service is a necessity for healthy seeds. Aside from adequate inspection services, it is necessary to have proper areas for seed production. This means low rainfall, freedom from contagious diseases transmissible through seed, and proper irrigation facilities. In the Republic of Guatemala a promising cultivation area in the San Jeronimo Valley is being used for seed production.

PRODUCTION SYSTEMS

In Latin American and in general, in developing countries, it is necessary to change the traditional subsistence farming systems into efficient dry bean production systems. The present production systems by which dry beans are grown in association with maize can be made more profitable if improved varieties are used, if the sowing systems are improved, if the type of maize used is really a good support for the bean plant.

RURAL COOPERATIVES OR PRODUCTION UNITS

In Latin America a common problem in agriculture is the lack of, or limited promotion and publicizing of new production techniques. Regarding dry beans, promotion programs are needed, such as that being carried out in Honduras (Francisco Morazan Project) and perhaps in other countries, directly with farmers.

I myself believe that the "technology package" can be applied in an overall manner, and that farmers will accept and assimilate it, if and only if, the operation is performed through "production units" or rural cooperatives. The main point of these units is the integration of small farms into a more profitable joint production. This type of rural cooperative is being tried successfully in Colombia, Mexico, Panama, El Salvador, and other countries.

The proper way to smoothly run the production units is to have the farmers of an area join their efforts, taking active part in the operation. It is advisable that in this type of unit crops other than dry beans also should be planted.

The greatest advantage of the "production unit" is that it has the support of a staff and a group of agronomists interested in the organization and technical development of the unit. The management of each crop turns out to be more economical through increased capacity for obtaining loans, better utilization of agricultural machinery, greater facility for the purchase of inputs at better prices, and better marketing prospects.

INTEGRATION OF RESEARCH EFFORTS

There is strength in union. Extensive advances will be made in dry bean production in the tropics if an effective coordination of efforts is obtained between the various governmental and private institutions that carry on research on this field.

Creation of model "production units" at the national level, well organized, in well selected production areas, in which this legume will be playing a major role, represents an immediate move toward solution of the problems of dry bean production in the tropics.

A short term solution is to obtain dry bean varieties with high yield potential, with characteristics able to stand prevailing tropical conditions.

I. Commentary upon:

POTENTIALS AND PROBLEMS OF PRODUCTION OF DRY BEANS IN THE LOWLAND TROPICS

Luis H. Camacho

Field beans (**Phaseolus vulgaris**) are native to the Western Hemisphere and important in the diet of Latin American people. The seed is nutritionally important and the plant useful in the improvement and conservation of soil fertility. But beans have low levels of productivity and production increases have not kept pace with population growth.

Table 1 shows the bean production and productivity figures for 1968, 1969 and 1970 for both the temperate and tropical zones of America (7). The temperate zone includes Argentina, Chile, Uruguay, the United States and Canada. The rest of the countries, including the Caribbean, are included in the tropics.

According to these data, the cultivated area of the temperate zone is 12 percent of the cultivated area of the tropical zone. Yields in the temperate zone, however, exceed those of the tropical zone by 100 percent. In 1969 and 1970, there were production increases in the tropical zone as a result of an increase in the cultivated areas in Brazil and Mexico.

The data show that bean production has been more successful in areas outside the original habitat of the species. The many reasons for low bean productivity in the tropical area include 1) the temperature, the humidity and the typical characteristics of tropical soils; 2) the natural enemies of the species in its original area, such as diseases, insects and nematodes; 3) the lack of advanced technology and of means to develop the present technology for better-yielding crops.

Table 1. Bean production and productivity in the temperate and tropical areas of America

	1968	1969	1970
		Temperate zone	
Surface x 10^6 ha.	0.77	0.77	0.77
Production x 10^6 m.t.	0.97	1.06	1.02
Yield x 10^3 kg/ha.	1.25	1.37	1.32
		Tropical zone	
Surface x 10^6 ha.	5.95	6.63	6.82
Production x 10^6 m.t.	3.70	3.97	4.57
Yield x 10^3 kg/ha.	0.62	0.60	0.67

Effect of temperature, humidity and soil conditions on bean production

In areas close to the Equator, temperature is a function of altitude above sea level. In the low areas, the temperature may fluctuate between 26 and 36°C. Even though this temperature may favor vegetative growth, reproduction is severely affected because of the high percentage of flower and fruit losses. This phenomenon is associated with the low germinating power of pollen and the low level of formation of the substances that retain the fruits in the plant when the ambient temperature exceeds 25°C (10, 18).

Controlled studies have shown that beans develop normally with a relative humidity of 35 to 100 percent when the temperature fluctuates between 18 and 24°C (13). If these laboratory results are extrapolated, with other variables remaining at an optimal level, it could be affirmed that beans are easily adapted to the humid conditions of the tropics. Unfortunately, the high relative humidity stimulates the opening of the stomas (11), allowing the penetration of pathogens which constitute one of the main problems of bean production. ICA has conducted experiments in areas with a relative humidity of 70 to 80 percent, an average temperature of 28°C and at altitudes of less than 400 meters above sea level that show a satisfactory vegetative growth of the plant but a poor reproductive growth and a high incidence of leaf and root diseases starting at flowering.

Changes in humidity and soil fertility affect the normal growth of the bean plant. The root system of the plant is superficial and requires, therefore, an adequate supply of water during the reproductive cycle. The needed amount of water is not always available at the proper time because the irrigated areas in tropical America are not extensive and rainfall is erratic and poorly distributed. In addition, the acidity, the toxicity of aluminum or manganese, the calcium and phosphorus deficiencies and the possible interaction of these factors with the effectiveness of nodulation are also limiting factors.

Diseases, insects and nematodes

Diseases are a major limiting factor in bean production in the tropics. Among the bacterial diseases, common bacteriosis (**Xanthomonas phaseoli**) and halo blight (**Pseudomonas phaseolicola**) are the most frequent. The two develop under conditions of high relative humidity and fresh temperature, and both are transmitted through the seed. Common bacteriosis is especially favored in temperatures above 20°C and it is the most common bacterial disease in the Latin American bean producing area. The lack of resistant varieties and the use of uncontrolled seeds contribute to the dissemination of the disease.

Among the fungus diseases, the most important are anthracnose (**Collectotrichum lindemuthianum**), rust (**Uromyces phaseoli**, var. typica), stem rot (**Sclerotium** spp.) and root rot (**Fusarium selani** f. phaseoli). Anthracnose is more severe at low and medium temperatures and high relative humidity. Rust develops in dry temperatures and root rot develops in light soils and dry temperatures. The anthracnose-common bacteriosis-rust complex constitutes a great problem for bean production in the low and high Andean regions of Colombia.

The common and yellow mosaic viral diseases prevail in all the bean producing areas. The common mosaic virus is transmitted through the seed and also by insects, especially aphids. Wild malvaceous plants host the yellow mosaic virus which is transmitted by the white fly (**Bemisia tabaci**) (19).

Several insects attack beans in different ways and at different stages of development. Some, such as the Mexican bean beetle (**Epilachna varivastis**) and the podworm (**Apion godami**), are common in Mexico and in Central America while others, such as the green leaf hopper (**Empoasca kraemeri**) and the white fly (**Bemisia tabaci**), are widely disseminated throughout tropical America (19).

Light soils, under high humidity and temperature, favor attacks by nematodes (**Meloidogyne** spp.). Three methods are used to control the problem: chemicals, crop rotation, and resistant varieties. The first method is extremely expensive and small farmers cannot afford it. The second is easily applicable and the third is the most economic and efficient.

Technological aspects of bean production in the Latin American tropics

For many years, several national and international institutions in Latin America have studied bean production problems. Research has given good results in relation to improved varieties, insect and disease identification and control, fertilization and soil management, population densities and planting periods. The aspects related to the physiology and architecture of the plant and to quality improvement have not been studied.

Each research program has developed improved varieties adapted to local or regional conditions. The Northern Zone of IICA has coordinated studies for the adaptation of several varieties in the Central American countries. Some varieties have been successfully adapted in El Salvador, Honduras, Costa Rica, Nicaragua, Colombia and Venezuela. The IICA Research Center at Turrialba has developed improved varieties for Costa Rica and other Central American countries. ICA has developed improved varieties for cold, temperate and moderately hot climates (4). The Agricultural Research Center at Maracay has developed improved varieties of black beans and hopes to find new varieties adaptable to altitudes of less than 400 meters above sea level. The "La Molina" Experiment Station has developed early varieties of the "Canary" type (3). Several research and teaching institutions in Brazil, such as the Rural University of the State of Minas Gerais, the Instituto Agronomico de Campinas and the Secretariat of Agriculture of the State of Rio Grande do Sul, have successfully conducted research on improved varieties (15, 17).

Basic studies on the identification of pathogen strains have been conducted at several institutions. In Costa Rica, strains of viruses transmitted by the white fly (**Bemisia tabaci**) (9) have been identified as well as, at least, seven strains of the rust fungi (**Uromyces phaseoli**, var. typica). (6). Thirty-one strains of the same organism have been identified in Mexico and 26 in Brazil (17).

The potential yields of improved varieties obtained in different Latin American countries are promising. Research results indicate a production ranging from 1,300 to 3,000 kg/ha.

Fertilization studies in several countries show that beans grown on the Latin American soils respond to nitrogen, phosphorus and potassium. Recommendations on nitrogen application vary from 30 to 60 kg/ha. even though from 100 to 400 kg/ha. of N are recommended in some areas of Brazil and Costa Rica (15). The response to potassium is not frequent but the required doses range from 0 to 100 kg of K_20 per hectare (8). In some experiments conducted in Venezuela, there was a negative response to the application of phosphorus and potassium (1) but in the bean areas of Central America and Brazil, the application of phosphorus is essential to obtain satisfactory levels of production (12, 15).

Studies on nitrogen fixation in the root nodes indicate the effectiveness of inoculation with **Rhizobium**. The degree of fertility and acidity of the soils may require conditioning for effective nitrogen fixation (8).

Experiments in temperate and tropical zones indicate that bean yields increase when the plant population density increases. In Colombia and Venezuela (12, 14) significantly high yields have been obtained using the double row system (30 cm between the rows and 60 cm between pairs of rows) compared to the single row system. In Brazil and Guatemala, planting in close rows gives higher yields than planting in distant rows (17). This aspect should be thoroughly investigated because of the different degree of growth in cultivated varieties. Shrubby or dwarf varieties may respond better to large populations than voluble or climbing varieties. The unlimited growth of the latter requires harvest by stages and the planting rate may affect production at different times of harvest. Other aspects that should be kept in mind in relation to the planting rates are disease and pest control, mechanization, fertilization and irrigation practices.

SUGGESTED RESEARCH ACTIVITIES

Genetic improvement: Collection and evaluation of germplasm; establishment of new populations and utilization of selections. The collection must include the widest possible genetic variety including wild species of the **Phaseolus** genus.

Selection within these and newly generated collections through intra or interspecific crossing may give origin to new types of plants with high yielding potential that will respond to fertilization and high planting rates.

Selection for disease resistance based on polygenetic or horizontal resistance especially in those cases known to have pathogen strains. Selection by monogenetic or vertical resistance in the case of diseases is controlled by simple Mendelian inheritance.

Selection by quality in order to improve cooking, to eliminate gas-producing substances and to increase the protein content.

Agronomy: Study of optimal distances between rows and between plants in monocultures and in associated crops in shrubby and climbing varieties. Development of effective weed and pest control methods in several types of crops.

Soils: Recommendation of optimal doses and time of application of macro and microelements. Performance of different varieties in acid soils and the effect of nitrogen in nodulation and in protein content. Isolation of efficient **Rhizobium** strains and their eventual utilization as a means of decreasing nitrogen fertilization costs.

Physiology: Identification of the physiological parameters determining yields. Ideal structure of the bean plant in monocultures and in associated crops. Effect of the photoperiod and its interaction with temperature in the development of the plant. Water requirements in tropical soils.

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II. Commentary upon:

POTENTIALS AND PROBLEMS OF PRODUCTION OF DRY BEANS IN THE LOWLAND TROPICS

Colin Leakey

There is quite inadequate definition of "the tropics" and "lowland tropics." One must consider the distribution of rainfall and of temperatures in relation to possible planting dates and for cultivars of particular maturity characteristics. The concept of rainfall reliability based on calculated confidence limits for running means (Manning 1956) has made discussion of mean annual or even mean monthly rainfall obsolescent. For drought sensitive rainfed crops it is the reliability of rainfall expectation over the crop period that is important.

There is a large literature on the effects of moisture stress at different growth periods (reviewed in Leakey 1973, in press). In Colombia, at ICA, Cardona **et al** (1959), did useful work with Diacol Nima that could probably with advantage be copied throughout the region and be related to statistical studies of the genotype environment interactions using contrasting varieties and plant types.

TOLERANCE TO HIGH TEMPERATURE

The only detailed studies of the adverse effects of high temperatures on seed set have been made in Canada (Ormrod **et al** 1967) and we lack information on the differences in tolerance to high temperatures that may be expected to exist between genotypes. The pea (**Pisum sativum**) (L.) bean (**Phaseolus vulgaris**) (L.) Savi and cowpea (**Vigna unguiculata**) (L.) Walp, form an interesting series of increasing tolerance to high temperatures with respect to flower and fruit set, about which too little is understood. Work in beans for selection for tolerance to low temperatures in early growth in north temperate environments suggest that there might be useful genetic variation also for high temperature tolerance.

Dr. Hernandez-Bravo has referred to the tendency in tropical soils for available moisture in the root zone to change very rapidly. The ability of some bean genotypes to develop much more extensive root systems than others provides a clue to the relative success and stability of the indeterminate types over the determinate. There needs to be far more attention to breeding and selection for good root systems and care must be given to the danger of developing drought sensitivity as a correlated character by selecting for determinacy of the shoot system and early maturity. The problem is well known in cereals such as barley. It may be appropriate to point out here that in the United States the pinto and great northern beans, whose performance overall is regarded as superior to that of beans in the tropics, are indeterminate, and are often sown after pre-irrigation of the seedbed.

RAPID, UNIFORM GERMINATION CRUCIAL

The question of rapid and uniform germination is in our opinion crucial to successful bean production on the broad acres. If the moisture is right the texture and tilth of the seedbed is not critical but if the soils are nearly dry in the upper few inches an uneven seedbed accentuates the problem of producing a decent stand. In experiments at Kabanyolo with young agronomists in training as specialists for bean production, we have had the greatest difficulty in making any hand-operated machinery work satisfactorily in tropical red latosols such as exist for example in Brazil also. We think that hand sowing into a machine-made furrow may have to be the intermediate step between full hand planting and full mechanization in modernizing bean production on intermediate sized plots.

As has been pointed out, a large proportion of bean production in South America is in mixed populations with maize. I have in a recent paper (Leakey 1972) discussed broadly the potential advantages of crop mixtures in relation to our trying to understand why farmers persist in this practice even when they are happy to adopt other (and more wise) innovations.

In recent work at Makerere just published in the Journal of Agricultural Science, my colleague Willey and our research student Osiru have investigated intercropping in some depth and confirmed the synergism which undoubtedly exists between maize and bush beans in various patterns of intercropping beans between rows of maize. Their study did not include detailed analysis of the effect of the maize on bean disease epidemiology (particularly bacterial blight) but in the field effects were apparent of the maize rows acting at least as a temporary break to the spread of blight in the beans. In further studies now being undertaken the root and soil water aspects of the synergism between maize and beans in mixtures are being studied.

At IITA cropping systems for maximum productivity are a focal study. We have been much interested in competition in mixtures between bean genotypes (unpublished to date) but are also interested in the competitiveness of beans against weeds. Once again the vigorous indeterminate and indeterminate bush types are much more competitive than early bush determinates and have the ability to build up leaf area index faster and to compensate between plants for an uneven seedling stand. Weed supression is also interrelated with the importance of rapid early germination and vigor of the crop.

SEED PRODUCTION TECHNIQUES ARE CRITICAL

One cannot solve problems of making good quality seed available to farmers, even in principle by legislation about certification standards. The production techniques for getting the quality seed must be developed first or the new laws will be worth no more than the paper they are written upon and will be brought into disrespect. The United States has led the world in the production of disease-free bean seed and this has been possibly the predominant factor in the excellence of their bean production.

I cannot too strongly stress the importance of producing beans for seed under conditions of minimum precipitation. In Tanzania this has been achieved without irrigation to supply the Dutch seed industry, using stored water in deep volcanic ash soils around Mount Kilimanjaro by planting "at the back end of the rains" and growing through a reliable dry season. Perhaps this possibility is unique to Tanzania but it is possible that parallel situations exist in the Andes.

Our African experience, especially in Kenya, indicates that farmers do in fact respond to the availability of truly good seed but are not hoodwinked by inferior seed grown under government control. The so called "watchful eye of the agricultural expert" is no substitute for the proper environment in producing disease-free seed.

One cannot - in the short or medium term - hope to produce enough improved and disease-free seed for all production. Many or most farmers will continue to keep their own seed. Farmer education in the selection of the best parts of his production for seed under the common knowledge Biblical doctrine of "whatsoever a man soweth, that shall he also reap" must be encouraged. The most effective way to increase production of improved beans may be by the participation of those farmers who have already themselves accepted the reality of their improvement.

FOOD SUPPLIES AT REASONABLE PRICES IS A GOAL

I am not confident that beans can ever be made a crop for "profitable investment" nor perhaps should we expect this of a staple food crop. What I consider most valuable is to try and develop the production technology to a point where food supplies at reasonable prices can still be assured to the market economy of the towns and cities while leaving the farmers who produce them sufficient land and time to grow more profitable crops as well.

I would foresee the possibility of regular and widespread production to about the 1,000 or even 1,200 kg/ha level with relatively simple innovation. This would make an enormous contribution to food supplies. The jump to much higher production levels, while technically possible, is perhaps not likely to become widespread, for the same investment in cash and effort required would probably be better spent in alternative crops.

For arable farmers with large acreages to put to a leguminous crop I would tend to favour the soybean to the **Phaseolus** bean. The only beans likely to prove a profitable commercial development with an all-plus package technology are the specialized types for particular market requirements such as navy beans for canning. For these, however, the relative inelasticity of the market does not offer much hope for this becoming a new wonder crop of the Green Revolution either in Africa or South America.

My final comments concern information already existing vis-a-vis the planning of new research.

The IICA in Costa Rica has for some years published very comprehensive bibliographies and supplements on beans. The Bean Improvement Cooperative —to which I imagine most of us belong— is a superb liaison organization under the guiding hand of Professor Dermot Coyne as secretary. Perhaps a Spanish edition of the Annual Report might be considered. Finally, I owe many of you here personal thanks for your assistance with reprints and other data for a rather large review that is in press in Field Crop Abstracts and is expected to be published in May and June in two parts. Too few scientists in the present age take time to read as well as to write and carry out experiments. I would commend a thorough survey of what is already known about beans to those in this Institute and elsewhere as a starting point for further planning.

BEAN PRODUCTION SYSTEMS

Juan Antonio Aguirre
Heleodoro Miranda M.

Discussants: Fernando Fernandez and David L. Franklin

Bean production systems are many and quite varied; although their persistence seems to be undeniable, the factors causing such persistence seem to be barely understood.

The objective of this paper is to describe the various bean production systems, stressing the interrelations between these systems and the socio-economic environment in which production evolves, in function of the variables which characterize said systems and which contribute to their permanence; stressing the deficiencies as well, in function of a high productive physical and economic level.

Before broaching the subject it is important to define what is an agricultural production system. The following statements can help us to grasp the subject.

The concept of agricultural production systems must be ample enough to include the technical, economic, social, political and cultural aspects of the members of a society that define and shape the basic relationships between man and his environment, channeled into agricultural production.

It is important to keep in mind that the production techniques and systems are locally standardized following patterns which tend to cooperate with nature. That means that cultural inheritance and socio-economic organizations strongly influence the agricultural production systems (6).

So far, an agricultural production system has been outlined as a unit framed by three kinds of components: a) biophysical, b) technologic, and c) socio-economic, giving to the latter the broadest socio-cultural-economic-organizational sense.

SOCIO-ECONOMIC ENVIRONMENT OF THE BEAN PRODUCTION SYSTEMS

The main factor characterizing bean production environment is the dispersion of the production units. Contrary to other traditional crops which are the base of our economy, bean is not easily located in space. For instance, out of 1,642 cotton farms reported in El Salvador, 670 are located in the Department of Usulatan, 642 in San Miguel, and 179 in La Unión, which means that 92 percent of the units are concentrated in three of the 14 departments of the country (4).

On the other hand, checking Table 1, which shows the geographic distribution, number of farms, net area and production of beans (solely or as an intercropping, mainly with maize) in El Salvador, it is evident that without a detailed analysis it is not possible to determine the main production areas, as is the case with cotton.

As a direct effect of said dispersion, the farmers must adapt their activities to multiple ecological conditions by introducing variations on the production systems. Even if with those variations farmers are not trying to improve their low yielding production systems, results are often disheartening.

Side effects of unit dispersion having a basic influence on the production systems are listed below:

It impedes the development of a technology within a reasonable ecological frame.

It impedes the development of high potential genetic material when, for instance, plant breeders try to achieve broad range of adaptability which might not be either practical or necessary.

It impedes the development of a system for the supply of agricultural inputs.

There is not ground for an integrated marketing system.

Costs of individual technical assistance go up.

It dilutes the limited technical resources.

Generally speaking, it impedes the development of an integrated system for a ready supply of materials and services basic for production.

The second limiting factor is the size of the fields. Working with beans, we face not only scattered but small units, e.g., in El Salvador, the size of farms planting solely beans is between 0.15 and 0.73 hectares, and the size of those having beans associated with other crops fluctuates between 0.51 and 0.95 hectares. See Tables 2,3 and 4.

The size of the farms has a definite influence on the final results. The first and most important one is the impossibility of absorbing fixed and variable investments which would make the exploitation economic and technologically feasible.

Introducing and continuing the use of a better technology in such an environment is rather difficult, because it means expenditures and economic obligations with an implicit risk; due to the low level of producers, said risk is hardly accepted by the investing agencies.

If the low technological levels of production are to be improved, due consideration should be given to those problems originated in the size and scattered location of plots.

Table 1. Space distribution of bean production in El Salvador

Departments	Bean			Bean/Maize			
	Number of production units	Net area (ha)	Production (kg)	Number of production units	Net area (ha)	Bean production (kg)	Maize production (kg)
Ahuachapan	1,456	324	406.963	1.877	1,283	1,036.047	1,819,794
Santa Ana	5,106	1,625	2,564,693	3,241	2,558	1,968,249	2,813,395
Sonsonate	1,290	547	531,689	307	292	186,752	382,522
Chalatenango	5,857	2,088	1,254,611	920	858	457,013	818,378
La Libertad	5,228	826	2,648,121	1,486	1,441	1,411,351	2,118,989
San Salvador	1,725	646	454,583	1,384	718	389,473	825,096
Cuscatlan	3,463	1,137	705,803	2,756	1,445	568,391	1,390,497
La Paz	2,395	982	564,318	756	449	234,130	445,134
Cabañas	4,617	3,393	1,450,403	1,219	946	354,862	807,674
San Vicente	2,818	1,642	1,153,139	266	148	78,003	128,533
Usulutan	1,879	841	828,267	270	151	123,931	194,781
San Miguel	1,542	882	681,251	931	562	334,109	504,780
Morazan	660	201	102,454	1,398	1,001	423,947	832,158
La Union	487	212	137,837	304	234	135,173	228,524

Source: Segundo Censo Agropecuario, 1971

Table 2. Average farm size and yield of bean in El Salvador

Departments	Size of		Yield (kg/ha)	
	Solely (ha)	Associated (ha)	Solely (ha)	Associated (ha)
Ahuachapan	0.22	0.68	1,256	807
Santa Ana	0.31	0.78	1,578	769
Sonsonate	0.42	0.95	972	639
Chalatenango	0.35	0.93	600	532
La Libertad	0.15	0.96	3,205	979
San Salvador	0.37	0.51	703	542
Cuscatlan	0.32	0.52	620	393
La Paz	0.41	0.59	574	521
Cabañas	0.73	0.77	427	375
San Vicente	0.58	0.55	702	527
Usulatan	0.44	0.55	984	820
San Miguel	0.57	0.60	772	594
Morazan	0.30	0.71	509	423
La Union	0.43	0.76	650	577

Source: Segundo Censo Agropecuario, 1961

SPECIFIC CHARACTERISTICS: A CASE STUDY

The communities chosen for the analysis are located in the Valley of Siria, Republic of Honduras, and the material can be found in the 1971 Annual Report of the Programa de Desarrollo de Granos Básicos - Proyecto Francisco Morazan, sponsored by the Banco Central and Banco Nacional de Fomento in Honduras (5).

The valley is located between 16°31′ and 16°13′ North latitude and 4°77′ and 4°98′ West longitude. The land is 500 m above sea level with a minimum absolute temperature of 8.8°C and a medium annual rainfall of 1,100 mm falling mainly between May and October; soils are alluvial deposits with mica schists, and volcanic alluvial soils.

Table 3. Number and size of farms producing bean (seeded alone) in different seasons, and production

Size of farms (ha)	No. of farms	Tilled area (ha)					Production (kg)			
		Gross	Net	May	Sept.	Other Season	Total	May	Sept.	Other Season
Less than 1	12.127	2,771.0	1,595.7	964.7	1,748.5	57.8	2,015.439	691,853	1,268,639	54,947
From 1 to 1.99	10,505	3,800.9	2,847.4	1,648.8	2,107.2	44.9	2,482,528	1,071,373	1,384,550	26,605
From 2 to 2.99	4,906	2,723.2	2,069.7	1,285.2	1,378.0	60.0	1,685,166	766,182	885,110	33.874
From 3 to 3.99	2,194	1,398.0	1,166.1	726.3	649.6	22.1	822,242	409,024	389.150	24,068
From 4 to 4.99	1,714	1,227.8	1,010.3	623.7	589.9	14.2	712,568	351,650	348,733	12,185
From 5 to 9.99	3,225	2,528.8	2,064.4	1,320.2	1,169.5	39.1	1,507.050	767,857	705,074	34,119
From 10 to 19.99	1,821	1,721.3	1,373.3	878.6	817.9	24.8	1,084,948	561,656	510,112	13,180
From 20 to 49.99	1,220	1,370.5	1,132.4	725,8	624,6	20.1	902.127	468.075	412,941	21,111
From 50 to 99.99	395	806.5	572,5	403,4	350.5	52.6	615,436	274,245	270,967	70,224
From 100 to 199.99	200	436.9	328.4	184.7	238.9	13.3	313,815	133,653	170,355	9,807
From 200 to 499.99	133	602.9	408.6	160.0	441.6	1.3	452,695	133,319	318,824	552
From 500 to 999.99	50	337.1	260.4	170.9	138.3	27.9	239.240	112,571	117,285	9,384
From 1,000 to 2,499.99	24	484.0	271.2	230.3	238.4	15.3	390.016	155,094	217,442	17,480
From 2,500 up	9	269.4	251.9	164.4	105,0	–	260,867	203,367	57,500	–
Total	38,523	20,478.3	15,352.3	9,487.0	10,597.9	393.4	13,484.137	6,099,919	7,056,682	327,536

Table 4. Synthesis of the size categories of bean producing farms in El Salvador

Size categories	Production units		Gross area		Production	
	Number	%	Number	%	Number	
Less than 9.99 ha.	34,671	90.00	10,751	70.00	9,224.993	68.41
More than 10.00 ha.	3,852	10.00	4,601	30.00	4,259,144	31.59
Total	38,523	100.00	15,352	100.00	13,484.137	100.00

The valley presents a varied topography. Next to flat areas exist others rather steep. Within short distances altitude changes from 544 m above sea level at the bottom of the valley, to 600 m above at the mountain slopes; however, the valley has always been considered as a bean producing region.

Land tenure and size of plots. Sixty-eight percent of the farmers are small landowners, the rest are "ocupantes." Of all the farms surveyed, 43 percent have a size of less than five manzanas, 32 percent are between 5 and 10 manzanas, and 24 percent are more than 10 manzanas. Sixty-six percent of the farmers have just one plot and 34 percent have two or more plots cultivated with beans. The average size of the farms is eight manzanas, out of which four are cultivated with corn, two with beans and the remaining two are kept for other uses.

Sowing season. Twenty-five percent of the farmers use the oarly varieties of bean while 51 percent use the late varieties. The latter ones are more popular because they are harvested during the dry season.

Production, use and costs. Two manzanas yield 20 quintals, out of which 67 percent is sold, leaving the remaining 33 percent for use at home. The total costs per manzana is 168.00 lempiras.

Income of a bean producer. The valley farmer's income could be itemized as follows: 380 lempiras from corn sales, 249 lempiras from bean sales, 568 lempiras from other agricultural items, 954 lempiras from non agricultural activities, and 424 lempiras from the consumption of agricultural products. Usually the farm they work is not enough to provide the farmers and their families with sufficient income and sustenance, therefore, they must get a good portion of their income from non agricultural sources.

Technology and credit. Among bean producers, the technological level is rather uneven. Sixty per cent of the seeds used are of domestic strains; 90 percent of the farmers do not fertilize their crops but 70 percent employ some kind of pest control. Only 20 percent of the farmers benefit from agricultural credit. This service is not readily available since the requisites to grant it are rather strict at this low level, which renders credit almost unattainable for those badly needing economic assistance.

Marketing of products. Marketing is in the hands of intermediaries. The farmers get news concerning the marketing of their products through traders, truck drivers or buyers in 55 percent of the cases, and through friends and neighbors in 31 percent of the cases. For lack of resources, storage facilities are scarce at farm level, and when they do exist, are rather coarse. Nevertheless, whenever the situation permits, farmers sell just a little at a time; in other words, beans are savings in kind.

Entranceway for technological knowledge. The group as a whole is not easily reached. Half of the people do not know how to read or write. In 73 percent of the cases friends and neighbors are the main source of information. Only 1.5 percent of the people, or less, have access to booklets, radio and newspaper. In 18 percent of the cases fertilizers were introduced by employees of banks and commercial houses.

General living conditions. School attendance in youngsters less than 15 years of age is 20 percent. The average number of members in a family is seven, five of whom do not attend school. Eighty percent of the houses lack electricity, 70 percent lack potable water, and 73 percent have earthen floors. Generally, farmers are aware of their problems; their opinions range as follows: 32 percent think of their low income as responsible for their problems, 41 percent lack of technical assistance, 11 percent drouth, 12 percent lack of land, 2 percent unavailability of medical assistance, and the remaining 2 percent mentioned other factors. Concerning the needs of their community, they give top priority to electricity, potable water and roads, and second priority to schools, more land and a sewage system.

The common people, whose environment was fairly if briefly presented, will be the ones benefited by the investigation, education and extension efforts made in a program trying to improve bean production.

SYNTHESIS OF CHARACTERISTICS OF BEAN PRODUCTION DUE TO THE SOCIO-ECONOMIC ENVIRONMENT

The characteristics of the bean production units could be summed up as follows:

Abundant and usually not close together.

Prevailing small holdings (minifunds) or the like.

Not definitely oriented towards a marketing economy.

Lack of funds, either own or from easily available public or private sources.

Crude technological levels.

Lack of information and/or of real knowledge of products or input market.

Clientele usually not accustomed to having contact with technical assistance.

Trading systems used are simple, fitted to the exchange of small parcels of products.

A defective network of community services.

Table 2. Average farm size and yield of bean in El Salvador

Departments	Size of		Yield (kg/ha)	
	Solely (ha)	Associated (ha)	Solely (ha)	Associated (ha)
Ahuachapan	0.22	0.68	1,256	807
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SPECIFIC CHARACTERISTICS: A CASE STUDY

The communities chosen for the analysis are located in the Valley of Siria, Republic of Honduras, and the material can be found in the 1971 Annual Report of the Programa de Desarrollo de Granos Básicos - Proyecto Francisco Morazán, sponsored by the Banco Central and Banco Nacional de Fomento in Honduras (5).

The valley is located between 16°31′ and 16°13′ North latitude and 4°77′ and 4°98′ West longitude. The land is 500 m above sea level with a minimum absolute temperature of 8.8°C and a medium annual rainfall of 1,100 mm falling mainly between May and October; soils are alluvial deposits with mica schists, and volcanic alluvial soils.

Hand labor could be recorded as the equivalent day wages put into seeding, cutting the weeds and turning them over, and into pulling, pole-threshing, and cleaning by blowing. This system of bean production employs a minimum of inputs and the greatest amount of hand labor goes into the last stages of production.

Physical and economical productivity

The physical and economical productivity of this system are not well known. However, studies so far made show that it gives very low economic as well as physical yield.

Duplan and Aguirre (2) studied the physical and economical yields of this system in Costa Rica, the results are presented in Table 5. Although at first the covered system was the one employed, it showed an interesting phenomenon. As the crop progressed unsatisfactorily the farmers fertilized the land, spread insecticides and tried to control slugs.

Several times it was pointed out to farmers that this late effort to introduce technology was useless, because not only was it too late a stage to start, but the fertilizer employed exceeded that used for coffee, the quantities of pesticides were

Table 5. Physical and economical productivity of covered bean in Costa Rica

Itemized expenditures	Colones
Hand labor	157.69
Seed	71.44
Manure	21.25
Slugicide	4.72
Pesticide	3.36
Bags	4.10
Other items	65.70
Total	328.26
Physical yield (quintals/manzana)	5.22
Gross income	382.20
Gross margin	54.94
Cost per quintal	62.88

too low to eliminate the insects, and the chemicals used for slug control did not include the poison, just the bait and the paralyzing agent. Adding all this to the way the seeding was done at the beginning, the result was practically doomed to a low level of productivity.

The situation described above is easily found in the traditional bean production systems. When poor farmers see their crops heading directly towards disaster, they try to curb failure with actions which will never avoid it, but which show that they have some idea of what to do when a problem arises.

Implications of the System

The system described is framed within one of the lowest economic and socio-cultural levels in Latin America. When the producers own the land they work, usually the plot is so small that they do not have capital, the only investment being the land and the hut where they live and keep their working utensils. As the lands usually employed by bean producers are steep and rather eroded, growing annual crops only increases the erosion problems.

In the frequent case of the producers not being owners, they act as workers at a farm and are partly paid by being permitted to use some land for the time needed to harvest one crop. In this case the plot used varies each year, because the owner wants his plot clean to sow grass, usually the year after.

The purpose of the production is self-subsistence, and it does not matter if the producer is landowner, hand worker or a combination of both. If there is any surplus, it is taken to the market in small parcels which are sold to truck drivers or in the local markets, the quantities never being enough to influence the marketing channels or the prices.

Technical assistance at this level is practically unknown as such. Such technology as these producers know reaches them through their vicinity to large farms where technology is applied; they often work on such farms and have the opportunity to apply said technological practices.

Agricultural credit as such is also unknown to this group, the resources employed being hand labor and seed. The first usually does not require expenditures and the second generally is kept from the previous harvest. In the case mentioned in Table 5, the expenditures are actually 35.43 colones spent on fertilizer, pesticides, chemicals for slug control, and bags. The other costs at this low technological level do not actually occur. The experience shows that as long as the efforts they make cover the necessities of grain consumption for the family, leaving a surplus to pay for cash expenses, farmers consider the crop as a physically and economically productive activity.

The main reason for the persistence of this system is that the farmer does not incur debts. In case of a failure, the farmer himself "pays off his debt" through his hunger and his family s.

Beans solely

The production system of beans "sown alone" is, as its name implies, a productive effort with a goal, and not an almost accidental means of obtaining beans as in the case of covered beans. In this system of beans sown alone, the four basic phases of cultivation can be distinguished: clearing and preparation, seeding and fertilization, tending, harvesting.

The basic identifiable variations are: (1) beans solely- manual, (2) beans solely animal traction, (3) beans solely with a certain amount of mechanization, and (4) beans solely with some mechanization and irrigation - the latter just a special variation of the others.

The system is always alike in the beginning and the differences appear according to the way in which the activities occur, and according to the number of such activities within each one of the four basic phases of cultivation.

Beans Solely - Manual

Description. In this variation the first step is clearing the plot with the machete. The weeds can be heaped or not, after they are thoroughly dry they are burned. Then the plot is levelled and thoroughly cleaned, completely by hand, and there is no soil preparation as such.

Seeding is usually by hand, with the aid of a spike to open holes for the seed. Even if there is actually no formal preparation, a certain order is kept in the seeding process.

The maintenance is simple and consists only of cleaning with the machete. The harvest exhibits the known stages: pulling, pole-threshing, and cleaning by blowing. The only inputs are seeds and bags to store the beans.

Seventy percent of the seed used is of native strains, bought in the local markets, or kept from the previous harvest, in which case a more or less good appearance is the criterion of selection.

Physical and economic productivity. Studies of physical and economic productivity of this system are somewhat less scarce, perhaps due to the fact that this is the first regular effort to produce beans in a technological way.

Table 6 shows the results obtained in Copan, Honduras, during 1966-67. Ninety-six pounds per manzana of native seed were used and no technological inputs were employed. From a physical point of view the results were not discouraging. The economic analysis is not comparable due to the difference of time and of economic conditions among different countries, nevertheless, it affords interesting points of reference.

Beans Solely - Animal Traction

Description. This variation differs from the preceding mainly in the preparation stage. After the weeds are burnt, and the plot is completely clean, the land is plowed, harrowed and furrowed. The rest of the operation is exactly as in the variation explained above, and there is no input except the farmer's hand labor until the crop is ready to be harvested.

Physical and economic productivity. Duplan and Aguirre (2) showed that by employing a certain amount of technology this system gives an average yield of

Table 6. Physical and economical productivity of bean sown alone-manual
Copan, Honduras 1966 - 1967

Itemized expenditures	Day wages	Lempiras
Land praparation	23.96	43.15
Seeding	15.71	14.15
Tending	22.55	20.30
Harvest	24.85	23.30
Supplies (96 lb. seeds)		13.55
Rent		10.00
Total		124.45
Yield (qq./manzana)	9.88	
Gross income		118.56
Gross margin		5.89
Cost per quintal		12.59

Source: Honduras, Secretaría de Recursos Naturales, Servicio Cooperativo de Desarrollo Rural. Costos de Producción. Sección de Economía Agrícola. Tegucigalpa. 1968. p.11

11.41 quintals per manzana, a gross margin per manzana of 150.47 colones with a cost per quintal of 60.95 colones (See Table 7).

A preliminary study of this system was made in El Salvador for several technological levels by Oviedo and Aguirre (1, 3). The results presented in Table 8 show a higher physical and economic yield when technology is used.

Beans Solely - Small Amount of Mechanization

Description. This variation is like the two described above, the only difference being the use of a tractor during preparation of the land, especially when plowing. The rest of the operation is with the help of oxen, complemented with the activities already described.

Physical and economic productivity. Studies in Copan, Honduras, in 1966 show the physical and economic productivity of this system; results are presented in Table 9. For the plowing of the land a tractor was employed, the cleaning of the land and seeding were done by hand, and oxen were used to make the furrows. In this study no technological inputs were employed, and all seed used was of native strains, 100 pounds per manzana.

Other Variants of the Same System

Within this "solely beans" system there are variants. Important aspects of these are not included in this paper due to lack of information. The variants are animal traction with irrigation, and with a small amount of mechanization and irrigation.

Table 7. Physical and economical productivity of bean sown alone-animal traction, in Costa Rica

Itemized expenses	Colones
Hand labor	366.61
Seed	90.12
Manure	109.28
Slugicide	12.61
Insecticide	10.04
Fungicide	1.96
Herbicide	21.14
Bags	7.20
Other items	76.53
Total	695.49
Yield (quintals/manzana)	11.41
Gross income	845.96
Gross margin	150.47
Cost per quintal	60.95

Basically, the system is the same, with the one exception of irrigation. Personal observations made of cultivations in Honduras and El Salvador where no technological inputs were used (save irrigation) showed that physical yield has not surpassed 15 quintals per manzana.

Implications of the System

This group of systems exhibits a partial use of technology, characterized by improvements in certain activities, usually those related to inputs easily available, i.e. oxen and hand labor. Usually no one invests in machinery to cultivate beans, therefore, only where machinery is easily rented does one see it in bean fields. Although this system described above follows the pattern of traditionalism and lack of economic resources characterizing bean production, beans produced within this system are not only for family use but for commercial purposes as well. In case the proper technological and socio-economic environment could be developed, the producers could become open to a reasonable improvement effort.

Beans associated with maize

Description

As the name implies, this system consists of a simultaneous cultivation on the same plot of beans and maize. This system requires good preparation and cleaning

Table 8. Physical and economical productivity of beans sown alone - animal traction, in El Salvador, 1971

Stages of cultivation	Technified		Traditional	
	Colones/mz	%	Colones/mz	%
Cleaning and preparation	18.71	9.55	23.20	17.52
Seeding and fertilization	16.41	8.39	6.22	4.69
Tending	19.13	9.77	9.64	7.28
Harvesting	29.68	15.16	21.92	16.56
Inputs	66.94	34.19	33.73	25.48
Transport	6.01	3.07	6.50	4.92
Rent	38.90	19.87	31.16	23.55
Operational costs per manzana	195.78	100.00	132.37	100.00
Yield	14.69	–	8.83	–
Income per manzana	365.58	–	242.26	–
Gross margin per manzana	169.80	–	109.89	–
Costs per quintal	13.32	–	14.99	–

of the land, which are done when seeding the maize, usually by means of animal traction.

Due to this overlapping of crops there is a series of activities benefiting both crops, and thus it is hard to itemize expenditures, especially where hand labor is concerned. Only the expenses of inputs directly attributable to each crop can be calculated without much difficulty.

Bean varieties employed in this system depend upon the distance between maize and beans. Common distances are two, four, or six rows of beans to one of maize. According to the distance, vine or bush varieties of bean are employed.

Physical and Economic Productivity

In this system both crops are so interrelated that it is next to impossible to itemize expenses. In several case studies made in El Salvador by Oviedo and Aguirre (analysis of several special cases exhibiting desirable characteristics) an attempt was made to estimate the economic productivity, based on the farmers' opinions concerning expense distribution. The results of such analysis are presented in Table 10. In this group the average size of plots was 1.5 manzanas and the highest production obtained was two quintals.

Table 9. Physical and economical productivity of beans seeded alone a small amount of mechanization. 1966. Copan, Honduras.

Itemized expenses	Day wages	Lempiras
Cleaning and preparation of land	35	74.00
Seeding	6	9.00
Tending	20	30.00
Harvesting	21	24.50
Unputs (100 pounds)		15.00
Rent		10.00
Total		162.50
Yield (quintals/ha)	20	
Gross income		220.00
Gross margin		57.50
Cost per quintal		8.12

Source: Honduras. Secretaría de Recursos Naturales. Servicio Cooperativo de Desarrollo Rural. Costos de Producción. Sección de Economía Agrícola. Tegucigalpa. 1968. p. 11

Implications of the System

Knowing as we do the limitation of land and cash resources handicapping bean producers, the fact that in this system both are employed intensively is a great advantage. On long range, farmers are benefited by this intensive use of resources.

Bean varieties employed depend upon how many rows of beans are between each row of maize. The system most often used is 2 and 1, and then 4 and 1. Since both crops grow simultaneously, it is important to investigate the whole cycle, not only from the socio-economic viewpoint but from the agricultural as well. Methods to evaluate bean - maize relations integrally should be developed.

Intercalated beans

Description

Perhaps this system of bean production is one of the most widespread. This system differs from the associated system in that beans are sown at the end of the maize production cycle.

Table 10. Physical and economical productivity of beans associated to maize, in El Salvador

Itemized expenditures	Day wages	Colones
Cleaning and preparation		
Cleaning	5	19.25
Plowing	5	19.25
Harrowing	2	7.50
Furrowing	1	4.50
Seeding and fertilization		
Seeding	3	7.75
Fertilization	1	3.00
Crop tending		
Cleaning	9	19.50
Harvest		
Pulling	6	12.75
Pole - threshing and blowing	5	11.25
Inputs		
Seed	–	11.00
Fertilizers	–	22.00
Transport	–	3.00
Rent	–	27.00
Total		148.50
Yield (quintals/manzana)	12	
Gross income		270.00
Gross margin		121.50
Cost per quintal		12.37

After the maize finishes its productive cycle, as many leaves as possible are removed, and the upper part of the plant is bent downwards, taking care that all the ears remain in the upper part.

The purpose is to make the plant dry as fast as possible, leaving the ears in an inverted position so as not to let water penetrate and to permit moisture to drain faster. In this way the crop is protected and stored in the plant at the same time.

The plot is then cleaned, farmers taking the opportunity to check the rows and fix those which are badly off. From now on the process for beans is just as in the other systems; seeding and sometimes fertilization, tending, and harvesting.

Physical and Economic Productivity

This system of bean production is one of the most commonly practiced. However, in calculating the economic productivity a difficulty lies in the fact that bending and removing the maize leaves are accounted for as bean costs.

It has been decided to include the costs of these operations in this paper, because costs as well as results are considered an integral part of a production process no matter whether they are necessary for maize production. Costs of the operations are included as components of total hand labor costs in Table 11.

This system has been compared to several of the most common bean producing systems, and the results obtained in Costa Rica (2), which are presented in Table 12, show that it is the one with the largest physical and economical productivity of all the systems studied.

Implications of the System

Experience in the field has given a background to this system which is important to consider. Many of the farmers interviewed think that vine varieties, being held upright and not close to the earth, are less susceptible to pests and diseases.

Table 11. Physical and economical productivity of intercalated beans

Itemized expenditures	Colones
Hand labor	325.28
Seed	70.85
Manure	102.36
Slugicide	8.40
Pesticide	8.54
Fungicide	3.54
Herbicide	13.71
Bags	8.94
Other items	60.34
Total	661.96
Yield (quintals/manzana)	13.13
Gross income	971.94
Gross margin	309.98
Cost per quintal	50.41

Table 12. Physical and economical productivity of four bean production systems in Costa Rica

Characteristics	Production systems			
	Intercalated	Sole	Sole-animal traction	Covered
Total variable expenses (permz)	661.96	696.95	695.49	328.26
Total expenses (per manzana)	843.47	892.43	848.63	439.72
Average yield (quintals/manzana)	13.13	12.31	11.41	5.22
Quintals to cover variable expenses.	9.01	9.48	9.47	4.47
Profit margin (quintals/manzana)	4.12	2.83	1.94	0.75
Quintals to cover total expenses (mz)	11.48	12.14	11.43	5.98
Profit margin (quintals/manzana)	1.65	0.17	−0.02	− 0.76

Also, it seems that since they remain longer in the field, these species have undergone a natural selection; the farmers think that if they survive it must be because they are really good. On the other hand, it is possible that in intercalated planting overlapping of benefits results from the care given to maize. Even if the above is only a product of field observations, results seem to confirm it.

It is important to have a better understanding of the technical agronomical, and socio-economic cycle in the relation beans-maize, from a technological viewpoint.

RELATIVE IMPORTANCE OF DIFFERENT BEAN PRODUCTION SYSTEMS

The diversity among the various bean production systems leads one to try to group and classify them. They are separated into two large groups: beans solely, and associated and intercalated beans. Establishing hierarchies among these systems is not so easily done.

The basic criterion to make such groupings is the difference between varieties employed in each system: to grow beans solely, farmers employ erect, shrubby or bushy types. In case beans are grown intercalated or associated to maize, varieties employed are vine or semi-vine, with their own technical and socio-economic characteristics and problems.

Table 13. Relative importance of both groups of bean production systems in two Central American countries

Countries	Percentajes of relative importance			
	Solely		Associated	
	Area	Production	Area	Production
El Salvador *	61	50	39	50
Guatemala **	72	49	28	51

Source: * Censo Agropecuario 1961 – ** Censo Agropecuario 1964

Analyzing the data corresponding to the indicators of relative importance, such as production and area, in two neighboring Central American countries, El Salvador and Guatemala, it is evident that both groups of systems are of equal importance. Thus, it seems logical to try to improve both. (See Table 13).

Trying to decide on the relative importance, it is evident that there is not a definite tendency and that both systems must be considered together with the implications of the different approaches in extension, investigation, technical assistance, and development, all considered on short, medium, and long term.

Accepting the fact that working with both groups is essential, one wonders if any improvement is possible when trying to introduce technological changes, under such incipient and rather problematic conditions. In the next pages we will examine the possibilities of improvement.

IMPACT OF NEW TECHNOLOGY ON A BEAN PRODUCTION SYSTEM

During the 1950's, the Central American countries and Panama started a Central American Cooperative Program for the Improvement of Food Crops (Programa Cooperativo Centroamericano para el Mejoramiento de los Cultivos Alimenticios - PCCMCA). One of the first crops considered was beans. The effort was intended as a device through which the physical-biological problems of the crop could be solved in a systematic way, in common for all the countries of the Isthmus.

The program faced early difficulties, but can now exhibit encouraging results, especially in phytopathology, entomology and plant breeding. This initial effort, which is paying off now, served to create a far-reaching technical base. Assistance was received from the Inter-American Institute of Agricultural Sciences of the OEA (IICA), which coordinated the work.

In 1969, the Government of El Salvador decided to create a National Program of Protection and Promotion of Bean Cultivation (Programa Nacional de Defensa y Promoción del Cultivo del Fríjol). This program was based on the technical efforts of PCCMA, and its goal was to help bean producers to produce more beans.

This program was to turn El Salvador from a bean importing country into a self-supplying one. To reach this, ever since the beginning the program had on

Table 14. Economic results of bean production for two levels of technology

Basic expenditures	Production systems			
	Technified		Traditional	
	Day wages	Colones	Day wages	Colones
Cleaning and preparation				
Leafe removial and bending of stalk (maize)	23.08	14.40	20.64	12.94
First cleaning	22.71	28.72	18.30	22.51
Other items	3.19	3.76	6.19	12.62
Total	48.98	46.88	45.13	48.07
Seeding and fertilization				
Seeding	21.37	31.03	19.35	37.03
Fertilization	8.20	13.27	–	–
Total	29.57	44.30	19.35	37.03
Tending				
First cleaning	20.51	32.95	18.46	34.95
Second cleaning	12.15	12.87	–	–
Pesticides, 1st. application	1.22	2.50	–	–
Pesticides, 2nd. application	1.46	2.62	–	–
Pesticides, 3rd. application	1.29	2.22	–	–
Slugicide	0.03	0.36	–	–
Fungicide	0.67	0.70	–	–
Total	37.33	54.22	18.46	34.95
Harvesting				
Pulling	21.00	33.93	21.77	42.87
Pole-threshing and blowing	15.38	26.17	15.11	20.86
Transport	–	7.31	–	8.68
Storage	–	3.27	–	–
Total	36.38	70.68	36.88	72.41
Other expenses				
Rent	–	68.01	–	73.87
Transport of inputs	–	4.96	–	–
Total	–	72.97	–	73.87
Hand labor and other items (Total expenditures/ha)	152.26	289.05	119.82	266.33

Table 14 (Cont.)

Basic expenditures	Production systems			
	Technified		Traditional	
	Pounds	Colones	Pounds	Colones
Input expenses Seed	136.59	36.71	135.78	40.30
Fertilizers				
Nitrogen	63.12	–	–	–
Phosphorus	129.61	–	–	–
Potassium	34.28	–	–	–
Total	–	37.81	–	–
Pesticides	87.66	15.20	–	–
Fungicides	17.00	4.33	–	–
Slugicides				
Bait	23.80	1.42	–	–
Poison	0.71	0.89	–	–
Total	–	96.36	–	
Hand labor, inputs and other items (cost/ha.)	–	385.41	–	306.63
Quintals/ha.	37.60		18.09	
Cost/quintal		11.82		16.95
Total input/ha		507.66		350.60
Cost/ha		385.41		306.63
Gross margin/ha		122.25		43.97

its side the basic ingredients of every improvement program: decision and political assistance, reflected in physical, human, and financial resources to see the program through. The problem was to make field technology available to people who so far had known little if any.

A group of two investigators, two supervisors, and nine promoters was first created. Also, assistance of personnel from the National Center of Farming Technology (Centro Nacional de Tecnología Agropecuaria - CENTA) of El Salvador was available in specific areas.

The idea was to make available to farmers certain practices useful in the field and to bring into the office field problems needing action.

The promoters were trained in special courses in the technical and economic aspects of the crop. They were to assist farmers to keep a record of incomes and expenditures. Promoters were to visit farmers once a week, checking the progress of the crop, giving advice and also helping with the records kept by the farmers.

After harvesting the crop the records are picked up to tabulate the data. Each farmer gets a copy of preliminary group results, as well as those of his own farm. The idea, though not new, has turned out well, since it allows giving advice in technical as well as in rural administration aspects, showing the results to the farmers and letting the promoters know the economic effects of the practices they recommend. This enables them to emphasize those practices more forcefully in the future. Promoters only work in one crop, covering the areas that exhibit both present production and production potential.

Results are presented in Table 14. The figures correspond to the harvest from August to December, 1971. The system employed was that of beans intercalated with corn, in the Departments of Santa Ana, Ahuachapan, and northern Sonsonate, in El Salvador.

Also in Table 14 appear in detail the results of both technological levels. The basic differences lie in seeding, fertilizing, and tending the crop, in the use of technological inputs, and in hand labor needed to apply these inputs.

Physical productivity was 32.60 quintals and economic productivity was 507.66 colones in the technified system, while in the traditional system there were 18.09 quintals per ha and 350.60 colones, respectively. Considering expenses together with productivity, we get more significant figures: cost per quintal 11.82 colones and gross margin per ha 122.25 colones in the technified system, while in the traditional system the cost per quintal is 16.95 colones and the gross margin is 43.97 colones. Evidently the effort made to technify bean production rendered good results.

We must add a brief profit-cost analysis to these results. The procedure is simple: between both systems there is a difference of 32.44 day wages at 2.04 colones each, for a total or 66.17 colones; 59.65 colones spent in simple technological inputs as fertilizers, slugicides, pesticides, and fungicides, plus 3.27 colones for storage expenses and 4.96 colones for transport of supplies. Adding these figures we obtain an increment of 134.05 colones on the total cost. Now, the increment in unit yield attributable to that increased cost is 14.51 quintals, which sold at an average price of 17.47 colones to give a total increased profit of 253.48 colones and a relation profit-to-cost of 1.89 colones.

An interesting phenomenon is the type of technology and the way to introduce it. Table 15 shows the number of extra days wages needed when a better technology - no matter how simple it is - was introduced. A total of 32.44 extra days wages were paid at 2.04 colones each for a total of 66.17 colones. Seen from this point of view, day wages are a kind of technological investment. Hand labor is an abundant form of capital, and there is little or no problem to obtain it.

As evident in this case, a better technology does not necessarily mean a high mechanization or substantital investment of capital, which would be very hard to get due to the low socio-economic level of bean producers.

The results presented were obtained through a technification process within easy reach of the common bean producer; it was based on the following:

A better and more frequent use of the practices already carried out by the farmers;

Table 15. Use of hand labor in bean production systems

Itemized use of hand labor	Production systems		Difference*
	Technified*	Traditional*	
Cleaning and preparation of land	48.98	45.13	+3.85
Seeding and fertilization	29.57	19.35	+10.22
Tending of crop	37.33	18.46	+18.87
Harvesting expenses	36.38	36.88	−0.50
Total	152.26	119.82	32.44

* Day wages

The systematization of said practices and the use of technological supplies within access of the farmers;

A maximum use of hand labor, the most abundant resource; fixing variable capital inputs to be used up to the best possible technical limit and up to the actual economic possibilities of the farmers.

It should be pointed out that the results mentioned were obtained solely by beans of native strains, not one of the farmers having employed improved seeds. If the improvement of cultural practices along with the use of inputs are capable of raising production levels as shown, it is possible to speculate on the possibility that, while plant breeders obtain better genetic material, much could be gained from a short-term program to augment production based on better agricultural practices.

The most interesting point about this program is that is shows how a well oriented effort, not requiring any change from the farmers in their socio-cultural patterns, can get encouraging results on a short-term basis. On the other hand, this process, even though not too ambitious or significant, prepares the way to introduce higher levels of technification in a systematic way and on solid and realistic bases.

PROBLEMS AND PERSPECTIVES

The comments and results presented up to this point make necessary an analysis of the problems, perspectives and implications of the various bean production systems.

Doubtless, bean is what could be called a socio-economic crop, in other words, it is a crop where the family's consumption of beans weighs as much in the production decision as the prevailing conditions weigh in the factors affecting yield levels. This is the first element to be considered when trying to understand the persistence of such production systems with their low technological and economic efficiency.

While other crops have undergone a concentration into productive localities, beans have not. The above described socio-economic characteristic of bean serves partly to explain the diversity of conditions under which beans are grown, and it is possible that because of this property people have lost sight of the main decision to be made: the need of zoning the crop to delimit the areas where it has an initial physical-biological advantage. The small size of the productive units should be added to the complex problem of dispersion.

Besides the diversity of ecological conditions under which beans are produced, due to the socio-economic characteritics of the crop, bean production has been mainly in the hands of small landowners and farm workes without land.

This means that the main producing group has an undesirable economic situation concerning capital, land, and enterprising capacity. Trying to provide those resources on an individual basis solves nothing, because the human, organizational, and economic resources to absorb them are seldom available. Besides, experience shows how hard it is to get productive and economic efficiency on a long term basis, without applying the concept of scale economy in production, credit and marketing, as well as providing supporting services.

The foregoing leads to the idea that the best way to take new technology to this clientele would be to select the potential areas and then group the farmers in order to provide them with capital, get farms large enough to be economically productive, provide technical assistance as well as marketing and support facilities. All this should be done in such a way that the limited economic and human resources that countries and farmers have will be employed in the best way.

Another factor which helps to maintain the present systems is the almost marginal standards of living of bean producers. Socio-culturally this is a group where any change offered must be foolproof, otherwise they will not accept it. Fear of crop failure is their greatest misgiving since it means hunger.

Also, considering the standard of living in these farming communities, it would not be strange that even if, through a new technology, an increase of physical productivity were possible, the economic benefits were channelled toward other sectors out of the farmers' control. It is common that due to the inflexibility of the marketing and credit systems, benefits resulting from production increases go to a few who control the necessities. Consequently, there could be the proper technological incentives for improvement of the bean producers' lot, but nullified by these other aspects.

Another aspect related to the adoption of new technology at the community level lies in the infrastructure of agricultural services, such as the provision of agricultural supplies of a technological type; i.e. improved seeds, fertilizers, pesticides, fungicides, herbicides, machinery, etc.

It is common that farmers, even knowing the advantages of the use of such inputs, do not use them, either because they do not have the money, or they are not given credit. Sometimes, even if they have the money, the supplies are not within easy reach, eliminating the incentives.

These problems have created the environmental conditions allowing such production systems to persist, however archaic. Considering the limiting factors, people do not have many alternatives.

All these facts have created a socio-economic marginal mentality toward beans. Producers do not think of beans as either a cash crop or a crop adapted for cultivation in large scale, and if anyone hopes to get out of his marginal situation it is not by growing beans.

Everyone concerned shares blame for this socio-economic marginal mentality. People in charge of technical assitance see bean producers as a difficult group either from the economic, social or cultural viewpoint. Researchers see bean as a difficult crop, easily affected by diseases and pests, and as bean producers are neither politically nor economically strong, researchers are under no pressure, so they give their time to other activities, generally easier to manage and more profitable. Besides, official and private credit agencies are not interested in financing bean production because they consider it a risky enterprise. Traders in beans do not bother trying to improve the system, probably feeling that they can easily deal with producers of small parcels.

Food consumption patterns of the people help to create confusion. Normally, in Latin America countries favoring red beans can be easily differentiated from those favoring black beans. Even though much has been said about well oriented campaigns bringing about mass changes in people's tastes, so far nothing has been accomplished.

Those different tastes mean a price differential large enough to orient production toward a given color, and to make researchers keep it in mind when choosing varieties for a given country. Preferences in size and brilliance of the grain must also be kept in mind.

Another aspect on bean production which should be considered is the relation maize-bean. Although they are so often grown together, and any action taken concerning one crop influences the other, little is known about their interrelations. The socio-economic effect of those interrelations is not well known, notwithstanding that between 30 and 50 percent of all beans produced are grown together with maize. Exploring these interrelations is a challenge for all who are trying to improve bean production.

The problem is rather complex, and too much optimism could arise from successes obtained in rice. It is true that certain characteristics of bean producers are similar to those of rice producers, but there is a great difference between the crops. In Asia exists a rice culture, while in Latin America bean is only a part of a competitive crop complex.

The concept "rice culture" should be amplified. In Asia all the social, economic, political, and cultural mechanisms are organized around and in benefit of production, marketing and consumption of rice. Any change rapidly penetrates this mechanism.

In Latin America there is no such organization built around beans; therefore, the system's reaction to introduced changes is not as swift (if any at all occurs) as in the case of rice. It is obvious that any action taken concerning maize-bean intercropping must be an integrated one. This is only possible with assistance and political decision coming from high levels of government, influencing all parts of the mechanism wherever and whenever necessary.

Even though the problems affecting bean production are many and complex, results so far obtained in El Salvador make us feel optimistic, provided that the need of increasing bean production is regarded as an interdisciplinary problem, needing an integral approach from the physical-biological as well as from the socio-economic viewpoint.

We firmly believe that a sharp definition of problems as well as their permanent solutions will only result from a combined effort made by specialists from various disciplines. Only then it will be possible to improve those production systems and the physical-biological and socio-economical environment which have caused them to persist for centures.

GENERAL RECOMMENDATIONS

It is hard to give recommendations on how to orient training, research and technical assistance to improve bean production in Latin America, when there is still so much to learn. The following recommendations are products both of experience as well as of research so far and represent rather personal viewpoints. They are divided into groups.

General

The approach in production development must be from an integral viewpoint, including physical-biological, and socio-economic aspects, the efforts on training, research, and extension keeping the same emphasis.

Investigation

(1) High potential production areas should be defined by means of regional and zonal stratification to make use of their ecological advantages.

(2) Consumption characteristics such as color, size, and brilliance of the grain should be studied in order to achieve acceptable varieties through regional plant breeding trials.

(3) The maize-bean intercropping cycle should be studied from the physic-biologic and socio-economic viewpoints, considering intercropping as a real phenomenon and as important as those systems seeding solely beans.

(4) The physical-biological research should stress "technological packets" and not just certain practices, seeds, or groups of practices.

(5) Due importance should be given to the selection of high yielding native varieties, checking their reaction to a complete set of agronomic practices. This could attain substantial production increases on a short term basis, giving time for research work to follow up.

(6) The socio-economic characteristics of production, such as: profitability, credit, marketing, and attitudes towards change should be investigated in order to design better strategies for improvement programs, and to find the most effective ways to transmit new findings.

Training

(1) Courses for the formation of specialists in production stimulation should be prepared.

(2) The type of training given at these courses would both have agronomic and socio-economic emphasis; agronomic, with an introduction to bean technology; socio-economic, toward the preparation of integral projects for promotion of the crop.

(3) Personnel for these courses would be selected preferably among executives and supervisors of bean-promotion programs in each country.

(4) Massive dissemination of the results gathered in all the fields concerning the crop should be made, not only of results from international research centers but from local centers as well. Foundations could sponsor publication of selected technical papers produced in local centers, avoiding loss of high quality papers through lack of funds.

(5) Once the critical issues are identified, the technical level of local professionals should be raised through intensive courses in selected priority fields.

Technical Assistance

(1) Assist the countries to perform diagnostic studies to identify problems blocking production.

(2) Help the countries identify problems blocking production and assist them in programming and conducting action to eliminate problems.

(3) Help the countries in the formation of teams of specialists able to work as a group to achieve specific goals.

(4) Concentrate efforts and help those farmers with policy decisions to act, as a strategy to convince more farmers of the advantages of such decisions.

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Commentary upon:

BEAN PRODUCTION SYSTEMS

Fernando Fernandez
David L. Franklin

Messrs. Aguirre and Miranda have presented the agronomic systems of bean production within the socio-economic framework in which these operate. We would like to concentrate on two points: (a) the "systems" approach applied to production of field beans; and (b) an examination of the components of the agricultural "supra-system," where the main obstacles may occur that prevent production increases and improvement of the producer's living conditions.

THE AGRICULTURAL SYSTEM

The concept of systems conceives the unit of production of a given species as a dynamic assembly with several components and having "inputs" and "outputs." This system is not isolated; on the contrary, it is part of a major assembly or a "supra-system" which has other components, each one of these being a system in itself. These components could be called "exogenous systems", considering that the (sub) system of production is the "nucleo-system" of the center of the entire agricultural complex. (Figure 1).

Although every component of the agricultural supra-system (and of its subsystems) can be identified, studied or influenced separately, all of them interact with the "production system". They provide inputs and determine or influence the characteristics and operation of the nucleu. (Figure 2).

Several components such as transportation, marketing and community infrastructure; credit and inputs, etc., are interrelated.

The authors emphasize the importance of what they call the "socio-economic environment" which we recognize within the agricultural supra-system, declaring:

> "The concept of agricultural production systems must be ample enough to include the technical, economic, social, political and cultural aspects of the members of a society that define and shape the basic relationships between man and his environment, channeled into agricultural production".

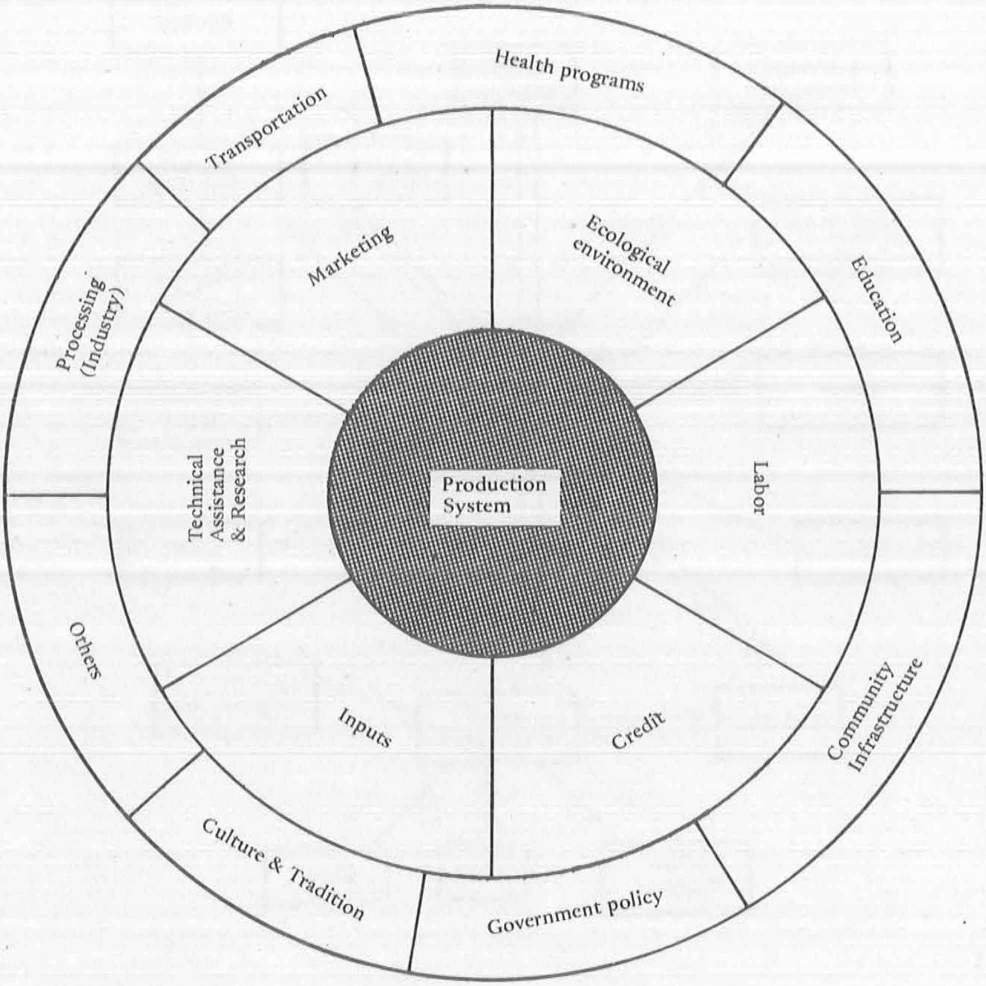


Fig. 1. The agricultural supra-system

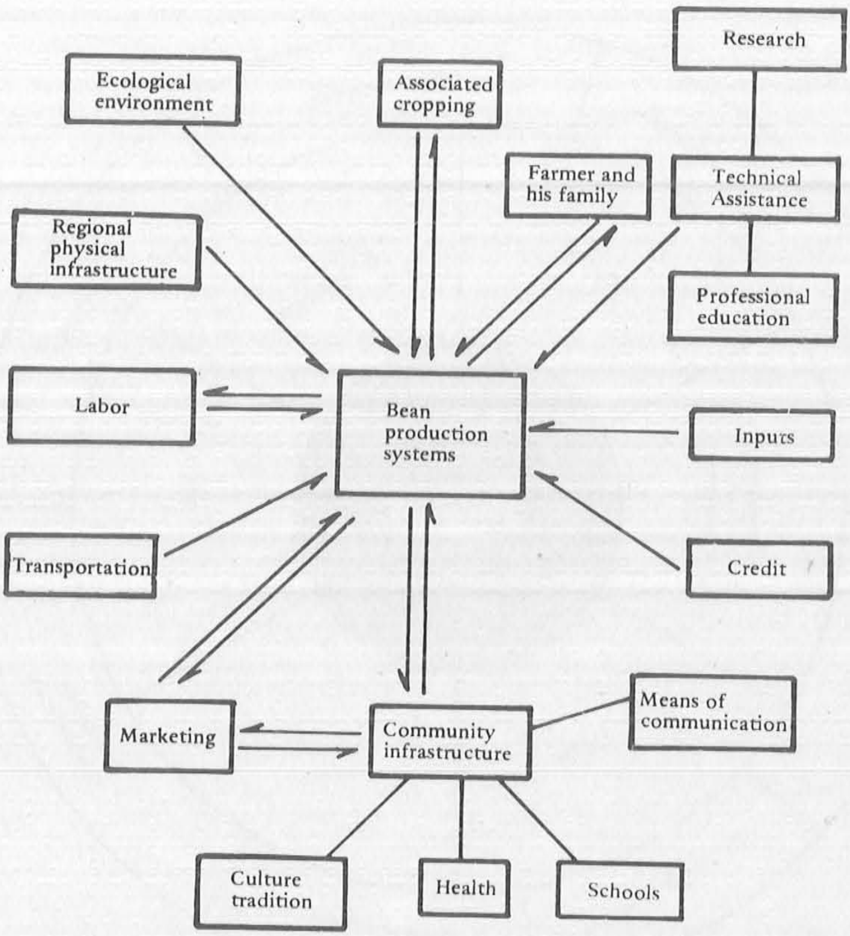


Fig. 2. The agricultural system of the field bean

The authors identify two basic characteristics of the components of the agricultural system of which bean production is a part: geographical dispersion of the production units: small size of the farm and/or lot.

Other characteristics could be mentioned (and the authors state these) such as: difficulty to obtain credit; low level of education; insufficient market information; low capacity of the marketing system; inadequate infrastructure of community services; little or no political power of the producing community; lack of managerial criteria; rudimentary levels of technology; tendency to minimize risk.

These characteristics are true, but not peculiar to the bean production system. They belong to the agricultural system of the small farmer and of subsistence agriculture.

Under the most primitive conditions, production of field beans is a mechanism for obtaining "savings in kind," a source of food for the family and an assurance of employment for family labor, rather than a commercial activity oriented toward the market. An increase in the size of the lot and/or the technification of the unit of production generates an expected surplus of the product which the farmer seeks to market. In this case, bean production becomes mainly a commercial activity.

A situation exactly opposite to that of the subsistance bean producer is found in medium-sized and big operators, whose product is intended mainly for the domestic market and for export, as found in the State of Sinaloa, Mexico; in several Central American countries and in extensive areas of the Departments of Valle, Tolima, Huila and others in Colombia.

In this country, the technified farmer represents only three percent of the producers, he cultivates eight percent of the area planted to beans (78,000 hectares in 1972) and contributes 15 percent to national production (total national production 46,000 tons in 1972). Most of the Colombian bean production is handled by small farmers and, according to the authors, this is likewise the case in Central America.

THE PRODUCTION SUBSYSTEM

Every system has at least the following set of characteristics:

(a) It is dynamic, which means that time is an intrinsic part of the system.

(b) A set of conditions contained in the system.

(c) Channeling of inputs into the system.

(d) Creation of new conditions resulting from a process in which initial conditions interact with the inputs.

(e) Generation of outputs (or products) which depend on the conditions and the inputs.

The process in the system leads to new conditions as a result of the interaction of original conditions and inputs. In other words, the product or products of a system are a function of the inputs and the process.

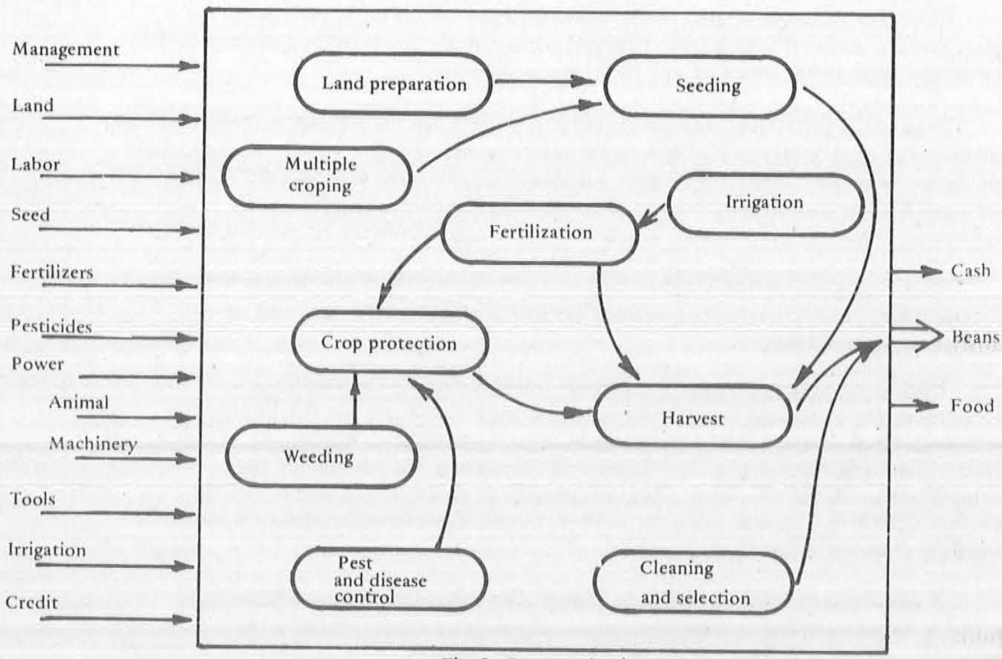


Fig. 3. Bean production system

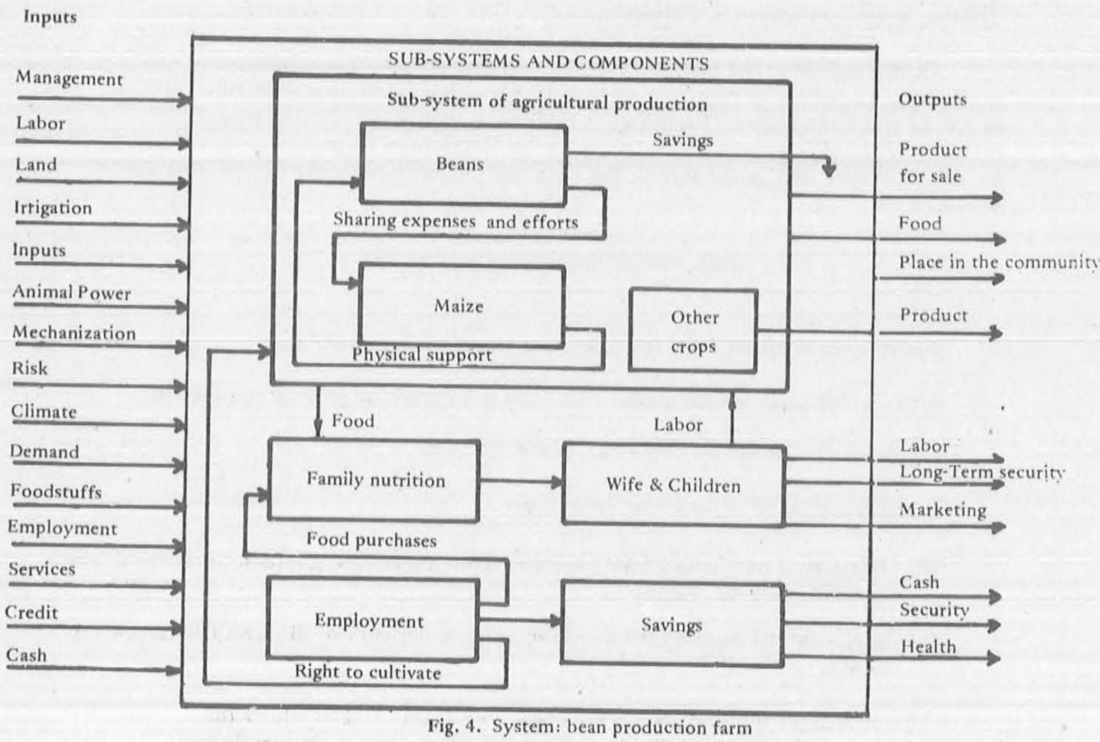
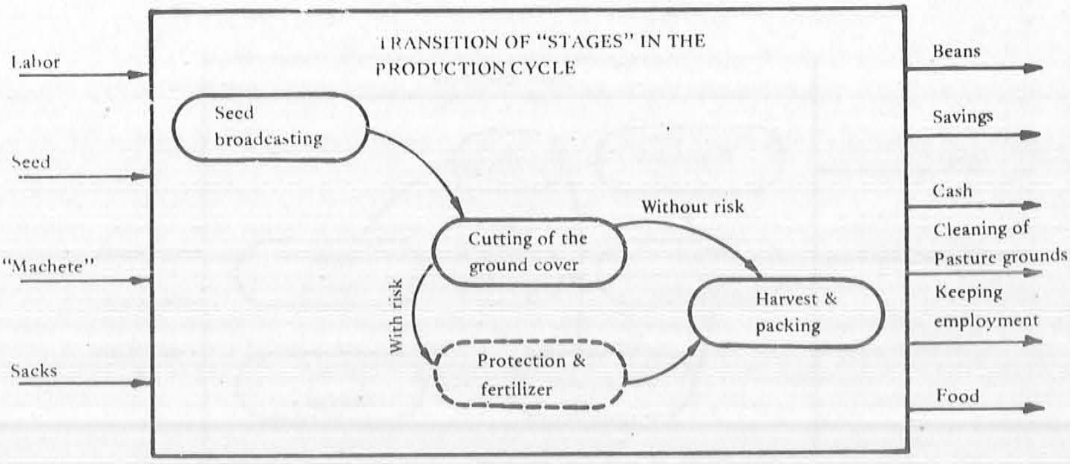


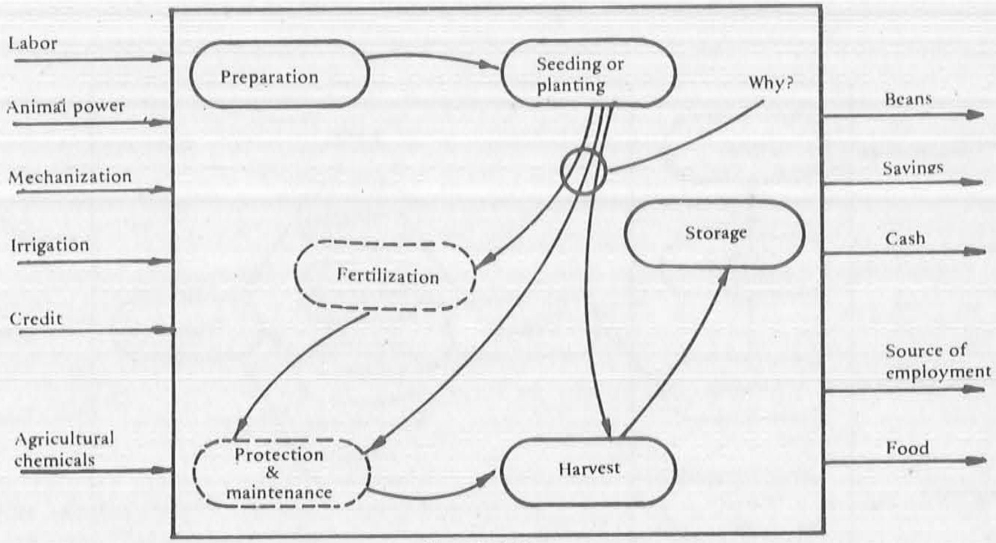
Fig. 4. System: bean production farm



Characteristics:

- Low level of productivity
- Mechanism of "savings in kind"
- Self - consumption of the product
- Source of employment
- Minimization of risk
- Transition to grass

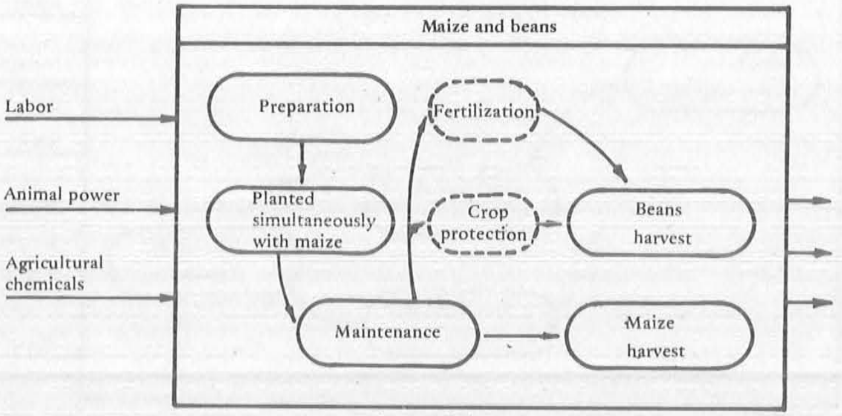
Fig. 5. Production systems: "Frijol Tapado" (Weed covered beans)



Characteristics:

- Variable level of technology
- Variable level of productivity
- Orientation mainly towards market
- Tendency to minimize risks
- Introduction of animal power and /or mechanization.
- Availability and use of limited credit

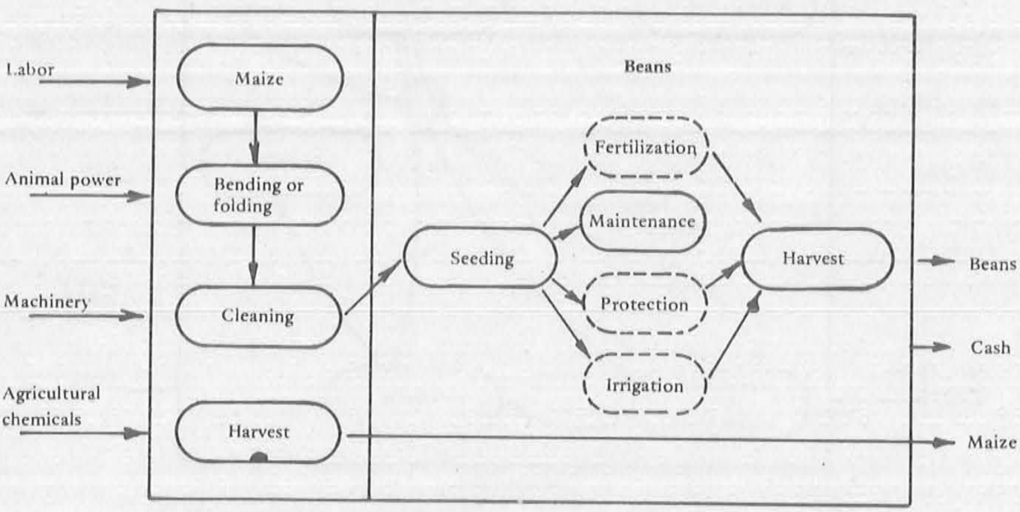
Fig. 6. Production systems: Frijol Solo" (Beans alone)



Characteristics:

- Simultaneous association with maize, potatoes or other crops
- Twining or shrub plant type
- Tendency to low yields due to competition
- Better use of land and capital
- Partial orientation towards the market
- Limited credit available
- Low or variable level of technology
- Competition among crops
- Sharing of expenses and efforts between the two crops
- Physical support of maize

Fig. 7. Production sub-systems: "Frijol Asociado" (Associated cropping)



Characteristics:

- Beans are planted when maize has reached physiological maturity
- They do not compete with the other crop
- Voluble, sometimes shrubby plant
- High yields and productivity
- Limited credit available

Fig. 8. Production sub-systems: "Frijol Intercalado" (Intercropping)

The above characteristics may be represented for the generalized bean production system in a relatively simple graphic form (Figure 3).

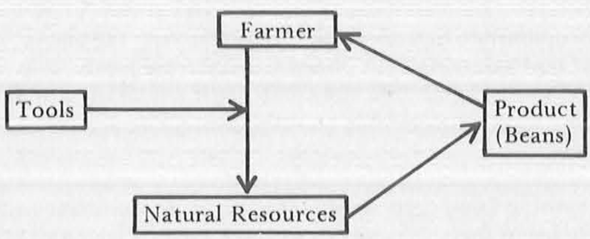
Based on the information supplied by the authors, it is possible to graphically ilustrate the system of the maize and bean production farm as shown in Figure 4.

The model of the generalized bean production system may be modified by the producer, depending on the existing conditions in a certain area. This modification results in a number of alternatives which are grouped into sub-systems according to a given characteristic or a limited number of specific characteristics. From a physical or technological standpoint, these sub-systems could be rather called "methods."

The authors have identified four of these methods that they present as bean production systems for the small farmer, with utilization of a very low level of technology at all.

Using patterns similar to that used to illustrate the generalized bean production system, the four sub-systems can be illustrated as in Figures 5,6,7 and 8.

The system illustrated in Figure 5 is similar to the subsistence agriculture system which is the simplest of all, as shown here.



This is a closed system which does not depend on external factors or on exogenous systems.

THE CRITICAL COMPONENTS OF THE AGRICULTURAL SYSTEM

The landscape of agricultural system in which beans are produced in Central America, according to the authors, is largely covered by small farms operated by "campesinos" of limited resources who have a piece of land often on the hillsides.

For these farmers the authors recommend a combined effort in the technological and socio-economic fronts. The goal of the technological effort would be to develop a "package of technology" with a high level of physical and economic productivity. The goal of the socio-economic effort would be the simultaneous transformation of the socio-economic environment and of the social and cultural patterns, in order to accelerate the adoption of the entire package.

The authors rationale is that even though we may increase production substantially by means of a great technological effort, the economic structure and existing conditions in the production areas do not guarantee a rapid crystalization of the conditions required for adoption of the new technological package.

The problem has considerable proportions due to the subsistence situation, to the low levels of technology, and to the socio-economic conditions of most producers.

Based on the information presented by the authors and on data from other sources, it is apparent that the most common case is one of subsistence or semi-subsistence where the unit of production is less than one hectare and where yield is less than one ton per hectare. The land tends to be marginal for crops and the resources provided by the communities in terms of education, marketing, communication, transportation and credit are minimum or non-existent.

Furthermore, two basic considerations are outstanding. First, the contribution of the bean crop to the activities of the typical farm in the Siria Valley in Honduras represents, according to the authors, approximately 20 percent of the agricultural income, and one third of the total income comes from non-agricultural sources. Second, there is a space dispersion of production and places of sale where beans are sold mainly in small quantities. The authors suggest that beans are a product that can represent savings in kind.

This last point indicates that, under the present means of distribution, the most common marketing system is rudimentary or operates at the village level and that there may be an equilibrium between supply and demand. The above considerations suggest that a development program to increase production significantly could affect this equilibrium and could cause a malfunction in what is probably one of the few ways of promoting security, protection against risks through savings in kind.

The first basic consideration suggests that if we want to simultaneously promote family well-being in these circumstances and increase yields and productivity, the problem must be solved with something more than just the "package of technology" for a bean production program.

The results obtained from research and production development programs, reported by the authors, show that the new technology provides an opportunity to increase and even to double the traditional yields. Also, there are indications that productivity has increased without replacing labor by mechanization, but increasing employment instead. Similar evidence has been obtained in Mexico, Colombia, Brazil and other countries.

It is interesting to note, however, that the case of the Bean Promotion Program in El Salvador, presented by the authors, illustrates the importance of giving attention to the different components of the agricultural systems and of having: (a) a previous or projected real demand for the product, and (b) a marketing system that can handle and distribute the increases in production.

In other words, in the case of El Salvador, the existing conditions permitted the introduction of a package of technology and its successful adoption by the farmers which led to increased bean yields and production and contributed to raising the farmers' income. Those conditions were as follows :

(1). During the 1967-1969 period, the amount of beans demanded was double the amount produced. The deficit had to be imported.

(2). The marketing and transportation systems that in 1967-69 had handled imported beans, had the capacity to handle the distribution resulting from produciton increases that substituted imports since 1969.

(3). High prices provided an incentive for producers and the traditional cultural habits were inclined towards bean production.

(4). The biophysical environment of the producing communities was relatively favorable.

(5). The government policy on bean production provided: (a) research, personnel training and technical assistance to develop and promote adoption of the package of technology; (b) an ample supply of inputs and channels for input commercialization, especially for fertilizers and agricultural chemicals; (c) credit readily available for those farmers who wanted to produce field beans.

If the market demand for beans had not been high at the beginning, a development program would not have been necessary. If a program had been carried out, it would have caused more problems than those it was intended to solve.

The authors point out that the basic differences between the traditional and the technified system are in planting, fertilization and maintenance of the crop, in the utilization of technological inputs and in the amount of labor used for the application of the new systems.

These differences resulted in doubling production in three years. But the technological package would not have been effective if the sub-systems of the bean agricultural system had not been in favorable conditions or had not been manipulated in the right way to create those conditions.

SPREAD OR CONCENTRATION

The success in El Salvador also indicates that it is not necessary to manipulate all the sub-systems affecting bean production. Frequently, several sub-systems, even though not optimal, may still provide conditions favorable enough to attain the projected goals. Other sub-systems, in turn, may need a well planned and executed effort to enable them to make a significant contribution.

It is suggested that, before starting development programs, a study should be made of the situation of the farm family in the small agricultural production unit as a system in the agricultural supra-system. The various components of the production unit could be analyzed, to determine their critical functions in reaching the objectives and meeting the family needs within the system. The influence of the dynamics of the supra-systems on decision-making within the system should be determined.

We conclude that a scientist or administrator alone cannot study an entire agricultural system in complete detail with all its sub-systems and components. The degree of dilution implied would give only vague results. In practice, the sub-systems should be isolated for purposes of diagnosis and planning, and the efforts of specialists or teams of specialists should be dedicated to identifying the most relevant elements effecting production, concentrating all efforts in the solution of these problems.

The starting point must be the unit (the system) of production. Since bean production is the object of our interest, the technology of bean production might have chronological priority when it is not possible to make a simultaneous study of the whole agricultural system related to beans, but not before it has been established that poor technology is a primary obstacle in a given case.

Which are the components of the system that constitute the main obstacles to production and to the improvement of living conditions for the farmer?

If it is determined through an integrated systems analysis that technology at the farm level is a limiting factor, development programs oriented in that direction can be established, provided that they operate in function of the conditions of other sub-systems that affect the systems of production.

The fundamental contribution of the modern tool of systems analysis to the solution of agricultural production problems is the identification of the coupling of the production system with other systems affecting it, which allows the isolation of the production system for study in relation to the inputs and conditions, without being concerned about the conditions of other systems.

Our intent here is not to present a methodology of analysis and modeling of systems but rather to formulate, through the elementary concepts of this science, some questions that need to be answered and to suggest that this methodology can be useful in the solution of agricultural and livestock development problems. (See the works of Wymore A. Wayne, especially, **A Notebook of Systems Engineering Methodology.** University of Arizona, Tucson. 1971).

The exogenous sub-systems critical to bean production are those providing inputs and those that accept outputs from the production sub-system. There are also endogenous sub-systems critical to the unit of production. They are those that transform essential resources to meet the needs of the farm family and of the consumer.

We often find that in a biophysical environment, where conditions are favorable for growing beans, the most critical exogenous sub-systems are marketing, credit, land tenure, technical assitance supported by research, and economic regional and community infrastructure. These sub-systems need to be carefully studied in nearly every region.

In the last part of their presentation the authors make a series of pertinent recommendations that show the complexity of the system and suggest several solutions. We believe that it is very important to follow those recommendations within the framework of the respective sub-systems, recognizing that the recommendations should be adapted to the conditions or the respective sub-system in every individual case.

AGRONOMIC PRACTICES FOR FOOD LEGUME PRODUCTION IN LATIN AMERICA

George F. Freytag

INTRODUCTION

Before thinking of the particular agronomic practices to be considered, a farmer or researcher must decide on how the crop is to be handled. He must clarify his thinking as to the overall philosophy that will be utilized in handling the crop. This he may do by considering how it will be utilized; production system, mechanized or not, that will be used, and whether there is a profit motive or not. Though this is not the principal topic before us at this time I do think it is particularly important that we have some clear idea of what our governing philosophy is and how it compares with others when we discuss particular agronomic practices and their relative values.

CROP UTILIZATION

The major methods of utilization and some examples of each are:

Soil Improvement (Soiling). Incorporation of root systems and other crop residues, such as with high foliage producing crops (alfalfa, clovers, cowpea, etc.) for organic matter and for nutrients, especially nitrogen and phosphorous returned to soil.

Forage. Again for high foliage types, such as soybean and cowpea, etc. used for direct feeding, hay or silage.

Vegetable. Most frequently as tender green pods or seed, as with the Lima bean and the green bean, but also cowpea, soybean and others.

Ornamental. Often in combination with use as a vegetable around rural homes, as with **Dolichos, Cajanus** and the scarlet runner bean.

Dry Grain. The most frequent commercial use since it probably offers the best way to preserve food value, particularly with soybean, field bean and cowpea.

Seed. All are produced for seed, either commercially or traditionally in order to plant a new crop.

PRODUCTION SYSTEMS

Here it seems to me that the governing criterion is that of how much capital is available, with adequate know-how to permit use of equipment or machinery. The simplest breakdown is:

Manual. All, or practically all of the agronomic practices will be done by the farmer or his family with a minimum of tools, perhaps only hand tools.

Mechanical. Here there is a wide choice, from animal traction equipment (plow, disc, planter) to motorized (including threshers) and of all types and sizes.

Combination. Extremely variable combinations; perhaps a valid example would be land preparation and planting by machine, cultivation and care and harvesting by hand, threshing by machine.

PROFIT MOTIVE

Here is a truly philosophical question – that is, whether or not there exists a conscious realization of expected gain. To simplify this let us express it as:

Traditional cropping. This attitude is tied up in systems handed down from father to son, often with religious concepts, so that apparently little conscious thought is involved and failures are generally attributed to "hard-luck, bad weather, the moon, and God."

Marginal cropping. Here the farmer recognizes a risk involved and is not willing to make any cash investment. He uses his poorest land and hopes for a good year.

Commercial cropping. Generally this practice is found on the larger, more mechanized farms which invest capital and require a return to pay off investment.

In addition to these philosophical aspects we shouid have a good understanding of the general biological situation of the legumes themselves. Generally the food legumes are crops of the tropical and subtropical zones. They have extended to temperate climates where they may be found in two principal habitats: cool and humid climates, adequate for the production of the vegetable, snap beans, or the dry or desert-like climates where the majority of the dry field bean production is located.

CHARACTERISTICS

Their two centers of origin are in the Americas (purple, white or red flowers), and in the Old World, especially Asia (generally yellow flowered, but also white and purple). Taken together as food legumes we may see the following principal characteristics:

(1). All are legumes with nitrogen-fixing bacteria in nodules on the roots. This predisposes the crop to better results in well drained soils, preferably sandy, and with relatively high pH. High organic matter content also results in better production.

(2). The plant type tends towards the vine so that some type of support (stake or stalk) to twine around permits greater development. The bush types have lost this twining characteristic but generally require strong stalks or neighboring plants to help support the plant or branches.

(3). Their foliage is trifoliate, very delicate, and can generally change position to adapt for low light intensity or loss of moisture. They are very susceptible to damage by wind, disease, nutrient deficiency or senility.

(4). Protein is one of the principal storage products, particularly in the seed. In the green stage all parts of the plant are quite attractive to insects and animals as food, though in the latter stages of maturity the seeds are often protected by unpalatable or toxic substances.

In the centers of origin we find that the beans are generally grown by indigenous people or by the small agriculturalist of limited resources. In both of these cases the food legumes form a very important part of the basic nutritional pattern, supplying a large part of the protein. It is often in these circumstances that the agriculturalist requires that the legume crop provide at least a minimum yield in spite of the most adverse conditions, for it has more value in times of scarcity of food than it does as a crop of great yield potential during favorable times. Perhaps because of this conservative nature of the food legumes we seldom find types capable of high yield potential.

SELECTION OF SPECIES AND VARIETY

We will be speaking mostly of the common field bean as we discuss the various agronomic practices, but we must remember that there are many other food legumes which will require modifications to a greater or lesser degree of many of these practices. Let us just enumerate the major ones of these:

American origin

Species	Type	Use	Comments
Phaseolus vulgaris	white (pea, navy)	dry grain	Dry temperate climate or irrigated. Semibush.
	bayo	dry grain	Dry temperate climate. Semibush.
	pinto or color (kidney)	dry grain green pod	Dry temperate climate or irrigated. Semibush or bush.
	black or red	dry grain	Semitropics, medium rainfall. Semibush or vine.
Phaseolus coccineus	ayocote (scarlet runner)	ornamental dry and green grain	High altitude and dry climate. Indigenous.

Species	Type	Use	Comments
	acalete piloy, cubaes	dry and green grain	High altitude and humid climate. Indigenous.
Phaseolus lunatus	Lima	dry and green grain	Hot dry climate, or irrigated.
Phaseolus acutifolius	tepary	dry grain	Tropical, hot climate. Restricted range.

Asiatic origin

Species	Type	Use	Comments
Glycine max	soybean	dry grain forage	Temperate climate.
Vigna sinensis	cowpea	dry and green grain and pod forage	Hot, humid or dry climate.
Phaseolus aureus	mungbean	germinated seed	Hot, humid climate.
Phaseolus calcaratus	rice bean	dry grain forage	Hot, humid climate.
Cicer arietinum	garbanzo	dry grain	Semitropic, dry climate. Restricted range.
Lentilla lens	lenticel	dry grain	Semitropic, dry climate. Restricted range.
Canavalia gladiata	sword bean	dry grain	Tropical, hot, dry. Scattered.
Dolichos lablab	dolichos	ornamental green grain forage	Tropics, humid climate.
Vicia faba	broad bean	dry grain	Cool, humid tropics.
Cajanus cajan	pigeon pea	dry and green grain forage ornamental	Tropics, humid and/or dry climate.

DATE OF PLANTING

Generally the date of planting is calculated to permit the harvest to take place in the season of least precipitation so that there will be a greater probability of accomplishing the threshing easily and with low loss from water damage. Dates of planting are also calculated to permit good moisture at planting time and at least some moisture during the main growth and flowering times.

There are usually three well defined periods: (1) first season (primera or humid season); (2) second season (postrera or dry season); and (3) irrigation.

FIRST SEASON

In areas where the "cut-burn" land preparation is practiced this must be accomplished before the rains begin in order to take advantage of the first few rains for planting. If planting is delayed it may mean problems with harvesting during the dryer summer period if the beans are not mature on time. In areas with a cold, rainy winter, delays may be caused by excessive moisture and resulting problems with opportune land preparation, again causing problems, either not enough moisture during the growing season or too much during the harvesting season. At all events it is important to have the beans mature or maturing when appropriate warm and dry days come along to permit a harvest. Usually this planting date has low disease and insect incidence since both of these will be reduced either by a prolonged dry or cold season immediately preceeding planting.

SECOND SEASON

In general this is the season selected for the majority of the traditional planting of legumes. It provides a somewhat lesser amount of precipitation, but at the same time more or less safety in that the rains will be reduced at the time of harvest either by the beginning of a prolonged dry season or by the advent of a cold period. Because there may be a fair amount of moisture in the soil, land preparation can be a problem. Traditionally the crop is planted during a cultivation of an established crop. Often times the planting is delayed excessively to avoid moisture, disease or other problems and the result is that the crop may suffer from insufficient moisture for adequate yields during flowering or shortly thereafter.

IRRIGATION

This permits selection of the exact date of planting with complete control of moisture at seeding and harvest. Unfortunately it is limited to areas with water resources, and with land level enough and with proper structure to permit application. We must remember that water can be applied with overhead sprinklers, by surface methods, and by subsurface systems either laterally from deep furrows or vertically from underground reservoirs. Generally speaking this season is the easiest to handle and gives the best yields.

LAND SELECTION

Land selection will depend principally on availability, characteristics, and economic considerations. Climate will not generally be a factor but will be more determinate in selecting species or varieties and date of planting.

AVAILABILITY

Small farmers are often not presented with the problem of land selection since they may be limited to only a few hectares and therefore must rather decide which crop to plant. As size increases however, or if they are sharecroppers and have the opportunity to pick from several fields they would need to know about the suitability of the land for a legume crop.

CHARACTERISTICS

Topography obviously is of great importance since with increasing slope and irregularities all labor becomes more difficult. Erosion also may become an important criterion if land is exposed to high rainfall. Nevertheless the small farmer often finds himself on sloping land, planting legumes on rocky irregular fields with no alternative. A uniform slope is of great importance if the land is to be irrigated by surface methods. Rocks, stumps, and sharp irregularities such as holes and ditches must be eliminated if large machinery is to be practicable.

Soil type and structure are very important considerations. The ideal soil should be on the sandy side, deep and loose, and with underlying drainage. Many other soil types can give good results including even heavy clays if structure is good, though these will be much more difficult to manage, especially as concerns water application and drainage. Germination is an especially sensitive period in this regard. High sodium (gypsum) or aluminum contents are especially undesirable.

Good legume growing soils should have pH around 6.5 to 7. Good phosphorous levels are preferred as are good levels of calcium. Unfortunately in the majority of the bean growing areas of the tropics, pH, phosphorous and calcium levels are inadequate. High levels of potassium are also required and this seems to be obtained in most of the American tropics. Though nitrogen is not required in large amounts the better yields are obtained in the more fertile soils. Good legume soils will also have a high content of organic matter not only as humus but apparently also as partially decomposed plant material. Minor elements must be present, especially sulphur, iron, magnesium, and zinc.

ECONOMIC CONSIDERATIONS

At the present time we find most of the food legumes being grown on definitely marginal lands from the point of view of the soils best suited to their production. The best lands are occupied with crops producing a higher profit, including: cotton, tobacco, coffee, sugar cane and others, even pastures. With the possible exception of soybean perhaps, the food legumes tend to be difficult, sensitive and low income crops and are continually displaced from the more productive lands. A few places have maintained legumes as the principal crop, possibly because no other crop can be grown there in competition. Some of these areas are noted for very short rainfall, very shallow or rocky soils, small fields, and zones particularly adapted to bean culture.

In the traditional small farm, hillside culture food legumes are probably still being grown in the same way and with the same results as in years past. Nevertheless, the increase in population and utilization of national lands is reducing the natural areas in so-called "conservation". Eventually there will be no lands left to recuperate during the rotation cycle and yields will probably continue to decline

LAND PREPARATION

There must be almost as many ways of preparing land as there are different food legume zones. Nevertheless, all provide the following basic conditions. They incorporate plant residues (or eliminate them); remove stones, trunks, roots, and level land; reduce weed seed, disease spores and insects; pulverize soil; conserve moisture.

Precisely how this is accomplished will depend on the land and the facilities at the disposal of the farmer. Some of the more common systems in use are:

TRADITIONAL SYSTEMS

Tapado. This is certainly the simplest of all and is often practiced in the humid-tropics, usually in isolated, mountainous areas where there may be almost no soil. It consists in cutting all vegetation (usually forest) with ax or machete at ground level and repeatedly, to form a uniform mulch over the land surface. Seeds are then distributed broadcast and the vegetation mulch shaken to allow the seed to reach the ground. No other steps are taken as seed will germinate and seedlings reach up through the mulch producing a stand. No soil movement or fire is involved so that it would seem to be well adapted to conservation. I have heard reports of good yields being obtained but have seen no figures of actual results.

Cut and burn. This system is very similar to the preceeding and requires either forest or heavy, broad-leaf second growth to supply enough fuel to burn. This system is very common in all mountainous areas where rocks make up a large part of the soil. Burning is done in the dry season just previous to the expected rains. If the area is not separated by an adequate fire lane it is often possible to burn up the countryside, a fairly common result. Nevertheless, it is probably the only system possible in these rocky, mountainous areas if crops are to be grown there. It is not effective against grasses and generally the invasion of these tend to make an area unusable by this system until a normal succession replaces them with woody growth. This may take from 3 to 5 years to more than a dozen. I have seen many fields of this type which should have yielded well over the national averages. Again good data on yield results under this system are few indeed.

Plowing. In some areas with pronounced slope and friable soils the hoe or machete is used to turn the soil. This system tends to be ineffective in incorporating the organic matter, and quite slow. Generally the operation utilizes the slope and gravity to move soil so that movement is in the same direction and tends to contribute to erosion.

The ox-drawn wooden plow (chuzo) is often utilized in the plowing of relatively flat land, often in fairly arid and/or rocky areas. Where there is considerable slope, the plowing tends to be in the direction of slope and so contributes to erosion. If plowing is done across the slope, the deep ridges left by the plowing help considerably to control erosion. This type of plow also tends to leave the organic material on the surface of the soil which also helps to control erosion. Usually two passes at angles over the field are required for proper preparation, with the use of a board or bunch of branches at times being used for land smoothing.

MODERN OR MECHANIZED SYSTEMS

Plowing. Some areas have utilized the rototiller type with the small two wheeled machines being preferred where there is a great deal of slope. These once-over machines tend to be quite expensive both for capital investment and for operation costs, and prepare a very loose seedbed which sometimes needs firming for planting. Organic matter is also distributed throughout the seedbed so that if it is excessive, a competition develops for available nitrogen and increase of root-rot fungi may result. The machines do not operate well where rocks and roots are present.

Generally the use of disc plows or moldboard plows is the preferred method for primary land breaking. The disc plow is generally preferred in land preparation where there are low moistures or heavy soils. It generally penetrates well in hard, dry soils and wears well (uniformly) and maintains a cutting edge in the highly abrasive sandy soils. It is also not particularly affected by rocks and stumps. It is cheaper to purchase and operate than the moldboard if the soils are not appropriate for the latter. It is slower and does not do as good a job of plowing as the moldboard.

The moldboard with replaceable parts (point, share, shin and guide plate) are high quality tools capable of doing a fast, neat job, especially in grassland or with chopped crop residue. They are best for soils which are deep and friable and not particularly abrasive. They can only work well with a certain amount of moisture in the soil. Roots and stumps are no particular problem but large stones can occasionally break points if working at high speed; moldboards tend to throw these obstacles to the surface where they can be removed. If the plowing is done with care the moldboard will leave the land level except for the back-furrows.

Discing. The offset with large, notched discs (commonly called "Bush and Bog") can be used for once-over land preparation in areas with sandy, friable soils and where there is a minimum of crop residue. Usually it is preferable to make one pass several weeks before the second which may be just prior to planting, the second pass being in the same direction as planting.

The two split-gang disc harrow is generally preferred for secondary preparation or pulverization of the soil. At least two passes are required to reduce the clods on the heavier soils or if the soil moisture is too low. Disc-plowed soils may also require more than two passes in different directions, and if organic material is present it is desirable to allow a week or two between passes for more efficient decomposition.

Leveling. This may be accomplished by the use of a spiketooth harrow which will also continue to break up clods, or, more commonly, by the use of a heavy board or railroad rail connected to the tractor by each end with a cable. The best job of smoothing or leveling can be accomplished by a land-leveler with a movable blade which can cut high areas and dump soil to fill in lower ones. These are especially valuable where the crop is to be irrigated.

Special. If the pH is to be corrected by the addition of limestone or hydrated lime, this should be accomplished during the last discing or after the leveling, with incorporation being done by the disc. A fertilizer or lime spreader especially designed for the job should be used for this purpose so that appropriate uniformity and dosage can be obtained. Finely ground material should be used, applied when wind is at a minimum and immediately incorporated to prevent wind and erosion loss. The application should be done at least a month before planting and it is possible that it may take considerably more time before the soil microflora adjusts to the changed pH. Applications may be from 2 or 3 to more than 6 or 7 tons/ha. to obtain a pH of 6.5 or greater.

Some special precautions should be observed to obtain good results in food legume production. Work soil at proper moisture content in order to reduce soil compaction and obtain good granulation. Try to leave the surface uniform - that is, level and evenly prepared, with no ridges or furrows. The last pass over the field should be within 24 hours of planting, preferably just before planting.

SEED PREPARATION

Success in food legume production often depends to a large degree on the quality of the seed used. The traditional small farmer usually recognizes the importance of quality seed and generally meets the exacting conditions for its production. He will select individual plants carefully, harvest them separately and handle them personally, often giving them a place in the home for drying, threshing and cleaning. He may have limitations on his knowledge and understanding of underlying causes of certain problems. Some of these limitations are: recognition of casual agents of disease and knowledge of their life cycles; chemical fumigation or seed protection: control of storage conditions such as humidity and temperature. His materials or equipment available for these jobs are often limited.

VARIETAL PURITY

Varietal purity and uniformity of type are required to permit the maximum efficiency of cultural practices which require a certain stage of development to get the best results. Rapidity and uniformity of germination, branch development, blooming onset and maturity are examples of characteristics which should be uniform in amount of development and times of initiation and termination. Varietal purity can be best insured by the plant breeder who establishes criteria for variety type and uses a system which will insure relative conformity through several generations of increase.

The traditional farmer sometimes seems to utilize systems of increase which insure a purposeful mixture. These systems seem to be confined to the indigenous and small-plot farmer who must realize some advantage from the practice. Possibly these farmers are utilizing a certain amount of heterosis or are maintaining a high degree of adaptability for changing circumstances of the area.

PHYSICAL COMPOSITION

Genetic variability as well as cultural conditions can create a good deal of difference in size and shape of the grain. Adequate selection and cleaning can help control the accumulation of these "off-size or off-shape" seed. Generally the best viability and germination are obtained from plump mature seed. These are also the easiest to utilize in machinery for obtaining uniform stands. Seed cleaning equipment for sizing (round holed screens) and grading (elongate holed or wire screens) is commonly utilized though the precision grader for length and width separations is generally superior.

Threshing and handling the seed at very low moisture contents (7 to 12 percent) will cause excessive breakage or splitting of the seed coat, which are difficult to remove later and will cause reduced stand and defective seedlings. Off color types can be removed best by hand or by the use of an electronic sorter.

DISEASE AND INSECT CONTROL

There is no substitute for an area which is free from disease and insects for the production of quality seed. For this to be effective one must start with seed which is free from the seed transmitted diseases, particularly virus and bacteria. Fungi and yeast have also been reported as being problems with certain crops. The same is true with nematodes, though these are less frequent. Insects are also a problem but are not so serious as the diseases and are also easier to control, both by field preventive measures with proper insecticides and by the use of appropriate fumigants after harvest (cyanide, methyl bromide or phosamine) or by prolonged humidity and temperature control in storage (usually 35 percent RH and 40° F for several months). Secondary attack can be prevented by seed treatment with chlorinated insecticides (DDT, lindane).

Internal seed-borne diseases are difficult to eliminate though some are susceptible to prolonged storage periods at either high or low temperature, which will reduce but may not completely eliminate the pathogens. For this reason it is very important for seed to be carefully and adequately tested to detect the presence of even low numbers of infected seed. Additional help may be obtained by the use of chemicals which may be active during storage period or as the seed germinates (in part to protect the plantlet). The systemic type of chemical seems to offer special promise for this type of control or prevention. Benomyl and carboxin are particularly promising through use by themselves or in combination with thiram.

Chemical pesticides, some of which may be harmful or deadly to humans and animals, or by accumulation pollute soil and water, must always be used strictly according to directions and regulations in effect for the area.

A special note of caution should be given: if seed has been treated with chemicals of any kind this should be stated on accompanying labels. Use of bright color treatment also is advisable to prevent such seed being used on purpose, or by error, for food or feed.

INOCULATION

Normal legume growth and production is dependent on nodule formation, and though apparently equivalent results can be obtained by fertilization this is a more costly and difficult procedure. Food legumes being grown in their area of origin, or frequently in one area, do not seem to require inoculation with nodule forming bacteria since these will be established in the soil. There is usually need for inoculation in areas where a crop has not been grown and in areas with a cold temperate climate.

Selection of highly efficient strains of bacteria may sometimes be of value in increasing yields. It is important to select for a particular combination of variety, bacterial strain and soil type; that is, a gene to gene action is certainly involved.

Adequate pH, calcium, phosphate and organic matter seem to stimulate or preserve bacteria in the soil. High aluminum and manganese contents in the soil greatly inhibit bacterial growth and nodule formation. Apparently nitrate nitrogen also acts as a deterrent to nodule formation. In lands previously planted to the common bean, flooding for rice paddy does not seem to eliminate the bacteria.

Planter box inoculation in the field is generally successful but often inconvenient so that internal inoculation of the seed by vacuum may be a better alternative.

PLANTING

In my estimation, planting is the most important of all the operations which must be carried out for the production of food legumes. It is, of course, important for the successful production of any crop, but food legumes are generally large-seeded and have more difficulty at emergence. Conditions must be especially appropriate (proper temperature, soil moisture, structure and compaction, etc.) in order to obtain rapid and uniform emergence. It does not matter particularly how the seed is placed in the soil during the planting operation (whether by hand, machine or other) but it must be carefully done with attention to all the details. The most common failings are improper conditions, wrong timing, careless placement, and lack of attention to details.

SPACING

A system of broadcast planting has been mentioned already, and though this is generally used for grain production only for the common bean, broadcast plantings are more frequently used for distributing seed for stands to be incorporated later for soil improvement. The quantity of seed should be adequate and well distributed to obtain a population heavy enough and uniform enough to compete successfully with weed growth.

Plantings in furrows are generally made when the crop is planted between existing crops or when the legume is to be cultivated or irrigated. The distance between rows will depend on the spacing required to permit the equipment that will be used in these operations to enter when necessary. If tractors are used, it will usually depend on the width of the tire on the vehicle plus the width of the plant across the furrow at approximately the time of flowering, plus a few inches of freedom. Sometimes compromises will be made depending on the planting equipment to be used. If a drill, common spacings will be in increments of 7 inches (the disc spacing), corn planters' minimum spacing is usually about 28 inches, while the bean and beet planter may be increased in 2-inch increments from about 12 inches.

Hand and animal traction plantings may be more flexible though the yoke for oxen for an area may fix plow distances since the oxen are generally trained to walk in the furrow, therefore the planting distance is often in increments of one-half or one-fourth of the distance between the two animals. At other times it may depend on the width of the furrow, which depends on the size of the plow, or plow point.

Hill planting is usually used with associated or interplanted cropping, and is almost always done by hand. Machinery has been devised for this but is not widely used. Any distance can be utilized but the most frequent are those which are convenient to the farmer and to the main crop within which the legume is interplanted. If the legume is vining there is a tendency to place the hills at the base or near the base of the main crop, while if the legume is semibush or bush it is usually planted between the rows of the main crop with little relation to the distance at which the main crop has been planted. Usually these interplantings will use a reduced spacing from that which might be used in a planting of the food legume by itself.

POPULATIONS

Total population is usually adjusted by the distance between seeds in the row or by the number of seeds per hill. It is often a very difficult matter to judge whether the population was appropriate or excessive, while deficient plant populations are generally quite obvious and results are very inferior. Population should be at least enough to utilize total fertility of the land and the water available. With higher fertilities and more, or better distribution of available moisture, higher populations can be used. If either may be deficient at any of the early stages of growth (before pod set) the population must be reduced. Varieties characterized by large plant size or vining growth habit will require lower populations.

The effect of over-population is apparent by the production of thin, weak stems which tend to lodge early, excessive foliage, and high incidence of flower and pod drop. If water or nutrients are limiting the plant may be small and stunted in growth. In associated plantings where the vining plant type is used the problem of over-population generally does not occur since some plants become dominant and crowd out the others. Under-population will be most evident by weed invasion and low yields. The most frequent type of under-population is that of "skips" caused by lack of germination or other population loss from insects, disease or cultivation.

PLACEMENT

Hill placement facilitates germination in heavy soils, but it has the disadvantage that one or two plants become dominated by others and do not develop to their complete potential. A diseased seed among those in a hill will likely transmit this problem to the healthy seed with which it is associated. Uniformly drilled seed does not have these problems but will have to emerge under their own power so that a very shallow soil covering is preferred. Under practical conditions of machine planting this may be from one-half inch to one inch of soil above the seed. If chemical herbicides are to be used or if erosion is a problem, deeper planting may be necessary.

Seed should be placed in moist soil and no further moistening of the surface should take place for best results especially if there is any appreciable clay component in the soil. The worst disaster is that when a fairly light rain occurs immediately after planting with the following days bright and sunny. This will usually produce a very durable surface caking which can substantially reduce emergence. At placement, seed should be lightly firmed into the moist surrounding soil and loose soil should cover the row.

Phosphate fertilizers may be placed with the seed in the furrow while those that have high levels of a soluble portion should be placed to one side and somewhat below seed level.

EQUIPMENT

Hand planting is often done with any sharp pointed instrument (stick, macana, machete) and though theoretically it should be possible to place each seed at the precise depth and spacing desired, it is impossible in practice to obtain any amount of uniformity with this system. Nevertheless, good results at emergence can be obtained. Plantings made with the animal drawn plow have the same problems with uniformity but again good results are often obtained. Both of these methods are extremely slow and only small areas can be planted in a reasonable length of time.

The small mechanical planters can be utilized and will do a much better job at distributing and placing the seed precisely. Some of these are used for horticultural crops but have not caught on commercially in the majority of the bean growing areas. The belt planter and the cone planter are used for the more precise experimental work, as is the Planet Junior for the more simple plot work. These may be operated by hand or with small two-or four-wheeled garden tractors.

The larger drill-planters, either those manufactured specifically for beans and beets or those generally intended for maize and cotton, have found great acceptance for larger, commercial farms. These machines can plant both drilled and hill-dropped and with greater or lesser precision depending on the exact design features. Some can apply herbicides, mix them with the soil before the planter or apply them on the soil surface immediately after placement of the seed and are for either liquids or granulated chemicals. They can also be obtained to place fertilizer at various rates and positions beside the seed. Some machines can accomplish all of these operations at one pass and at fairly high speed. Usually two or four rows are planted at a time but equipment is available to plant several times this width.

The grain drill has been utilized with fair success to plant food legumes. Though it can apply fertilizer beside the seed there is usually no regulation of placement. Depth is usually controlled by a pressure regulation. Exact quantities and precise placement are not obtained and problems are often encountered with adequate coverage of the seed by the soil.

Practically all of the larger planters can plant extremely fast and do a very precise job of placement of seed and chemicals. It is the only way large areas can be planted in a reasonable length of time and at a minimum cost. On the larger, speed becomes a problem with nylon plates being used on some machines. Lubricants such as diesel fuel and talcum for seed and parts are being used with some success.

FERTILIZATION

Perhaps this should be discussed at the same time as planting since most fertilizers are applied at this time. Liming and organic matter are also parts of the problem of soil fertility and balance and may need to be added previous to planting.

Soil type will have a great influence on fertilizer requirements as will the total amount and distribution of rainfall. Soils which supply adequate nutrients under conditions of low rainfall will probably not need additives while those which do not supply nutrients or are under conditions of high rainfall will need fertilization, and possibly in a form which will not be lost through leaching. In areas of very constant rainfall a good deal of the soluble nutrient will be leached from the soil as well as from the plant and may include a good portion of the nitrogen, phosphorous and calcium needed for grain yield.

Nitrogen needed by food legumes is mostly produced by the nodule bacteria, but evidence exists that small quantities are extracted from the soil, especially for the first 30 days. Apparently there is not much difference in the nitrogen source applied to supply the small early nitrogen requirements. Though this may be in the form of nitrate, large quantities seem to be either toxic or inhibitive to nodule function. In some cases partially decomposed crop residues (**Crotalaria**) are a satisfactory source.

Phosphorous is extracted from the soil throughout the growing season by the legume and is very important in the nitrogen fixing process. Low extraction efficiencies are encountered so that the larger portion of fertilizer applied is lost to the plant. Soils with high aluminum content not only tie up the phosphorous but also are toxic to the bacteria and to nodule formation. Crop residues and foliar applications are also satisfactory sources.

Minor elements are found to be limiting factors in certain areas. Zinc and iron are sometimes deficient where high pH is found. Sulphur may be deficient where continued burning is practiced. These elements may be easily applied by foliar applications or by adding them to the fertilizer applied to the soil.

Availability, price and facility of handling are important considerations. Hygroscopic fertilizers are very troublesome as are those which are powdered as they tend to stick to equipment, cause build-ups and generally gum up the machinery. Generally very small amounts of fertilizer may be recommended, often only superphosphate.

WEED CONTROL

Weeds of all types are one of the most serious problems of bean production in the tropics. Among the most difficult to control we may find nut-grass (**Cyperus** spp.); annual grass (**Eleusine, Cenchrus**); perennial grass (**Cynodon, Paspalum**), malvas (**Sida, Waltheria**); bind-weeds (**Ipomea, Merremia**); plantain (**Plantago**); composites (**Baltimora, Bidens, Synedrella**); and others (**Acanthosperma, Richardia**).

Every area will have its particular problem probably brought on by the weed control practices used. There is no doubt that the bean is a weak competitor and particularly susceptible to loss of yield by weed invasion during the first month.

Control methods to be utilized should be selected from an appropriate combination of rotation system, mechanical control, and chemical control.

ROTATION SYSTEM

One of the best rotations for weed control includes the use of pastures for at least 3 to 5 years. Pasturing greatly reduces the amount and type of weeds and legumes immediately following can be nearly weed free. Native vegetation which appears by allowing the land to revert to the natural succession for the area also will eliminate troublesome weeds, though in this case replacing the grass pasture with broad-leaved perennials.

Idle fallowing with repeated discing can reduce some stoloniferous weeds in the hot dry tropics, though it does not seem to be very practicable for reducing annual weeds. Flooding as practiced in rice paddy areas can be very useful for eliminating both weeds and disease. This land, if it has been planted to legumes, can be reused for legume production even when quite heavy clay with no apparent reduction in nodule formation.

More common rotations, which certainly are of some benefit in weed control, though probably used for other more important considerations, may include the following crops: maize, manioc, bananas, sugarcane, coconut palm, citrus, tobacco, sunflower, coffee, peanut, and tree cotton.

Of these, by far the most common is the maize-bean rotation or association. This may be practiced in many ways; using one season for one crop and another during the same year for the other. These crops may overlap, in the same or adjoining land, or in time, etc. They are often consumed together in the diet and it would be interesting to know if proportional yield balance under these conditions is the same as that which offers the greatest efficiency as regards nutritional balance. Certainly there are many aspects of this particular rotation which are not well understood.

MECHANICAL WEED CONTROL

Cultivation generally as of itself does not seem to stimulate production. The bean root consists of a very shallow fibrous system, easily damaged by even light cultivation, and very susceptible to disease. However it does recuperate and very deep cultivation is used in the humid tropics as a routine practice.

Cultivation may be of great benefit in the following cases: (1) use of rotary hoe to break crust during germination; (2) opening furrows to irrigate (or provide surface drainage; (3) breaking surface capillarity early in the season during periods of prolonged drought.

There seems to be no equipment for mechanical cultivation which will do a good job between the plants or hills. The work of a hand hoe certainly leaves a great deal to be desired even in the hands of a careful farmer. Between row weeds can be controlled in plantings very satisfactorily by use of bean knives and steerable cultivators. The bean plant is likely to be damaged directly or through subsequent disease or insect attack by any amount of soil build-up against the stem after hilling-up or use of most tractor mounted shovels or sweeps.

In my opinion the traditional farmer does not have any great problem with weed control, unless he is over-extended. Weeds are mostly a problem in marginal lands or in commercial planting where there is no interest in, or capabilities for giving careful, patient attention to the crop.

CHEMICAL WEED CONTROL

Generally this type of weed control is not applicable to the small farmer. It requires know-how, equipment, and an investment in chemicals and equipment. Nevertheless, used properly it can give amazing control of weeds. Whether or not this cost is adequately recuperated by increased yield is often debatable. Some chemicals can be mixed with the soil previous to planting (EPTC and trifluralin), others should be applied on the soil surface and may give relatively short term effects (dinitros) or long term effects (chloracetamides, amiben, linuron).

Most of these can be quite toxic to the legume plant and so care should be taken in their use or serious damage can result. Placement of seed should be deeper than normal and in most cases chemicals should be applied immediately after planting. Light precipitation right after application can make the herbicide more effective, thus permitting reduced dosage. Firming or smoothing the soil surface is also advantageous.

Legumes are very susceptible to damage by certain herbicides used for other crops, and soil residues, as may occur in rotations, may cause damage. Among these herbicides are 2,4-D, diuron and others of this group, and the triazines.

The applications may be made as granulateds, wettable powders or liquids. Equipment for application of granulateds is easily adjustable and cheap but results are often spotty or poor and costs for the chemicals are much higher. Sprayers should have large, easily serviced filtering systems, and large nozzle orifices if a lot of down-time is to be avoided. More accuracy in application rates can be obtained if sprayers have good pressure indicators and regulators, tanks have good agitators, and nozzle parts are of hardened stainless steel.

PEST CONTROL

Insects, diseases and other pests can best be controlled by preventive rather than curative measures. Genetic factors surely offer the best system for all around control. Diseases can be controlled by single factor resistance in many cases, several or more factors in other cases; but there are so many diseases it seems impossible to get them all into a single given variety. Generally speaking the traditional farmer is using varieties which not only contain some of these factors but also a great many factors for general resistance which often make his varieties able to produce a yield even though many diseases may be present. Varying degrees of resistance seem to be available for insect pests (such as pod worms, weevils and leafhoppers) but not a great deal of work has gone into the search for this.

A great deal can be said for the production of clean seed to be distributed and planted as a preventive measure for the spread of pests. A great deal more attention should be placed on utilization of quarantine methods. Movement of machinery and crop materials from farm to farm or field to field can diseminate weeds, diseases and insects.

Rotations have already been mentioned as valuable systems in the control of weeds, and may be most useful for control or reduction of insects and diseases present in a field. Associated plantings may have some value in slowing up the rate of spread of a disease within a field and may function as "traps" for reducing damage by some insects.

Timing for some operations can be of enormous benefit to escape insect or disease attack. Elimination of grassy weeds in legumes prior to ovoposition by some insects (notably **Spodoptora**) can be very important in reducing insect numbers. Early and timely harvest and prompt removal of crop from the field can greatly reduce weevil (**Acanthoscelides**) attack. Roguing virus diseased plants and elimination of leafhoppers can reduce the spread of virus disease in a field.

CHEMICAL CONTROL

Sooner or later the farmer is faced with the possibility of losing a crop from disease or insect attack and will then consider the possibility of using chemicals to reduce losses. The use of seed treatments has already been mentioned. The use of insecticides at time of planting, either mixed with the fertilizer or apart, can be considered. If soil insects are present (such as wireworm, white grub, cutworms) use of chlorinated insecticides (aldren, chlordane or dieldrin) may be of great value. Systemics (phorate, disyston) usually applied in granular form in the furrow with the seed may be very worthwhile to control leafhoppers and other virus vectors.

Chlorinated insecticides (DDT) are cheap, easy to apply and for general purpose use. Many phosphate insecticides are available to control sucking insects (leafhoppers, etc.) and chewing insects (caterpillars and beetles) and though many are extremely dangerous to humans, others have a low order of mammalian toxicity (Malathion, Dipterex). Other types, such as the carbamates (Sevin), are finding broad usage in spite of their relatively high cost.

Early applications on the germinating plantlet or shortly thereafter are preferably made by sprayer with water as the carrier. Granulateds are usually the preferred form to apply during or just before planting. Dusts can best be utilized when there is considerable foliage and moisture on the plant to get the best adherance. Good equipment is available in all sizes, from the small hand duster to the large tractor type, and good applications are easily obtained with all. On the other hand, the spray equipment should have a relatively high pressure and utilize a cone spray to obtain uniformly small droplet size and adequate penetration of foliage.

Other pests may include rabbits and grazing animals for which there are no better controls than good fences and hunting or trapping. A special problem is presented by the slugs and snails which seem to be on the increase in cool humid climates. Though bait with metaldehyde can be very effective it must be applied repeatedly and in large quantities if rains are frequent.

IRRIGATION AND DRAINAGE

Both of these are common problems in areas with little slope and with heavy soils. Though lack of moisture can be a problem, causing blossom drop or poor growth with resulting low yields, it is not as serious or positive in its effects as can be the lack of drainage and excess moisture. Most legumes have a relatively shallow (three foot) root system and require good aeration. Excess surface or subsurface moisture will very quickly cause root death; 68 percent to 70 percent of total field capacity is generally regarded as adequate for most food legume production.

Sprinkler application can be used for most conditions including sandy soils and irregular slopes which would be difficult to irrigate by surface methods. Applications will need to be fairly frequent, as often as once every week or two during high stress periods, and may require from one to three inches of applied water per set. Costs will be high since minimum pressures wili be around 30 pounds psi and losses may be over 50 percent of applied water. I sincerely doubt that there is much probability of commercial use of sprinkler irrigation for bean culture except for the production of seed.

Surface irrigation by the furrow method can be used in soils with a relatively high clay content if they do not shrink and fissure easily on drying. Better control and uniformity can be obtained by use of level head ditches, and siphons or portable no-pressure gated aluminum pipe. Alternate row application is preferred with high initial rates and relatively short runs. Care should be taken to see that there is no secondary seep and irrigation should proceed from high to low ground.

HARVEST

There is nothing like good hot dry weather, or a light frost, to hasten maturity in preparation for harvest. Lacking these it has been common practice to utilize herbicides (arsenites, dinitro) to defoliate and kill weeds, but this practice has its dangerous aspects and probably should not be recommended. Use of 2,4-D for spot control of bindweeds may also be very practical and effective for control of these weeds prior to use of machinery, but may also be undesirable.

Hand pulling of food legumes gets around the maturity problem but at considerable cost. The customary method is to pull several rows and place the plants, roots up, in small groups along the central row. The pulling can be more easily accomplished during the morning hours when pods are somewhat moist and less susceptible to shelling. Machine pulling can be accomplished in very level fields by large knives that should be adjusted to run just under the surface of the soil. Plants which are somewhat united by the vining tips of the plants will cut and windrow much more uniformly than either very vining types or bush types. Nevertheless, most machine pulling will cause considerably more field shelling than hand pulling.

Some erect food legumes can be harvested directly by the combine using special lift guards on the cutter blade and cutting practically at ground level. Fields must be practically weed free and with no rocks or sticks if stoppage and breakage are to be prevented. Draper pickups give the best results for windrowed pulled plants. Combines must be fitted with special peg-tooth cylinders to avoid problems with vining types (or weeds) and adapted for low cylinder rpm. Hand threshing can be done on raised slatted platforms or on tarpaulins or cleaned ground. Piles of plants are beaten rhythmically with fairly short wooden sticks until shelling is complete. A winnowing and final hand cleaning is then given the product before sacking for transport.

Very large kidney type beans and many cowpeas are impossible to combine without excessive breakage. Special shellers or dehullers which utilize fairly smooth rolls for a combination pressure-friction action must then be used, or else the crop must be handled manually. Bare metal parts (instead of rubber covered or wood) and high speeds will cause more than the normal amount of peeling, splitting and hidden damage. Fairly high seed moisture contents (14 to 18 percent) will also help prevent these damages.

CLEANING AND DRYING

Unless harvest has been delayed excessively, the grain will contain too much moisture for safe transportation and storage. To effectively and economically dry the grain it should first be cleaned and possibly graded. The job can be accomplished manually, though this will be very slow, and then spread out in the sun to dry. Large quantities, however, cannot be managed in this fashion and will need to be cleaned in proper mechanical equipment. Usually a scalper with one or two screens and a blower will be utilized, but a much faster and better job can be done on a four-screen grain grader with a separate aspiration given both before and after the grader. This can be followed by a gravity table to remove stones and weevily grain, with a sizing operation to follow if the product is for seed.

Grain can be dried to 11 to 12 percent moisture content in either batch dryers or one-pass tower systems with both loading and unloading by gravity feed on endless belt conveyors.

GOALS AND MEANS FOR PROTECTING *PHASEOLUS VULGARIS* IN THE TROPICS

W. J. Zaumeyer

Discussants: Leonce Bonnefil; Rodrigo Gamez.

Beans in the tropics often suffer heavy losses from diseases and insect pests. I have made a number of bean disease inspection trips to Latin America while employed by the U. S. Department of Agriculture but naturally I am not nearly as well versed on the diseases of this crop in these countries as some of you are who have worked full time in this field. Although I have visited Brazil, Chile and Colombia several times and Costa Rica and Guatemala only once, most of my work on bean diseases and their control in Latin America has been in El Salvador which I visited about five times from 1964 to 1969. Dr. Floyd Smith, an entomologist formerly with the U. S. Department of Agriculture, and I worked cooperatively with a number of scientists at the Santa Tecla Station in El Salvador. This work was also in cooperation with AID. I worked very closely with Bernardo Patiño testing many lines of beans for resistance to certain of the diseases, such as angular leaf spot, round spot, common bean mosaic, golden mosaic, web blight and rust. We also initiated a breeding program to develop new varieties resistant to some of the more important diseases. Dr. Smith and Dr. Roger Lawson of USDA are still cooperating on a part-time basis with Dr. Gamez of Costa Rica and the El Salvador group on certain insect and virus studies.

Beans are grown under many different environmental conditions throughout the tropics of Latin America. In Brazil, the largest bean producing country of the world, they are grown in the Amazon basin where it is warm and wet, hot in the north. They are also grown in the highlands in southern Brazil which is subtropical.

In Chile they are produced in the central part of the country where it is moist and in the dry lowlands which are irrigated. In Colombia, the second largest producing country in Latin America, they are mostly grown in the cool valleys having two rainy and two dry seasons annually. In Venezuela they are grown on the north coast at sea level where it is hot and humid and in the mountain valleys and tablelands which are subtropical. In Costa Rica they are produced on the dry warm Pacific slopes.

In El Salvador beans are also produced on these slopes, on mountain sides and in the cooler high valleys, while in Guatemala production is on the Pacific side of the volcanoes which are relatively dry and in the mountains which are cool. In Honduras they are grown in the warm moderately dry interior lowlands as well as in the cooler highlands. In Mexico they are produced in the north which has a continental climate, in the warm central tablelands without excessive rain and some in moist areas at sea level.

Beans are not widely grown on the Atlantic side of Central America and in the Caribbean area where rainfall is heavy and high humidities prevail. Neither are they grown at high altitudes such as in parts of Peru, Ecuador and Bolivia, but sizeable amounts are produced in the first two mentioned countries at lower elevations. Thus dry beans are grown under many different environmental conditions, some of which are very conducive to the development and spread of many diseases. Some are more serious than others in certain countries or in parts of some countries. The severity or absence of some diseases vary between the wet and dry seasons.

In Guatemala and El Salvador it was reported that in some of the best bean regions, fields had a Pacific slope exposure where there is a short wet season during which the crop grows to near maturity. In some years there might be a slightly lengthened period of rain when anthracnose and common bacterial blight would develop. During one season in El Salvador a hillside planted to beans, facing toward the northeast so the moist trade winds came directly to it, was especially suitable for bean rust. On the same mountain at the same elevation but on the other side where the air was dryer and the trade winds were not felt, rust was not a factor.

Angular leaf spot is much more serious in the tropics than it is in the temperate zone. In the tropics the presence or absence of shade appears to have a distinct effect on it. Beans planted between maize stalks with old dried leaves may be shaded to a 40 percent condition. Under these conditions there is about half the number of infection points of the angular leaf spot organism as on those growing in full sunlight. Where edges of bean fields are planted so they come under the influence of shade from trees or buildings, it has been reported that the diseases severity is much reduced.

In Costa Rica, Dr. Echandi found that **Ascochyta** leaf spot and round spot were fairly well restricted to cool conditions such as are found in the highlands. In contrast, angular leaf spot and powdery mildew are most severe in the tropical warm dry ecological zones. From this it is clear that the presence, absence or severity of a disease depends upon the environment of the area where the beans are grown.

IMPORTANT DISEASES IN THE TROPICS

Space will not permit me to discuss in detail the important bean diseases found in the tropics. I will only cover the pertinent points of each.

Virus diseases

Common Bean Mosaic

Common bean mosaic is found wherever beans are grown. It is seed borne and often causes a severe mottling and malformation of the leaves, a stunting of the plant and a serious reduction in yield. It is transmitted by many species of aphids. As in the United States, there are strains of the virus in the Latin American countries which produce almost identical symptoms to those of the type strain. They can be identified by the reaction of certain differential bean varieties.

The most satisfactory control of the disease is the use of resistant varieties. Practically all varieties grown in the United States resist the type and the important widespread strain of the virus known as the New York 15 virus.

When I made my first visit to El Salvador in 1964, it appeared that the most important bean disease noted was common bean mosaic. Since then Bernardo Patiño has developed a new variety known as No. 184 which resists this disease, as well as some strains of bean rust.

Golden Mosaic

Another important and possibly the most important virus disease now in many of the Latin American countries is golden mosaic, which is transmitted by the sweet potatoe white fly, **Bemesia tabasci**. It is most commonly found near plantings of cotton or other malvaceous hosts.

Mottle Dwarf

The third most important virus disease is mottle dwarf, producing symptoms similar to those of the curly top disease of beans found in the United States, which is transmitted by a leaf hopper. Mottle dwarf is sometimes called pseudo cruly top. It is also transmitted by the white fly. It causes a severe curling of the leaves, a stunting of the plant, and a severe reduction in crop yield.

Bacterial diseases

Common Blight

The only bacterial disease of importance which I have observed in my surveys in the countries mentioned has been common blight caused by **Xanthomonas phaseoli**. It is a warm weather disease requiring relatively high moisture conditions, especially rain. Although it is commonly found in many fields, I have only observed it on one occasion where it caused extensive damage in a commercial field.

Some years ago it was a very serious disease in many eastern, midwestern and southern states of the United States. This was prior to the widespread use by farmers of disease-free seed produced in the arid western regions of the United States, such as in southern Idaho, eastern Washington and California where the disease is not present because of environmental conditions unsuitable for its development and spread.

The first symptoms noted are small water-soaked spots on the leaves which later become large brown necrotic lesions. On the pods water-soaked spots are first noted which gradually enlarge and may spread over much of the pod. These lesions later take on a brick-red coloration. The disease is seed borne and can be spread in this manner. It is also spread by driving rains, by field equipment such as cultivators and by workers walking through or working in infected fields, especially when the plants are wet from rain or dew.

Halo Blight

The other bacterial disease which is not noted frequently in the Latin American countries, is halo blight, caused by **Pseudomonas phaseolicola.** It requires cool weather for development and hence is not very widespread. I have noted it on one occasion in Guatemala and in experimental bean plantings of the Rockefeller Foundation near Bogota in 1955. It has also been reported from Venezuela.

Halo blight produces lesions similar to those produced by common blight except in the very early stages of infection when yellow chlorotic spots are noted on the leaves, resembling "halo-like" areas. Later these become necrotic and cannot be distinguished from the lesions of common blight. The pod symptoms of both diseases are likewise similar. It is also seed-borne and spread in this manner.

The only satisfactory control measure for both bacterial diseases is the use of disease-free seed. Concerning common blight there are several resistant varieties; Emerson, Tara and Jules developed by Dr. Coyne at the University of Nebraska. There are no satisfactory chemical control measures. Drs. Shuster and Coyne of Nebraska have isolated a new, highly virulent strain of the organism from seed originating in Colombia. All of the new varieties are susceptible to the new race of common blight.

As mentioned earlier, the principal control measure used in the United States is the use of healthy seed and as a result the disease is rarely observed, except in certain years in Michigan when locally grown seed is used and where weather conditions in some years favor the development of the organism. Certified seed is, however, disease free.

Concerning halo blight, most U. S. dry bean varieties are resistant to the disease although all garden bean varieties are susceptible. Because of the use of disease-free seed, the disease is seldom noted throughout the country.

Fungus diseases

Anthracnose

Bean anthracnose, caused by **Colletotrichum lindemuthianum,** has been reported from Mexico and every Central and South American country growing beans. The disease is most easily recognized by the symptoms on the pods where large dark, sunken, circular cankers are produced. The centers of the spots are light buff in color, later turning dark. Within the cankers are flesh colored spore masses which are scattered by various agencies and cause infection to other plants.

On the leaves, the anthracnose fungus generally follows the veins on the undersides of the leaves, causing them to turn dark red. In a severe attack dead and angular spots appear on the upper surface. The disease is seed borne and the symptoms are noted as dark brown, sunken cankers. On dark seeded varieties these symptoms are difficult to observe.

Control of the disease is by the use of disease-free seed and resistant varieties. In the United States only the varieties grown in Michigan are resistant.

About 50 years ago anthracnose was the most important bean disease in the United States. At that time most of the beans were grown in the east, south and midwest where the environment was ideal for the development of the organism. At present the disease is seldom found. The reason for this is the use of disease-free seed produced in the western United States where arid conditions prevail which are not conducive for the development of the organism —also the use of disease-resistant varieties of several dry beans of the pea bean and Red Kidney types. They are grown principally in Michigan, the largest bean growing state in the United States, where the disease can occur on susceptible varieties. In tests at Beltsville, Maryland, it was found that among 15 El Salvador lines tested, one, Hondureño Blanco (P. I. 304110) was resistant to all four races of the organism.

Rust

Bean rust, caused by **Uromyces phaseoli typica,** like anthracnose, is found in all of the Latin American countries and is considered to be of major importance in many of them. In Brazil and Peru it is possibly the most important bean disease where it causes considerable crop loss. It is mostly found in dry seasons.

The organism attacks principally the leaves. The first symptoms appear on the lower surface as small white spots. Within a few days these develop into rust-colored lesions or pustules. As many as 2,000 have been counted on a single leaf. A week or so after these appear, the entire leaf turns yellow. Later it turns brown, dries up and falls from the plant.

The rust fungus has several stages. The uredo spore stage shows up as reddish-brown pustules containing thousands of reddish-brown spores which are blown by the wind and spread the disease from plant to plant and from field to field. Toward fall, if the temperatures drop, the rust may produce another kind of spore known as teliospores which are black and are very hardy. I do not know if any of these spores are produced in the tropics.

When finely ground sulfur is applied to beans as a dust fairly early in the season before the rust spots appear, the disease can be controlled. Sulfur destroys the comparatively few rust pustules present at that time. Spread of spores from these spots is stopped and other rust pustules are prevented. If dusting is done after the rust is widespread, the control is not nearly so complete. Manzate, used either as a dust or spray, is also effective but more expensive than sulfur.

Breeding rust-resistant varieties is difficult because of the many strains or races of the organism. More than 34 races have been identified in the United States and others have been described in the Latin American countries. Two varieties that resist many of the races in the United States are Pinto U. S. 5 and 14. These were released by the USDA many years ago but are no longer grown commercially.

A plant pathologist from Brazil, Mrs. Elaine Agustin Oliveira, who studied at the University of Nebraska under Dr. Coyne, found that Great Northern 1140, another USDA introduction, resisted the most important race in southern Brazil.

Angular Leaf Spot

Angular leaf spot, caused by **Isariopsis griseola,** is another of the important bean diseases of the tropics. I found it very serious in Brazil, Colombia and El Salvador. It is most important during the wet seasons. I can recall visiting with one of the Rockefeller Foundation plant pathologists in Medellin in 1955 and observing his experimental bean plots. At the time there was a trace of the disease present in his plots. We returned to them less than two weeks later and the disease had become so widespread that most of the plants were defoliated.

One of the outstanding symptoms of angular leaf spot is described by its common name. Spots which originate on the underside of the leaves are delimited by the veins and veinlets. The lesions, which are gray at first, later become brown. The striking angularity of the spots distinguishes this disease from other leaf spotting diseases. Angular leaf spot can cause almost complete defoliation beginning with the lower leaves. Leaves are infected more frequently than pods.

Control measures for the disease have not been perfected. Tests conducted in El Salvador have shown high tolerance among certain plant introduction material and crosses with these lines. Tests at Beltsville, Maryland, with one isolate of the organism from the United States indicated a few resistant varieties. Although races of the organism have not been identified, I am convinced that some exist. Resistance studies should be conducted in a number of locations with as large a collection of bean varieties as possible and if any resistance or high tolerance is found a breeding program should be initiated in order to develop varieties adapted to the various areas where the disease is important.

Web Blight

Web blight, caused by **Pellicularia filamentosa** or **Rhizoctonia microsclerotia,** (whichever you prefer) is a common and important disease in the tropics during the wet seasons. It has been reported in most Central American countries as well as in Brazil and Peru. It most likely occurs in several other South American countries.

The web blight fungus produces small circular, water-soaked spots on the leaves and spiderweb-like mycelial growth on the stems, pods and foliage in which many small brown sclerotia are imbedded. As the infected area enlarges, light tan hyphae develop on both surfaces of the leaf and spread rapidly over the non-infected areas. With favorable weather conditions the mycelium spreads to all parts of the plant, binding the leaves, petioles, flowers and pods together with a web or mat of hyphal strands.

In the tropics, beans should be planted so that they may complete their growth before the beginning of the rainy season. The plantings should be in well aerated situations in rows and not broadcast. In tests conducted in El Salvador in 1965 bush varieties were noted to be very susceptible but pole and intermediate types somewhat tolerant.

Root Rots

There are a number of important root-rotting diseases of beans which are caused by several different organisms. Dry root-rot caused by **Fusarium solani f. phaseoli**, rhizoctonia root-rot caused by **Rhizoctonia solani**, and pythium root-rot caused by **Pythium aphanidermatum** and **P. phaseolorum**, are common in the tropical countries.

The symptom of dry root-rot is characterized by a reddish discoloration of the tap root. Sometimes the main root and lower part of the stem become dry and pithy. The small rootlets are frequently killed, the plants stunted and readily pulled up from the soil.

Rhizoctonia root-rot is more serious on young bean seedlings than on older plants. On seedlings the disease in known as damping off. The cankers that are formed on the roots are reddish brown and cause sunken lesions on the part of the hypocotyl below the ground level.

The symptoms of pythium root-rot are sometimes confused with rhizoctonia root-rot. If the plants are attacked when very young **Pythium** causes a wet rot and soon kills the plants. The disease is then known as damping off. When half grown plants become infected, they later wilt and finally die.

When the weather is hot and moist, a rot of the stem and lateral branches may occur. These symptoms have been referred to as pythium wilt. Large plants 8 to 12 or more inches high are as susceptible as small ones.

No satisfactory control measures have been developed except crop rotation. Except for **Fusarium** root-rot no tolerant or resistant varieties have been developed. In the United States good progress is being made in the development through breeding dry bean varieties highly tolerant to **Fusarium** root-rot. Dr. D. W. Burke of the USDA at Prosser, Washington, is releasing a red Mexican variety which is **Fusarium** resistant. He is also making progress in the development of several pea beans (white-seeded), a California pink type and a pinto which are highly tolerant to this disease. The root-rot tolerant parent was found in Mexico and is designated as P. I. 203598.

Deep plowing or chiseling, up to 51 cm in depth, of land heavily infested with the **Fusarium** root-rot organism has increased bean yields by allowing the roots of the plants to penetrate the soil more readily and breaking of root barriers permits a larger root system to develop and thus producing larger plants and greater yields.

Southern Blight

Southern blight, caused by **Sclerotium rolfsii,** is an important disease in many of the Latin American countries. Its symptoms are sufficiently clear-cut to distinguish it from root diseases caused by other fungi. The earliest symptoms are a slight yellowing of the lower leaves and a water-soaking of the stem just below the soil line. The infection of the underground part of the stem and tap root extends downward and destroys the cortex and is readily separated from the stele. At the base of the stem and on the ground about the plant a moldy growth of white mycelium intermixed with a large number of sclerotial bodies is produced. If the plant is pulled up, a collar of soil and mycelium adheres to it.

No very effective measures can be recommended for the control of this disease. Rotation with cereals and other crops resistant to the disease may assist to some extent.

Sclerotinia Wilt

Sclerotinia wilt, or white mold as it is sometimes called, caused by **Sclerotinia sclerotiorum**, is also an important disease of the tropics. The first symptoms of the disease appear as irregularly-shaped water-soaked spots on the stems followed by similar spots on the branches and leaves. The organism grows rapidly, causing a soft watery rot of the affected parts including the pods. If several days of warm weather follow the infection, a cottony growth spreads over the branches, leaves and pods. A few days later, irregularly shaped, small, hard, black charcoal-like bodies known as sclerotia occur in large numbers. These are the resting bodies of the fungus. The plant usually dies in a few days.

No adequate control measures are known. There are no tolerant or resistant varieties. A rotation of two or three years or longer with such crops as maize or other cereals that are not affected should be used if possible. Planting beans in rows far enough apart to allow good air circulation in a field may prevent a high field humidity and often reduces infection.

Other Diseases

There are several other diseases which I have not mentioned such as powdery mildew caused by **Erysiphe polygoni**, round spot caused by **Chaetoseptoria wellmanii**, Asochyta and Cercospora leaf spots caused by **Asochyta boltshauseri** and **Cercospora cruenta** respectively. When I was in Brazil in 1964, gray spot, caused by **Cercospora vanderysti**, first reported the previous year, was the second most important disease in the Viçosa area.

Space does not permit me to discuss the above mentioned leaf spots. Some are important and cause considerable damage when weather conditions favor their development and spread.

BEAN INSECTS

Although I am not an entomologist, having been associated with Dr. Smith while working in El Salvador I managed to learn something from him about the bean insects there. I also majored in entomology as an undergraduate student at the University of Wisconsin.

I will only dwell briefly on this subject since Dr. Bonnefil, who has been working in this field in the tropics for many years, is to contribute his comments.

An insect of great importance, particularly because it is a vector of golden yellow mosaic and mottle dwarf, is the white fly **Bemesia tabaci** mentioned earlier. Found in large populations in Central America and possibly the South American countries as well, they are responsible for the widespread transmission of these two viruses throughout Latin America.

Another very important group of insects which frequently cause severe bean losses by destroying the seeds belong to the genus **Apion**. These are known as pod weevils and attack the seeds when they are developing in the pods. They may destroy as many as 60 percent of them. The most common species causing damage is **Apion godmani**. Three bean varieties have been reported by Mexican entomologists to resist this species.

A third important pest, especially in low hot areas, are bean leaf hoppers **Empoasca** sp. I have noted bean fields in El Salvador which were almost a total loss due to stunting injury caused by **Empoasca krameri.** Workers in Mexico have found five varieties which are tolerant to this leaf hopper.

Other insects of importance to beans are the banded cucumber beetle, leaf web caterpillar, leaf miner, leaf beetle, lesser corn stalk borer and army worm.

It has been estimated that the field loss in beans due to insects in Central America is about 25 percent and the storage loss about 35 percent. Losses due to **Apion godmani** have been nöted to be as much as 60 percent in some fields in El Salvador.

The bean weevil is the most important storage pest in Brazil and eats mature beans in the field and in storage. The lesser corn stalk borer attacks the plant stems at the ground level and is the most important field insect. Often 10 percent of the plants in a field may be killed by it. Leaf hoppers during the dry seasons are often responsible for heavy losses.

In Colombia the most important bean insects are spider mite, leaf hopper, leaf beetles, weevils, bean pod weevil and the stem borer.

GENERAL RECOMMENDATIONS

There are a number of recommendations that can be utilized to protect beans from pests.

Use of Resistant Varieties

The most satisfactory way of controlling certain bean diseases is to grow varieties that are resistant to them. A grower should never plant a bean variety known to be susceptible to a disease when he can plant a resistant one.

Using Disease Free Seed

Because some of the principal diseases are seed-borne, such as the bacterial blights and anthracnose, growers should make every effort to use seed produced from disease free crops. Some of the seed-borne diseases cannot develop in localities that have low rainfall and high temperatures during the growing season. I feel convinced that areas such as these can be found in some Latin American countries, especially during the dry seasons, where such seed could be produced. In addition a seed certification program could be established whereby such seed fields are examined for the presence or absence of these diseases and a tolerance established regarding the amount of such diseases allowed for certification.

In the United States this tolerance is very low for the bacterial blights and anthracnose and in some cases it is zero tolerance. If any is found, the field examined cannot be certified.

Crop Rotation

The organisms causing most of the bean diseases can live in the soil for several years on dead plant material, ready to infect a new bean crop. If beans are grown year after year where such organisms are present in the soil, the organisms often multiply. How long a crop rotation should be in effect to control some bean diseases or how much time is needed to starve out some of the disease organisms in different climates and different soil types is not known. In some of the diseases discussed previously, recommendations were made as to what crops should be rotated with beans where these diseases are present.

Field Sanitation

The longevity of some disease-producing organisms in the soil is shortened if the dead plant material decays rapidly. For this reason, refuse remaining in a field after threshing and bean straw returned to a field should be plowed under as soon after harvest as possible.

Some of the fungi and viruses causing bean diseases attack weeds growing in the bean fields or nearby. The fungus causing sclerotinia wilt, for example, attacks a number of weeds. When a bean crop has been seriously affected by disease and the field is abandoned, any weeds in or near the field should be plowed under as soon as possible to prevent infection of future crops.

Seed Treatment

Disinfecting bean seed with chemicals, with the possible exception of streptomycin for the control of halo blight, has failed as a method of controlling seed borne diseases. Chemicals destroy the organisms on the surface but cannot reach those within the seed without causing injury to the seed itself. Where beans are to be planted in cool, wet soils good results in preventing seed decay and for the control of the seed corn maggot are usually obtained by a slurry treatment of the seed with a fungicide and an insecticide at the rate of 1.5 to 2 ounces per bushel. Delsan was such a product.

RESEARCH OBJECTIVES

Continued search should be made for resistance to angular leaf spot, round spot anthracnose and rust. Also for powdery mildew, common blight, common bean mosaic virus and the white fly-transmitted viruses. A world bean collection should be tested for these and other serious diseases.

The races of rust, anthracnose and possibly angular leaf spot present in the various countries should be determined. Differential bean varieties for the first two diseases are available. This would aid in any bean breeding program.

Chemical control for web blight should be investigated. Web blight also is very dependent on the culture. In El Salvador, if beans are planted so the rains can splash soil on the leaves, one notes web blight. Minimum cultivation to reduce such splashing aids infection control.

Continued search should be made for varieties tolerant or resistant to the bean pod weevil and bean leaf hopper using the above mentioned world bean collection. If and when resistance or high tolerance is found to any of these diseases or insect pests, a breeding program should be initiated for the development of new varieties resistant to one or more of these pests. Multiple resistance is superior to resistance to a single pest.

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I. Commentary upon:

GOALS AND MEANS FOR PROTECTING *PHASEOLUS VULGARIS* IN THE TROPICS

Leonce Bonnefil

At about the same time, but within different institutions, Dr. Zaumeyer, Dr. Gamez and I worked in Central America on the identification and control of agricultural pests.

As Dr. Zaumeyer mentioned, I have indeed worked for some time on the control of bean pests. I was then under an assignment to the Turrialba Center from the Food and Agriculture Organization of the United Nations (FAO). I presented a paper in March, 1965, on the subject, at a meeting of the PCCMCA held in Panama City. Reviewing this work recently, I noticed that the part describing the insect pests was fairly accurate but that dealing with their control had become somewhat obsolete in the areas dealing with the use of chemicals.

TAXONOMIC CLASSIFICATION OF BEAN PESTS

As it appears from my reconnaissance trip of 1965 in Central America and the limited knowledge I have of other countries of Latin America, the taxonomic classification of bean pests is far from being accurately defined. There probably are many reasons for that unfortunate situation, including insufficient effort dedicated to collection, preservation, authoritative identification, exchange of prototypes with regional and foreign institutions, research of ecotypes, and phylogenetic studies. All this effort may seem of academic interest and far-fetched, but although it may not be of first priority it may help avoid confusion in dealing with a particular pest.

Our studies of Central American leafhoppers revealed an extraordinary variation of forms with different distribution and environmental requirements, chiefly humidity. From a practical standpoint, these specific differences can be ignored without great consequence. It may not be futile however to know that not all leafhoppers are alike as to their prolificacy, for example, or the severity of their damage.

THE ECOLOGY OF BEAN INSECT PESTS

While the biology of the insects is known, mostly by extrapolation of study data of related forms in countries of Latin America or outside that region, the ecology of the pests and mostly their interrelationships with their host plants, is not known at all. It is of course obvious that such information is of very great importance. Without elaborating on that subject, certain plant categories may very well encourage the multiplication of a pest and favor an infestation. This holds true whether the plant species is a cultivated crop or only an occasional wild host.

The effect of the physical components of the environment is also of great importance, since it may be profitably used in anticipating the rise or the fall of pest populations.

The influence of predators and parasites should not be minimized although it is generally slow at manifesting itself unless definite action is taken in favor of the biological control of a particular pest.

Reverting to the pest-host plant interrelationship, it is not very well known within the context of the cultural practices for beans in Latin America. Some obvious features can be listed, which have a definite bearing on pest abundance and feasibility of control.

Bean cultivation being generally a small domestic enterprise, it is not anticipated to give much financial return. Consequently, it is carried out:

(a) on marginal land;

(b) without great care as to soil preparation, application of fertilizer, etc., which would assure optimum growth and good recuperating power to eventual pest damages;

(c) without substantial effort to prevent or discourage the growth of weeds or to control the abundance of insects and other pests;

(d) without taking enough advantage of the repressive effect of physical factors, natural or induced.

Except for commercial plantings, the tendency is virtually to ignore insects and nematodes and be content with whatever is left by the voracious enemies of the crop.

From rather extensive observations made in Central America, some if not all the main pests of bean can be encountered in the neighborhood of bean fields the year round. They are in the soil or on alternate hosts in variable numbers and will transfer to **Phaseolus** as soon as the seedlings have emerged. Exact greenhouse tests in Turrialba have shown that the bean is largely preferred to a great variety of plants, for feeding or egg deposition. This plant, in turn, enhances the fertility and the longevity of the insects.

It is postulated that as soon as the first planting is established, the insects move in from second-choice hosts and start breeding at a faster rate, building large populations if no action intervenes to stop their multiplication, e.g., late rains or application of insecticides. Whatever the damage to the bean stand, an increased number of insects will be at hand at harvest time, say July to August. They will linger in the old bean field, move to surrounding vegetation, and attack in force the second planting in September.

This situation is probably the one of most common occurrence, justifying the statement that the second crop is more heavily attacked. If any adverse influence reduces the build-up on the first crop, the second can be little damaged, hence the divergence of views as to which of the two crops is more heavily infested.

As a rule, it is highly justified that a close watch be maintained on all pests. This is particularly beneficial in the case of sucking insects such as aphids or leafhoppers (**Empoasca**) which can produce grave injury even if only a small number attack the plants early in their vegetative growth.

Equally misleading is the action of such insects as armyworms, rootworms, leaf beetles, thrips, which can be extremely numerous and even cause spectacular damage to the foliage or to the root system without appreciable effect on the grain production. If action is deemed necessary, it should be prompt and thorough.

CONTROL BY INSECTICIDES

Insecticides afford the fastest action, although they may be dangerous if not used properly.

I have compared the recommendations which were in force in 1965 with the 1972 recommendations extracted from the Pest Control Guide of the state of Florida, U.S.A. Organophosphate insecticides such as Diazion, Phosdrin, Systox, Parathion, Guthion are still being advocated. So are the carbamate Sevin and a few fast-degrading chlorinated camphenes like Toxaphene and Thiodan. Long-residual organochlorines like DDT, Dieldrin, Methoxychlor are already phased out or are being phased out.

The new trend is in favor of nonpersistent, fast-acting, narrow-spectrum compounds. They may display high mammalian toxicity, e.g., Parathion, Guthion, but no dangerous residues accumulate in plant and animal tissues.

Such features are of primary importance in the control of an insect like the bean pod weevil (**Aphion**) and thrips in the control of which a fast knockdown is in order while residues slow to break down are undesirable.

The Mexican bean weevil (**Epilachna**), the lesser corn stalk borer (**Laspeyresia**), the salt-marsh caterpillar (**Estigmene**), are still controlled by more persistent pesticides.

Systemic insectides are successfully used against sucking insects such as aphids (**Aphis**) and leafhoppers (**Empoasca**). It seems, however, that certain of these compounds because they are hazardous for humans or are likely to incite phototoxicity are not recommended. Demeton (Systeox), Phosdrin and Thiodan (Endosulfan) are on the safe list.

Whiteflies (**Bimesia**), vectors of the golden yellow mosaic, are known to develop resistance to insecticides, but only when application are exceedingly frequent.

Diazinon has remained a satisfactory control for leafminers (**Chapelus, Liriomyza**). Demeton is also claimed to be a good control. In either case, applications must be done early when adults are moving in. In case of very heavy infestations Parathion is used.

The lesser cornstalk borer is controlled by Parathion in wet application prior to and at emergence of the seedlings. The banded cucumber beetle **(Diabrotica)** and leaf beetles **(Ceratoma, Andrector)** are controlled by the same insecticides as leafminers. They should not then require a separate treatment, unless no treatment is made for leafminers and the beetles are very abundant. The damage by the adults may look more serious than it is; the damage by the larvae (rootworms) can be very important.

CONCLUSIONS

Satisfactory control of bean pests can and must be achieved.

The bean field, if it is kept free of obnoxious weeds, and if properly fertilized, will resist better the attack of pests. It should not be located on marginal land.

Although bean culture does not leave much profit, chemical control is feasible. Full advantage should be taken of biotic agents so as to limit the use of insecticides and make it less costly.

If the ecology of the pests is well known, a spray schedule can be worked out which would be most efficient, putting the number of applications at a minimum.

Biological control has not so far proved to be of significant value.

Varieties of beans tolerant or resistant to some insects, **Empoasca, Apion,** have been developed. This must be considered a great achievement which should incite more work in that direction, as there are no better substitutes for chemicals. In addition, the bean plant would appear to offer unrestricted potential for genetic manipulation. Its short growing period is a great advantage.

RECOMMENDATIONS

If the control of bean pests is to be economically feasible and highly effective under Latin American conditions, research should be actively pursued along the following lines:

The correct taxonomic determination should be made of all the main pests.

Collection should be made at frequent intervals, conveniently put away with all possible information regarding location, time of collection, host plant.

Observations should be made and records kept of numbers, movements of the pests themselves, their predators and parasites.

An inventory should be made of the alternate host plants of all the insects.

The effect of the planting date on the severity of the infestation should be investigated.

The effect of mixed cropping maize-bean on relative numbers of pests would make a very interesting and important study project.

The economic injury level, that is the numbers of a pest which justify pesticide treatment, should be determined for each pest in particular.

II. Commentary upon:

GOALS AND MEANS FOR PROTECTING *PHASEOLUS VULGARIS* IN THE TROPICS

Rodrigo Gamez

Dr. W. J. Zaumeyer has clearly presented the nature and importance of the problems caused by bean pests and diseases in the tropics.

My knowledge, limited as it might be, regarding the diseases that affect this plant is the fruit of work I have carried out during the last five years, which I have spent working with viruses and viral diseases of beans in the Central American area. My experience has been exclusively in this area, with the exception of one visit to Peru to evaluate the same problems. Pathogens and insects constitute one of the most important limiting factors in bean production in Central America. The genetic diversity of the materials used, and the ecological conditions under which beans are grown in this region, result, among other things, in the occurrence of a wide range of pests and diseases, which may differ in identity or severity from one locality to another and from one season to another. In his talk Doctor Zaumeyer has made an in-depth discussion of the problems caused by bacterial and fungal diseases which are common in Central America, and Doctor Bonnefil has mentioned the problems caused by insects. My comments will try to broaden the observations regarding viruses and viral diseases and the vector insects. The role played by insects in the dissemination of viruses that affect beans in the tropics is outstanding; therefore, I consider they should be involved in every analysis of viral problems. For a general synthesis of the problems, it seems convenient to group the problems in relation to the type of vectors, which in this case facilitates the identification of common characteristics of different diseases.

APHID TRANSMITTED VIRUSES

Among the aphid-transmitted viruses, the common bean mosaic is the most significant in the tropics. The aphid most commonly associated with the dissemination of this disease is Myzus persicae. This virus is also transmitted through seeds from infected plants. Although it has a broad geographic distribution, its importance changes from one region to another. In the Peruvian coast it is frequent to find plantings with close to 100 percent incidence of the disease. The Peruvian varieties, mainly those with white or yellow seed, are very susceptible to this virus; the virus is seed-borne in a very high percentage of cases.

Incidence might be very high in Central America when susceptible varieties are grown in regions with mean temperatures ranging between 20-25°C. and in altitudes above 600 m. A large amount of the Central American material, red or black seeded, selected by local breeding programs, presents resistance to the different races of the virus. Common bean mosaic is almost non-existent in the Guatemala highlands.

Different races of the virus have been identified in Central America and Peru, mainly on the basis of the reactions presented by different bean varieties. Striking differences may occur in the behavior of commercial varieties toward different races of the virus.

Wild species do not seem to have striking importance as natural hosts for common bean mosaic. This disease is introduced in the plantings by the use of contaminated seed and then it is disseminated by aphids in their erratic migratory movements in search of a host plant. Consequently, when we deal with susceptible materials, the use of disease-free seed is of primary importance in the control of the disease. Healthy seed production programs should logically use the basic control principles such as eradication of contaminated plants and avoidance of presence of vector aphids that will introduce or disseminate the virus, selecting for seed production purposes isolated geographic areas and seasons when the occurrence of winged aphid populations is low. The mentioned aspects have been thoroughly considered in the seed production programs in Peru.

WHITE FLY TRANSMITTED VIRUSES

Two types of virus are transmitted by the white fly **Bemisia tabaci.** These are of common occurrence in Central American and Caribbean bean plantings. These viruses were described by Dr. A. S. Costa, in Brazil, and were called "golden bean mosaic" and "mottle dwarf." In Brazil they seem to have little importance and a rather reduced distribution, which is not the case in Central America.

In the Central American area golden bean mosaic is widely distributed in the Pacific coastal plains where it produces severe losses. It is the most important viral disease in these regions. Its incidence seems to be directly related to the occurrence and mobility of the vector. In the Pacific Central American area cotton and kenaf are grown, and these plants are insect hosts in which large populations develop, later migrating to neighboring crops. There are other wild malvaceous hosts such as **Sida**, and numerous other species of different wild plant families, which constitute natural hosts for the insect. The ecological conditions of the region seem best for development of these insects, as can be deduced from their usual abundant populations.

Studies in El Salvador by Engineer Antonio Diaz have made it possible to single out some legume species which are natural hosts of the golden bean mosaic virus; in these legumes the insects acquire the virus and then transmit it to the bean plants. Infected plants exhibit severe bright yellow mosaic and show a pronounced decrease in production. These reactions of course, may vary among varieties, and also according to the time of infection and climatic conditions.

Both in El Salvador and in Puerto Rico, strains have been isolated that seem to be variants or races of the golden mosaic virus, but which differ from the latter in the symptomatology of the infected plants; however, additional research must be done to adequately characterize them.

In trials performed in El Salvador and in Costa Rica with over 5,000 bean cultivars, no resistance has been found to the mosaic virus, neither in greenhouse nor in field conditions. Similar results have been obtained in Puerto Rico. Studies in El Salvador indicate that long vegetative cycle cultivars with indeterminate growth habits present a marked tolerance to the disease in the field. An exhaustive assessment of germplasm is imperative for the localization of tolerant materials in order to obtain adequate disease control measures.

An adequate knowledge of the vector's biology could supply information to improve the control possibilities. Eradication of natural host plants could also contribute to reduction of the incidence of this disease.

Bean dwarfing is caused by the **Albutilon**, or infectious chlorosis virus of the **Malvaceae**. Though the disease produced by this virus in beans is more severe than that produced by the golden mosaic, its occurrence in beans is usually rather low, despite the fact that the incidence of the virus in cotton, kenaf and wild **Malvaceae** is generally very high, and white flies migrate easily in large numbers from the latter species to the bean plants. Apparently, this plant is highly tolerant to the **Albutilon** virus. For this reason, no emphasis has been placed upon search for control measures for this virus.

BEETLE TRANSMITTED VIRUSES

Insects of the genera **Diabrotica** and **Ceratoma** cause considerable damage in bean plantings in Central America. Some species belonging to these genera have been identified as important vectors of certain viruses belonging to a group with rather particular biologic and biophysic characteristics. Viruses belonging to this group identified so far include southern mosaic, chlorotic mottle and three different races of rugose mosaic. Both the southern mosaic and the rugose mosaic present outstanding symptoms, characterized by corrugated malformation and mosaic of the trifoliated leaves, and also a stunting of the plant and a decrease in production. Typical of the chlorotic mottle virus is a slight yellow mottling that produces only a slight reduction in yields. As in the southern bean mosaic, its geographic distribution is rather limited and its incidence is usually low.

Though the rugose mosaic has a wider distribution in Central America, its incidence is also generally low. Apparently, wild legume species are hosts to this virus. A large number of Central American cultivars are resistant to this virus and it is also feasible to control vector insects by the use of insecticides.

GENERAL COMMENTS AND RECOMMENDATIONS

I wish to stress some of the recommendations made by Dr. Zaumeyer, which are also involved in my brief comments on viral diseases.

The use of disease-free seed would contribute to reduce the incidence of viral diseases such as common bean mosaic as well as other bacterial and fungal diseases. It is of first importance to strengthen or to develop high quality seed production programs.

The use of resistant varieties is, without doubt, the least expensive and most efficient control measure. There are resistant varieties, or sources of resistance to the common bean mosaic and other viral diseases that could be used in breeding programs. Research for materials tolerant to golden mosaic must be stressed, since this is the most important viral disease in the warm dry regions of Central America and the Caribbean. Parallel to the above said research, characterization of the races or variants of the golden mosaic virus, or of other related viruses transmitted by the white fly, should be carried out.

An adequate knowledge of the biology of the insect vectors will contribute to the design of measures leading to the reduction or eradication of the insect transmitted viruses. As specific examples we can mention the aphids, white flies and chrysomelidae.

The identification of wild hosts supports the need of eradicating weeds as a possible measure to reduce the incidence of viral diseases.

Section 3.

PLANT TYPE AND BEAN BREEDING

Plant introduction and germplasm of *Phaseolus vulgaris* and other food legumes

Clibas Vieira

Discussants: 1) Efraim Hernandez X.; 2) Harold F. Winters; 3) Colin Leakey.

Plant architecture and physiological efficiency in the field bean

M. W. Adams

Discussants: 1) A. M. Evans; 2) D. H. Wallace; 3) H. C. Wien.

PLANT INTRODUCTION AND GERMPLASM OF *PHASEOLUS VULGARIS* AND OTHER FOOD LEGUMES

Clibas Vieira

Discussants: Efraim Hernandez X.; Harold F. Winters; Colin Leakey

ORIGIN

After the discovery of the New World in the 15th century, the common bean (**Phaseolus vulgaris** L.) was taken to the Old World. The bean adapted so well and became so familiar to the farmers that its American origin was forgotten. The old botanists considered the common bean to be of Asian origin. Yet, in the past century, De Candolle (1883), in his work about the origin of cultivated plants, included **Ph. vulgaris** with those species of unknown or uncertain origin.

Based on his phytogeographic method, Vavilov (1949/50) showed that the center of diversity of **Ph. vulgaris, Ph. coccineus, Ph. lunatus** and **Ph. acutifolius** is located in Mexico and Central America, because of the great variety of forms found there. Although the center of diversity and the center of origin may not be exactly the same thing, the discovery by Vavilov provides strong evidence in favor of an American origin of the common bean.

Today, after the discovery of wild forms in Argentina, Mexico and Central America and archaelogical finds in the U. S. A., Mexico and Peru, the American origin of **Ph. vulgaris** is accepted without controversy.

Burkart (1941) collected wild races of **Ph. lunatus** and **Ph. vulgaris** in the Tucuman and Jujuy mountains of Northern Argentina. They grew spontaneously in the humid valleys of these mountains at 1,500 to 1,800 meters above sea level. The wild forms of latter species were described as **Phaseolus aborigineus** by Burkart (1952) and were considered to be the ancestor of the cultivate forms. Later, it was reduced to a subspecies of **Ph. vulgaris** (Burkart & Brücher, 1953). Wild plants of the common bean were also found in Mexico and Central America by O. W. Norvell and G. F. Freytag, as mentioned by Kaplan & MacNeish (1960), and by Gentry (1969).

The various collections identified as wild **Ph. vulgaris** have all been vining types with seeds smaller than those encountered in most cultivated varieties. The small pods are twisting dehiscent, ejecting the seeds violently when they reach a certain point of dryness. Apparently, the determinate growth habit, the increase in seed size, and the reduction of pod-shattering have been established under domestication. The wild **Ph. vulgaris** cross easily with the modern cultivated varieties producing fertile offspring and F_2 generation. This indicates close compatibility in the respective germplasms. Gentry (1969) considers the wild Mexican beans as the progenitors of the present cultivated varieties.

Archæological investigations have permitted the discovery of prehistoric bean remains, whose age was determinated by carbon ^{14} dating. According to these studies, the common bean was domesticated in Mexico about 7,000 years ago; **Ph. coccineus** 2,200 years ago; **Ph. acutifolius** var. **latifolius** 5,000 years ago; the small Lima bean (**Ph. lunatus**) 1,400-1,800 years ago and the big Lima bean about 5,300 years ago in Peru (Kaplan, 1965).

CENTERS OF DIVERSITY

N. I. Vavilov was the first to establish the phytogeographic basis for plant exploration. He showed to the plant breeders that variation in cultivated plants is geographically unevenly distributed and that a large concentration of genetic diversity in our crops is geographically confined to relatively small areas - the "centers of origin" according to Vavilov's concept, now preferably called "centers of diversity."

He found the widest variation in **Ph. vulgaris, Ph. coccineus** and **Ph. lunatus** in Southern Mexico and Central America. Thus, this area constituted the "**primary center**" of diversity. There are other areas of diversity, less richly endowed, and for this reason called "**secondary centers**": (1) South American Center, including mountainous areas of Peru, Bolivia and part of Ecuador (secondary for common bean and Lima bean); (2) Chinese Center, where recessive forms of the common bean were found. Admitting that this species was only spread throughout the world after the Columbian era, we have to assume that the secondary Chinese Center of diversity is relatively new. It is interesting to note that apparently the bean breeders and the plant explorers did not pay much attention to China as an area in which to collect bean germplasm.

GENETIC VARIABILITY

The common bean exhibits a wide range of variation in growth habit, yield, pod size, color and texture, seed size, brilliance and color, resistance to diseases, chemical composition, adaptation to different growing conditions, etc. Publications which describe the variation in **Ph. vulgaris,** such as those of Muñoz & Cárdenas (1950) and Freytag (1955), and those which describe characteristics of varieties (Hedrick, 1931; Steinmetz & Arny, 1932; Puerta Romero, 1949; Barrios, 1969; and others), although covering hundreds and hundreds of varieties, only give a partial vision of the genetic variability which this species carries.

As happens with other cultivated species, only a fraction of the genetic variability of the common bean has been used. The collection of varieties has been made more or less haphazardly and not systematically as would be desirable. It must cover not only the centers of diversity, but the whole geographical range of the species, including even those countries where beans were introduced after the discovery of the New World.

The breeders will need to exploit better the available germplasm, to search for traits which permit them to make the bean plant more efficient, productive, nutritive and utilizable by a rapidly growing population. Up to the present, the main concern of bean breeders has been the introduction of disease resistance into varieties now in use.

With relative success in this activity, their attention is now turning principally to improvement of protein quantity and quality with better amino acid balance. Yield has been elevated to 2,000, 3,000, rarely to 4,000 kg/ha, mainly by control of the environment by the application of fertilizers, controlled irrigation, plant protection against pests, diseases and weeds, and other practices. I believe that we will soon begin to see a major emphasis on studies aimed at developing bean varieties capable of surpassing 4,000 kg/ha, in order to place this crop at the level of other important crops, such as wheat, soybean, maize, rice and others.

For this, better use of the germplasm will be necessary. The discovery of a few truly revolutionary traits may bring about such an impact. The Japanese "Norin" wheat is a good example. It is a dwarf, high tillering variety which was utilized in crosses that permitted the creation, by CIMMYT in Mexico, of the high yielding, fertilizer responsive varieties. Yields of more than 14 tons per hectare are already mentioned. In addition to Mexico, these varieties are causing a "green revolution" in agriculture in Pakistan, India and other countries (Krull & Borlaug, 1970).

VARIABILITY UNDERUTILIZED

The existance of so much genetic variability, which has been poorly explored and poorly understood, permits one to raise doubts about the present use of mutation breeding. Despite the advances in this field of research, such as the various known mutagenic agents, the truth is that induced variability has made little impact in agricultural production.

This is not to say that this type of research should stop or that useful mutants cannot be created. The truth, however, is that the natural variability of the bean, or even the presently available world collections of this crop, are being underutilized. Developing countries frequently divert their scarce funds and research personnel from the task of immediate improvement of existing varieties to the more academic and uncertain work in mutations.

In many parts of Latin America the farmers grow several bean varieties that are frequently mixtures rather than uniform populations. This material developed locally, principally through a system of natural selection, and was little, or not at all, "improved" by breeders. Normally, it exhibits a good deal of horizontal resistance. This resistance plus the genetical diversity that is maintained by the multiplicity of varieties and the lack of uniformity, or mixtures within varieties, may exert a dampening or stabilizing effect on some pathogens, particularly rust.

In developed countries the situation is quite different. The transformation from primitive to "advanced" varieties has had the effect of narrowing the genetic base. Uniformity is demanded by the consumer as well as the grower, forcing the breeder to create pure lines for their use. Besides, the selections have been made with closely defined objectives. The crosses and backcrosses, diluted the horizontal resistance when the vertical resistance was introduced. Specifically desired improvements are introduced through the backcrossing technique with a minimum of disturbance to the genotypic structure of the "advanced" bean varieties.

NECESSITY FOR IMPROVED VARIETIES

The agricultural situation in Latin American countries is beginning to change, accompanying their economic and social development and the increase of their populations. As a consequence of the modernization of agriculture, it is necessary to develop improved varieties, which are capable of higher yields than the primitive or local varieties, which lend themselves to mechanical harvesting and which are uniform. This last requirement will be unavoidable, as a consequence of the increase in the purchasing power of the urban masses, who will demand higher quality in the products they buy. The success with hybrid maize, and now with the improved varieties of several crops, shows that the farmers in many parts of Latin America will accept the new varieties of edible beans readily, once it has been demonstrated that they are superior to the old varieties. And what is going to happen with these?

The primitive varieties or land races are threatened with extinction. Therefore, it is urgent that these bean varieties be collected to preserve this rich genetic resource for our use and for future generations. No one can predict with much certainty what genes will be necessary for the agriculture of the 21st century. We must remember that until only a few decades ago, characteristics such as male sterility were considered as mere abnormalities having no agricultural value.

Evidently, this threat to the common bean germplasm is still a long way from what is happening with other crops such as African rice, **Oryza glaberrima**, and the wheats from the Near East, whose extinction is now taking place rapidly. Successes in the development of new varieties, such as those obtained by CIMMYT with wheat and by IRRI with rice, constitute a real and immediate threat to our genetic resources. The same will happen, in the future, with common beans. We must prepare for this, now.

GERMPLASM BANK

It can be seen that the vast genetic variability exhibited in **Phaseolus vulgaris** has as yet been little used. It can also be seen that the population explosion and the economic and social progress in the developing countries are requiring a modernization of agriculture in these countries. One of the consequences of this modernization will be the substitution of the indigenous populations of beans by the improved varieties that are more productive, nutritious, disease resistant, uniform and adapted to machine harvesting. These indigenous populations, as well as the wild types, constitute a magnificent and valuable gene pool which should be preserved for this and the future generations.

By means of well organized plant explorations, bean genotypes must be collected and preserved in germplasm banks. It must be remembered, though, that there already exist, on the American Continent and outside it, many valuable collections maintained by experiment stations and other research institutions (examples in Table 1). In many cases, however, these collections are threatened with loss through discontinuity of maintenance or genetic erosion. Many of these collections resulted from the enthusiasm and dedication of some researcher or collector, whose replacement may have different interests. Besides, many experiment stations struggle with a lack of adequate resources, both human and material, for this job. Consequently, the collections are maintained imperfectly and with difficulty. Sometimes, when the collection reaches a large number of introductions and there is not adequate room for storage, their maintainers must decrease its size. This results in the elimination of all the items in the collection which seem worthless. However, not all the introductions that seem worthless are really useless. No one knows when an apparently worthless introduction may turn out to be extremely useful.

EXISTING COLLECTIONS

Table 1 shows that there are excellent collections of beans and other food legumes in America and elsewhere. With the exception of India, where apparently the common bean is not of major interest, in other countries this species predominates in the collections. It should be noted also that in general the genetic stock from the primary center of diversity (Mexico and Central America) is well represented in these collections.

This representation must be larger than the table shows, since probably many entries from the U. S. A., Europe and other countries are really material collection of common beans, not mentioned in Table 1, is that of the Plant Introduction Station at Pullman, Washington, U. S. A., which up to 1969 had 4,500 lines (Hudson, 1969). Roberts (1970) mentioned that the U. S. Department of Agriculture, with the collaboration of the Department's AID = supported programs to improve several of the food legumes in India and Iran, assembled germplasm collections of approximately 26,000 entries representing ten species. The Department - continued Roberts - is now increasing the seed of these collections, some in collaboration with CIAT, IITA, and the Colombian Institute of Agriculture (ICA) so that these can be made readily available to the breeders around the world who may be interested in evaluating them.

Preserving genetic resources is a task that interests the whole humanity. For this reason, it should not be the responsibility of one nation or a few nations. The conservation should be accompanied by adequate classification and evaluation, a task which requires the participation of diverse specialists in a national and even international effort. The ideal would be the existence of an international effort. The ideal would be the existence of an international gene bank available to all nations, with excellent seed storage facilities and maintained, for the purpose of a long-term conservation, by a group of specialists. Due to its own nature, a bank of this type would be better conducted or coordinated by an international organization or agency.

GENE RESOURCE PRESERVATION

The easiest and least expensive way of preserving a plant gene resource is seed storage in chambers with low temperature and low relative humidity. Good storage conditions prolong the life of the seeds and decrease the number of introductions that need to be multiplied annually for rejuvenation. In addition to the storage chambers, the germplasm bank needs facilities for evaluation and distribution. These facilities correspond to those of a well-equipped plant breeding station: greenhouses, isolation houses, laboratories, etc.

Obviously, the bank should count upon adequate scientific personnel. It is evident that if one considers that the task of evaluation of the material should be

Table 1. A few collections of beans and other food legumes maintained by research institutions and experiment stations

Institution and location	No. of introductions	Species	Origin of the entries	Informer and/or reference
IPEAS, Pelotas, Río Grande do Sul, Brazil	400....	Ph. vulgaris Ph. angularis Vigna sinensis	Costa Rica, Peru, Colombia, Brazil, Japan, U.S.A., U.S.S.R.	J. F. Antunes
Dirección General de Investigaciones Agropecuarias, Lima, Peru.	825....	Ph. vulgaris		O. Voysest V.
	782....	Vicia faba		
	541....	Pisum sativum	U.S.A. (the majority)	
	93....	V. sinensis		
	23....	Lens esculenta		
IPEANE', Recife, Pernambuco, Brazil	73....	Ph. vulgaris	Brazil	S. Krutman (Krutman et al., 1968)
	79....	V. sinensis	U. S. A., Brazil	
Station Centrale de Génétique et d'Amélioration des Plantes, Versailles, France	790.... Several species of Phaseolus also Cajanus, Canavalia, Dolychos, Vigna, Rhynchosia.	Ph. vulgaris	France and Europe (the majority) Guadeloupe (cowpea)	G. Foulloux
Universidade Federal de Viçosa, Minas Gerais, Brazil	1200....	Ph. vulgaris	Brazil, Mexico, Central America, Venezuela, Peru, U.S.A. and other countries	C. Vieira
	120....	Ph. lunatus	Brazil	A. Mizubuti
Seçao de Genética, Instituto Agronômico, Campinas, Sao Paulo, Brazil	600....	Ph. vulgaris	America, Europe	A. S. Pompeu
U. S. D. A., Federal Experiment Station, Mayaguez, Puerto Rico	2766....	Ph. vulgaris	Honduras, PI accession (USDA), Misc. locations, hybrids and selections	N. G. Vakili
	890....	V. sinensis	PI accession, Univ. of Florida, misc. locations, hybrids and selections	

Table 1 (continued).

Institution and location	No. of introductions	Species	Origin of the entries	Informer and/or reference
Instituto Interamericano de Ciencias Agrícolas, Turrialba, Costa Rica	1638.... 605....	Ph. vulgaris other species	Mostly from Central America, also U.S.A., Peru, other Latin America countries and countries outside the American Continent	A.M. Pinchinat (Pinchinat & Matarrita, 1970)
Centro de Investigaciones Agronómicas, Maracay, Venezuela	657....	Ph. vulgaris	Venezuela, Mexico, Central America, Brazil, U.S.A., and other countries	S. Ortega Y.
	220....	V. sinensis		
Instituto Colombiano Agropecuario, Medellín Colombia	2100....	Ph. vulgaris, Ph. coccineus, Ph. lunatus, Ph. angularis, Ph. mungo, etc.	Mostly from Mexico, Colombia, Guatemala and Equador	J. Ivan Alvarez G.
Estacao Experimental de Uberaba, Minas Gerais, Brazil	604....	Principally Ph. vulgaris, but also other species of Phaseolus	Brazil, Mexico, Portugal, Venezuela, Central America	R. J. Guazzelli
Indian Agricultural Research Institute	6620.... 5135.... 1491.... 1422.... 943.... 839.... 310.... 418....	Cicer arietinum Cajanus cajan Ph. aureus V. sinensis Lens esculenta Lathyrus sativus Ph. mungo Pisum sativum	From 21 countries From 16 countries From 18 countries From 49 countries From 14 countries From 7 countries From 1 country From 1 country	Indian Agricultural Research Institute (1971)

left to each bean breeding program, then the task of the germplasm bank would be facilitated. Anyway, whoever manages the introductions of the bank for the purpose of registration, rejuvenation and multiplication, will always have an opportunity to select something of interest and to make some evaluations of the material he manages.

The maintenance of a germplasm bank presents many problems and difficulties (Frankel, 1970). No one knows a practical way that really assures that the plant material in storage maintains the same variability that it had at the time the collection was made. Actually, hybridization, mutation and natural selection (plus human errors) contribute to genetic erosion. The inevitable rejuvenation cycles always expose the material to selection action and to outcrossing, when there are many entries in the field. Even the seeds are subject to genetic change, in view of the fact that the different genotypes show substantial differences in their ability to survive in storage.

When the collection is formed, genotypes or populations are brought from an environment in which they are adapted into one in which they are not. Here they consequently suffer the action of natural selection when the seeds are rejuvenated or multiplied on a large scale for distribution.

To reduce these effects, or even to permit the preservation of certain introductions that require a specific environment, the field planting may have to be spread over a number of environments. This will require the cooperation of many nations. The storage facilities, however, can be more efficiently and economically maintained if centralized under the supervision of a specialized staff. Such a system of bean germplasm storage will function only if it has the support of the interested nations and if it stays under international supervision or under the orientation of an international agency.

Should the other cultivated and weedy species of **Phaseolus** be collected as well? According to Burkart (1952), the genus **Phaseolus** includes approximately 180 species distributed in the hot zones of both hemispheres, but which are predominantly found in America. With the exception of **Phaseolus coccineus**, the other species have not been important in the common bean breeding programs. This is not to say that tomorrow, with the development of new scientific techniques or interests, these will not be important. The Asiatic cultivated species should be collected as well as any other crop. The American wild species should someday be protected also; however, at the moment it is more important to preserve the genetic stock of the cultivated species.

BEAN INTRODUCTION

Plant introduction has the following goals:

(1). The immediate use of introduced material as new varieties. In Brazil, for example, some of the best dry bean varieties presently recommended by the Ministry of Agriculture were introduced from other countries: "Rico 23" (Costa Rica), "Venezuela 350," "S-89-N" (Central America) and "Costa Rica," all black beans. Yield trials carried out by Guazzelli (1969) at two experiment stations in Minas Gerais, Brazil, showed the excellent behavior of the Mexican and Central American varieties when compared to the Brazilian.

(2). Selection of desirable lines from the introduced material. One of the best black bean in Brazil, "Cuva 168-N," was selected from an introduction from Costa Rica. In many Latin American countries the edible beans planted by the farmers are actually a mixture of genotypes. In material so constituted, a simple selection can give good results. Muñoz & Cárdenas (1950) mentioned that it was possible to isolate, from Mexican varieties of edible beans, lines that yielded up to 64 percent more than the varieties from which they were selected.

(3). The utilization of the introduced material for crossing with local genotypes, in order to try to obtain new and interesting recombinations. "Vavilov was among the first to advocate combining genotypes from widely differing environments, and many of the varieties produced by his Institute are the result of such combinations, as are, notably, the successful Mexican and Philippine wheat and rice varieties" from CIMMYT and IRRI, respectively (Frankel & Bennett, 1970).

(4). The utilization of one or a few genes of these introductions through the use of backcross breeding. In this way, new characteristics are incorporated in the improved varieties with a minimum of disturbance of their genetic composition. This method has been used primarily in countries with a developed agriculture already having a large number of superior varieties which have been well accepted by both the farmers and the consumers. Backcross breeding has been criticized in one respect; it permits genes with additional fringe benefits to be eliminated, therefore not giving them the opportunity to express themselves. "If doublecross or only one or two backcrosses are used, most of the parental type can be recovered but there is still some opportunity for other new, desirable genes to be introduced assuming very large F_2 populations are grown." This phrase from Kull & Borlaug (1970) is specifically applicable to the incorporation of new rust resistance genes in wheat, but may also be applicable to edible beans and other crops.

To avoid the introduction of seed-borne fungi and viruses, it is necessary that the institution responsible for the germplasm bank have all the facilities for quarantine services.

GERMPLASM EVALUATION

Once the germplasm is assembled, then comes the more difficult work of exhaustive and careful evaluation of the material. If the germplasm bank activities were centralized, with cooperation from regional, national and international groups, then the evaluation job must follow a certain system. All data must be catalogued and published. Seed supplies must be maintained in sufficient quantities for distribution to anyone who may wish to use them. Then, the institution or breeder which receives material from the bank must later send information about the perfomance of the entries tested to complete the notes of the bank's catalog.

The initial tests of evaluations must be done in a favorable environment. However, abnormal conditions may later reveal useful characteristics. For this reason, it is also recommended that tests be conducted under a wide range of environmental conditions. Some characteristics are easily identified under certain environments but not under others. Climatic factors, such as temperature, day length, rain, relative humidity and light intensity, may alter the perfomance of the material under screening. These environmental factors should include soil characteristics such as, fertility, water or aeration.

Until now, the great concern of the bean breeders has been the procurement of sources of resistance or tolerance to the many diseases that attack the crop. The search for resistance genes may necessitate the screening of hundreds and hundreds of entries in the germplasm collection, but once it is found, the incorporation into a suitable background is generally simple.

However, when the pathogen must be separated into races and the screening done on an individual race basis, then the procedure can be long and difficult. First, it is necessary to identify the races. Then, the source of resistance to each race must be found. Finally, the resistance genes must be incorporated into commercial varieties. **Uromyces phaseoli** var. **typica**, the rust causal agent, has a large number of races, complicating attempts to create resistant varieties. Maybe, in this case, the breeder has to turn his attention to the horizontal resistance, common in the nonimproved varieties of Latin America (Vieira, 1972). In certain areas of the Latin American countries, this type of resistance, and the large number of varieties that the farmers grow, explain why the rust does not cause heavier losses.

The anthracnose organism, **Colletotrichum lindemuthianum**, has a smaller number of races. The discovery by Mastenbroek (1960) of the dominant gene **Are**, in the "Cornell 49-242" line, simplified the incorporation of anthracnose resistance into common bean varieties. This gene gives resistance to the races alpha, beta, gamma and delta, and constitutes an excellent example of the impact that the discovery of "exceptional" genes may cause. Recently, it was found that the "Cornell 49-242" line is resitant to the seven anthracnose races identified in the state of Minas Gerais, Brazil, two of which belong to the alpha group (Oliari, 1972). In France, Bannerot (1965) screened 430 bean varieties, finding five (including "Cornell 49-242") that were resistant to all six races used in the study. In Uganda, however, the gene **Are** did not give complete protection against some races (Leakey & Simbwa-Bunnya, 1972).

The screening of collections in order to find genes for insect resistance has not received as much attention as for disease resistance. However, limited work has been done in relation to **Empoasca** sp., Mexican bean beetle, bean weevil and other pests. Wolfenbarger & Sleesman (1961), for example, screened a large collection of beans for resistance to Mexican bean beetle and potato leafhopper. They found two **Ph. vulgaris** P. I. lines resistant to the former and two **Ph. vulgaris** P. I. lines resistant to the latter pest.

CONCERN WITH PROTEIN

At the moment, there is a great concern on the part of the breeders to improve the protein content and quality in dry beans. **Ph. vulgaris** seeds contain about 22 percent protein, but with a low content of the sulphurcontaining amino acids, methionine and cystine, and also tryptophan. Preliminary screening of germplasm collections at various institutions has shown appreciable variation in total protein as well as in sulphur amino acids.

Freytag **et al.** (1956) analyzed a total of 110 collections of common beans, mainly of Mexican origin, and found a variation of 14.6 to 26.7 percent in the total protein content. They also found that high protein content tends to be associated with small, spherical seed, either black or white, having a vining habit and a tropical provenance. Low protein content tends to be associated with large, elongate seed, having a brown color, a bush habit and a temperate provenance.

From 3,600 common bean varieties, lines and single plant selections screened by Kelly (1971), 63 were selected as having greater than higher microbiologically available methionine in the mature seed than the "Sanilac" standard. This author concluded that there is sufficient variation in the level of methionine within the species to permit improvement through hybridization and selection.

The search for other traits has achieved results, for instance, plants adaptable to mechanical harvest, i. e., erect, with pods high off the ground, or plants adaptable to a given environment, such as tropical lowland or soil with low zinc content.

SEARCH FOR HIGHER YIELD

As previously mentioned, it appears that the maximum yield potential of the present common bean varieties is about 4,000 kg/ha, which places this crop among those of low efficiency, if compared, for example, with soybeans, rice or wheat. In my opinion, the next big task of the bean breeders is to try to exceed that yield ceiling by in-depth research on all aspects of the plant and its culture.

It will be necessary to manipulate the germplasm collections in such a manner as to search for production characters, although such characters are the result of many physiological processes which are only beginning to be understood. In the agriculturally advanced countries, varieties have been developed which are highly adapted but that have already reached a plateau of productivity. The yielding ability of these varieties has not been increased intentionally, unless indirectly, i. e., by the incorporation of "resistance genes" confering resistance principally to diseases.

Apparently, the breeders are satisfied with the "improved" varieties that have been developed; therefore, they have paid little attention to the plant characteristics relating to productivity, such as yield components, leaf area, plant "architecture" or photosynthetic efficiency. Such characteristics, as a rule, have not been drastically and deliberately changed.

Recently, this tendency has changed, perhaps because the disease problem is not now so serious in the agriculturally advanced countries and the breeders can devote their time to other aspects of bean improvement; or perhaps, because of the successes attained in the field of "production breeding" with other crops, principally wheat, maize and rice.

As previously stated, in many countries modern varieties have a relatively narrow genetic base. To increase their yield potential, it will be necessary to incorporate new genes to improve their production characters, using a number of widely different stocks in multiple crosses. Another solution would be to start all over, exploring more deeply the enormous gene resources of **Phaseolus vulgaris** to develop completely new varieties. Which ever course is chosen, the breeder will have to reckon with collections of germplasm, which are as yet poorly researched. Therefore, it is almost certain that these collections have genes that alone, or more likely in association, will permit the common bean to produce more than 4,000 kg/ha.

OTHER FOOD LEGUMES

Other food legumes are cultivated in Latin America Lima bean, cowpea, pigeon pea, chickpea, lentil and others, but they do not have the importance of the common bean. Most of what was said about this species also applies to the other species. In the following paragraphs, I will present some information specific to these other food legumes.

Lima bean (Phaseolus lunatus L.)

Vavilov found that the primary center of diversity of this species is in Southern Mexico and Central America and that a secondary one exists in Peru, with an abundance of largeseeded forms. According to Mackie (1943), the species originated in Guatemala, a country where wild forms are found. From this center of origin it dispersed in three directions, namely: (1) the Hopi branch, extending northward into areas of the U. S. A.; (2) the Caribe branch, carried to islands in the West Indies and to the Amazon basin; and (3) the Inca branch which traveled south from the point of origin to Peru.

The seeds of the last branch are large, weighing up to 200 grams per 100 seeds, while in the other branches the weight generally is 40 to 70 grams per 100 seeds. Recently, in a plant exploration carried out in Brazil, it was found that in the north and northeast, where the Lima bean is a common crop, the seeds are principally small and roundish. In the Amazon valley, however, they are very large, reaching up to 32 mm in length. These findings do not support entirely Mackie's hypothesis (Erickson et al., 1967).

The wild forms are perennial, producing very small seeds (5 to 14 grams per 100 seeds). The cultivated forms are annual, or perennial planted as annual, dwarf or vining.

The nutritive value of Lima beans is similar to that of the common bean. All Lima beans contain cyanide, due to the glycoside linamarin, which imparts the characteristic flavor of this bean. The cyanide is not injurious when the amount is not in excess. A survey in California demonstrated that the local varieties contain from 25 to 55 p.p.m. as HCN, which is far below the limit of human tolerance. One lot of wild Lima beans from Puerto Rico contained 970 p.p.m. of cyanide as HCN, a quantity that impedes their use for human consumption.

The yielding ability of Lima beans is similar to that of the common field bean. It is a crop that has been studied very little in Latin America. In Brazil, late varieties are planted, which have a vining habit, and nonuniform maturity that has not permitted large scale commercial production.

Cowpeas (Vigna sinensis (L.) Savi).

Vavilov found two primary centers of diversity of this crop, in India and Ethiopia, and a secondary center in China. Cowpeas have spread throughout the world, but they are planted principally in Africa. It is a tropical crop, resistant to high temperatures and drought. In Brazil, for example, cowpeas substitute common beans in areas unfavorable to the latter, as the Northeast (warm and dry) and the Amazon valley (hot and humid). Cowpeas yield approximately the same as the common bean. They have an average total protein content of 23 percent and somewhat higher content of sulphur-containing amino acids than the common bean. The great variability occuring in characteristics such as plant habit, pod and seed characteristics, disease resistance and other traits opens many possibilities for work by the plant breeders.

Pigeon peas (Cajanus cajan (L.) Millsp.)

This is probably a native plant of tropical Asia. From there, it was introduced into Africa, tropical America and Australia. Pigeon peas are the second most important food legume crop in India. In the New World they are grown to some extent in Central and South America. The average total protein of pigeon peas is slightly lower than the common bean, but they are higher in sulphur amino acids. Pigeon peas yield normally 800 to 1,500 kg/ha, but yields in excess of 5,000 kg/ha are reported in India (Roberts, 1970). This legume is particularly drought resistant. Only very recently have breeding programs been started with this crop. The Indian Agricultural Research Institute (1971) has an impressive collection of pigeon peas; 5,135 entries, 5,028 from India and the remainder from 15 countries.

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I. Commentary upon:

PLANT INTRODUCTION AND GERMPLASM OF *PHASEOLUS VULGARIS* AND OTHER FOOD LEGUMES

Efraim Hernandez X.

INTRODUCTION

The quality of a germplasm bank depends basically on a well meditated and executed ethnobotanical exploration conducted during successive periods in accordance with concomitant phytogeographical and genetic studies of the materials collected. With regard to this point, Hernández X. (1970) has suggested the following guidelines:

(1). There are antecedents which should be reviewed (botanical, phytogeographical, ethnic, etc.) as a basis for the planning of the exploration.

(2). The environment, both physical and biotic, determines the geographic distribution of the crops and the genetic diversity.

(3). Man is and has been the most important factor in determining the genetic diversity of the cultigens.

(4). Each species or variety has distinctive morphological and adaptive characteristics.

(5). The knowledge accumulated throughout the millenia by the agricultural cultures takes time to register and understand.

(6). The ethnobotanical exploration is a dialectic process.

Keeping these points in mind, it should be noted that the greater part of the bean collections to date have been made by explorers interested in other crops, devoted to other scientific interests and in rare instances have they had a specific knowledge of beans. There are several studies of **Phaseolus vulgaris** (Miranda C., 1966), of **P. lunatus** (Mackie, 1943) and of **P. acutifolius** (Freeman, 1918) which are helpful in obtaining initial information on the morphological variation of the seed. Burkart (1952) shows that this structure is of great use to differentiate the existing variation through its morphological characteristics.

We insist on the seed, since this is easy to collect, it is the part that is usually available and it can be handled with facility for the desired purpose. The procedure followed to date for collecting results in partial data and ignorance of the phenomena because the materials collected are of the commercial types available in the markets This situation can be improved only through a special effort to visit the regional markets and insisting upon collecting material directly from the farmers.

Obtaining knowledge of the multiple ecological and social niches of a given area and collections in those that might be of interest require time that is not often available to the plant explorer. For this reason some of the most interesting series of collections have been made by ethnobotanists or anthropologists who have lived for some time in ethnic areas under study.

If plant exploration is coordinated with an active center of genetic research, a feedback system may be established to keep the explorer informed as to when he might be in an area especially interesting due to the genetic variation found and the morphological characteristics which might serve as indicators. This type of arrangement enabled Dr. Howard S. Gentry quickly to locate the center of diversity of the type of phytopathological resistance desired during his bean collecting trips to Mexico.

THE *PHASEOLUS VULGARIS* GERMPLASM BANKS IN MEXICO

Table 1 summarizes the available information on the germplasm banks in Mexico, complementing the information presented by Dr. Clibas Vieira. Due to my personal participation in establishing these banks, I am in a position to make the following observations:

(1). The greater part of the collections represent contributions by persons indirectly concerned with beans and these collections have not been increased in number, as a result of the study of the material, with the exception of the wild species which are of specific interest to Ing. Salvador Miranda Colín.

(2). These banks have never been under the care of personnel trained specifically for this purpose.

(3). The presence of these banks has not given origin to specific research programs dealing with the biology and phytogeography of the materials, to the increase in the number of accessions, etc.

(4). Although the collections have been reproduced several times, no uniform system of registering the data has been established, nor a system of rapid retrieval of information.

(5). Several studies have been made indicating various degrees of outcrossing in beans, but this knowledge has not been taken into account during the process of increasing the material to regain viability and maintain the genetic variability.

Ethnobotanic exploration of beans has not been dynamic because the biosystematic studies which might put order in the existing genetic variation, indicate the morphological expression of this variation and show the geographic distribution of said variation, have just been initiated. This genetic, morphological and phytogeographical information is essential in planning future explorations.

Table 1. **Phaseolus collections, classified by place of origin, and kept at the Instituto Nacional de Investigaciones Agrícolas, Secretaría de Agricultura y Ganadería (INIA), y del Colegio de Postgraduados, Escuela Nacional de Agricultura (CP), in Chapingo, Mexico, up to 1972.**

Mexico	INIA	C. P.	Other countries	C. P.
Aguascalientes	180	26	Africa	24
Baja California	12	3	Argentina	9
Campeche	21	2	Brazil	14
Coahuila	17	42	Canada	2
Colima	13	8	Colombia	53
Chiapas	643	177	Costa Rica	12
Chihuahua	29	35	Cuba	17
Durango	33	53	Chile	3
Guanajuato	127	155	Ecuador	42
Guerrero	166	120	U. S. A.	48
Hidalgo	74	60	Guatemala	126
Jalisco	159	160	Honduras	16
Mexico	220	176	Japan	3
Michoacan	197	125	Peru	80
Morelos	65	150		
Nayarit	41	25	Subtotal	449
Nuevo Leon		1		
Oaxaca	265	115		
Puebla	765	414		
Queretaro	50	46		
Quintana Roo				
San Luis Potosí	25	26	INIA	3,765
Sinaloa	46	29	C.P. Mexico	2,274
Sonora	77	10	C. P. other	
Tabasco	4		countries	449
Tamaulipas	13	10		
Tlaxcala	140	112	Total	6,488
Veracruz	230	112		
Yucatan	45	2		
Zacatecas	108	80		
Subtotales	3,765	2,274		

The **Phaseolus** germplasm bank of INIA has received important contributions from: Efraim Hernández X.; Salvador Miranda C.; Howard S. Gentry; George Freytag; Lawrence Kaplan and Alfonso Crispin.

The **Phaseolus** germplasm bank of C.P., ENA, has received important contributions from: Salvador Miranda and Efraim Hernández X. This bank has a large collection of wild species.

(Source: Register of Germplasm Banks).

For this reason, there is no basis for future explorations except for collecting in areas not represented in the material in the banks.

BIOSYSTEMATIC CONTRIBUTIONS ON BEANS

One of the most interesting biosystematic studies made to date (Hernandez X., Miranda C. and Prywer, 1959) indicates constant introgression between **Phaseolus vulgaris** and **P. coccineus** in transition areas between the hot humid and the temperate humid zones of Mexico and Guatemala. The importance of this information might be appreciated from the futile attempts made by researchers in Europe and the U. S. A. to incorporate resistance to insects and diseases from **P. coccineus** (perhaps the least domesticated of the bean species) to the common bean. We have evidence also that a natural cross between **P. vulgaris** and **P. lunatus** has occurred in the Jalisco-Michoacan regions of Mexico.

In our initial studies tending to define the morphological characters of the plant suitable for the differentiation of the varieties, we have found evidence of frequent introgression of a wild bean complex and the "upland black" bean complex, a phenomenon which does not appear in the collections of the "lowland black" bean complex.

EROSION OF GENETIC RESOURCES OF BEANS IN MESOAMERICA

The erosion of the genetic resources of primitive cultivars in Mesoamerica has caused concern especially on the part of international organizations which have before them the experience from areas where modern agricultural technology has eliminated the primitive varieties. The conclusions presented in a recent report to FAO (Hernández X., 1972, unpublished) based primarily on maize in Latin America, probably will give rise to certain doubts on the matter. Taking as a base the recent collections of maize in certain critical areas, it is concluded that after a period of 25 years, the same varieties persist and that new recombinations have appeared. These are being conserved in accordance with the new necessities of the ethnic groups arising from an increase in their agricultural areas and to changes in the edaphic conditions of their lands.

EROSION OF GENETIC RESOURCES

It seems that erosion of the genetic resources is a function of:

1. **Cultural erosion.** With greater degree of disorganization of the agricultural cultures, there is a greater degree of erosion of the genetic resources of the primitive cultivars. This means that the indigenous cultures are the ones that have conserved and given rise to the basic genetic diversity through their prolonged periods of existence. These cultures have conserved the greater part of the variants, eliminating only those that have been replaced with advantage by new types in the multiple ecological, economic and cultural niches of the ethnic group in question. These cultures, one should remember, are at the center of many of the attempts of change by the diverse Indian programs in Latin America.

2. **Introduction and acceptance of improved varieties.** This occurs especially in commercial agricultural systems. For the subsistence farmer, this process has a very reduced effect. This process might affect the selection under domestication or the quality of seed sown in accordance with the degree of commercialization of the regional agriculture. In Mexico, the establishment of the CONASUPO, an official institution involved in the maintenance of a minimum price for certain crops, among them beans, and in regulating prices of certain basic food products, has favored a preferential price for a uniform product and the bean types known as "canario," "bayo grande," "garrapata," "cacahuete," "flor de mayo" and "mantequilla or garbancillo." This commercial preference probably has displaced the multiple varieties produced previously in certain areas.

4. **Degree of natural crosses.** Beans had been considered an autogamous plant. Recent studies have demonstrated that natural outcrossing varies in accordance with ecological conditions and that a high enough percentage might occur to consider the species, through time, as an allogamous plant in the regions of its cultivation in Mesoamerica. Under subsistence agriculture, one finds the general practice of associating beans and maize and the use of a mixture ("revoltura") of seed as a possible answer to extremely fluctuating ecological conditions. Table 2 shows the components of a "revoltura" collected in the bean growing region of northeastern Puebla, Mexico.

Table 2. Composition of a mixture (composite sample) of bean seeds planted in the northeast region of the State of Puebla, Mexico, under uncertain climatic conditions, low soil fertility and in association with maize. Notice that two species of **Phaseolus** are involved.

Diameter in mm	Black	Black (white)	Red	Red (variegated)	Brown	Brown (variegated)	Gray / Gray (variegated)	Yellow	Yellow (variegated)	Olive	Olive (variegated)	White	White (black)	No. of seeds	Species
.5 to .55	21	8	3	89	26	1	2	19		3	3	4		179	**Phas. vulgaris**
.6 to .65	24	18	6		22	38	2/7	53		33		31	3	237	" "
.7	4	5	3		8	9	3/7	49				15		103	" "
.75	4	5		3			5/3	46				5		71	" "
.8	1				1		2	39				1		44	" "
.85	2					3	1	8						14	" "
.9	1						1	7						9	" "
.95					1		2	2/2						7	**P. coccineus (3**
1.0	1				6			1						8	" "
1.1					1			2						3	" "
1.2						3								3	" "
Totals	58	36	12	92	65	54	12/22	225	3	36	3	56	3	678	

5. Opening of new agricultural areas. The increase of the human populations in almost all of the Latin American countries and the various attempts at agrarian reform have stimulated the opening for agricultural purposes of new areas, especially in the hot humid regions. This process has created a demand for new varieties, a demand which in the case of maize has been met by existing indigenous varieties and by the formation of new varieties by the indigenous cultures. As a result, this process has tended to increase the genetic variability.

6. Changes in the long-established agricultural areas. In spite of the programs of agricultural extension and the increase in agricultural inputs, large areas still face the problem of agricultural production under limiting ecological conditions and a low level of use of agricultural inputs. This has resulted in land erosion and a reduction of soil fertility after prolonged periods of agricultural utilization. As a consequence, one might forecast the selection by the farmers of varieties with capacity to insure the production of a minimum crop. This phenomenon will tend to increase the genetic variability.

STIMULUS FOR THE ETHNOBOTANICAL EXPLORER

One of the most important stimuli in science is the recognition of the researcher for his work. In the case of the botanical collectors, their names remain as essential information of the collection and in certain cases the generic and specific scientific names of the plants have had their origin on the collector's name. In contrast, we have noticed that the name of the ethnobotanist rapidly falls by the wayside in all of the schemes of management of the material of useful plants. For instance the collections of the U. S. Department of Agriculture are handled by means of the initial P. I.; the CIMMYT bank handles its material through abbreviation which indicate the political state of origin, for example, Ags. 7, Mich. 21, Tamps. 38; a similar procedure is followed by the banks of the National Institute of Agricultural Research (INIA) and of the Graduate College, ENA, both at Chapingo, Mexico. May I suggest a modification in the present systems by the addition, after the established abbreviations, of the collector's or collectors' surname in parentheses, for example, Mor. 592 (Miranda C.); P. I. 28970 (Gentry).

II. Commentary upon:

PLANT INTRODUCTION AND GERMPLASM OF *PHASEOLUS VULGARIS* AND OTHER FOOD LEGUMES

Harold F. Winters

In the U. S. Department of Agriculture plant introduction is basic research. The main object of the Department's activities in this area is to assemble genetic pools for every crop now important in our agriculture and for crops which might become important at some future time. These genetic pools supply the plant breeder with new parent materials. Food legumes (pulse crops) are important components of these collections.

Historically, plant introduction began in the area, now the United States of America, with the foundation of the first European colonies. The colonists brought seeds and plants with them. They also sent to the mother country for additional materials as the settlements became more permanent. Even those crops which originated in Central and South America for the most part came to us via Europe. Later our embassies and consulates in foreign countries were directed to send home plants and seeds. After its establishment in 1862, the Department of Agriculture was charged with plant introduction and the development of new crop varieties.

It was not until 1898, however, that a definite agency within the Department was charged with the work. It was designated Section of Seed and Plant Introduction. Dr. David Fairchild, well known for his World wide plant collecting, was its head from the beginning until his retirement in 1929. Through the years, this agency has undergone several name changes. By whatever name, responsibilities of the organization remain the same as those stated previously. Over 377,000 plant introductions have been processed to date.

FOUR REGIONAL STATIONS

Prior to 1946, the great bulk of plant introductions received as seed were distributed to federal, state and private agencies concerned with breeding and development of these crops. Generally, these agencies lacked facilities for the permanent maintenance of germplasm collections. When a given breeding program was terminated or interrupted by the death or transfer of the scientist in charge, much valuable germplasm would be lost.

Under the Research and Marketing Act of 1946, funds became available for the first time to establish a truly national cooperative program for the introduction and testing of plant material for crop and industrial uses and for the preservation of valuable genetic stocks as seeds. This program is divided into four regional state experiment station organizations with headquarters at Geneva, New York, for the Northeast; Experiment, Georgia, for the South; Ames, Iowa, for the North Central; and Pullman, Washington, for the West. Each facility is located at one of the state agricultural experiment stations of the Region. The Regions provide the land, greenhouses, laboratories, offices, cold storage facilities and part of the staff needed to grow and evaluate plant introductions received as seed. The federal government provides plant introductions and leadership for each project.

The Germplasm Resources Laboratory is responsible to ARS for all foreign exploration, introduction and exchange of plant materials. New introductions are catalogued at its Beltsville, Maryland, headquarters. Plant introduction numbers are assigned and the material ordered to one of the four regional stations for increase, evaluation, distribution and maintenance.

Because of geographic location certain regions are better suited than others to undertake the evaluation and increase of the different stocks. For this reason, common beans and lentils go to the Western Region, peas (**Pisum**) to the Northeastern Region and cowpea and mungbean to the Southern Region. Since this conference is particularly concerned with food legumes, I have listed in Table 1 the approximate USDA inventories of these crops.

You will note that the largest inventories correspond to the food legumes of greatest economic importance in the United States such as **Phaseolus vulgaris** and **Pisum sativum**. The common bean, **P. vulgaris**, is represented by 5,193 accessions. The collections include an almost infinite degree of variability: black to white, tall climbing to dwarf, etc. While seed is being increased, we record as many characteristics as possible. The collection of common beans was greatly expanded during the period 1964 - 1968. During these years Dr. Howard Scott Gentry spent many months collecting beans in Mexico and Central America. A primary objective was the primitive perennial **P. vulgaris** of Mexico thought to be resistant to Fusarium root rot.

During this period, also, donations of several sizeable collections by collaborators in Central and South America served to swell our inventories. Complete evaluation of this sizeable collection will require many years. First, the supply of seed must be increased. This task is complicated by many of the introductions requiring short days for flowering. Many such introductions are killed by frost at the full bloom stage. When this happens, a second planting must be made either in the greenhouse or in a tropical area. Eventually, the introductions are available to plant breeders and other investigators, however.

In addition to our domestic distributions, the U. S. Department of Agriculture follows a liberal policy in supplying increased seed of plant introductions to collaborators in other countries. Sometimes they are sent in exchange for materials we need but more often they are donated outright for whatever scientific or humanitarian value they may have.

The USDA also makes available its germplasm collections to the multi-sponsored international institutions for agricultural research such as CIAT, CIMMYT, IRRI, IITA and the new Asian Vegetable Research and Development Center in Taiwan. Beginning in 1970, several food legume germplasm collections were sent to CIAT and to cooperator Dr. Luis H. Camacho, Instituto Colombiano Agropecuario, Palmira. These collections are as follows:

Table 1. Inventory of pulse crops

(February 1973)

Species	Working collections			New accessions[1/]	
	N. Y.	Ga.	Wash.	India	Iran
Arachis hypogaea	–	3,816	–	–	–
Cajanus cajan	–	282	–	4,000	3,280
Cicer arietinum	–	259	–	1,730	2,116
Dolichos biflorus	–	25	–	–	–
D. lablab	–	59	–	–	–
Lathyrus sativus	–	–	–	–	840
Lens esculenta	–	–	600	1,065	2,475
Phaseolus aconitifolius	–	–	21	–	–
P. acutifolius	–	–	17	–	–
P. acutifolius latifolius	–	–	4	–	–
P. adenanthus	–	–	2	–	–
P. angularis	–	26[2/]	24	–	–
P. anisotrichus	–	–	2	–	–
P. atropurpureus	–	–	5	–	–
P. aureus	–	1,403[2/]	48	681	1,056
P. bracteatus	–	–	6	–	–
P. calcaratus	–	–	26	–	–
P. caracalla	–	–	7	–	–
P. coccineus	–	–	195	–	–
P. erythroloma	–	–	2	–	–
P. grandiflorus	–	–	1	–	–
P. lathyroides	–	–	5	–	–
P. lunatus	–	–	423	–	–
P. metcalfei	–	–	2	–	–
P. mungo	–	67[2/]	3	–	310
P. panduratus	–	–	5	–	–
P. phyllanthus	–	–	1	–	–
P. pillosus	–	–	1	–	–
P. polystachios	–	–	5	–	–
P. radiatus	–	–	3	–	–
P. stenolobus	–	–	1	–	–
P. strobilophorus	–	–	2	–	–
P. trilobatus	–	–	2	–	–
P. vulgaris	2,880	–	5,193[2/]	644	2,647
Phaseolus spp.	–	–	6	–	–
Pisum sativum	1,800	–	–	356	407
Vicia faba	–	–	150	–	311
Vigna sinensis	–	1,238	–	–	1,430
Voandzeia subterranea	–	60	–	–	–

1/ Accessions received from closeout of Regional Pulse Improvement Projects in India and Iran. This material is held in cold storage until it can be absorbed by USDA plant introduction programs. For some crops considerable duplication is suspected between the Indian and Iranian collections.

2/ Introductions listed by more than one Regional Station are duplicates. The larger number should be considered as the total available.

Cicer arietinum (Chickpea)	– 133	accessions
Lens esculenta (Lentil)	– 409	"
Phaseolus angularis (Adsuki bean)	– 20	"
P. aureus (Mungbean)	– 160	"
P. coccineus (Scarlet runner bean)	– 123	"
P. vulgaris (Common bean)	– 3780	"
Vigna sinensis (Cowpea)	– 454	".

COLLECTIONS ARE AVAILABLE

Originally our agreement with CIAT stipulated that a portion of the seed increase was to be returned to the USDA. At this time, I am not sure this would be desirable. It may be more important to retain all of the seed in Colombia as a repository of germplasm. From Colombia it is more readily available to much of Central and South America than from the United States. I suggest retaining the U. S. Plant Introduction numbers at all times since they refer to documentary information about the origin and individual characteristics of the collections.

Large collections of **Phaseolus vulgaris** also have been sent to Mayaguez, Puerto Rico and El Salvador. These collections should be increased for redistribution within the areas in which they are located. Before movement of seed stocks from one area to another, I suggest that consideration be given to the possible spread of diseases and insects. Self imposed quarantines may be desirable in some instances.

Finally, I should like to state that USDA policy is to make its germplasm collections available to all who need them. However, the quantity of seed we can send of each introduction is limited. We have been unable in many cases to increase our stocks rapidly enough to replace those distributed. To conserve materials we urge researchers to define their objectives as completely as possible before requesting seed collections. Considerable data is accumulated about the individual introductions when they were increased here.

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III. Commentary upon:

PLANT INTRODUCTION AND GERMPLASM OF *PHASEOLUS VULGARIS* AND OTHER FOOD LEGUMES

Colin Leakey

NOTE: Dr. Leakey has provided this thoughtful contribution as an addendum to the seminar discussion. It is inserted as a commentary at this point, since it bears upon plant breeding issues.

CIAT RESEARCH PRIORITIES

CIAT should be seeking ways to overcome the major restraints to high yield apparent from the difference between existing low yields and presently known yield possibilities.

CIAT should also be working on breaking through the present yield ceiling to aim for the productive limit of the crop species.

Farmers' field production levels will always be well below yield ceilings but this does not make it irrelevant to push those ceilings up.

The first major constraint to present production levels is the supply of disease-free seed of productive varieties (or even varietal mixtures). My own contribution and Zaumayer's have highlighted the importance of having seed production a separate and specialized production activity. Beans are food. Seed beans are a high-value commercial crop. The initial drive in high-level agronomy could well be aimed at economically attractive production of seed beans in Latin America.

I suggest that CIAT investigate dry season production, either on the flat with furrow irrigation, and/or on deep volcanic ash soils on the piedmont slopes of Andean volcanoes following the Kilimanjaro model. This sort of production for disease-free seed justifies the input of such things as insecticides and acaricides for the control of seed-borne virus vectors while the zero precipitation will take care of fungi and bacteria.

In contrast, it can be seriously argued – and has been in the seminar – that there are strong social, cultural and technical reasons for research to maximize stability and safety of yield, rather than yield itself, in the farmers' food crop.

The question of the importance of effective **Rhizobia** is a vexed one. Many of us with much bean experience would doubt whether **Rhizobia** rather than mineral nitrogen is relevant to the maximum productivity concept. **Rhizobia** (as also **Mycorhiza** in other crops) may be most important, however, at the farmer levels of yield and production sophistication where expensive mineral fertilizers are not appropriate.

Therefore, research and development should aim to produce not only healthy seed of good varieties but healthy and inoculated seed (or inoculum separately). The Swedes and the Danes are probably the most advanced in this technology at present.

Our great interest in yield physiology must not be allowed to overdominate our approach to practical breeding for yield. There is obviously from the seminar a great danger of this. Lysenko in Russia held back Russian plant breeding for 15 years through similar thinking. Dr. Grant asked the pertinent question: "What makes the bean plant tick? " The answer, quite simply, is the genes in its genome brought into orderly use during programmed development.

Plant breeding operates on genes and their frequencies and not on parameters of yield. This must not be lost sight of. There have been practically no attempts whatever in the world so far to breed intelligently for yield on sound genetic principles, since practically none of the genetic diversity of the species has been called upon.

Diverse genotypes may be expected to contain different balanced polygene complexes for yield whereas closely related lines, even if within their own group they are superior, probably contain similar complexes. It is the bringing together of the plus genes from diverse sources that can be expected to give the jump we hope for. (One can justify the same sort of crosses perhaps on architectural/physiological terms but the genome is still fundamental.)

We should go all out to breed for yield **per se** through sound genetic principles even if we play with biological algebra at the same time. We must not postpone a start to serious breeding while we wait to be advised on non-genetic grounds of suitable parents.

If we wish to start at once, one might suggest a diallel among the following parents which have been so far seen or discussed in this seminar:

NEP 2–habit and yield (the top at present).
ICA Guali–hypocotyl and root vigor and leaf presentation.
R. 184–virus resistance; El Salvador
Goiano Precoce–Vieira's program Viçosa.
New Red Kidney–ex Wallace, Cornell.
LV 1210 – ex Uganda, ex Puerto Rico; exceptional vigor.
Cofinel–Group 5, stringless determinate with "are" genes.
R 25–general disease resistance.

The diallel could be backed by recurrent intercrossing among selections from its progenies to develop composites for widespread testing and selection in contrasting environments on a cooperative basis.

The only advantage of breeding via yield components rather than by yield **per se** is if the heritabilities of the parameters are so much higher that it makes the operation of the process of selection more efficient. Since pods per plant is the overriding yield component and is equally as unreliable as yield itself as a single plant criterion, this offers little advantage. The combination of a good eye –feeding the brain, which is still a fairly well functioning computer in an intelligent head— with filed note taking, and yield data may still be the most practical tools of the breeder. Since Crop Index does not vary very widely between varieties, there is in beans a very high correlation indeed (in the absence of any genetic infertility, etc.) between biological yield (observable as vigor) and seed yield. This is in contrast to the cereals.

Physiological studies should be side by side with ongoing breeding.

Crop protection studies must be carefully controlled so as to make sure that the outcome of research is not material that cannot grow without massive chemical assistance. Of course protection studies are important. I suggest firstly in relation to seed production, however.

In Phase II of the CIAT program one may expect a spin - off - in to production of the crop as food from what has been learned from studies in the production of the crop as seed.

PLANT ARCHITECTURE AND PHYSIOLOGICAL EFFICIENCY IN THE FIELD BEAN

M. W. Adams

Discussants: A. M. Evans; D. H. Wallace; H. C. Wien

Bean plant breeders acknowledge that there has been no decisive breakthrough in yield of dry beans achieved by genetic means in Mendelian times, except those increases derived from disease resistance or favorable maturity adjustments. While dry bean yields have remained on a nearly stationary level, we have seen dramatic increases in yields of maize, wheat and rice from genetic causes, and gradual but continual increases in soybeans.

In wheat and rice the yield increases are attributable to changes in plant type, the main features of which are reduced culm length, culm strength, high tillering capacity, short erect leaves, nonsensitivity to day length, and responsiveness to nitrogen with no reduction of grain to straw ratio. In maize, the genetic replacement of the single-eared plant by the multiple-eared type has given a new dimension to yield breeding. Similarly, the most promising advance in soybean yields currently is found in types that are narrow-leaved with 3 to 4 seeded pods in contrast to the wide leaved types with 2 to 3 seeded pods.

Although these are obviously morphological changes, they are not unrelated to physiological function. For example, the shorter culm of the cereals makes it feasible to fertilize more heavily with nitrogen without rendering the plant susceptible to lodging.

THE PROBLEM OF THE IDENTIFICATION OF AN IDEAL PLANT TYPE

There are three possible approaches to this problem that I should like to discuss, two rather briefly, and one more extensively.

The statistical approach of factor analysis

Factor analysis consists in the reduction of a large number of correlated variables to a smaller number of hypothetical and uncorrelated variables called factors. These factors in a biological experiment comprise the basic patterns of influence in the data set, they can be given biological meaning, and they replace the more numerous original variables since they explain most of the variation in the original data.

In practice a random sample of F_3 or F_4 lines is taken from a population in which numerous plant type recombinations occur. From field experiments metric data are recorded on an array of what are judged **a priori** to be important morphological and physiological contributors to yield. There will be patterns of characteristics that tend to be more highly correlated **inter se** and with yield. The analysis will group the variables into sets or factors, and from inspection the investigator will interpret the factors in a biological context.

Some recent applications may help to clarify the method:

(1). Morishima and co-workers (1967) identified two principal factors related to yield in rice, one expressed as "a panicle-length-panicle number" axis, in which leaf length and width were also prominently involved, and a second factor characterized as "mean internode length-elongated internode number," involving also leaf angle. These are the morphologic patterns which characterize the new high yielding rice varieties of south-east Asia.

(2). Walton has just reported (1973) the results of a factor analysis performed on 14 characteristics measured in a 5 x 5 diallel of spring wheat. The 14 variables were reduced to four main factors. Flag leaf area and duration of its activity were the principal variables in Factor 1. The second factor was a stage of development factor, with a long filling period having a negative loading, and a long period from emergence to anthesis having positive loading. Factors 3 and 4 included the number of heads per plant, kernels per head, and kernel weight.

(3). In a recently completed thesis, Denis (1971), working with bean varieties representing both North and Central American sources, performed a factor analysis on data collected on 22 morphological characteristics of 16 varieties grown at two locations. The 22 traits were reducible to two main factors, and a third slightly less important factor.

Variables with highest positive loadings on the first axis included seed weight, pod fresh weight, pod dimensions, basal internode length, and diameters of hypocotyl, basal and upper internodes. Factor 1 is therefore essentially a **weight** factor, equating size and diameter measurements with weight.

The variables with strong **negative** loadings on this axis included mostly those with strong **positive** loadings on the second axis, namely a group of interrelated variables expressing a **number** concept - number of nodes bearing pods, total number of branches, number of racemes, number of pods, etc.

Factor 3 included significant positive loadings only from three variables, total number of nodes per plant, number of long internodes and average length of long internodes. This factor is a **structural** factor, meaning many nodes, many leaves, and upper leaves in particular spaced far apart by long internodes.

The use of isogenic lines or populations

Varieties with contrasting plant type components are crossed, and repeated backcrosses are made to both parents, with selection for the plant type component of the non-recurrent parent in each generation. After several generations of backcrossing and selection, lines should be obtained which are essentially idential to the parental lines in all genes except those for the component under selection and closely linked genes.

The parental lines and their "isogenic" counterparts may then be validly compared. Differences in performance may be attributed with some confidence to the particular components for which selection had been practiced. This procedure is straightforward when only a single gene effect is involved. For multi-genic components the procedure is the same, but the process of recovering fully contrasting renotypes over all the loci involved in the selected component is considerably more difficult, and inferences from a comparison of recovered type with parental must be more tentative.

The breeder may also select in the F_2 or F_3 of an appropriate cross for contrasting phenotypes of a given component. A comparison is then possible between lines of the "low" level of expression of the component with lines characterized by the "high" level of expression. It is assumed that, on the average, the background genotypes of both sets of lines are similar, and a valid comparison is therefore possible.

There are numerous examples of the use of isogenic lines in genetic and breeding studies.

Model building or construction of ideotypes

This involves the following steps:

(1). Identification of morphological and physiological components related to yield for which genetic variation exists.

(2). From an understanding of the plant functions that must be carried out in one or more selected environments, gained from experience and/or experiments, one or more plausible plant-type models are formulated. Donald (1968) suggests the ideotype be designed for the most favorable or idealized environment. The basic ideotype would be successively modified as necessary to function efficiently under successive curtailment of the idealized environment.

(3). Construct plausible ideotypes by suitable breeding processes.

(4). Test the constructs varieties in the appropriate environments, comparing them with standard varieties.

(5). After testing, re-assess the models to determine whether adjustments in particular components would lead to better performance.

This was the approach followed by Vogel (1963) in wheat, suggested by Jennings (1964) for rice, and it is similar in principle to the suggestion by Donald (1968) to select for the "ideotype" in cereals. Donald (1968) has stated clearly and persuasively the case for model building in plant breeding.

APPLICATION TO BEANS

I think that breeders of dry beans should give serious consideration to a similar approach in **Phaseolus**. Let me now illustrate with two examples.

The first example represents a rather tentative and empirical approach in model building. It derives from the pattern of navy bean development followed in Michigan the last several years. Once the Sanilac variety, with its early maturity, determinate growth habit, small leaves, and non-sensitivity to day length, was shown to be the most successful type for Michigan conditions, we have preserved these characteristics in each successful variety released since Sanilac (Seaway, Gratiot, and Seafarer). Before we understood this principle, however, we released Michelite-62, re-selected from the old standard Michelite, and the variety Saginaw, like Michelite, a long-season indeterminate growth type. Both varieties were failures, even though each one possessed advantages not found in the Sanilac types.

Can we extrapolate from this experience to discover a more useful bean plant type for the tropics? A small beginning has been made to provide a partial answer to this question. Let me describe an experiment being conducted by Gaspar Silvera of Panama which is based on this hypothesis that the plant type represented by the Sanilac family of varieties could be a successful model for the temperate tropics.

Previously we had received reports from cooperators in many other countries where Sanilac and Seaway had been tested that these varieties showed a surprisingly high level of adaptation. These locations included such distant places as South Africa, Ethiopia, Rumania, Australia, Chile, and Peru.

We guessed that such wide adaptability might depend upon one or more of four characteristics common to these varieties, namely, determinate (bush) plant habit, non-sensitivity to day-length, early maturity, and medium to small leaf size.

The plan adopted was to cross Seafarer, a Sanilac type, to each of eight selected Central and South American varieties, each of the latter being well adapted to local conditions of climate and culture. The nine varieties are described in Table 1.

The F_1's were backcrossed to the respective local tropical parents, selfed three generations, and selections made in each population for bush form, early maturity, and small leaves. Some intermediate generations were grown in Costa Rica in cooperation with Dr. Pinchinat, and there may have been some unavoidable natural selection for maturity or vigor in these nurseries. Silvera's goal in selection was to recover seed types and unidentified factors relating to local acceptance or fitness of the tropical varieties, together with the main type components from Seafarer. These selections have now been made and are currently being seed-increased to provide seed for testing the recovered lines along with their parents in the Central and South American localities in which the parents originated.

We hope to learn, for example, whether a plant with the outward form and maturity of Seafarer, but which resembles Sangretoro in seed type and in many other unidentified ways (75 percent of the germ plasm of the selection is expected to be of Sangretoro genotype) will perform as well as or superior to Sangretoro, not only in Colombia, but in Central America, and in North America; similarly for the other selections.

AN IDEOTYPE FOR FIELD BEANS

The ideotype to be presented is intended to be monocultured under favorable conditions of moisture, light, nutrients and temperature, in a time period of about 100 days, with individual plants spaced about 6 cm apart in the rows 35 cm apart. This is approximately 500,000 plants per hectare.

Table 1. Origin and agronomic characteristics of nine field bean varieties including Seafarer, a parent plant crossed to eight selected varieties

Variety or Strain	Origin	Plant Form	Leaf* Size	Days to Ist Flower	Days to** Harvest	Seed*** Size	Seed Color
1 Canario	Peru	Vine	70.0	75	140	34	Olive Yellow
2 Cocacho	Peru	Vine	47.1	75	140	30	Very light tan
3 Liborino	Colombia	Bush	73.7	55	130	51	Mottled brown on tan
4 Sangretoro	Colombia	Bush	90.3	58	140	44	Very dark red
5 27-R	El Salvador	Bush	78.4	50	115	48	Light red
6 Col. 1-63-a	Honduras	Vine	56.5	54	110	25	Dark red
7 Riñon Oscuro	Guatemala	Bush	85.4	53	125	60	Very dark red
8 Compuesto Negro	Costa Rica	Vine	66.5	58	130	27	Black
9 Seafarer	Mich.(USA)	Bush	34.6	39	100	20	White

* Average area in sq. cm. for 1 leaf.

** Field 1972 (prolonged 14-20 days because of excess moisture in maturity period)

*** g per 100 seeds.

The ideotype will be described on the basis of morphological characteristics, but most of these are related to physiological functions.

Central axis - single stem, or with 2 to 4 basal upright branches

These axes should be sturdy, of thick diameter, with internodes that are slightly elongated, both basally and at upper positions. Denis (1971), in his principal factor analysis of characteristics related to yield in beans, showed these stem traits to be important. At present, we can only speculate as to why this should be so,

First, the stem should be sturdy to provide support for the leaf display and the load of pods. Thick diameters of the stems may also promote freer transport of water and nutrients. A compromise is necessary for internode lengths. Long internodes allow for a more open display of leaves, with better light penetration into the canopy. But long internodes tend to be weak and more subject to lodging. Also, in the vascular strands of long internodes, there is greater opportunity for binding of positively charged nutrient ions (Polson, 1967).

A sturdy hypocotyl and stem, thickened at the base, almost always indicates a strong thick tap root, which contributes to lodging resistance and possibly would be advantageous in some soils for protection against water stress, and for uptake of nutrients.

Number of internodes and length of the stems

The number of leaves has a direct influence on number of pods per plant which is the single most important yield component in beans (Duarte and Adams, 1972). The relationship holds because leaf number is determined by number of nodes on stems, and number of nodes determines the number of racemes since racemes are axillary. The stem of the ideotype then should have as many nodes as possible, consistent with the height requirements associated with lodging resistance, and a non-bunch habit of growth (slightly elongated hypocotyl and internodes).

Leaf size and leaf orientation

In the same paper, Duarte and Adams (loc. cit.) obtained data showing a strong relationship between leaf size and seed size. It may be difficult, therefore, to obtain small-leafed types in a large bean size variety. Nevertheless, the correlation is not complete and some latitude exists for leaf size selection. The smaller leaf appears desirable, however, because of less shading of lower leaves. The smaller-leafed types also appear more able to orient the leaves toward the vertical position during daylight hours. As a result, light penetration into the canopy is enhanced, and the more basal nutritional units function more efficiently.

LAI (Leaf Area Index) need not be sacrificed, however, since the ideotype calls for an increased number of nodes which is reflected in an increased number of leaves.

It is well to recognize the interdependency that exists between the reproductive meristems or organs in the leaf axil and the leaf itself. Elsewhere (Adams, 1967) I have referred to this assemblage in beans as a "nutritional unit." Photosynthate in a stem leaf is to a large extent directed to and/or stored in the developing seeds of pods borne on the raceme in the axil of the leaf. This is the "source-sink" mechanism in simplest form.

We shall see that we want in our ideotype a large sink size-numerous long pods on each raceme. According to Stoy (1969) a large sink size promotes greater activity of the photosynthetic enzyme, ribulose diphosphate carboxylase, functioning in the leaf. But, at some point, one could not expect to further reduce leaf size, however desirable it might be from the standpoint of reducing mutual shading, without reducing the total photosynthate produced. Stoy points out in this connection that when a portion of the leaf area in beans is removed, the RUDP-carboxylase activity increases in the remaining leaves.

One may conceive of the bean ideotype as composed of a sequential stacking of nutritional units, one upon the other, progressively up the main stem, indeed in part comprising the main stem.

Determinate growth

Were it not for considerations of lodging and of time —length of growing season— the stacking process might continue quite beyond reason - a veritable "Jack's beanstalk." Determinate growth therefore seems desirable. Photoregulation of onset of reproductive meristems is very important in such an ideotype. It should also be noted that successive formation of terminal vegetative meristems, leading to indeterminate plant form, produces sinks that continually divert photosynthate from reproductive to vegetative tissues, resulting in lower harvest indices.

REPRODUCTIVE STRUCTURES

No component of yield is more important quantitatively than number of pods per plant or per unit area of land (Duarte and Adams 1972, Denis 1971). This component is dependent upon number of nodal positions where axillary racemes might be formed, upon the number of florets per raceme, and upon the percentage of fertility. But normal pods in certain genotypes may contain as few as three seeds each, ranging up to pods with 12 to 14 seeds per pod in other strains. Seed size is constrained by market or consumer preference.

Under competitive conditions negative correlations occur among these components - large numbers of seed are associated with small sizes, and large sized beans with lower numbers of beans, on a per plant or unit area basis. These correlations appear to be developmental since they can be made to approach zero by removing all competitive stress. For ideotype design the genetic ceiling on pod number should be raised toward a limit that is set by number of nodal positions for the insertion of axillary racemes,and by the number of florets that can be borne on a raceme whose length does not exceed the half-diameter of the plant profile.

The genetic ceiling for number of seeds per pod must be high enough so that this component does not constitute a restrain to sink size, and high enough to compensate for a low pod number if it should happen that an unfavorable environment suppressed pod formation.

Seed size is a trait for which we would desire great uniformity. In the bean this is a highly heritable trait and particular size levels can readily be fixed genetically.

Under ideal environmental conditions all components should have sufficient resources to reach their genetic potential. If the environment is less favorable then the components, through developmental plasticity, adjust themselves in sequential fashion to utilize the available resources.

With these suggested genetic potentials, pod number, pod size and seed size, representing the sink, would not be expected to dampen photosynthetic activity in the leaves (source). It is quite probable that the distribution of limited resources among these components of yield has some optimum form. That is, greater volume (yield) will result from a given limited amount of resources (edge material) if the allocation of the edge material among the three components is made optimum. A simple example will illustrate the point:

Let the total resources (or edge material as used by Grafius (personal communication) equal some value, say 12 units. This is to be divided by allocation, according to the genetically regulated plan of development of the basic reproductive units, into a portion for pod number (X), a portion for number of seeds per pod (Y), and a seed size portion (Z). The product X. Y. Z = W, the volume (yield). The 12 units of edge material can then be divided in various ways; for example:

(a)	4	.	4	.	4	=	64
(b)	6	.	3	.	3	=	54
(c)	6	.	4	.	2	=	48
(d)	8	.	2	.	2	=	32
(e)	12	.	1	.	1	=	12

The cubic form, as in (a), is the optimum in this instance because it gives the greatest volume, but in the actual biological situation of a crop growing in the field, the flow of metabolic input to the X. Y. Z system may not be regular, or the biological efficiency of the components may be different, so that more resources have to go into one component than another, and the final shape of the yield construct may not look like a cube.

The dynamics of these processes are so complex and little understood that detailed modelling of the reproductive structures is not feasible at this time.

Physiological components

Although the foregoing discussion has dealt primarly with structural features of the bean plant, it should be understood that these features are important essentially because they are related to or have an influence on physiologic function.

Perhaps the most important of such relationships is that of leaf size, leaf number and leaf orientation to light interception.

Smaller leaves and more vertical leaf orientation permit more uniform distribution of light throughout the leaf canopy. This has at least two important consequences of a physiologic nature. The incident light energy is sufficient to (1) maintain a positive net CO_2 exchange for all leaves including the basal leaves, and (2), to induce, in the presence of nitrate, the formation of the enzyme nitrate reductase which is necessary for the conversion of nitrate to the reduced state (NH_2) and its incorporation into amino acids and protein. It remains to be shown that response to nitrate fertilization of beans is limited in field situations by lack of uniform light distribution in the canopy. The properties of absorbance and reflectance of light by the leaf surface also play roles in the efficiency of light utilization.

Particular attention in design of a bean ideotype should be paid to the net carbon dioxide exchange rate, which Wallace and co-workers (1972) have shown to vary significantly among varieties and to be under genetic control, and to rate of translocation of photosynthate out of the leaf to a meristem or storage site. The measurements on which these conclusions have been based are short-term measurements made at one or only a few times during the life of the plant, and may not reflect a seasonal-long rate. Nevertheless, the ideal bean type should carry genes which favor the higher rates of net CO_2 fixation, and of photosynthate translocation.

SUMMARY OF THE COMPONENTS OF A BEAN IDEOTYPE FOR CONDITIONS OF MONOCULTURE

(1). Central axis - single stem or with minimal number of erect branches; sturdy large diameter; numerous nodes and medium long upper internodes.

(2). Racemes - axillary at each node; many-flowered; short pedicle; over-all length not long.

(3). Leaves - numerous; small; capable of vertical orientation; numerous small mesophyl cells and high stomatal index.

(4). Pods - long, many-seeded; thin-walled at maturity.

(5). Seeds - as large as possible within the acceptable limits of the commercial class to which the variety belongs.

(6). Growth form - determinate, narrow, erect profile.

(7). Growth rate - rapid accumulation of optimum leaf area.

(8). Growth duration - early and sequential establishment of nutritional units, and long period from flowering to maturity.

(9). Mineral uptake and transport - sufficient for all requirements, generally high.

(10). Photosynthesis rate (net CO_2 exchange) - high and durable for all leaves.

(11). Translocation rate - movement of photosynthate from leaf to sink, high.

ASSOCIATED CULTURE

Mixed planting of maize and beans, already extensive in Latin America, will, I believe, continue to be widely practiced. The special requirements of plants to be grown in association adds new dimensions to the task of model building. In the case of a maize-beans association it would seem appropriate to specify sets of characteristics for both crops. Before attempting this task for the bean component, however, I would like to discuss a hypothesis, partly based on speculation, concerning the interdependency of maize and beans in association.

First, these species have been grown in association in parts of Meso America for hundreds, perhaps thousands, of years. There surely has occurred during this time both natural and intentional selection in both species for traits tending toward greater compatibility. Tropical soil scientists have stated that the nitrogen pool in the tropical soil is found largely in organic matter, both the living and the decaying forms; which may prevent its loss by leaching. There is a continuous cycling of nitrogen in the succession of growing plants on a given site. Dr. R. H. Hageman of Illinois has found that certain inbred lines of maize take up more nitrate than is reduced by nitrate reductase. The excess nitrate is stored in the lowe stalk, at least until physiological maturity is reached.

In the usual mixed cultural system beans are planted in the maize at about the time maize has reached physiological maturity. Under field conditions beans depend heavily upon mineral nitrate for the first several weeks of growth, until natural nodulation supplies an increasing amount of the reduced nitrogen needed for fruiting and seed filling.

These seem to be the essential facts - now for the speculation. Is it possible that the most successful compatible types of maize and beans represent co-adapted systems for generating, using and storing nitrogen more efficiently than in monocultural systems?

The system is envisioned to work as follows: maize draws mineral nitrate from decaying organic matter in the surface litter and upper few centimeters of the soil, the nitrate having been produced from organic matter by bacterial nitrification. The maize, via the nitrate reduction pathway, converts only a portion of the mineral nitrate taken up to the amino or amide form; the residual nitrate remains in the lower vascular regions or stem pith. As the end of the rainy season approaches, the stored nitrate, not to be used by the maturing maize plant, is released back to the soil or rhizosphere of the maize roots. Meanwhile, beans have been planted at the base of the maize plant.

Effective nodules not having yet formed, the bean plants draw upon the nitrate being gradually released by the maize. For the period from early seedling to commencement of the flowering stage beans contain a very active nitrate reducing system. After this time the level of nitrate reductase drops off rapidly, and then more slowly until maturity. Beans therefore are able to utilize nitrate for vegetative development and building a reduced nitrogen pool. Beans complete their seed production in the early weeks of the dry season, the harvest is made, and the organic matter remains of both maize and beans are returned to the soil.

If the system works approximately as hypothesized, it presupposes that over time mutual genetic adjustments of a morphological and physiological nature have occurred, a co-adaptation, in both species. The maize must have been able to take up, store and release nitrate efficiently. Maturity would have been adjusted to fit the wet season. But our first concern is with the bean. What did it become as a result of co-adaptation with maize and can this be improved upon?

The bean plants are very successful competitors, being indeterminate types, with long internodes, many branches, medium sized to large leaves, and generally requiring a long period for maturing. They respond to nitrogen in terms of total vegetative growth, and in yield primarily because of response of one yield component, number of pods per plant or per unit area.

When grown alone, varieties of this general type are vegetatively aggressive, form a dense canopy that limits light penetration, and are slow to mature.

No major changes need be made in the morphological plant type, except to keep the leaf size medium to small, and increase the sink capacity by raising the number of flowers per raceme, and number of seeds per pod. On the physiological side it would be desirable to raise the net rate of CO_2 exchange, increase the rate of translocation of photosynthate to sink, and select for a high harvest index.

Slash and plant culture

Beans are frequently planted on top of burned or decaying vegetation on steep hillsides in the upland tropics. If planted with maize the type can be the same as for the regularly tilled fields where mixed cropping is practiced. If planted alone, the bean will encounter a relatively high fertility level, and probably, competition from wild plants. Conditions may not exist for creating a pure dense stand of beans.

In this situation perhaps an ideotype with the following characteristics would be appropriate:

(1) medium to large seed to give a larger sturdier seedling, larger seedling root system, and large primary leaves.

(2) early establishment of a high leaf area index.

(3) tall determinate plant, with many side branches and stiff stems resistant to lodging (long thick internodes).

(4) pod number high because of numerous nodes on branches.

(5) long pods.

(6) plant capable of responding to nitrogen and phosphorous which will be plentiful on a site like this.

(7) photosynthetic and translocation efficiency as suggested in all ideotypes.

(8) high harvest index

Multi-cropping culture

For the multicropping culture an ideotype similar to the monoculture type would probably be appropriate, with one major qualification, namely, duration of growth. If necessary, the total life span of the bean can probably be compressed into a 65-70 day period by selection.

CONCLUSIONS

A physical environment favorable (non-limiting) in all production aspects has been assumed. Of course, this seldom prevails, environments vary widely, and for many different reasons. It is unlikely that a given ideotype will be ideal for many environments. The two environments of coastal Peru are an example. The short-season, higher temperature, high light intensity "summer," and the long-season, lower temperature, lower light intensity "winter" periods surely require different ideotypes. The type suitable for highly mechanized and technologically advanced monoculture will equally surely require significant component changes to render it suitable for the association culture with maize on the small hill farms of parts of Brazil.

Within the species, **Phaseolus vulgaris**, genetic variation exists for each component or component-complex named here, with the possible exception of the single main stem characteristic. However, the genes responsible for the particular expressions of these components desired in the ideotype are dispersed in many different varieties or individual strains, none of which contain more than a few of the favorable genes.

It is the urgent task of the bean physiologist to confirm these components as essential to yield, or to identify new or different ones if these are insufficient. He should also devise means of screening genetically segregating populations for recovering the desired characteristics.

It is the paramount task of the bean breeder, in accepting an ideotype as a desirable goal, to assemble from the diverse sources the array of genes that in concert will give a close approach to the ideotype.

There may be great barriers to such a task that occur because of genetic linkages, multiple effects of alleles (pleiotropism), or from developmental associations. It is plant breeding dogma that a stable well-adapted genotype represents an array of genes that are functionally balanced in their effects on the phenotype. The balance has been achieved through selection, and is maintained, in the bean, through self-fertilization and linkage.

In the construction of an ideotype that departs drastically from any previously existent balanced state, a new state of harmonious adjustment will have to be achieved through breeder selection. Some compromises may be necessary. But if experience from the cereal grains is reliable on this point, it should be possible with the bean to achieve a new level of yield by "designing, breeding, testing, and exploiting plant ideotypes" (Donald 1968).

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I. Commentary upon:

PLANT ARCHITECTURE AND PHYSIOLOGICAL EFFICIENCY IN THE FIELD BEAN

A. M. Evans

Dr. Adams has made a case for constructing a particular plant ideotype in breeding for higher yields in **Phaseolus** beans. Plant breeders are agreed that breeding for increased yield is of prime importance. There is, however, a divergence of opinion on how to achieve this objective. Breeders divide over the issue of whether to breed for the strict ideotype as designed by the physiologist where there is generally specific adaptation to a given environment or whether to breed for adaptability to a range of environments and hence to select for low genotype by environment interaction. I would like to consider these two approaches.

Before doing this, I propose to examine the broader aspects of variability in plant architecture in the bean and to discuss how this can be exploited to meet breeding needs. A germ plasm collection of some 4,000 accessions of **P. vulgaris** has been assembled in Cambridge and the genetic variability available in the species has been investigated over a number of years (McWalter 1964, Rathgen 1965, Smartt 1969, Froussios 1970, Evans 1972). The collection includes varieties from the center of diversity of the species in Central and South America, wild populations from Mexico, land races from Uganda as well as varieties from temperate North America and Europe.

Under field conditions at Cambridge, five races have been recognized which vary in growth habit, leaf size, internode length and internode number. (Table 1).

The pattern of evolution appears to be as follows:

Central America

Race 1(a) small seeded indeterminate climbers

↙ ↓ ↘

small seeded indeterminate semi-climbers	small seeded indeterminate bush types	small seeded determinate multi-noded types
Race 2	**Race 3**	**Race 4**

South America

Race 1(b) Large seeded indeterminate climbers

↓

large seeded determinate bush types

Race 5

Table 1. Variation in vegetative characters in P. vulgaris varieties.

Race	Habit of plant	Internode length	No. of internodes	Leaf size
1	Indeterminate climber	long	17 - 35	1(a) small 1(b) large
2	Indeterminate semi-climber	long	14 - 30	small
3	Indeterminate bush	short	13 - 25	small
4	Determinate multi-noded	short	12 - 15	small
5	Determinate bush	long	3 - 5	large

The survey of the fruiting characters of these races shows variation in pod length and texture, in seed numbers per pod and in seed size (Table 2).

It is clear that considerable variation exists in P. vulgaris cultivars and this can be exploited by breeding.

Exploitation of variability to meet breeding needs

The plant breeder has already exploited some of the variability available in this species to meet the variety of uses to which the crop is put and the range of environments in which the crop is grown. In tropical countries, beans are a valuable

Table 2. Variation in fruiting characters in P. vulgaris varieties.

Race	Pod length (mm)	Seed no. per pod	Seed size (mg.)	Pod texture
1	75 to > 150	3 - 7	1(a) small 200-400 1(b) large 400-800	parchmented leathery and fleshy
2	< 75 to 112	5 - 7	small 200-400	parchmented and leathery
3	< 75 to 112	5 - 7	small 150-300	parchmented
4	< 75 to 112	6 - 9	small 150-250	leathery
5	75 to > 150	3 - 4	large 400-1000	leathery and fleshy

pulse crop and are consumed as cooked dry beans, while in temperate regions where dry beans are grown, they are also used for canning. In addition, varieties have been developed in temperate regions for fresh pod consumption and for processing as frozen vegetables.

A few examples will illustrate how the plant breeder has modified the types available to meet breeding needs. Most work has been devoted to race 5 and to a lesser extent to races 3 and 4, but varieties of large seeded climbing beans from races 1 and 2 have also been developed where the support is e.g., a maize plant in the tropics or a pole in temperate regions. Types from race 3 have found a place in tropical regions e.g., Uganda (Leakey 1971),where the indeterminate bush is an assurance of continued growth after some temporary environmental stress.

From race 4, (the determinate multinoded types of Central America) the successful Michigan Navy beans have been developed. These are small, white-seeded, determinate varieties with about 7-10 nodes and were produced to meet the needs of the canning industry. To meet the needs of production of **haricot vert**, varieties which are stringless and with fleshy pods have been developed from race 5. More recently, Dutch plant breeders have developed small seeded types with few (3-5) elongated nodes; an example of the breaking of the associations found in races 4 and 5.

For ease of mechanical harvesting, there have been considerable attempts, in the bush varieties, to ensure that the pods are held high on the plant and above the leaves, to prevent damage at harvest. The most striking examples are presented by the European varieties where the leaves have reflexed or declined petioles and the pods form a cone above the rosette of leaves. Although large leaf size is generally associated with large seed size and vice versa in the original fine races, it has been possible to break this association and varieties are now found of a small leaved, large seeded, bush bean.

Of necessity, the aims of the breeder of culinary (snap) bean varieties and the breeder of dry bean varieties have been different, and the exploitation and generating of variability has been in different directions. A study of the evolution of varieties within the species enables one to see the overall picture, and much advantage could now be gained by including the culinary, temperate region varieties in breeding programs for the dry beans of the tropics. The European culinary varieties present a distinct gene pool of variation which could be usefully used in extending the variation in plant architecture.

Evaluation of the genetic diversity for plant characters and correlating these with seed yield

An understanding of the genetic control of plant characters aids in exploiting the variability for these characters in plant breeding programs. In an investigation to assess the characters, node number and time of flowering in varieties derived from races 3, 4 and 5, the genetic basis of these characters was studied in a diallel cross of eight varieties (Cheah and Evans 1973). The choice of mating design which allows the maximum amount of information on specified components of variation with the minimum cost in time and labor is important in this type of work. In this connection the diallel cross has been of central importance but it has the disadvantage in practice that only a limited number of parents can be handled. We have more recently used the triple cross mating design of Kearsey and Jinks (1968) which

Table 3. Comparison of growth habit class with mean node number and days to flowering.

Growth habit class	Variety	Origin	Mean node no.	Days to flowering
Indeterminate bush	Mexico 120 (MX)	C. America	15.0	74.3
Determinate-many noded	Chimbolo (CH)	C. America	11.4	75.4
Determinate-intermediate	Gratiot (GR)	U. S. A.	7.3	66.8
Determinate-few noded	Higuerillo (HG)	S. America	4.4	59.0
	Canadian Wonder (CW)	U. S. A.	4.0	61.0
	Harvester (HV)	U. S. A.	4.8	62.0
	Prelude (PR)	Europe	4.7	60.0
	Glencarse (GC)	U. K.	4.0	61.0

involves the use of two inbred lines and their F_1 as testers against which crosses can be made with a number of varieties. This method reduces the numbers of crosses required while still providing considerable information on the underlying genetic architecture in the varieties under investigation.

The varieties included in this study, their growth habit class, the mean node number and number of days to flowering under field conditions are given in Table 3.

The models which explain the inheritance of node number and flowering time are shown in Tables 4 and 5. The results suggest the involvement of two genes controlling node number. These genes D_1 and D_2 are additive and dominant for suppression of node number to the extent of 2.5 leaf-bearing nodes per gene under field conditions. Plants having the determinate habit of growth can have the number of nodes controlled by polygenes only or by a combination of polygenes and D genes.

The D genes also reduce the number of days from sowing to flowering and the model suggests a reduction of four days per gene. There is a high and positive correlation of node number with flowering time ($r = 0.93$ +++).

The significance of studies of the genetic control of these characters is evident. The knowledge, for example, of the presence of D genes means that genetic progress in reducing or increasing node number and number of days to flowering is more rapid when dealing with major genes rather than the slow process of accumulating minor genes for these characters.

It is of interest to determine the correlations between these and other plant characters.

Table 4. Expected and observed values of the trait node number on the mainstem in the four growth habit classes.

Growth habit classes	Determinate types			Indeterminate
	Few-noded	Intermediate	Many-noded	Many-noded
Variety	(Example) Higuerillo	Gratiot	Chimbolo	Mexico 120
Genotype	D_1D_1/D_2D_2	D_1D_1/d_2d_2	d_1d_1/d_2d_2	d_1d_1/d_2d_2
Node Suppression	5.0	2.5	0	0
Node No. Observed	4.3	7.3	11.4	15.0
Node No. Calculated	9.3	9.8	11.4	15.0

	Node no.	**Days to flowering**
Pod number per plant	0.43^{+++}	0.49^{+++}
Seed number	0.59^{+++}	0.63^{+++}
Seeds per pod	0.18	
100 seed weight	-0.56^{+++}	-0.61^{+++}

Of still greater significance is whether these characters are correlated with seed yield so that they may be used as an indirect method of screening for yield. A series of experiments at Cambridge were designed to test this postulate (Cheah and Evans 1973, Hamblin 1973) and the results are shown in Table 6.

Table 5. Expected and observed values in the number of days from sowing to flowering in the four growth habit classes.

Growth habit classes	Few-noded	Determinate Intermediate	Many-noded	Indeterminate Many-noded
Variety	Higuerillo (Example)	Gratiot	Chimbolo	Mexico 120
Genotype	D_1D_1/D_2D_2	D_1D_1/d_2d_2	d_1d_1/d_2d_2	d_1d_1/d_2d_2
Flowering Time Reduction	8	4	0	0
Flowering Time Observed	59.1	66.8	75.4	74.3
Flowering Time Calculated	67.1	70.8	75.4	74.3

Table 6. Correlating plant characters with seed yield.

	Trial of 64 determinate varieties	F_2 of large x small seeded varieties	Dialiel cross of 8 contrasting varieties
Numbers emerged	0.63^{+++}		
Emergence date	-0.43^{+++}		
Flowering date	-0.31^{+}		0.31^{+}
Maturity date	-0.42^{+++}		
Leaf size	-0.12	0.30^{++}	
Height	0.15	0.49^{+++}	
Internode length		0.35^{+++}	
Node no.		0.24^{++}	0.33^{++}
Pods per node		0.85^{+++}	
Pods per plant		0.88^{+++}	0.55^{+++}
Seeds per plant		0.92^{+++}	0.79^{+++}
Seeds per pod		0.26	0.32^{++}
100 seed weight		0.21	-0.17

In the trial of 64 determinate bush varieties which originated from 21 countries, the best positive correlation was between numbers which emerged and seed yield. The high yielding varieties emerged, flowered and matured earliest although the correlations were low in all cases. There was no association between leaf size or height with yield in this experiment, but in another experiment when an F_2 generation of a large seeded and a small seeded variety was studied, there were positive, though low correlations between seed yield and leaf size, height, internode length and node number. The correlations of seed yield with the reproductive characters are in general positive and high. Of particular interest are the characters, pods per node, seeds per plant and seeds per pod; the latter with a low correlation with seed yield.

An understanding of the components of yield and their relationship with seed yield is thus a necessary first step, and our work so far has suggested that a determinate, many noded plant with long internodes, long pods per node with a high seed number per pod would be a desirable combination. However, unless genotypes with these characters also show adaptability to a range of environments, they are unlikely to be successful as varieties. This brings me to a consideration of breeding for adaptability.

Breeding for Adaptability

I believe that during the breeding program, parental varieties and their progenies should be tested over a range of environments and that selection for low genotype-environment interaction (G.E.) should be practiced.

Sprague (1966) pointed out that G. E. interactions constitute an important limiting factor in the efficiency of selection program. However recently, we have acquired a greater understanding of G. E. effects largely through the work carried out at Birmingham University in England (Bucio Alanis 1966, Bucio Alanis and Hill 1966, Perkins and Jinks 1968(a), Perkins and Jinks 1971). The basis of their work has been that the G.E. interaction is linearly related to the environmental effects and the analyses have involved a linear regression.

From the breeder's point of view, the consideration of the linear relationship between the performance of the genotype and the environment as also described by Finlay and Wilkinson (1963), and Eberhart and Russell (1966) is important because of the possibility of obtaining a measure of the general adaptability of a number of genotypes. Finlay (1963) provided evidence from a combining ability study to show that the two components of adaptation, namely, mean yield over all environments and yield stability were largely independent of each other, and he maintained that it should be possible to combine high yield with wide adaptations.

Some work has also been done with segregating generations by Perkins and Jinks (1968(a)) and by St. Pierre et al (1967). The latter, working with generations of barley from F_2 to F_5, divided the progenies and carried out selection in two locations; the yearly exchange of material provided various selection pathways. The adaptability depended upon the selection pathway, and they maintained that selection of barley varieties of wide adaptation could be enhanced by selecting over a range of environments. This is the philosophy of Borlaug (1966) and Finlay (1968) with the Mexican wheat program. They selected over a range of environments, irrigated and non-irrigated, fertilized and unfertilized, at sea level and 10,000 feet altitude and from 0^{o} to 50^{o} of latitude. By this method, different genotypes emerged having high yield and adaptability and these varied greatly in their plant type.

Testing material over a range of sites is time-consuming and costly, and often there is insufficient seed available in the early generations of the breeding program. Hence at Cambridge we are examining the possibilities of selecting genotypes in a number of simulated environments which will hopefully act as a means of screening narrow-range adaptable genotypes. Such micro-environments include different levels of fertilizer, different densities, different times of planting and behaviour in mixtures and pure stands (Sotiriadis and Evans 1973).

So far I have discussed the importance of understanding the genetic control of plant characters and their relationship with seed yield and also the importance of selecting for adaptability in the breeding program.

Now I would like to return to the strict ideotype as first described by Donald (1968) in wheat breeding and by Dr. Adams in this seminar. Although at its best this is an attractive, logical approach, at its worst it is unfortunately dogmatic and unrealistic. It seeks to rationalize the plant breeder's program, to create the ideal plant and to suggest an ideal environment for it. Unfortunately, no environment is ideal (except perhaps that of a glasshouse) and the environment is continually fluctuating. A model, of necessity, narrows the spectrum of a breeding program, and we know that several models can lead to high yield. Plant design may be both difficult and profitless because the application of the principle of design may lead to a range of theoretical models. The question arises whether any of the principles of design can have substantial constancy of expression over a wide range of environments. Until such a situation is achieved, I think the breeder would be well advised to give greater priority to the adaptability concept rather than the ideotype concept.

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II. Commentary upon:

PLANT ARCHITECTURE AND PHYSIOLOGICAL EFFICIENCY IN THE FIELD BEAN

D. H. Wallace

Dr. Adams has excellently described bean plant ideotypes that should be selected in breeding for higher yield. I agree with him and will only expand on the concepts. He emphasized plant and canopy architecture, and indicated that the ideotypes described endow the plant with superior physiological capabilities. I will discuss these capabilities using the modeling approach that he identified as one way to identify ideal plant types.

Efficient breeding of higher yielding varieties requires extensive understanding of the system (the summation of all processes and component processes) leading to phenotypic expression of yield, the latter being the output of the system. It requires knowledge of the contributions made by individual component physiological processes. Table 1 shows that virtually all nuclear and also cytoplasmic genes affect yield. The informational content of each of the several thousand genes is implemented (put into action) by the protein, i.e. enzyme whose synthesis is controlled by that gene. Each enzyme catalyzes the synthesis of specific molecules from other, either smaller or larger, substrate molecules.

A specific group of enzyme-activated molecular syntheses are integrated through sequential or parallel pathways into the physiological process of photosynthesis. Other gene groupings are integrated to give dark respiration, translocation, partitioning of photosynthate, protein synthesis, and the other processes listed in Table 1 as being physiological components of yield.

Finally, parallel and sequential actions of these physiological processes lead to phenotypic expression of yield. From this, it is obvious that yield is a complex character. It results from control by almost all genes, and from actions and interactions of fewer but numerous physiological processes. Systems analysis is essential to efficient breeding of higher yielding varieties.

A first step of systems analysis is measurement of the output of the system. The output (economic yield) is measured in kilograms of bean seed per hectare. We have all measured this output with yield trials and statistical genetics procedures. The next step is to methodically sub-divide the system into component processes, so that the effect upon seed yield of varied performance by the different components can

Table 1. The physiological-genetic system for phenotypic expression of crop yield

Informational components		Information implementation components		Physiological-process components				System output
Gene A	→	Enzyme A	→					
" B	→	" B	→					
" C	→	" C	→					
" .	→	" .	→	Photoperiod response	→			
" .	→	" .	→	Days to maturity	→			
" .	→	" .	→	Mineral uptake	→			
" .	→	" .	→	Water uptake	→			
" .	→	" .	→	Protein synthesis	→			
" .	→	" .	→	Photosynthesis	→			
" .	→	" .	→	Leaf area	→	Photosynthate accumulation	→	Phenotypic expression of economic yield
" .	→	" .	→	Leaf angle	→			
" .	→	" .	→	Leaf thickness	→	Photosynthate partitioning	→	
" .	→	" .	→	Leaf cell size	→			
" .	→	" .	→	Stomate resistance	→			
" .	→	" .	→	Dark respiration	→			
" ∞	→	" ∞	→	Photo respiration	→			
Cytoplasm A	→	Cytoplasmic Product A	→	Translocation	→			
" B	→	" B	→	Disease resistance	→			
" C	→	" C	→					
"	→	" .	→					
" N	→	" N	→					

be determined. As each component is varied, we must analyze for both the influence upon output (seed yield), and for feedback signals to other component processes, i. e. interactions among components.

It should be noted that the researcher can vary few if any of these component physiological processes at will. As a consequence, he is forced to analyze their effects via observational trials, where basically he can only study correlations and he cannot be sure that some unmeasured process is not the causally important correlated factor. He is very much limited in determining the role and relative importance of these physiological components, as compared with fertilizer or irrigation trials where the treatments are supplied according to the will of the investigator.

If the component analysis begins with the gene, at the informational and substrate-input end of the system, then there are thousands of gene-enzyme components to analyze. There are fewer components to consider if the analysis begins with the physiological-process components. It is most easy and effective, moreover, if the sub-division into components begins near the output end of the system.

BIOLOGICAL AND ECONOMIC YIELD

Such a component analysis can begin by subdividing phenotypic expression of yield into only two major physiological components, namely accumulation of photosynthate and partitioning of photosynthate. For the simplified growth analysis that we shall discuss, photosynthate accumulation is most easily measured as total plant dry weight (biological yield) and partitioning of photosynthate as seed weight (economic yield) divided by biological yield. The latter ratio is commonly called the harvest index (Donald, 1962). These two component processes are all inclusive and all physiological components listed to the left of them in Table 1 are sub-components of these two processes. It is recognized that there is feedback and interaction among all these processes (Wallace and Ozbun, 1973).

As an adjunct to yield trials, measurements of total accumulated plant dry weight per hectare, and of days from planting to maturity which is the time component of photosynthate accumulation, will provide much insight as to whether it is overall net accumulation of photosynthate (biological yield) or partitioning of photosynthate that is conditioning genetically controlled variation in yield.

This information identifies the lines possessing these complementary physiological capabilities which are essential for highest yields. Such lines should be used as parents. This adjunct to yield trials is called **simplified growth analysis** since it gives information similar to, but less detailed than, the growth analysis procedures of crop physiologists (Watson, 1952; Radford, 1967) for obtaining relative growth rates and net assimilation rates.

USE OF SIMPLIFIED GROWTH ANALYSIS

Simplified growth analysis should be used by all agronomists interested in improving yield by cultural means, and especially by researchers trying to breed higher yielding varieties. It requires but two simple additions to the standard effort of yield trials. The first is that an accurate measure be obtained of days to maturity, which is often done anyway. The second is that total plant dry weight, i. e. biological yield be measured. Days to maturity measures the duration of active photosynthesis and growth. Biological yield (total accumulated plant dry weight per hectare) is the most easily obtainable measure of overall photosynthetic efficiency.

More detailed studies of the sub-components of these two major components can be made later. They will indicate whether it is leaf area, or leaf angle and light interception, or rate of photosynthesis per unit leaf area, etc. that endows a genetic line with high overall photosynthetic efficiency. However, detailed data about these processes are most informative when interpreted in conjunction with knowledge as to whether the overall photosynthetic efficiency per unit land area is high or low for a given line. Measurement of biological yield provides the latter information, and is thus identified as an essential step in systems analysis of phenotypio expression of yield.

With simplified growth analysis the dry weight of bean leaves is ignored, because it would not be simple —it would be very difficult— to collect all the leaves falling from maturing bean plants. For standardization, therefore, some effort must be put into removing leaves that have not abscissed at harvest, so that all biological yield measurements will include an essentially equal number of approximately zero leaves. The roots are also ignored. For simplified growth analysis the measurement of biological yield is, therefore, the air dry weight of all the above-ground stem and fruit tissue produced on each plot of the yield trial.

This weight is obtained just prior to putting the plants into the threshing machine for separating the economically important seeds from the economically unimportant plant parts. I am impelled to ask how many yield trial researchers have been guilty, as I have, of carefully placing the biological yield of each plot of yield trials into a burlap bag, and then pushing it into the threshing machine and judging it only as waste to be carried from the straw pile accumulating at the end of the threshing machine.

Surely, this measure of overall efficiency of photosynthesis can provide much information for analysis of the physiological basis of yield differences among varieties, and also among cultural treatments, and for the selection of parents possessing physiological capabilities that are complementary with respect to phenotypic expression of yield.

TIME IS A FACTOR

It is seen above that simplified growth analysis requires three items of original data, seed weight per plot or hectare, total plant dry weight, and days to maturity. Seed weight is the produce of economic interest and its interpretation and importance is obvious and has long been recognized and used. Biological yield per hectare was interpreted above as a measure of overall photosynthetic efficiency, and time was identified as a component of overall photosynthate accumulation, as measured with biological yield.

Dividing biological yield and economic yield by the number of days from planting to harvest respectively provides a modified measure of overall photosynthetic efficiency (of total plant dry weight accumulated per day), and modified measure of efficiency of accumulation of economic yield (gms of seed accumulated per ha per day). Gms of economic yield accumulated per ha per day has very applied significance in a tropical environment where every day is a growing day and another crop might be planted as soon as the present one is harvested. It is also obviously important, as a measure of biological efficiency. The breeder should know how his lines compare with respect to gms of economic yield accumulated per ha per day.

It is possible for the biological yield, and hence photosynthetic efficiency, to be very high, but for the attendant economic yield to be low or even zero. The ratio of economic yield divided by biological yield, commonly called the harvest index, measures the efficiency of partitioning of accumulated photosynthate to the economically important plant organs. Plants with very high biological yield and very low attendant economic yield, and plants with low or moderate biological yield and low or moderate attendant economic yield may both be properly dropped as potential varieties. It should be obvious, however, that the high photosynthetic efficiency of one and the efficient partitioning of photosynthate to the seed (high harvest index) of the other may be the exact complementation of physiological capabilities required for a very high yielding variety.

Table 2 presents simplified growth analysis data for four dry bean varieties. Except for days to maturity and harvest index, the data presented are relative. Charlottetown had far lower economic and biological yield per hectare and per hectare per day than the other varieties, but it had the highest harvest index. Charlottetown, a yelloweye type variety, was crossed with Red Kidney. However, it was impossible to select for yield in the progenies, because all plants were susceptible to both common bean mosaic and seed-borne halo blight, illustrating the point that disease resistance is a physiological-genetic component of yield. Charlottetown was later crossed to Redkote, a halo blight and mosaic resistant

Table 2. Simplified growth analysis data for four dry bean varieties

(original data from Wallace and Munger, 1966)

	Relative seed yield	Relative biological yield	Actual days to maturity
Red Kidney	84.5	81.7	100
Cornell 7-16	100.0	100.0	95
Charlottetown	66.3	52.2	85
Michelite	97.0	115.6	90

	Actual harvest index	Relative seed yield per day	Relative biological yield per day
Red Kidney	57.2	84.5	69.9
Cornell 7-16	63.7	100.0	100.0
Charlottetown	66.2	66.3	52.6
Michelite	54.6	97.0	109.9

version of Red Kidney. The simplified growth analysis data for some mosaic and halo blight resistant red-kidney type selections are shown in Table 3. Twenty-nine single-plant F_5 progenies (bulk increased through F_7) were included in this yield trial. Redkote is the check variety. The progenies are listed by rank for seed yield per ha, and the data and rank are also given for all the other parameters of simplified growth analysis. The 14 progenies listed above Redkote are just those required to include the top 5 ranked progenies for each of the parameters kgm of seed per ha, kgm of seed per ha per day, kgm of biological yield per ha, kgm of biological yield per ha per day, and harvest index. The progenies listed below Redkote are the four with lowest seed yields. There were only two classes for days from planting to maturity, 93 and 114 days, a difference that our studies suggest is controlled by a single gene.

The 10 top ranking progenies for kgm of seed per ha included the top 5 ranks for all other parameters, except that rank 16 was required to include rank 5 for kgm/ha/day of biological yield, and ranks 18, 21, and 25 were respectively required to include harvest index rankings 2, 3, and 1. Seed yield per ha was most closely correlated with kgm/ha of biological yield, but much less closely with kgm/ha/day. Seed yield per ha ranks 4, 6, 7, 8-9 (two progenies shared this ranking), and 10 respectively had kgm/ha/day rankings of 1, 2, 3, 4, and 5. All five of these lines had early maturity. On the contrary, kgm/ha ranks 1-2, 1-2, 3, 4 and 5 respectively had kgm/ha/day rankings of 17-20 (four progenies shared this ranking), 17-20, 21-22, 1, and 26. All of these progenies were late except the one ranking 4 for kgm/ha and 1 for kgm/ha/day. This latter progeny also ranked 4 for harvest index, while seed yield ranks 1-2, 1-2, 3 and 5 respectively ranked 27, 26, 25 and 28 for harvest index.

For these progenies, both high kgm/ha/day of seed and high harvest index appear to be linked with early maturity while late maturity has low seed yield per day but high seed yield per ha, and very low harvest index. We do not have sufficient data to judge the potential of breaking this linkage for seed yield per day, but the fact that Cornell 7-16 is moderately late but has a high harvest index (Table 2) indicates that high harvest index can be combined with later maturity.

We have made crosses between Cornell 7-16 and Redkote, but these progenies have not progressed as rapidly as the ones from Redkote x Charlottetown because the genetics of the seed pigment differences between yelloweye x red-kidney colored beans is much less complicated than that between Cornell 7-16 and Redkote.

We have evidence, but not from comparable yield trials, that certain Michelite x Redkote progenies have biological yields much higher than any presented in Table 3. This would indicate that the higher overall photosynthetic efficiency of Michelite, as judged from the higher biological yield in Table 2, is heritable and therefore exploitable in breeding for higher yields.

THE PHYSIOLOGICAL PROCESSES

After presenting the concept of simplified growth analysis and a few relative data, I want to discuss briefly some of the physiological processes listed to the left, in Table 1. All are components of either photosynthate accumulation or photosynthate partitioning. Some will affect both, through feedback mechanisms and resulting interactions (Wallace and Ozbun, 1973). There is ample evidence (Athwal, 1971; Zelitch, 1971; Yoshida, 1972; Hayashi, 1972; and Wallace, Ozbun and Munger, 1972), that there is genetic variability for all physiological and

Table 3. Simplified growth analysis data for selected Redkote X Charlottetown F_5 progenies (tested in F_7) (1972 yield trials)

F_3 Progeny No.	F_6 Family No.	Days to maturity	Economic yield Kgm/ha		Economic yield Kgm/ha/day		Biological yield Kgm/ha		Biological yield Kgm/ha/day		Harvest index		No. reps.
			Data	Rank	Data	Rank	Data	Rank	Data	Rank	Data	Rank	
5	015-016	114	2700	1-2	23.7	17-20	5658	2	49.6	2	48.3	27	16
52	025-028	114	2700	1-2	23.7	17-20	5572	3	48.8	3-4	48.7	26	31
65	0044-046	114	2683	3	23.5	21-22	5435	5	47.7	10	50.5	25	24
1	001-007	93	2597	4	27.9	1	4488	6	48.3	6	59.4	4	47
104	055-056	114	2528	5	22.2	26	5469	4	48.0	7	47.2	28	16
4	008-011	93	2511	6	27.0	2	4334	11	46.6	11	58.9	5	32
52	020-021	93	2497	7	26.8	3	4541	7	48.8	3-4	56.6	17	15
62	032-034	114	2459	8-9	21.6	27-28	5847	1	51.3	1	43.3	29	24
65	047-049	93	2459	8-9	26.4	4	4455	9-10	47.9	8-9	56.7	15-16	24
115	077-079	93	2425	10	26.1	5	4265	12	45.9	12	57.9	7	23
104	053-054	93	2321	16	25.0	11	4506	8	48.5	5	50.8	24	10
115	066-067	93	2270	18	24.4	14	3835	26	41.2	26	60.5	2	14
52	022-024	93	2219	21	23.9	16	3749	28	40.3	28	60.3	3	22
105	057	93	2167	25	23.3	23	3663	29	39.4	29	61.1	1	8
	Redkote	114	2563	4-5	22.5	26-27	5435	5	47.6	7-8	47.7	27-28	99
111	062-063	93	2115	26	22.7	21	4128	18	44.4	18	53.0	19	16
111	064-065	93	2098	27	22.6	25	3956	24	42.5	24	53.5	21	14
5	012-014	93	2012	28	21.6	27-28	3990	21-22	42.9	21-22	52.8	23	24
104	050-052	93	1961	29	21.1	29	3818	27	41.1	27	53.2	22	24
Range (Highest + Lowest)		128 %	138 %		138 %		160 %		130 %		141 %		

biochemical processes, and therefore potential to breed and select desired levels. This genetic variability should be used primarily as a means of identifying parents for crosses, after which selection procedures will not differ much from those long practiced by breeders.

One physiological component of photosynthesis which is most important is variation in distribution of intercepted radiant energy across all the leaves of the canopy. Beans have a unique mechanism of achieving this. Wien and Wallace (1973) have shown that the pulvinule of bean leaflets is the organ responsible for light-induced leaflet orientation of beans and other legumes. Leaflet blades do not respond when light impinges on the leaf blade. When light impinges upon the pulvinule, however, the pulvinule bends toward the light, moving the leaflet also toward the light. The result, for light from above (as for the sun), is that the leaflet is oriented more parallel with the source-direction of the light. Each responding leaflet, therefore, intercepts less light and permits more light to pass by to be intercepted by leaflets that are lower in the canopy.

There are varietal differences in responsiveness. When the leaf canopies of relatively unresponsive varieties are viewed from above, only 2 to 3 layers of upper leaflets can be seen. All the lower leaflets are hidden from view and shaded by the upper leaflets. With responsive varieties the leaflets are oriented more or less vertically in bright light. Five or six or more layers of leaflets can easily be seen. The light penetrates to the lower leaves in the canopy and the overall rate of photosynthesis should be maximized. This phenomenon will also reduce the heat load and thereby transpiration rate of bean leaves. Inability under a bright sun to supply sufficient water to the leaves clearly limits bean yields under lowland tropical conditions.

The limted data presented for a very few varieties indicate that using simplified growth analysis to identify varietal differences in overall photosynthetic efficiency and in partitioning of photosynthate can be very helpful in breeding for higher yields. I suggest that much extremely useful data could be accumulated in 2 to 3 years if simplified growth analyses were routinely used as an adjunct to yield trials. This would provide data about overall photosynthetic efficiency and photosynthate partitioning for a broad germ-plasm base. Such data would greatly assist plant breeders in intelligently selecting parents for crosses.

There have been many studies on all aspects of photosynthesis and photosynthetic efficiency. On the other hand, almost nothing is known about mechanisms controlling partitioning of photosynthate. Much research is needed to understand why photosynthate is partitioned to one plant organ rather than another, or to one physiological process in contrast to another. The phenomenon of partitioning of photosynthate is much broader in influence than its effect on harvest index as discussed in this paper. Through feedback and interaction mechanisms it affects almost all physiological processes (Wallace and Ozbun, 1973). In the near future, much effort should be made to improve man's understanding of physiological and genetic control of partitioning of photosynthate.

MEASURING PROTEIN AS ECONOMIC YIELD

It may be that yield of protein per ha should be recognized as the economic yield, since the major objective of increasing bean yields in tropical areas is to improve protein content of human diets. If the total protein is measured, the protein accumulation per ha per day is easily calculated. With protein as economic yield, the major components would still be photosynthate accumulation and photosynthate partitioning. Now however, it would be important to study the pathways by which variation arises with respect to how much of the photosynthate partitioned to the seed is re-partitioned to storage protein as contrasted to carbohydrate, fats, and other compounds. Upon accepting protein yield per ha as economic yield, the pathways of nitrogen uptake and protein synthesis would merit more immediate and direct consideration.

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III. Commentary upon:

PLANT ARCHITECTURE AND PHYSIOLOGICAL EFFICIENCY IN THE FIELD BEAN

H. C. Wien

Dr. Adams mentioned the desirability of having many small, erect leaves in the field bean ideotype. Some recent work at Cornell provides an explanation why bean leaves assume a more vertical orientation under sunny conditions in the field (1). Orientation of bean leaflets depends on the pulvinule, a small, round portion of the leaflet petiole, that acts both as the hinge on which the leaflet turns, and also as the photoreceptor that undergoes positive curvature when illuminated by light from a unidirectional source. Only illumination of the pulvinule produces a change in the leaflet angle (Figure 1). We also found varietal differences in the amount of leaflet angle change with exposure of the pulvinule to a given amount of light (Figure 2) with Redkote showing significantly less leaf movement than the other three varieties tested.

Since the orientation of the leaflets depends on whether the pulvinules are exposed to unidirectional light or not, any morphological factor that would maximize pulvinule exposure to the sun increases the leaf turning of a variety. Small leaflets, held on an upright petiole, with a minimum of overlapping of the basal lobes of each leaflet, are highly desirable for optimum light response. The Michigan pea beans mentioned by Dr. Adams show these characteristics, although we have found that the older leaves of Michelite-62 tend to be curved so that leaf turning results in no reduction of light interception by these leaves.

Recent findings on translocation patterns of C-14 assimilates in two varieties of field beans during the reproductive period (2) generally support the concept of a "nutritional unit" comprising one leaf and the pods in its axil. This is true particularly for the terminal main stem and branch leaves of the determinate cultivar Redkote. More general distribution of assimilates occurs from lower main stem leaves of Redkote, and from upper leaves of the indeterminate Michelite-62. Thus, at the close spacing that Dr. Adams proposes, the upper leaf canopy would consist primarily of the terminal leaves of main stem and branches, leaves that are most directly involved in dry matter production for the pods. The canopy structure, thus, resembles that of wheat and rice where flag leaves are primarily responsible for dry matter production in reproduction growth.

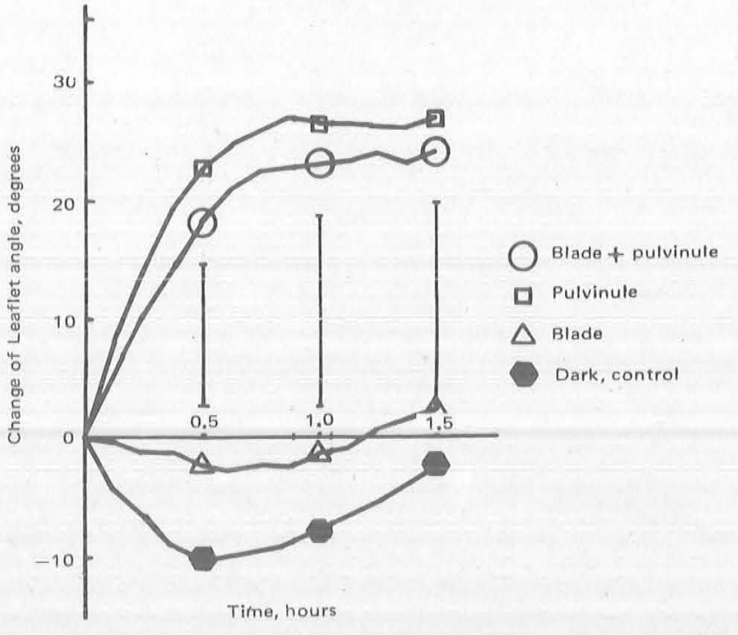

Fig. 1. Change of leaflet angle with time of cv. Redkote in response to light directed on blade, pulvinule, or blade and pulvinule combined, from vertically above. Vertical bars indicate differences between control and treatments required for significance at the 5 percent level.

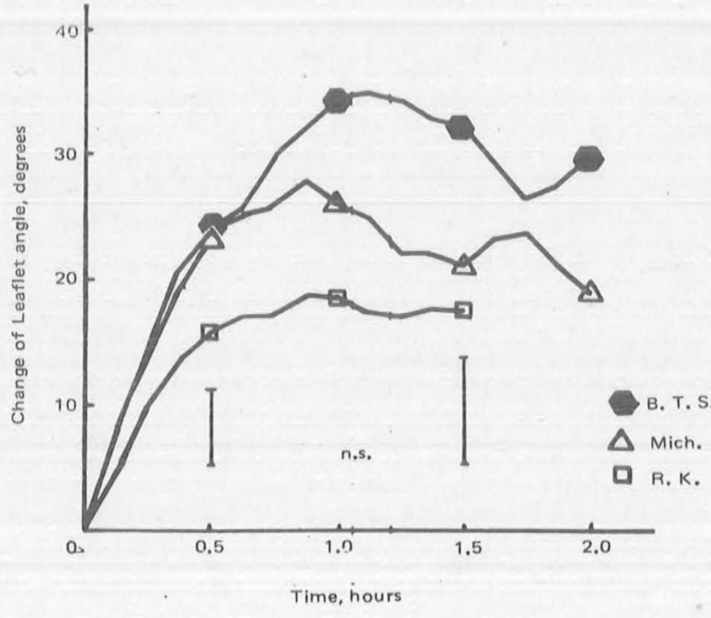

Fig. 2. Change of leaflet angle with time for attached leaves of cultivars Redkote (RK), Michelite-62 (Mich.) and Black Turtle Soup (BTS) in response to lighting of the pulvinule from above. Vertical bars indicate LSD values required for significance at the 5 percent level.

SECTION 4.

IMPLEMENTING INSTITUTIONAL COOPERATION

ORGANIZATIONAL AND INSTITUTIONAL OPPORTUNITIES FOR LEGUME PROGRAMS IN LATIN AMERICA

A. Colin McClung

This seminar has been called to consider the current status and future potential of food legumes in Latin America and to plan a strategy for research and development. It has brought together many of the scientists and research organizers who are concerned with this crop. Before this group there is no need for me to talk about the crop per se, or the specific research which might be needed to stimulate its production and utilization. We have also heard a comprehensive survey of existing manpower and institutional resources at work in the field. Instead of going further into these matters, I would like to consider with you ways and means of organizing our resources and efforts to better achieve our individual and collective aims.

The situation we see in bean research in Latin America is one in which a great many individuals and centers are carrying out rolatively modest programs. Bean research is not top priority for any agency, yet taken in its aggregate, many people and considerable sums of money are involved. None of us is satisfied with the results. There has been no green revolution with beans, and none is in the offing. Instead, we find that yields are essentially static and profits to farmers are low. Other crops are proving more profitable in some areas and are tending to replace beans. If this crop were not so deeply imbedded in traditional agriculture, we might find that it would be dropping even further behind other crops. At the same time, beans are being priced out of reach of the poorer segments of society where nutritionally they are most urgently needed.

I believe that this situation can be reversed and that we can reorganize ourselves to carry out a program that will result in increased yields, higher net returns to farmers and better supplies to consumers.

What we want to do here is the kind of job that has been accomplished with rice and wheat and that is starting with other basic commodities. But should we do it in the same way? I doubt it. The rapid successes with wheat and rice were based upon a body of information and materials assembled or developed by major international centers organized for this purpose. Success depended, of course, upon close involvement by numerous national agencies who adapted basic technology to local conditions and saw it into the hands of farmers.

Should we think in terms of some sort of international bean research center? I think not. There are two basic reasons why this does not seem to me to be the indicated approach. First, as important as beans are, they do not hold a place equivalent to rice, wheat and some of the other cereals in anyone's priorities. Second, there are other ways of getting the job done more efficiently.

LINKING UP A NETWORK

What I visualize is a network of national stations throughout Latin America which work together as a coordinated team. Each station would have its own local objectives and its program would not in any sense be dictated from the outside. However, the work would be done with an awareness of activities and results throughout the region. Materials and procedures would be tested under a wide range of conditions, and we could expect to come up with a more widely applicable technology.

This is not a new idea of course. In fact, from conversations I have had with some of you, I rather expect that it would represent something of a consensus on how to get bean research going. I have a general picture in mind of how such a network might function and I expect that many of you do, too. But one objective of this seminar is to consider just this point and I don't propose to outline ahead of time what looks to me like the best model. Instead, I would like to describe to you some of the operating programs which I have had an opportunity to observe in recent years. Perhaps we could obtain some ideas and guidance from these. Most of my experience in this regard has been in Asia and with rice. I hope that you will forgive me if I now stop talking about beans and start talking about rice.

THE EXPERIENCE WITH RICE

Rice in Asia has seen a great deal of progess in the past decade and much of this was because of various programs of international collaboration. Means have been developed of working together on common problems. Cooperation outside your own cultural or ethnic group in Asia has not in the past been common. On the contrary, the traditional pattern has been to go it alone.

About a year ago, I attended a seminar on the subject of regional cooperation within Asia. The seminar was called by the Asia Society, a private organization interested in Asian affairs, and they had brought together a diverse group to discuss matters ranging from food to population and the success, or lack thereof, of various regional projects. The results in general had been discouraging. Most regional projects had started out with high expectation and expressions of interest, but all too often they had ended with little more than words and reports for the files.

One of the speakers who was from the British Commonwealth recounted generally disappointing results even within a group of nations with certain ties of a political or consultative nature. He pointed out that the same had been true early in this century when the same group of nations were part of the British Empire with political and administrative ties between units which were a great deal stronger. He mentioned mutual programs initiated under the stress of World War I which died out with little accomplished shortly after the emergency had subsided.

The group at this Asian conference agreed that rice research and development was an exception. It had been successful and gave promise of continuing to be. What was the difference? The crisis situation of a war was there.

THE PRESSURE OF CRISIS

It was a war against starvation. Suddenly in the middle 60's there was a food shortage that was continent wide, that involved people in the billions and that wouldn't go away with the next season of good monsoon rains. No place on earth was there a source of food to meet these needs. It had to be produced in Asia and mostly it had to be produced with one crop, rice. Anyone with something to say about rice was bound to be heard whether he was right or wrong. New ideas and materials moved across major political barriers. IR8 rice seed is believed to have moved into North Vietnam and China almost as soon as it became available. No one anywhere tried to interfere with the development or use of new rice technology.

Within the countries, agriculture was elevated to top priority. Top ministers were shifted within cabinets so that the strongest and most capable were in agriculture. In some cases the president or prime minister moved directly into getting agriculture moving and most especially into getting rice moving. Small wonder, then, that cooperative activities were possible with rice that were not possible before.

It is worthy of note that the population problem of Asia is equally pressing, yet we have not seen anything like this concentration of effort. Feeding people is a far more appealing activity than limiting their numbers. Population growth remains Asia's dark cloud. No discussion of food for Asia goes long without population coming into the equation. Sometimes it seems that agriculturists are more aware of the inevitable crisis than anyone else.

Returning to rice developments, the other factor which was different with rice than with other attempted regional projects was the interest and effectiveness of international agencies. In spite of common problems of a crisis nature, effective regional cooperation did not develop spontaneously. Most of it involved international agencies which fostered such exchange. This was true back in the 50's with the International Rice Commission of the FAO. It was particularly true when the International Rice Research Institute came on the scene.

STIMULUS OF INTERNATIONAL EFFORT

In this case, the international agency was not just a broker or clearing house. It had major new inputs of technology to introduce. IRRI and the national agencies formed a highly effective partnership which continues to be productive. The partnership has stimulated national agencies and has brought focus to their efforts. As important as the direct output of IRRI's research has been, it is rapidly being approached by results coming from the national programs with which it cooperates.

International conferences or symposia were one of IRRI's first steps towards fostering international action programs. These brought together scientists from around the world, much as this bean seminar has done. Scientists who knew each other only by name were able to meet and discuss problems of mutual concern. One feature of the IRRI conferences was that they were made up of working scientists. This was something of a departure from Asian protocol which calls for the oldest and most honored man to represent his group at international conferences. As a result of these symposia, data frequently came into the world literature which had previously been available only in Japanese, Chinese or other languages. Sometimes specific research objectives were identified and action planned. More often the groundwork was laid for future joint studies. I'm sure the same process is at work here. Let's make the most of it.

During the years 1963 - 68, some 35 cooperative projects were undertaken in genetics and breeding, soil microbiology, soil chemistry, agronomy, plant physiology, entomology, cereal chemistry and communication. These were modest research undertakings directed toward specific objectives. They did not require extensive negotiations or elaborate accords between agencies. Usually a project was discussed and prepared by the two cooperating scientists. When their work plan was approved by the directors of the respective agencies, it became operative. Regardless of what means of long term collaboration among Latin American bean scientists may be developed at this conference, I hope that similar projects will grow out of the contacts we are now making.

TRAINING OF SCIENTIFIC STAFF

Training of scientific staff provides another basis for international cooperation and a strong one. There is nothing like the "old school tie" to break down barriers. It was revealing at some of the Asian conferences to see scientists from Pakistan and India who had been students together before partition resulted in the formation of these two countries. They had no trouble meeting on neutral ground and exchanging not only reminisences but also current data on rice technology. Scientists who had met as students in IRRI's training program and elsewhere were also able to cooperate on problems of mutual interest, regardless of political barriers. Where such barriers do not exist, of course, exchanges can be even more direct, rapid, and effective. Again, I submit that a training program should be an integral part of any network of bean research which we may develop. This subject is to be discussed later in the conference, and I feel sure some useful avenues of cooperation will be identified.

The next step in developing Asia's network of rice research involved major changes in each of many national centers. Again several agencies were usually involved in each such operation. The International Rice Research Institute was involved in one way or another in almost all of them. In many IRRI was (and is) an active partner with the national agency in developing its program.

The basic philosophy of IRRI's involvement in these programs was clear on one important point: the programs were in no sense intended to be branch operations of IRRI. They were national programs designed to foster improvements in the local rice situation. The degree and pace of IRRI participation depended upon the wishes of the host country. Emphasis was on improving research capability, but each project moved rapidly into action programs to get the new technology into use in farmers' fields. New materials from IRRI or elsewhere were put to use as rapidly as test results permitted.

NEW VARIETIES RAPIDLY ADOPTED

The speed at which new varieties were adopted under certain situations was truly unbelievable. Actually, it was sometimes more rapid than even the most enthusiastic researcher could wish, for production programs were established when only preliminary test results were available. In 1967, IR8 gave outstanding results in test plots in West Pakistan. The next year all available seed went into increase fields. Additional seed was imported and by 1969 there were 600,000 hectares of this variety in commercial production. Average yields in West Pakistan increased by 60 percent within a two-year period.

IR8 did not perform well in Bangladesh because of diseases and climatic factors. However, another line which later came to be called IR20 did perform well. When the government decided to move with it, the rate of acreage increase was even more startling. In the main season of 1969 there were about five hectares of IR20 in test plots scattered about the country. All the seed was saved and planted in increase fields during the off-season. An additional 1,800 tons of seed was purchased abroad. In the main season of 1970, the total area planted to IR20 in Bangladesh came to about 125,000 hectares. The risks of such a rapid adoption were of course real, but in subsequent seasons results have continued to be favorable. It was a successful gamble.

VARIED INSTITUTIONAL DEVELOPMENTS

Institutional developments in Asian rice research varied widely from country to country. Bangladesh, one of the most hard pressed countries in Asia, took early and extensive action to improve its rice research capability just as they did on the production side.

Rice growing conditions in Bangladesh are difficult, particularly during the main monsoon season. The rains are heavy, but two large river systems channel an enormous amount of additional water to the country. About 20 million acres of rice are grown, but some 900 million acre-feet of water falls on or flows through the country. As a result, about 60 percent of the rice area is flooded with from 75 cm to 6 meters of water. Insects and diseases abound during this season. The soils of the region are generally less fertile than many, and appreciable saline areas occur along the coast. Deep water or floating rices are required for this type of culture. These have been selected over the centuries and some amazingly intricate cultural systems have been developed by farmers to permit them to produce rice under rigorous conditions. Science has contributed rather little.

To improve the technology available to Bengali rice farmers, a decision was made to develop a full-fledged rice research and training center. This is a long-term project but in spite of wars and typhoons, progress is being made. Experimental fields have been laid out, modern laboratories and greenhouses have been constructed and equipped, training facilities are being built, and staff at all levels are being trained both at home and abroad. IRRI has been involved in this project for eight years through Ford Foundation funding and probably will participate for another six or seven years. When the Bangladesh Center is fully operational, it should be something of a regional leader on some of the problems which face Bengali farmers and those of neighboring countries.

CEYLON A DIFFERENT PATTERN

A different sort of cooperative program was undertaken in Ceylon. Ceylon already had an active research program and some varieties rather well adapted to local conditions were available. However, the rate of adoption of these varieties was slow because the extension workers and farmers were basically unfamiliar with modern rice growing methods. The program which was developed by Ceylon and which IRRI helped implement was one of massive farmer training.

About 30 Ceylonese extension officers took six-month rice production training courses at IRRI in which they learned the art and science of modern rice production. Particular attention was paid to communication and farmer training techniques.

When these trainees returned to Ceylon they staffed two national training centers where they gave short courses on modern techniques of rice production. In a period of one year they gave such courses to every rice extension worker in the country, about 2,000 people. These extension agents, in turn, trained about 45,000 farmers in village level courses. They further helped farmers by distributing rice production kits which contained new seeds, fertilizers, insecticides and so on, plus instructions on how to use them. In the first season, 100,000 kits were distributed in the country which has a total farmer population of about 700,000. This extension technique has been used in several Asian countries with much success, but nowhere with the massive approach of Ceylon.

MEETING THE NEED TO MODERNIZE

Still other types of action may be identified among the IRRI cooperative projects. In South Vietnam there is a great need to modernize rice production. The country has done well with applying the new technology coming from abroad. IR8 and IR20 have been widely used and rural incomes have risen as a result. Still, local problems of disease and climate are such that the new varieties are not fully suited. Local studies are needed.

Because of war, however, it has been difficult to mount anything more than rather simple adaptive research. The indicated procedure in Vietnam seems to be to make maximum use of IRRI's breeding program as a source of advanced lines and segregating populations. Hundreds of lines can be rather quickly screened in this way and with nothing like the effort required to maintain a full breeding program. Since IRRI has a major crossing and selection program for similar objectives, it seems almost certain that some much better varieties can be identified for Vietnam. To achieve this, IRRI has channeled hundreds of lines to experimental sites in the Mekong Delta and elsewhere. Results have been good in spite of what was described as some plots lost to cows, rats and mortar shells.

In Egypt, IRRI has stationed a top Japanese breeder to help determine if high yielding varieties can be evolved which will have suitable disease resistance for the Nile Valley and at the same time meet market requirements as regards grain type. When it is winter in Egypt, breeding nurseries are to be airshipped to the Philippines for growing a second generation each year.

A similar program of cooperation has existed with Korea for about eight years. It has resulted in the release of two new varieties of the IR8 plant type. They are distinctly different from anything grown in Korea before, but the grain type is what the Koreans want, and the plants are adapted to their cool weather.

All of these projects suggest similar activities that might be established as part of a network of bean research in Latin America. However, all of them started out with an international center which had developed some quite advanced techniques and was staffed to continue research at an intense level. The model is similar to the program of CIMMYT for corn and wheat, but should it apply to beans?

A STARTING POINT FOR BEANS

I started out by saying that I doubted that the situation would justify an international bean research center. Neither is it likely that one will be developed for cassava or any one of a number of other important crops. Still it is our conviction that a relatively small group of scientists can significantly influence future production if organized and supported in the right way. In the absence of a truly major effort by an international center, I believe the key to success lies in bringing the scientists of several national and international bean research groups directly together in a coordinated manner.

The largest single project with which IRRI cooperates is the All-India Coordinated Rice Research Project (AICRIP). I would now like to describe it in some detail and cite it as possible point of departure in designing a Latin American bean research program. Those of you who might be interested in some specifics about the program will find an article about it by its leaders, Freeman and Shastry in the proceedings of a Symposium on Rice Breeding published by IRRI in 1972. (Freeman, Wayne H. and S. V. S. Shastry. 1972. Rice Improvement in India - the Coordinated Approach: Symposium on Rice Breeding. IRRI).

India is one of the most populous and most complex countries in the world. It incorporates into one nation diverse geographic and climatic areas and units of distinctly different ethnic, cultural, religious and historical origin. Although Hindi has been designated as the national language, it is by no means universally used or understood. In practice, different parts of the country use different languages, some of which are of different origin and not at all comprehensible to other linguistic groups. English is the common language of agricultural science throughout India.

With more than 600 million inhabitants, India is the second largest nation in the world in population. Not only is it large, but it is growing. During the period in which serious efforts to improve rice technology have been underway, India has added 100 million people to its numbers, a truly frightening statistic when extrapolated towards the future.

Indian agriculture has traditionally been in the hands of small farmers who have followed the practices developed by their forefathers over thousands of years. Fortunately, in spite of their traditional orientation, they have proven to be quick to take up new techniques if profitable to them. They are as profit-motivated as any other farmers.

Rice research in India was first started in 1910 with the formation of two centers, one in the southern part of the country and one in the northeast. By 1965 this effort had grown until some 130 sites in the country were devoted to some sort of rice research or development. Some were little more than seed increase fields, but others were complex organizations with many scientists. The Central Rice Research Institute, staffed with several hundred people was, and probably still is, the largest rice center in the world. It has conducted work on many phases of rice science, but has tended to leave the more applied aspects to other centers.

BULK OF WORK IN HANDS OF STATES

The bulk of the research effort and of agricultural development has, by design, been left in the hands of the individual states. When food shortages demanded that new action programs be established in rice technology on a national basis, there was no clear route to mobilize existing resources. One agency, the Indian Council of Agricultural Research, did have country-wide responsibility and it developed what has proven to be a highly effective mechanism for mobilizing resources of most of the key centers, including many over which it had no administrative jurisdiction. This was done by forming the "All-India Coordinated Rice Improvement Project," which I have already mentioned. About 100 of Indian's rice research units are involved in this program.

A National Coordination Center was established at an easily accessible site in the middle of the country. This center was staffed by a group which grew to about 20 well-qualified scientists in the areas of breeding, pathology, agronomy, plant physiology, entomology, and engineering. The assignment of these scientists was to establish applied research in their fields which would permit rapid testing of new ideas and, as soon as possible, to develop new technology based on their own research. Where necessary they would move directly to more basic work. An early example of this was in plant physiology, an essentially virgin field in India. The primary duty of the engineering group was to help all cooperating centers to improve their field research facilities.

ZONAL AND REGIONAL CENTERS

The country was divided into seven zones based upon agroclimatic differences. The major station in each zone was identified as the Zonal Center, and a senior scientist was designated as Zonal Coordinator. He continued to be administratively responsible to his home organization which might be an agricultural university, a state experiment station, or a nationally-funded unit. Technically, he was responsible for the AICRIP program in his zone. Other major stations in each zone were designated as Regional Centers, responsible for the AICRIP program at that site and at other locations in their region. The number of "regions" within a zone varied according to conditions to give a total of 12 in the seven zones. As many as eight or ten other experimental units might cooperate in one way or another with a program of a particular Regional Center.

The National Coordination Center and its parent agency, the ICAR, undertook to station at least two scientists at each regional center in each of the basic disciplines-breeding, agronomy, pathology, and entomology - and to provide additional funds for equipment, transportation and other facilities for each such Center. Funds for this supplementary support at present amount to about $500,000 per year at current rates of exchange.

SPECIALIZED RESEARCH

At another level the program identified certain research units as particularly well suited for more basic research of national importance. Research on virus and bacterial diseases, previously thought to be of relatively minor importance, was supported at the broadly based Indian Agriculture Research Institute. Another center where certain insect pests are particularly prevalent was supported in more basic phases of this problem, and so on.

International participation has involved stationing up to six foreign scientists (American, Dutch and Japanese) at the National Coordination Center under USAID and Rockefeller Foundation funding. Along with them came considerable help in funds for equipment and supplies not available locally. This part of the program has ben organized and supported technically by IRRI. Through Rockefeller Foundation funding a co-leader of the entire program has led the IRRI group of scientists.

In writing about this program Freeman and Shastry have stated:

> "The underlying objective of the All-India Coordinated Rice Improvement Project is to promote the spirit of involvement by all rice scientists of the country in a common program. The provision of extra personnel and facilities is thus merely an augmentation of inputs. This objective has been achieved to a considerable extent through the active cooperation of the personnel involved. The testing programs of AICRIP is not just limited to 24 research centers receiving ICAR assistance, but is conducted at over 100 research stations all over the country. Two Central Institutes (IARI and CRRI), nine Agricultural Universities and several State Departments of Agriculture are involved in the program of multi-location testing. Rice workers from most of the cooperating centers participate in two AICRIP workshops each year to review the research results of the preceding season and to draw up the program for the following season."

KEY FEATURES

The same authors cite a number of key features which have led to rapid progress in Indian rice research:

(1). A system of semi-annual workshops was established where representatives of all regional and zonal units meet after each cropping season to present their results and plan the work of the next season. This requires a high level of discipline in reporting each unit's work so that results are promptly brought to bear on plans for the next season. The workshop is held at different places every other season so that individual scientists get to know something of problems in other parts of the network.

(2). A "memorandum of understanding" was developed between state centers and the Coordinating Center. Freeman and Shastry comment that "basic to the effectiveness of a written memorandum is the "intent" of the parties involved and the spirit of cooperation which exists."

(3). The research program is designed for prompt pay-off in farmers' yields and in national production. The scientist can see the importance of his work and so can the government agency which supports it.

(4). Flexibility of action is an important element of this approach. In practice this has been one of the principal contributions of the international assistance component.

(5). Team spirit has developed as a result of continued close collaboration and is a key element in the success of the program.

(6). The multi-disciplinary team approach which has proven so effective in problem solving around the world is encouraged by this kind of effort. Further, it is encouraged without excessive expense or duplication, for a particular specialist, wherever he may be, can make his contribution.

(7). The multi-location characteristic inherent in the AICRIP program is of great advantage in arriving quickly at a decision on the validity of a particular material or practice. In some phases of rice research, the most reliable data obtained anywhere in the world has come from AIRCRIP where it has been tested rigorously at scores of locations. A poor experimental line or practice quickly falls by the wayside when it is tested this widely.

COORDINATION IN SOUTH AMERICA

The coordinated approach has created much interest in other parts of Asia. It has been studied by the Indonesian Government and adopted in outline as their strategy for rice research. Here in South America we have heard of Brazil's coordinated national programs for several key commodities. Perhaps they, too, have studied the Indian experience in planning their programs. If not, I recommend that they do so.

On a broader basis, I am attracted by the thought that a Coordinated Latin American Bean Research Program could move this crop forward. Many of the essential features are here. We have many scientists working on the crop, but doing so in relative isolation. We have international and regional agencies interested in the problem and capable of making their unique contributions. Communication and travel within our area is relatively easy. Language is no serious problem. While there are international boundaries that need to be crossed in our network the boundaries are friendly ones.

Much cooperation already exists. I see it as a relatively easy matter to strengthen these linkages. If we come up with a practical program, not too complex but capable of developing as we gain experience, I feel confident that we can find ways to obtain the necessary additional financing.

There are many features of Asian regional cooperation which we can well adapt and amplify with beans here in Latin America. I particularly recommend that the AICRIP approach be thoroughly examined

REPORT ON SURVEY OF THE FOOD LEGUME SITUATION IN LATIN AMERICA

Antonio M. Pinchinat

INTRODUCTION

The organizers of the Seminar on the Potential of Beans and other Food Legumes in Latin America considered a prior survey of the legume situation in the Latin American countries (including the Caribbean) necessary to determine the type of international cooperation that could be offered to those countries.

In 1969, the Instituto Interamericano de Ciencias Agrícolas (IICA) of the Organization of American States carried out a survey in Central America which served as a basis to review the plan of technical cooperation for the bean program in the countries of that area (2). In 1972 (1), IICA carried out the same type of survey in a Caribbean country, with similar purposes.

Those surveys served as a background and model for the organization and completion of this survey. A questionnaire divided into 12 sections with a total of 63 questions was sent to every country included. The official IICA representative in each country was requested to act as an intermediary between the national informant and the person in charge of the survey, to facilitate communication.

Through the survey, we emphasized that: (1) the most recent and reliable information on the biological, economic and social aspects related to bean production and utilization in the specific country should be included in one document; (2) specialists in different fields within the country should exchange information and cooperate in the preparation of the document; (3) national deficiencies should be reported for those aspects covered in the questionnaire; (4) the countries should indicate or suggest the most relevant type of international cooperation needed to solve these deficiencies.

This report summarizes the answers of the different countries emphasizing the organizational aspect and the impact of research. Other aspects of the survey will be analyzed in detail at another time.

RESULTS AND DISCUSSION

Table 1 shows that most (14 out of 21) of the countries surveyed, particularly those that we had previously considered traditional or important bean producers, filled out the questionnaire or sent us informational material for the survey.

Table 1. Reaction of the different countries (x) to the survey on the bean situation in Latin America, 1972

Country	Reaction *			
	(1)	(2)	(3)	(4)
Argentina	x			
Bolivia	x			
Brazil		x		
Colombia		x		
Costa Rica		x		
Chile	x			
Dominican Republic		x		
Ecuador		x		
El Salvador			x	
Guatemala		x		
Haiti		x		
Honduras		x		
Jamaica	x			
Mexico	x			
Nicaragua		x		
Panama		x		
Paraguay		x		
Peru		x		
Trinidad-Tobago	x			
Uruguay	x			
Venezuela				x
Total (of 21)	7	12	1	1

* The numbers in parenthesis correspond to the following:

(1) The country did not supply any information
(2) The country filled out the questionnaire
(3) The country did not fill out the questionnaire but sent literature
(4) The answer was sent but delayed in the mail.

Venezuela's contribution did not arrive on time due to a mail delay; therefore, we had only 13 reporting countries. The list of technical personnel that contributed their efforts to the compilation of data in each country is included herewith.

This indicates that the researchers interested in beans at the national level have a spirit of cooperation with their colleagues or with international institutions. This is a good omen for the success of the plans under study by international organizations to strengthen and increase the present inter-American campaign for the improvement of bean productivity and utilization in Latin America.

COMMERCIALLY GROWN BEANS

Common beans (**Phaseolus vulgaris** L.) are grown commercially in all of the 13 countries (Table 2). They are followed, in order of importance, by cowpeas

Table 2. Distribution of commercial (x) bean crops in Latin America. 1972

Country	Type of grain				
	Common beans(1)	Cowpeas (2)	Lima beans(3)	Pigeon peas(4)	Other (5)
Brazil	x	x	x		
Colombia	x	x			x
Costa Rica	x				
Dominican Republic	x	x		x	
Ecuador	x				
El Salvador	x	x			
Guatemala	x				x
Haiti	x	x	x	x	
Honduras	x				
Nicaragua	x				x
Panama	x	x		x	
Paraguay	x	x			
Peru	x	x	x	x	x
Total	13	8	3	4	4

* The corresponding scientific names are as follows:

(1) **Phaseolus vulgaris**
(2) **Vigna sinensis**
(3) **Phaseolus lunatus**
(4) **Cajanus cajan**
(5) **Dolichos lablab, Phaseolus acutifolius, P. angularis, P. aureus and P. coccineus, among others.**

(**Vigna sinensis** Ėdnl.) in 8 countries and by pigeon peas (**Cajantus cajan** Millsp.) in 4 countries. Lima beans (**Phaseolus lunatus** L.) and other legumes are produced commercially only in a few countries.

Pigeon peas have acquired an increasing commercial importance and, in some countries, they are more important than other beans. This is due to increased demand by the industrial sector (canners and packers) which utilizes the product as raw material. Pigeon pea processing plants are located in Panamá, the Dominican Republic and other parts of the Caribbean.

Bean production in Latin America has a deficit because of low yields (about 600 to 700 kg/ha).

ORIGIN OF THE CROPS

The information received on the history of bean cultivation in the different countries (Table 3) is compatible with the theory that common beans and Lima beans originated in Latin America. Cowpeas saving the reports supplied by Colombia and Paraguay) as well as pigeon peas, were initially brought from the Old World, apparently when the negroes came from Africa to the American continent in the 16th century.

Table 3. History (x) of the main bean crops in Latin America

Type of bean	History *	
	Tradition	Introduction
Common beans (**Phaseolus vulgaris**)	x	
Cowpeas (**Vigna sinensis**)		x
Lima beans (**Phaseolus lunatus**)	x	
Pigeon peas (**cajanus cajan**)		x

* The crops that date back to pre-Colombian times are considered traditional. Those established after the arrival of Columbus in America are considered introduced (from the Ancient World).

Cowpea cultivation is considered traditional in Colombia and Paraguay, perhaps because informants did not give the intended meaning to the expression "traditional crop," that is, "crop dating from pre-Columbian times." Collateral information, such as age of the crop on the Atlantic coast of Colombia and the nearness of Paraguay and Brazil, tends to support the argument that cowpeas were introduced to Colombia and Paraguay, as well as to the rest of the continent, after the arrival of Columbus. The history of other bean crops included the "traditional" as well as the "introduction" categories.

The long-time tradition of bean cultivation in Latin America, mainly in a primitive way according to the informants, has been one of the reasons for the slowness or resistance of the producer to adopt modern cultural practices. On the other hand, this situation plus the fact that some beans (such as common and Lima beans, in particular) are native of this part of the world, provide an opportunity to find a wide range of genetic variation for the selection of superior varieties.

NATIONAL PROGRAMS

Beans are grown mainly in subsistence lots by small farmers; therefore, the support of national governments is essential to speed up the initial success of the efforts aimed at improving the productivity yield and profitability of these crops.

Table 4 shows that in 12 of the 13 countries, the state or federal government set minimum prices and offered credit and sometimes technical assistance for bean production. This reflects the general interest existing in those countries in the development of domestic bean production. Only six of them, however, can be called adequate domestic bean production programs, officially supported and where research and extension are coordinated to increase productivity of the bean crops.

With a few exceptions, the magnitude of the efforts that national institutions dedicate to bean research and to extension work cannot be expressed in figures (Table 5). This is mainly because, in most countries, specific resources (personnel and budget) are not allocated to bean production. We all know by experience that there is a considerable turnover of scientific personnel in the national institutions working on beans and a lack of coordination of activities among these institutions. In general, the informants admitted that the resources allocated to bean activities are insufficient.

Table 4. Governmental support (x) to bean programs in Latin America. 1972

Country	Type of support	
	Minimum prices, credit & other	National program, officially formed and supported*
Brazil **	x	
Colombia	x	x
Costa Rica **	x	
Dominican Rep. **	x	
Ecuador **		
El Salvador	x	x
Guatemala	x	x
Haiti **	x	
Honduras	x	x
Nicaragua **	x	
Panama	x	x
Paraguay **	x	
Peru ***	x	x
Total	12	6

* Includes coordinated extension and research.

** In this country, there are several institutions working on beans but they do not have a real national program.

*** National program in the re-organizational stage (Nov. 1972).

Table 6 shows the fields of research, by country, where there has been a practical impact in bean cultivation through extension work during the last three years. The selection of varieties (mainly through introduction and yield tests) and the tests of planting systems (commonly very incomplete technological packages) have been the most profitable fields. This is because, in the countries surveyed, the scientists dedicated to bean production are mainly "agronomists-breeders" with very few specialists in other fields.

It is very complicated to explain the difference among countries as far as achieved positive impact is concerned. There are many factors to consider, among them: (1) the practical (economic) relevance of the research results and the effectiveness of the extension methods used; (2) the receptivity and adaptability of the producers regarding the proposed technological changes and (3) the organization, intensification and continuity of the efforts at the national level.

This last point, which also covers the number and composition (variety and competence) of scientific personnel, has influenced the number and diversity of publications (Table 7). Publications have been more numerous and diverse in those places where the quality and quantity of national efforts in the way of human or physical resources are better structured. This trend agrees with our own experience in those countries, even in those which did not give us a complete list of publications.

In regard to priority problems related to bean production, the countries gave completely different answers (Table 8). Most of them (9 out of 12), however,

Table 5. National resources (technical personnel and budget)* dedicated to bean research and extension work in Latin America. 1972

Country	Fields					
	Research only		Extension only		Research & Ext.	
	Personnel	Budget	Personnel	Budget	Personnel	Budget
Brazil **			850			
Colombia **					24	872,000
Costa Rica **			42			
Dominican Republic	3					
Ecuador						
El Salvador ***						
Guatemala	9	45,614	17			
Haiti	11		121		132	37,776
Honduras						
Nicaragua	2	10,100				
Panama **					53	100,000
Paraguay						
Peru	300	6,443,686				

* Personnel is expressed in terms of man/years and the budget is expressed in U. S. dollars. Blank spaces indicate lack of figures.

** Includes crops other than beans.

*** Did not provide an answer.

showed several socio-economic factors as the most serious problems affecting bean production development (especially common beans). Such factors are mainly (1) the low level of agricultural education of the producer; (2) the small amount of capital of the producer and inadequate incentives for credit and marketing; (3) the deficient financing of research and extension. Other priority problems mentioned refer mainly to the technology (the technological package) of production.

The socio-economic factors can be pointed out or studied but not easily changed. The nature of these factors hinders the effectiveness of research programs in most countries. Therefore, as operating policy, these programs should be adapted to the socio-economic reality of the environment they are intended to serve.

BEANS OF NATIONAL INTEREST

Most countries (10 out of 12) chose common beans and cowpeas (8 out of 12) for production promotion and research (Table 9). Pigeon peas were chosen by five and Lima beans by two countries.

With the exception of Ecuador, the type of beans indicated by country varied from one (Honduras) to six (Guatemala and Peru) but in most cases (8 out of 12) it was two or three. Ecuador stated that "in the rural areas, where meat and milk consumption is limited, direct legume consumption constitutes the main energy source." Ecuador proposed oilseed cultivation (without specification) because "their oil content makes marketing easy." Previous correspondence received

Table 6. Research fields (x) that, through extension work, have had a considerable practical impact on bean production in Latin America in the last three years (1969-1972)

Country	Fields *							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	Total
Brazil	x	x	x	x	x	x		6
Colombia	x	x	x	x		x		5
Costa Rica	x							1
Dominican Republic	x							1
Ecuador								0
El Salvador	x		x		x	x	x	5
Guatemala	x		x					2
Haiti	x							1
Honduras	x	x	x					3
Nicaragua	x	x		x				3
Panama	x		x	x				3
Paraguay								0
Peru	x							1
Total	11	4	6	4	2	3	1	31

* The numbers in parenthesis correspond to the following:

(1) Selection of varieties
(2) Fertilization and inoculation with **Rhizobium**
(3) Cropping system (includes zoning, planting date, planting rate combined with fertilization)
(4) Weed control
(5) Disease control (includes plant pathology)
(6) Pest control
(7) Economic studies

from Ecuador indicates that the country is greatly interested in increasing bean production (mainly common beans).

From our own experience in El Salvador, we know that the interest is centered in common beans and, to a lesser extent, in cowpeas. The same can be said of Venezuela and other Latin American countries where beans are produced commercially.

This justifies the concern of certain international agricultural institutions to increase common bean productivity in Latin America. The support that these institutions are presently giving or want to give cowpea and pigeon pea production, especially in areas that are marginal for common bean production from an ecological standpoint, is very significant.

THE ROLE OF INTERNATIONAL COOPERATION

The countries surveyed hope, in the first place to receive technical cooperation from international organizations interested in bean production (Table 10), in the way of research counseling, including work visits and temporary exchanges of technical personnel and research planning. By work visits is understood the effective partipation

Table 7. Number of publications of extensive circulation related to research and extension work in Latin America produced in the last three years (1969-1972)

Country	Type *		
	(1)	(2)	(3)
Brazil**			
Colombia	10	4	28
Costa Rica***			
Dominican Republic	0	1	0
Ecuador	0	0	0
El Salvador**			
Guatemala	00	7	0
Haiti	0	0	0
Honduras	0	0	0
Nicaragua	0	0	1
Panama**			
Paraguay	0	0	0
Peru	5	23	17

* Publications are classified as follows:
(1) technical articles for magazines and books
(2) extension bulletins
(3) extension handouts

** Incomplete information but apparently there are many publications

*** Incomplete information but apparently there are few publications.

Table 8. Priority problems (x) in bean production in Latin America, 1972

Country	Plant health	Ecological zoning	Cropping* practices	Seed production	Improved varieties	Socio-economic factors**
Brazil	x	x	x	x	x	x
Colombia	x	x			x	x
Costa Rica		x	x			x
Dominican Rep.				x		x
El Salvador ***						x
Guatemala	x		x			
Haiti		x		x	x	x
Honduras						x
Nicaragua	x					
Panama		x	x			x
Paraguay	x					x
Peru	x				x	
Total	6	5	4	3	4	9

* Includes fertilization and other specific practices

** Mainly agricultural education of the producer, marketing and financing of research and extension work

*** Did not answer the question.

Table 9. Recommended bean species (x) for production and research in Latin America, 1972

Country	Species			
	Phaseolus vulgaris	Vigna sinensis	Cajanus cajan	Phaseolus lunatus
Brazil	x	x		x
Colombia [1/]	x			
Costa Rica [2/]		x	x	
Dominican Republic	x		x	
Ecuador [3/]				
El Salvador [4/]				
Guatemala [5/]	x	x		
Haiti	x	x	x	
Honduras	x			
Nicaragua [6/]	x	x		
Panama	x	x	x	
Paraguay	x	x		
Peru [7/]	x	x	x	x
Total	10	8	5	2

[1/] Also **Glycine max** for direct consumption and **Phaseolus aureus**

[2/] Also **Dolichos lablab**

[3/] Oilseed legumes recommended (without specification)

[4/] Question was not answered

[5/] Also **Phaseolus aureus, Phaseolus coccineus, Vicia faba** & **Cicer arietinum**

[6/] Also **Phaseolus acutifolius**

[7/] Also **Vicia faba** and **Cicer arietinum**

of the international specialists in a specific activity of the country visited. Personnel exchange means the assignment of an international specialist to a country while his national counterpart is being trained. The cooperation in research planning at the national level can be given by an international specialist or group of specialists through a work visit, an international meeting or, better yet, an intra-regional meeting.

Formal or special training is the next step, especially in the fields of plant improvement, plant health, seed production, irrigation and communication. This reflects the lack of competent specialized technical personnel in national institutions working on beans.

There was a certain degree of preoccupation about the analysis and preservation of bean germplasm. This idea was expressed by three countries, two of which (Guatemala and Peru) are located in areas considered important centers of bean genetic diversity. Peru suggested that the international institutions distribute among the countries segregating populations (possibly of the F_2 generation) and other types of basic genetic material.

Table 10. The role of international technical cooperation in bean production programs proposed (x) by the countries of Latin America. 1972

Country	Type of cooperation		
	Research counseling 1/	Formal & special training	Analysis & preservation of germ plasm
Brazil	x		
Colombia 3/		x	x
Costa Rica 4/	x		
Dominican Republic	x	x	
Ecuador	x		
El Salvador 5/			
Guatemala	x	x	x
Haiti	x	x	
Honduras	x	x	
Nicaragua	x		
Panama		x	
Paraguay	x		
Peru 6/			x
Total	9	6	3

1/ Includes work visits and temporary exchanges of technical personnel and research planning.

2/ Especially in plant improvement, plant health, seed production, irrigation and communications.

3/ Also mentioned research on food utilization of the product.

4/ Also mentioned compilation and distribution of technical information.

5/ Did not answer any questions.

6/ Also mentioned distribution of segregating populations and other type of genetic material.

Colombia proposed the promotion of research on the utilization of the product as food (grain and other parts) and Costa Rica proposed the compilation and distribution of technical information.

It is important to note that, in answer to a general question, the countries proposed that emphasis be given to the same type of services that the international organizations (especially at the inter-American and regional levels) have rendered in bean production since the early 1960's. What these countries want is an extension or intensification of those services.

CONCLUSION

With a few exceptions, all the countries were willing to participate in the survey and most of them sent their answers on time. This shows the spirit of international cooperation of the technical personnel working on beans in Latin America.

Several of the contributions sent by the different countries and prepared specifically for the survey are valuable documents that synthesize the present overall bean situation in the different countries. Some countries are planning to publish the document they prepared for the survey.

In several countries, the preparation of the answers originated cooperation and exchange of technical information among professionals in the same or different fields.

From a socio-economic standpoint, common beans, cowpeas and pigeon peas are the most important crops in Latin America, according to the information supplied by the different countries. The cultivation of these crops dates back to the arrival of Columbus in the New World, or even before, and has been kept primitive by small farmers.

The resources (technical personnel and budget) and the organization of national efforts to improve bean productivity and utilization are very inadequate. The research conducted to date shows very few practical achievements.

The most serious problems that the countries must solve to reach their objectives in bean production can be divided into two groups: those of socio-economic nature and those that form the "technological package."

Most of the countries want to concentrate their research efforts in common beans. There is also interest in cowpeas and in pigeon peas.

When specifying the type of international cooperation desired, the countries mentioned the same kind of services that thave been rendered (particularly in Central America and the Caribbean) by organizations at the inter-American or regional level for many years.

When trying to improve bean production, international cooperation must take into account competition among countries to ensure their markets. This cooperation must aim at the maximization of the profit obtained by the producer without hurting the consumer.

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MODERN APPROACHES TO TRAINING OF FOOD LEGUMES SCIENTISTS IN THE TROPICS

Fernando Fernandez

In this day and age the agriculture of the developing countries is going through a period that some have called "The Green Revolution." It is a period of rapid technological advancement, of ever-increasing pressure for economic growth and of loud demand for social change.

The relatively fast pace sought in the development of technology for grain legume crops and for the production and utilization of this human foodstuff rests upon a number of critical activities that generate the inputs and organize and energize the processes in what has been described as the "agricultural system." (14) The generation of such inputs and processes, related directly to technology and to social and economic factors of the production unit, calls for sources of qualified manpower to insure a constant or ever-increasing rate of progress.

Several distinguished scientists have emphasized in this seminar the immediate relevance of grain legumes species, particularly field beans, **Phaseolus vulgaris**, in the agricultural panorama of the tropics from the standpoint of their respective scientific disciplines and human values. Evidently, a large, urgent, short-and long-term task of research and change in the production systems of food legumes lies ahead.

If the above tasks are to succeed, an increasing number of competent research scientists in specific disciplines will be needed to work with field beans and other grain legumes in each one of the countries of the tropics.

Furthermore it will be essential to ensure that the results of research, the "package of technology" developed for each particular set of conditions, is made available to the farmer and that he is taught directly or indirectly to adopt and make the most out of that technology for his own benefit and for that of rural and urban populations. It will be absolutely necessary that a sufficient number of competent production specialists be on hand to validate technology, to effect change, to transfer that technology and to help create the socio-economic conditions favorable to adoption.

Table 1 shows the number of research scientists and production agronomists in extension work during 1967 and 1972 for two of the best staffed countries in the field of food legumes in Latin America. These figures show little change in a five-

Table 1. Numbers of research scientists and production agronomists working with food legumes in Colombia and Peru during 1967 and 1972

Country	Research Scientists					Production Agronomists	
	Breeding[1]	Agronomy[2]	Pathology	Entomology[3]	Total	Full time	Part time
Colombia							
1967	10	2	1	2	15		120
1972	9				9	2	180
Peru.							
1967	9	7	3	2	21		160
1972	5	11	1	2	19		280

Sources: 1967. IICA. Investigadores Agrícolas de la Zona Andina.
1972. Direct information obtained from ICA, Colombia and DGIA, Peru.

1. Includes seed processing
2. Includes Soils Science
3. Includes Nematology.

year period as far as research manpower is concerned. Substantital increase has taken place in the number of production agronomists that are only partially concerned with field beans in their work.

WHY IS TRAINING NEEDED?

At the professional level, training is intended to:

a) complement education;

b) develop skills, in research and in production;

c) lead to specialization, that is, increased depth of knowledge in a given subject;

d) qualify the professional for his intended work;

e) energize and motivate.

Being an instructional function, one might expect that training at the graduate level would belong essentially on the campus of the university. When it comes to training in sciences or for research, many graduate schools, both local and foreign, do a commendable job of forming competent research scientists within the realm of a given discipline. That seems to be the primary aim and immediate goal of the master's and doctoral academic programs.

As Autrey, Garces and Wough reported in 1971, (3) there are 15 institutions in ten countries of Latin America, including Mexico, Costa Rica, Colombia, Puerto Rico, Brazil, Chile, Argentina, Venezuela, Cuba and Peru, that have graduate academic programs leading to master's degrees, and one school in Mexico offering doctoral programs. This represents indeed significant progress in graduate education.

University education, however, in Latin America is discipline oriented and has been characterized by an emphasis on theoretical instruction often of good quality, high intensity and wide scope, at the undergraduate as well as at the graduate level. Many problems beset the universities and tend to affect unfavorably the quality of education in agriculture, but I do not intend to discuss those here. It is not at all uncommon, therefore, to find that to attain a high level of excellence and productivity in research, the scientist fresh out of graduate school, who is going to work with food legumes, needs additional training to acquire deeper and updated knowledge and develop field skills relevant to those crops.

Furthermore, in many countries, the number of professionals, possessors of M. S. or Ph. D. degrees are very few. This circumstance forces the research programs to recruit personnel from among agronomists emerging from undergraduate colleges and not from graduate schools. The need for complementary training of these professionals to qualify them to work in food legumes research is even greater.

Research scientists alone, moreover, cannot bring about the full agricultural development expected for a country or region. The corps of competent production agronomists is absolutely essential to bring to the producer the technology generated by research, test it on the farmers' conditions and spread that technology, once proven valid. (It is estimated that about 20 production agronomists are needed for each research scientist; this relationship may even be greater in the future). It is commonly found that the extension agents, change agents or technical advisers that are supposed to transfer technology are young professionals of recent graduatión. They are placed in the communities they are to help, often after only a crash course on classical extension methods and without the diagnostic skills and management competence needed to cope with the practical problems of production that the farmer faces in reality. Their theory-oriented university education falls short of qualifying them to fulfill their task (1,5,6,7,8).

Essentially any agronomist, who because of any circumstance, is not fully competent to accomplish his proposed objectives, must undergo a certain amount of "acquisition of experience," that is: to gain deeper knowledge about the subject matter, develop skills and reach familiarity with his subject. This acquisition of experience is an every-day human function. That experience may be acquired in one of two ways:

(1). By "trial and error"; that is, applying whatever knowledge and ability the professional has plus a good dose of commonsense logic. Successes and failures pave a long way to experience that may, or may not, make him a competent scientist.

(2). By training; that is, carrying out a series of tasks, designed to give him an opportunity for sequential learning and development of abilities, under the guidance of a knowledgeable skilled supervisor. The final results will depend primarily on the quality of the training, the trainee, and the supervisor.

Given objectives of rapid development of agriculture with respect to grain legumes, the national institutions of Latin America could hardly afford to follow the first method, in the hope of eventually having a sufficient number of competent professionals. Training is then the answer, to form teams of research and production personnel in the least possible time.

In 1971 and 1972, 24 young agronomists who participated in Crop Production Training at CIAT were asked after completion of their 12-month training period: "If you would have had to reach your present level of experience by means of working at the regular job you had before training, how much time do you feel that would have required? " The answers ranged between three and six years, and the mean was 4.2 years. The question was repeated to 13 of those 24, taken at random, one or two years later. Again the range was from three to six years, with a mean of 4.8 years. This group included a range from recent graduates to professionals with up to five years of work in extension.

Nevertheless, the greatest benefit of training is not just in shortening the time for acquisition of experience, but in assuring that the knowledge and skills developed are the most appropriate for the research or production tasks, and in energizing, motivating and mobilizing the professional.

Oftentimes some educators, who do not recognize the need for practical training, contend:

"The United States and European countries have been able to develop a numerous, strong, competent force of successful research scientists and extension agents by means of academic programs alone, that are similar to those in Latin America, in that both are largely theory oriented."

One might quickly admit validity in this statement, but three considerations must be taken into account.

First, in the past, over 75 percent of the professionals and students of agriculture in the United States and Europe have come from rural areas and have a strong farm insight and background, based on actual practice. In contrast, the comparable figure for Latin America is 25 percent rural extraction and 75 percent urban (1,7,11,12). Furthermore, most of those that had some farm background in Latin American countries have come from a social stratum that provides little opportunity for "down to earth" first-hand experience.

Second, in the advanced countries, large numbers of students and scientists have been, for a long time, devoted to research in well funded institutions that allow for "in-service training" of young scientists coupled with regular research progress. Agricultural research, in particular, is almost entirely in the hands of the land grant colleges (in the United States) acting as training centers for research scientists.

Third, extension agents in the United States have been dealing with a much more educated population of relatively sophisticated and well financed farmers very receptive to new technology, and operating in a more favorable agricultural system. The role of the extension agent in that case has more of an informative nature. The socio-economic ills that plague the agricultural lands of the tropics have been almost nonexistent in the United States and Europe. Thus, the problems faced by the production agronomists in the developing countries are far more difficult than those in the advanced ones.

Byrnes (8) hypothesizes that "the more underdeveloped is a country's agriculture, the more competent the extension workers must be - and in more areas of competency. The illiterate farmer in the developing country depends almost solely, on the extension worker. He does not have the diversity of communication media (telephone, television, newspaper, farm magazines, etc.) nor ready access to other sources of information that are available, for example, to the farmer in Iowa. If the extension agent cannot competently respond to the farmer's questions, or if he gives wrong advice, the farmer and many others suffer."

The orthodox methods of agricultural education that have characterized the education of agronomists in Latin America have been brought in as adaptations of those developed in the more advanced countries of western civilization for much different physical and social environments.

A survey, through personal visits, to 10 of the most outstanding colleges of agriculture of Latin America in 1969, revealed that, at least in the minds of deans and other academic administrators, the value of "field and laboratory practices" was rated highly, at the same level as lectures. However, in most cases the laboratories were lacking in equipment, the fields lay idle, machinery and tools were scarce, there was a great shortage of field instructors, student absenteeism was evident and down-to-earth work with one's own hands in the field was considered degrading. Lack of financing was the reason given almost unanimously for such void of practical training.

Every so often the colleges of agriculture embark upon "curricular reforms" prompted by changes in administration, or pressures from the faculty and/or the student body. However, the changes realized are usually in program and course content, not in philosophy and methodology nor in balance between theory and practice. Thus, the product changes little and continues to consist of well educated professionals who subsequently need to acquire experience by trial and error or must be trained if their education is to become viable (8).

There is much to be discussed in regard to agricultural education in developing countries, but I shall not pursue it here. The matter of change in educational systems must be approached constructively in the light of new ideas and in realization of the needs of these countries.

IN-SERVICE TRAINING

The method of "training on the job" has been utilized since ancient times to qualify a person for a given work. Perhaps it is the most commonly used procedure to develop skills and provide specialized knowledge, particularly to beginners or new personnel unfamiliar with a particular work or environment. This kind of in-service training is often done even without an intention to formally train but essentially is a way of training. How effective this method will be for a given person will largely depend on the amount of preplanning done, the degree of responsibility assigned to the trainee, and the extent of advice and supervision given.

This type of training is very often practiced in national research institutes when new young graduates are taken into their ranks. The extent of success in training competent scientists varies from almost none to a high degree, depending on conditions to be discussed later.

Selection plays an extremely important role toward successful in-service training, particularly when the training is directed to a specific discipline or commodity. Personal likes, or vocations, attitudes, habits, background, dedication to work, natural abilities, adaptation to the environment, besides intelligence, university education, and personality, are important characteristics that must be taken into account.

THE POSTGRADUATE INTERNSHIP

Among a number of adaptations of the in-service training model, there is one in particular that has persisted over the years due to its success. That adaptation is known as the internship in medical education, whereby the student, once he has completed most of his courses, enters a hospital in residence for one or two years. During that period, he is exposed to a very large number of cases, in various fields of specialization. He participates and takes responsibility in the diagnosis and treatment of diseases and disorders, plays a part in surgery teams and may become involved in some research project. All of this he does in consultation with colleagues and under the supervision of the most experienced doctors. In addition, the interns attend seminars, and become actively involved in discussions and reviews of particular cases. At the end of this period of internship training, the student graduates.

If the now graduated physician chooses to follow a field of specialization, say cardiology, he becomes an intern again (this time he is called a resident) for an additional two or three years of postgraduate training.

For the physician these internships are periods of "learning by doing" with a great deal of direct involvement in the practice of his theoretical knowledge under the supervision, assistance and advice of specialized professionals. There is a minimum of formal classes; instead a number of seminars and discussions are scheduled. Total dedication is another key characteristic of this kind of training.

In sharp contrast, the faculties of agriculture, that in Latin America originated along with the faculties of engineering, (thence the title of I. A.), release their graduates without any substantial period of practice. It may perhaps be admitted that engineering, a professional field that rests on the exact sciences, may have a lesser need for practical experience for its students or graduates. The professions in agriculture, however, rest more on the biological and social sciences, and those aspects of the physical sciences that are more difficult to measure and control. Thus, in working with the food legume plants, the professional faces a great deal of biological and socio-economic variability that makes first-hand experience essential for competency.

In recent years, the international research and training institutions have adopted the postgraduate internship and its "learning by doing" methodology, adapting it to fit the training of young agricultural scientists.

The International Rice Research Institute (IRRI) (17) was first to put the concept of postgraduate internship into practice in its full conception in 1962 with a great deal of success. CIAT has also incorporated the postgraduate internship into its training programs, making additional improvements.

Outlined below are the principal characteristics of the postgraduate internship as it applies to training in plant sciences.

(1). "Training by doing" for research or production takes place directly in the fields and in laboratories.

(2). Well defined "behavioral objectives" are established.

(3). A "training plan" is followed to reach these objectives.

(4). Qualified supervision and advice and evaluation are provided by direct adviser-trainee channels.

(5). Complete dedication is required full time.

(6). The trainee is given responsibility in his activities.

(7). Opportunity is provided for first hand experience right in the farmers' fields.

(8). Interaction with colleagues is promoted.

(9). The program offers seminars and conference-discussion sessions and time for independent reading and writing.

(10). The training leads to specialization in a discipline and/or a crop or small group of similar crops.

(11). The training seeks to develop specialized skills.

(12). Opportunity is provided to include aspects of social sciences, primarily economics and communication.

Five of the 12 characteristics listed deserve additional comment. These are training by doing, behavioral objectives, supervision, training plan and responsibility.

Training by Doing

Training by doing is the backbone methodology and a requisite for successful training. The trainee must personally carry through at least once all tasks related to the objectives of his training. Full involvement of this kind has often been avoided in the past as it has been considered, by some, degrading for a professional. This is understandable in the light of the social prejudice that is in these days being erased by social change.

Behavioral Objectives

The specific goals of training are best expressed in terms of "behavioral objectives" (18); that is, what change in behavior related to the field of specialization is sought through training? Or, what do we expect the trainee to be able to do upon completion and as a result of his training? By eliminating vagueness and defining those expectancies in the most precise terms, it becomes easier to draw a training plan to reach those objectives and to evaluate, at the end of the period of training, whether the objectives were accomplished.

Supervision and Advice

The main difference between poor in-service training and a successful postgraduate internship is supervision and advice. We should not expect a man to be trained by just giving him a task to carry out. He must be guided and advised, not to the extent of "leading him by the hand," but to the point where he will be oriented to apply his present knowledge and ability to acquire additional knowledge and develop further ability on the subject matter.

Responsibility

Supervision and advice must maintain a balance with giving responsibility. At no time should the first two substitute the latter as long as the trainee is capable of accepting that responsibility. One of the most developed instincts in man, one evident from a very young age, is that of ownership. The sense of ownership leads to the pleasurable acceptance of responsibility and also motivates. The postgraduate intern should be given the opportunity to feel that he owns the project in which he is being trained, by means of assigning him a research or production project in grain legumes.

Training Plan

A training plan is another feature of the postgraduate internship that contributes toward effective learning. A plan keyed to the objectives allows for an organized series of instructional experiences instead of haphazard work.

Candidates for postgraduate internship to train in research directed to food legumes in CIAT are identified and selected by the senior staff during their visits to the institutions involved in bean research in the various countries. CIAT itself provides a limited number of fellowships. Others are financed by national or international institutions.

Before the candidate comes to the Center, his prospective adviser together with the training coordinator draw up a training plan. This plan is in effect throughout the trainee's period of residence. Upon arrival at the Center, the professional is assigned a research project along the lines of the plan and is provided advice and supervision as needed. When he is not involved directly in his field research project, the trainee participates with other program trainees and personnel in discussions on selected subjects, involving various disciplines related to field beans. He also visits the research plots of other trainees and research scientists in the Center and whenever possible goes to visit farmers and study their problems. Attendance at regularly scheduled CIAT wide seminars is also required. At the end of his training he presents a report on the results obtained from his research, and both supervisor and trainee evaluate the training.

THE PRODUCTION SPECIALIST INTERNSHIP

CIAT has developed its own version of the postgraduate internship adapted to training in crop production and has called it the "Production Specialist Internship" (the term "postgraduate intern" is conventionally used in CIAT for research trainees). This kind of training has been practiced previously in IRRI with much success to qualify professionals that are going to advise farmers and transfer technology, (9, 17, 21) and train other professionals in rice production. CIMMYT also utilizes its own version in training maize and wheat specialists.

Oftentimes one hears criticism of extension services and commodity development programs for not being effective enough in bringing about the expected change in the production systems of which food legumes are a part (2, 7, 8). Several reasons have been given for the very limited success of these programs. Some blame it on the alleged traditional resistance of the farmer and others on the defective organizational structure of extension services or on problems of communication (7).

In more recent years, the lack of adequately trained, competent production agronomists has been given with increasing frequency, as an explanation for the failure of extension services, particularly when dealing with small farmers. Byrnes has analyzed the matter of credibility and competence of the development communicators or production agronomists, as key characteristics often missing (7). His observations in Asia and Latin America have led to the conclusion that many of the change agents lack credibility in the eyes of the farmer, mostly because these change agents are not technically competent, lack farming background and experience, have little to extend of economic value, and in addition are deficient in the communication skills the circumstances require. Credibility may be restored by means of increasing the competence of those agronomists through training to make them capable production specialists.

The same author (8) has identified five areas in which the production specialist must be competent to be effective. To quote Byrnes' five points:

(1). **Technical competency** or the level of knowledge and understanding relevant to the food legume species the farmer produces, the production practices involved and the physical environment in which the production takes place. This must include the ability to diagnose correctly typical problems and abnormalities of plants growing in the field.

(2). **Economic competency** or the ability to weigh alternatives of production input and marketing strategies, and to make his recommendations in the light of economic relationships within the reality of the physical and socio-economic systems in which the farmer operates.

(3). **Scientific competency** or a basic understanding of the philosophy of science and the ability to conduct simple replicated field experiments with food legumes which objectively test whether an innovation is worthy of adoption under the farmers' own conditions.

(4). **Farming competency** or the willingness and skills to perform the range of physical tasks involved in producing food legumes.

Once the food legumes production specialist has acquired these four competencies, a fifth competency becomes vital to this role of change agent.

(5). **Communication competency** or the ability to plan, prepare and present adequate messages for relevant audiences including the farmer, the credit agency, the input retailer, the market chain, or even the consumer.

The training program in CIAT for the "production specialist" includes inculcating these five competencies as its principal inmediate objective.

Participants in the 12-month program are selected from among promising young professionals in national institutions having extension services, development projects or production programs. Young professors from faculties of agriculture in colleges or universities are also selected for the program. Once in CIAT they follow a training plan that during the first six months includes 60 percent of the time devoted to field practice and 40 percent to conference-discussions and independent library work. The participants, in groups of four, are assigned a nine-hectare farm on which they will grow selected crops, personally performing all tasks involved in the production of the crop or crops, from planning and land preparation to harvesting and marketing. The field supervisors are on hand all the time but the trainees are the decision-makers and the responsibility for the farm in theirs.

The subject matter covered in conference-discussions sessions includes Crop Technology, Field Experimentation, Economics-Farm Management and Communication.

At least one experiment is established by the group of four on their assigned farm to practice ways of validating technology.

Detailed accounts are kept of each farm by the participants who then analyze the results of their decisions in the light of benefit/cost relationships and run a complete economic analysis of their operation.

After one semester of training as described, each trainee is assigned to an area away from the CIAT center, where he identifies a number of small to medium size farmers with whom to continue his training. The trainees visit the farmers daily and even live with them for periods of time. They practice what they have learned about technology, economics and communication and acquire further farming competency in the actual environment of a farmer's production system. This second stage lasts for six more months to complete one year of training.

As a result of the success of the production specialist internship program in qualifying the professionals, our attention has been drawn to the desirability of providing some opportunity to strengthen the farming competency of young research scientists through field practices in production, directly related to growing food legumes under commercial conditions. Pilot-programs along these lines are now being developed for testing of alternatives.

The objectives established in production training for research scientists are to qualify the scientists to:

(1). Identify field problems restricting production that deserve research.

(2). Achieve the maximum of success and reliance on data in their research efforts, through effective establishment, protection, and management of the crop under study.

(3). Plan their research and evaluate results in the light of economic factors and relationships affecting commercial production.

(4). Develop and make effective use of field problem diagnostic skills in order to prevent in field experiments unwanted variability caused by disorders, pests or diseases that could be prevented or cured.

(5). Take into account the technological and socio-economic relationships between the food legume species being investigated and other crops and components of the production system.

Contrary to the classical tendency to over-emphasize technology in the training of production agronomists, CIAT has recognized the urgent need for an integrated social science input (primarily economics and communication) into the training program. This input is considered an extremely essential part of the competency of production agronomists and highly desirable in that of research scientists. Besides being competent in science or technology the professionals must be sensitized to the fact that agricultural production is only a means to attain development, of which the final objective is man (10).

THE SUBJECT MATTER SPECIALIST

Except for certain areas of monoculture, in the Latin American tropics it is more common to find a situation of diversified agriculture involving several crop species. This fact plus the limited availability of personnel and financial resources of extension, change or development programs has made it necessary that the production agronomist be a crops-generalist rather than specialized in one single crop. But every so often he runs across problems that require the assistance of a commodity or subject-matter specialist. This latter is a professional who has deepened his knowledge of field beans or food legumes (in our context here) and has developed, through training, specific diagnostic and managerial skills. In this sense he is a very specialized production agronomist. He may also be involved in adaptive research or regional trials. He is qualified to act, then, as a liaison between the field agent and the research team.

This type of professional, although highly desirable, is not very commonly found in developing countries. A increasing demand for this kind of man should be expected in the future. That he be well trained is particularly critical, as he will be advising other professionals and will also be a channel of feedback to the research center.

The combination of production training, concentrated on field beans or food legumes, plus training in research, will produce this kind of professional.

TRAINING OF RESEARCH SCHOLARS

For some time, professionals from Latin America who went to a foreign country to pursue an advanced degree became involved in basic research, rather than applied research, for their theses or dissertations. This phenomenon has also been happening, although to a lesser degree, in some of the local graduate schools, when a disciplinary rather than a commodity approach predominates.

In 1963, Bradfield called the attention of the graduate schools to the desirability that students from foreign countries be provided opportunities to do applied research for their theses on problems closely related to their countries' environment and resources (5). Wortman, who has had long experience in agricultural training and research in the international spheres, indicates that the greatest need in research personnel in developing countries is "for people prepared for much adaptive rather than fundamental research" (22).

The Nobel Prize winner Norman Borlaug emphasizes that the research agronomist for the developing countries should have a rather broad training, should be trained to work with his hands, and must be motivated to serve human needs (4). More recently, Lam and Lamond urged that foreign graduate students in United States universities do their research back in their countries whenever possible (16).

There is, therefore, an opportunity for an early start in academic training of research scientists in food legumes to orient them along the problem solving routes of country needs. CIAT is doing this, and country programs should also open their doors to this kind of action by providing opportunities in national institutions to graduate degree candidates to do their thesis research in their physical facilities.

THE ROLE OF THE INTERNATIONAL CENTERS

Frequently the administrators, scientists and professionals from the developing countries rightly look upon the international centers, such as IICA, CIAT, and IITA that have programs in food legumes, as sources of training opportunities that they are supposed to be. The concentration of brain power, expertise and scientific physical resources make these places ideal sites for training personnel.

Indeed, this role is acknowledged by these international institutions, and training professionals is a primary goal along with research objectives. Furthermore, these centers realize the need to strengthen the national institutions if these are to effectively carry the responsibilities for agricultural and economic development of their respective nations. It is hoped that the prevailing scientific atmosphere and the sense of urgency that permeate these institutes will have an energizing effect on those trained. It is also expected that their graduates, along with other scientists in the various national programs, will help to structure a network of competent research scientists and production agronomists, with a common interest in food legumes that would facilitate the exchange of ideas, information and materials.

It is definitely foreseen that CIAT's contribution to the development of agriculture in the tropics will be at least as large through training as through research.

However, the role of the international centers is visualized as being more of a catalytic nature. The responsibility and manpower for developing each country's agriculture in the tropics rests basically in the hands of the national institutions and private enterprise of the various countries. It would be presumptuous for any international institution to claim or expect more than a catalytic action that would help to facilitate the role of the national agencies.

It is then evident that CIAT could train no more than a relatively limited number of research scientists and production agronomists in its food legumes (initially field beans) program. This institution hopes rather to devote its efforts in training to qualify a selected group from each country that would in turn train others. Examples that show the viability of this approach occur in the Philippines, Ceylon, Bangladesh, India, Indonesia and other countries where professionals trained at IRRI have organized and conducted training programs in association with colleges of agriculture or national government agencies. Initial steps to initiate this multiplication effect are now being taken at CIAT.

The international centers, in addition to training trainers, may also develop new methodologies and approaches to training, produce training materials to make them available for in-country training, and provide technical assistance to national training programs when needed.

THE ROLE OF THE NATIONAL AGENCIES

The need for multiplication of training is easily recognized by the national institutions. What is not very clear in the minds of their administrators is: Who has the responsibility for training? And when the responsibility is accepted, it is not yet clear what should be the approach to follow.

Very often the non-academic institutions feel that training is a responsibility exclusively of the local university, although the institutions themselves might do in-service training but without having an organized training program. When either the university or a governmental institution accepts the responsibility they find it very difficult to overcome the tendency for crash programs, short courses and classical approaches characterized by theoretical instruction, rather than adopting new pragmatic approaches.

An effort to identify barriers to modern approaches to agricultural training and education in seven Latin American countries led to the conclusion that there are four most frequently encountered obstacles.

(1). The value of guided practical training to provide considerable experience in a short time, so as to energize professionals into action, has not yet been fully recognized by national institutions. They are oriented to, and more likely to take advantage of, the frequent opportunities their professionals have to obtain more education in traditional theory courses.

(2). Trained personnel are scarce and there are constant pressures to launch national action programs. Thus the national officials tend to assign newly trained personnel to work directly in existing or new field programs rather than in the training of others, an activity which they consider belongs in the universities.

(3). Faculties of agronomy in the national universities cling to their traditional forms of education and lack the leadership and financial resources to introduce pragmatic training programs (which they often associate with vocational education) into their undergraduate and graduate curricula.

4. The limited number of production-oriented professionals capable of training others has not yet reached a "critical mass" in any country so as to be able to demonstrate to decision-makers the value of in-country production training programs.

It must be recognized that, by principle, the most logical place for training to take place is the national or local university, college or school of agriculture. Let us hope that in the near future the educational methodologies at the undergraduate level will be revised, the graduate programs will be strengthened and oriented toward problem solving research, and that production and training courses with a pragmatic approach will be organized. In the meantime other national institutions may have the responsibility for training. However, it is hoped though that these barriers will be overcome in the near future if the needs of the individual countries for sufficient numbers of well-trained professionals to staff national programs are to be satisfied.

In addition to the universities other places identified as sites for in-service training in Latin American countries are research stations, demonstration farms, rural development projects, and the farmers' fields.

It is likely that the growth of grain legumes programs in the various countries will bring new personnel to join the programs in research. In addition there will be need for numerous production agronomists and subject matter specialists in field beans and other grain legumes. With a little insight, vision for the future, and determination, the required manpower can be trained to be competent and to contribute effectively toward agricultural and economic development as well as to the improvement of rural life in the tropics.

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THE DESIGN OF AN INFORMATION NETWORK AS A SUPPORT TO SCIENTIFIC RESEARCH

Fernando Monge

I have allowed myself to slightly change the title of this presentation (Scientific Communication Resources for Food Legumes Personnel in the Tropics) mainly to emphasize the importance of scientific communication in any research and action program, not only in the food legumes area, but also to be able to deal with the subject of the creation of communication systems or networks, which constitutes one of the most powerful resources in the field of scientific information.

INFORMATION AND DEVELOPMENT

Advances in the field of cybernetics during the last two decades have supplied the intellectual world with an interesting way of approaching problems of different nature. Adopting as a definition the words of Wiener (9) "science of communication and control in the animal and machine," cybernetics allows us to form concept of the behaviour of any system, not by isolating its components and consequently detracting from its real functioning, but rather by looking at the system as an organic whole, whose essential characteristic is the interaction of its components.

Man, for instance, is the product of his genetic background and of his interaction during his life span with his surrounding environment. Yet, both factors, genetic or acquired, are in reality processes of transmission of information and control. In the first case, the characteristics inherited by man are the result of a natural mechanism by which the information borne by the chromosomes of the progenitors is combined and transmitted to the progeny following rules and principles that slowly become known to man through genetic research.

In the second case, which deals with the physical and intellectual characteristics acquired by man, we also see the occurrence of a process of communication of information, since man is continuously receiving stimuli through the senses, and these stimuli allow him to adapt his behaviour (modify the system) according to the conditions prevailing in the surrounding environment. In conclusion, man as an individual develops himself through information processes that let him survive by a continuous social and biologic adaptation.

If we enlarge our approach to the level of human groups, the degree of development of the countries is in direct relationship with the information they have and use. Lorenz (5) points out that:

"Information is one of the most important and powerful resources in the world today. But there exists an unbalance in regard to the quantity, quality and degree of sophistication of the available information in the various countries of the world. This is one of the basic reasons for the immense difference in the social, economic, educational, scientific and technologic development between the developed nations and those countries in process of development. If these differences are to be substantially reduced, and eventually minimized, the transfer of information at the international level will have to be improved and developed very strongly."

It is difficult, or rather, impossible, to envision a system or network without links that relate all of its elements. The interaction concept itself is the very basis of a system. As Parker says (8), what is not a system is merely a heap of incoherent things; hence the importance of information in a network.

GENERATION AND TRANSMISSION OF INFORMATION

Two basic processes are involved in scientific and technological development: (1) the process of generation of information, that in the present world is performed through institutions or through research organizations financed by the public and private sectors; and (2), the process of transmitting the information to those sectors which will implement it and produce the "visible" characteristics of development - such as greater production, advanced technology, increase in the standard of living, in educational levels, etc.

Now then, if we place ourselves in the hypothetical situation of a country that has decided to become self-sufficient in regard to generating all of the information required for its development, we would find a **sine qua non** condition of having a highly developed infrastructure, in order for this country to reach the frontiers of the unknown in every field.

Obviously, this does not happen even in the so-called "developed" countries where, on the contrary, great emphasis is placed in the exchange of information with other countries. This is because ideas originating in one mind usually become more fruitful when transplanted to minds who may enjoy the benefit of different scientific schools of thought. Besides, financial requirements as well as need for highly qualified personnel for a self-sufficient situation would surpass the actual possibilities.

This would be even more true in the case of the lesser developed countries where the movement toward institutionalizing scientific research is relatively new. Paradoxically, those countries in greater need of information to reach desirable levels of development are the least adequate to generate it by themselves, because of their infrastructures.

I do not intend to give the impression that this reasoning leads to underestimating the importance, for the countries in process of development, of strengthening their own research institutions. On the contrary, it is necessary to place greater emphasis on the desirability of a joint strategy that permits the consolidation of efforts and to making maximum use of the information generated, in every country of the world, if possible, through the transfer of information.

Japan presents historical evidence of the efficiency of this process. Japan's advances in the field of electronics, in the production of optical devices, and in many other fields, underwent processes of imitation and utilization of information generated in other countries, which later allowed astonishingly rapid advances. It is said, though the statement is exaggerated, that while it took the Germans over 50 years to produce their famous photographic lenses, it took one year for the Japanese to imitate them and six more months to excel them.

TRANSFER OF AGRICULTURAL INFORMATION IN LATIN AMERICA

Latin American socio-economic conditions require urgent solution of basic problems such as hunger, either real or masked as deficient diets, afflicting a large percentage of the population. In regard to agricultural research, therefore, the most desirable strategy would be to emphasize research on adaptation to conditions typical of these countries; that is to say, applied research that will permit short-term tangible results.

However, this type of research requires a great volume of transfer and exchange of information, both from the well developed countries and very especially, among the Latin American countries themselves in order to avoid, among other things, unnecessary duplication of efforts.

Two delicate problems arise as obstacles to the increase in the transfer of information in Latin America. The first is the general belief that production of scientific literature in Latin America is very low, and therefore, there is not a sufficient volume to justify establishing a mechanism of exchange. However, in a recent survey made by Felstehausen (3) in Colombia, it is stated that:

"Each year the Latin American countries produce hundreds of reports, articles and written documents on agriculture and rural development. Yet, many of these publications and reports are not available to administrators, planners, educators and scientists for whom they were intended. The majority of the agricultural bibliographic materials are produced and distributed in limited numbers. Few agricultural reports in Latin America are collected and systematically kept . . . The Colombian Institute of Land Reform (INCORA), one of the most important governmental agencies, produced over 250 studies and reports each year. The great majority of these studies is mimeographed."

Therefore, despite the fact that the flow of scientific literature in Latin America is not as abundant as in those countries that undergo the so-called "information explosion" a good part of this phenomenon seems to be related to the small numbers issued of each publication.

As a consequence, the problem of collecting literature native to the Latin American countries also presents particular characteristics. The most important and recent literature is mimeographed and distributed to a certain number of "key people" and what is even worse, this literature remains as inter-office memoranda, letters and similar papers of restricted circulation.

The second problem in the transfer of information refers to choosing that literature of interest for Latin America, among the millions of papers produced in the more developed countries. The U. S. A. alone produces over 5 million books per year, and it is estimated that the United States people read approximately 25 billion newspapers and 60 million magazines per year. In the field of science and technology it has been estimated that 75 percent of the scientists that have existed throughout history are still alive. With slogans such as "publish or perish" that have become an obsession of the scientific community, huge amounts of scientific papers are produced.

The problem, therefore, does not have a single solution but rather it implies the utilization of diverse mechanisms that together will contribute to improve the situation. In my opinion, one of these mechanisms would be the design of a system, that is to say: to bring into relation a compound of elements, the definition of its frontiers, the analysis of inputs and outputs, and their flow through the system in their interaction with the environment.

BASIC CONCEPTS REGARDING THE ESTABLISHMENT OF NETWORKS

One of the explicit purposes of this seminar is that of "mobilizing and stimulating the creation of a network of institutions and individuals in Latin America to carry out cooperative efforts and exchange of materials." It is therefore worthwhile to analyze briefly the diverse types of structure that a network might have, and the main characteristics of each type of structure regarding flexibility simplicity, costs, speed of transmission, etc. (4).

Figure 1 illustrates the **cyclic** network type, in which every nodal point has one incoming and one outgoing channel so that the total network constitutes a complete cycle. This is the simplest type of network and also the least elaborate to install. At the same time, the installation expenses are quite minimal. The main disadvantage it presents, however, is the slow speed with which information is moved within the network. A simple example of this type of network is the existing practice in many institutions of circulating a specific document according to a list of the staff members who should be aware of it. I believe we all have had the experience of documents, which in the best of cases, take months to return to the original source - that is, when they do not get lost.

Figure 2 presents a **decentralized** kind of network, which is characterized by the existence of two in -and- out communication channels between each nodal point. This network, therefore, supplies immediate access to the information, despite the fact of being complex and expensive to install. It must also be noted that the decentralized network is more reliable than the cyclic because the information may arrive through various routes and the closing of one channel or pathway would not imply a total disruption of communication within the network.

Taking again the example of office practices, the policy of supplying each party with a copy of a document to be read, instead of circulating the original document, illustrates the decentralized network.

Both cyclic and decentralized networks lack a main nodal point. The hierarchic networks are the ones having the shape of a genealogical tree (Figure 3), which might be advantageous or disadvantageous depending on the case. These networks share the disadvantage of cyclic networks regarding the slowness and the disruption in the whole chain when a single pair of channels or arcs is broken, yet they favour the control of flow of information should this be an important consideration within the system.

Obviously, the previous types of network are what we could call "pure types." In reality it is more frequent to find combinations such as a decentralized network

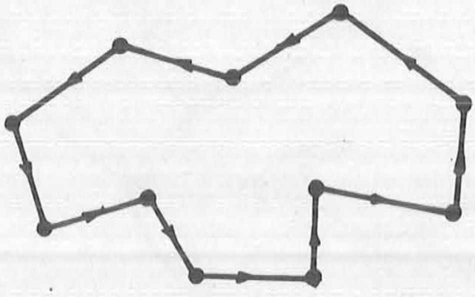

Fig. 1. Cyclic network

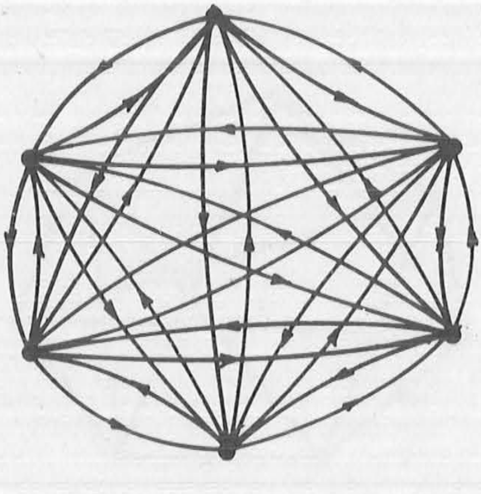

Fig. 2. Decentralized network

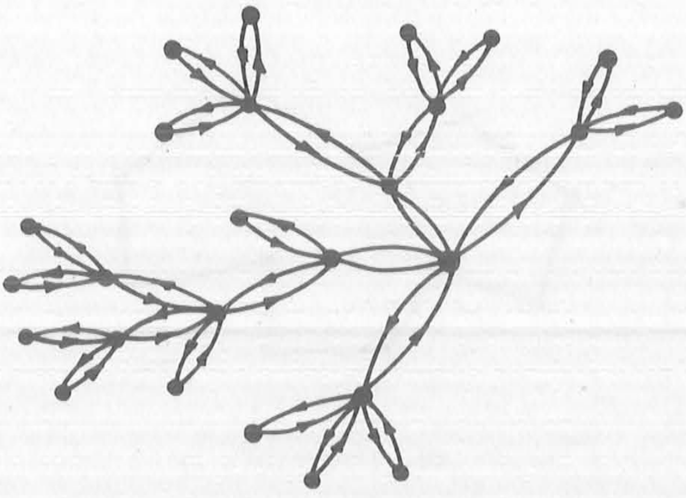

Fig. 3. Hierarchic network

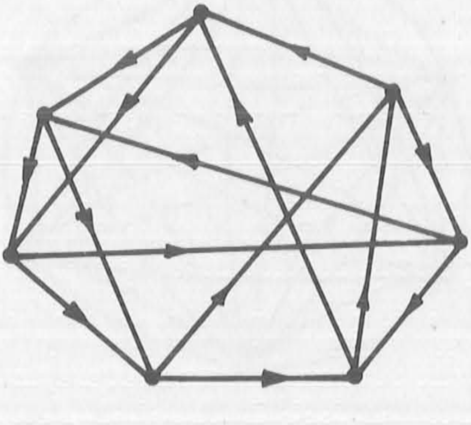

Fig. 4. Restricted decentralized network

restricted to two incoming and two outgoing channels for each nodal point (Figure 4). This type of network for instance, is very interesting in that it combines the reliability of the decentralized network with the low operational and set-up costs of the cyclic network.

There might also be systems in which a decentralized network is used for a reduced number of nodal points considered of primary importance within the system, with hierarchic or cyclic sub-systems as can be seen in Figure 5.

At this point, perhaps the question will come up of whether these systems are merely information networks in the general sense of the word. I do not wish to be involved in discussions of semantics regarding concepts of information, but rather to clarify the point: any element that carries a message is considered information, and not only the classical written or spoken message. For example, a bag containing seeds of a new variety might be a type of message producing greatest impact.

PARAMETERS OF AN INFORMATION NETWORK

Structure is, without doubt, an important factor in the creation of an information network but is far from being the only factor. Other parameters deserve attention. Once the nodal points are established, that is to say, the individuals or institutions that will be members of the system, it is imperative to answer questions such as the following:

(a) What communication media will it be feasible for all the members of the system to use?

(b) What storing facilities or filing techniques does the information require to be easily retrievable? For instance, a germplasm bank may require a kind of storage of genetic information quite different from the computer's memory which stores data.

(c) In relation to the above question, what equipment is needed for storing and supplying the services?

(d) What volume of information would the network move among the members?

(e) What methods would be most appropriate for the classification and what access means would be necessary for the different types of information stored?

All of these factors, including of course the considerations of total operation costs, interact, and a complete analysis of them would determine not only the network structure most appropriate for the prevailing conditions, but also a feasible strategy so that the network can begin operations and gradually progress.

CIAT has an integral multidisciplinary approach for the fulfillment of its programs. Given this philosophy, there already are activities in practice, that tend naturally toward the creation of international networks. In the specific field of scientific communication, one of the main concerns has been that of bringing closely together the scientist and the sources of information existing inside and outside of the institution.

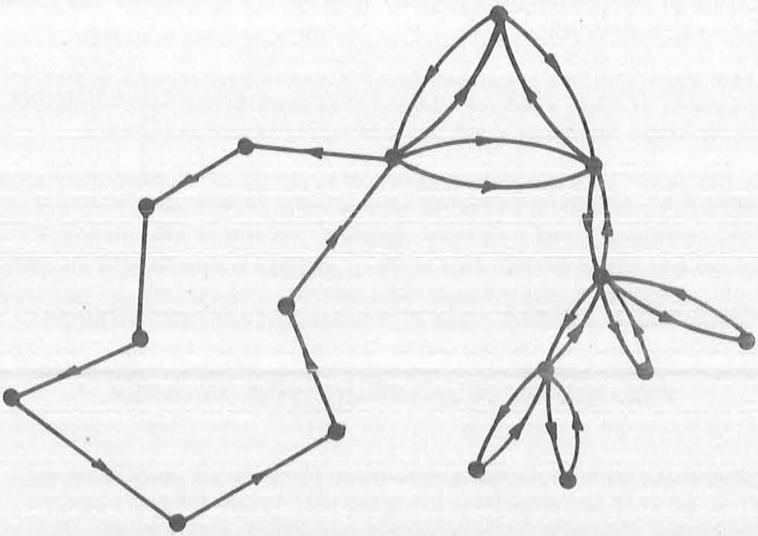

Fig. 5. Combination of decentralized main nodal point with a cyclic subsystem and a hierarchic subsystem.

2435 CIAT, Apartado Aéreo 6713, Cali, Colombia

SHURPALEKAR, S.R. et al. Studies on a spray-dried infant food based on peanut protein isolate and full-fat soy flour and fortified with DL-methionine and certain vitamins and minerals. II. Protein efficiency ratio and over-all nutritive value. Food Technology 18(6):110-112. 1964. Engl., Sum. Engl. 10 Refs.

Cassava. Human nutrition. Children. Groundnut. Soybean. Nutritive value. Sugar. Blands. Milk. Rats.

The protein efficiency ratio (PER) and over-all nutritive value of a spray-dried infant food, based on peanut protein isolate, full-fat soy flour, dextrimaltose, and hydrogenated peanut oil and fortified with DL-methionine and certain vitamins and minerals were studied with weanling albino rats. The PER of the infant food was 2.34, and that of the same fortified with DL-methionine was 2.86, compared with 3.19 for milk proteins. The over-all growth-promoting value of the food, with and without added methionine, ranged from 20.1 to 20.3 g/week and was significantly higher than that obtained for a milk food of similar composition (13.9 g/week). Similar trends were observed in the feed efficiency rations of the two foods. 3:1 blend of infant food and cane sugar promoted nearly the same growth (20.1-22.2 g/week) as did the infant food, which was significantly higher than that (16.1 g week) obtained for a 3:1 blend of milk food and sugar. No significant differences were observed in the mean liver fat content and the mean nitrogen and calcium contents of the carcasses of rats receiving infant food or milk food. (Author's summary)

Fig. 6. Card produced by CIAT's Documentation Center

People managing scientific information programs cannot afford to offer what I call a "cafeteria approach" by which bibliographic materials are displayed and scientists are allowed to either take them or leave them. This is an unreal situation in behavioral terms that brings as a consequence the very low rates of library use seen in Latin America (6, 7). Information programs must awaken from such a passive attitude under which the librarian is no more than an "organizer" of books, and must become active and dynamic in programs by which library services reach the user without waiting for him to come and ask for the services.

CIAT's Document Analysis Center began operations at the beginning of 1972 covering only literature relating to cassava. Through a mechanized management of information the Center supplies cards that contain a summary of each article, and also the full bibliographic citation as well as key words or main topics dealt within the article (See Figure 6). By using these key words, retrospective searches on any subject or combination of topics may be obtained, thus presenting the user in just a few minutes with a total series of summary cards corresponding to documents available in the library which may be consulted or photocopied immediately.

This service also permits a selective dissemination of information according to the specific interests of each scientist in a periodic and systematic way. Gradually and as financial and human resources permit, the Document Analysis Center is beginning to cover other areas such as animal nutrition, pastures and forages and agricultural economics, using for this purpose the direct cooperation of the CIAT scientific staff working in these areas.

Within this broader concept of an information network, the Conferences and Symposia Program of CIAT periodically organizes technical meetings that involve topics pertaining not to a single field, but covering aspects of other disciplines that relate to the integral management of a problem. It is interesting to note, for instance, that as a result of the evaluation of the Seminar on Swine Production Systems, held at CIAT in September, 1972, it was found that the increase in connectivity - a measure of the inter-relations among participants-was 237 percent and what is most interesting is that this inter-relation went beyond national borders (1).

These data, though preliminary, point out the tremendous potential that this type of activity has to mobilize and stimulate the functioning of what could become an international information network in the food legumes field. The importance of other activities such as training, have already been mentioned, or will be later.

In the more developed countries these networks have evolved almost by spontaneous generation, and constitute what Derek De Solla-Price (2) calls "the invisible college." In this paper I have tried to present certain ideas that perhaps will contribute to accelerate the institutionalization of these so-called "invisible colleges" which, in our environment, are of a very tenuous nature, even despite the ever increasing pressures exerted by socio-economic and agricultural problems.

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Appendices

I. Report of Moderators

II. Reports of Disciplinary Work Groups

III. Reports of General Work Groups

IV. Summary of the answers to the post-seminar evaluation questionnaire

V. List of participants

Appendix I.

REPORT OF MODERATORS

During the session where the reports of the 12 work groups and 6 disciplinary groups were presented, different ideas were expressed that have been recorded in the corresponding documents.

There was a unanimous agreement about the convenience of establishing a regional cooperative network or program. However, the ideas expressed on the objectives and the course of action of the network, even though not necessarily opposite, cannot be condensed in one document.

In general, it was considered convenient to review the experiences obtained in Latin American institutions such as the PCCMCA that could be the basis for the establishment of a wide-ranging network.

We propose to the members of the seminar that the organizing committee be asked to form a work group not to exceed three people to study the contribution of this seminar, to evaluate other relevant information and to prepare a document containing the points of a project for a regional cooperative program according to the desires expressed by the participants in this seminar. This project will be sent to the participants and to those people interested in the welfare of the bean and legume producers, for their consideration and suggestions.

Appendix II.

REPORTS OF DISCIPLINARY WORK GROUPS

ADMINISTRATION

Unanimous agreement on

1. The establishment of an international network;

suggestion on 1) a coordinating center;
2) a group of centers such as PCCMCA and others.

2. The international network must not substitute national activities but it must complement and coordinate them acting as liaison among them.

3. Activities of the network:

Cooperative research projects
Publications and documentation systems
Conferences and symposia
Personnel exchange
Training
Germ plasm banks

The network would also help channel research activities, technical and financial resources to their members.

4. It was suggested that the organizing committee of this Seminar appoint a "work group" to analyze and release a document based on the reports of the 12 general groups and 6 disciplinary groups that could eventually become a basic document to support financial requests and to suggest a course of action for the network.

BEAN BREEDING

1. There was a general consensus that CIAT should play an important role in the future as follows:

a) Collection of wild and primitive forms of **Phaseolus** spps.

b) Preservation, maintenance and distribution of **Phaseolus** germ plasm to interested bean researchers

c) Evaluation of germ plasm

d) Use of germ plasm in development of improved populations

e) Coordination and publication of information in regard to all of these activities.

2. **Germ plasm Preservation and Maintenance:** It was recommended that CIAT serve as a world **Phaseolus** germ plasm bank. The "Center" would serve as repository for seeds under cold storage to assist in seed preservation. The "Center" would also serve as a "working germ plasm bank"; the germ plasm would be grown, evaluated, and used in population improvement.

In cooperation with CIAT, working germ plasm regional banks would be established in Mexico, Central America, and Brazil. Cooperation with the Plant Introduction Stations in the United States was also recommended. It is important to establish these regional banks because of the ecological differences and the prevalence of different diseases. Considerable attention would be devoted to local adapted populations in each of the regions. Each of the regions would have the freedom and authority to determine procedures of operation.

CIAT would play an advisory and coordinating role between the different regions and could coordinate activities, computation and distribution of appropriate research information developed at the Centers. CIAT could provide technical information and assistance to the different regional Centers.

Dr. Hernández, Mexico, observed that careful attention should be devoted to documentation of information on germ plasm and a method used to ensure the rapid retrieval of information when required.

The establishment of a "Germ Plasm Workshop Committee" was recommended to study the matters of germ plasm collection, maintenance, evaluation and use. The membership of this committee should consist of plant breeders, plant pathologists, entomologists, physiologists, soil scientists, and plant taxonomists. All members of the committee should have a strong interest in plant breeding.

3. **Germ Plasm Evaluation:**

a) In phase I, the germ plasm collections should be evaluated for morphological traits and general adaptability in Colombia and in all regions.

b) In phase II, the germ plasm advisory committee should examine the main collection in Colombia to determine material that should be considered for more extensive and detailed evaluation tests and population improvement.

c) In phase III, selected materials should be critically evaluated for different purposes.

d) In phase IV, population improvement should be conducted.

4. **Population Improvement:** Dr. Alice Evans thought selected germ plasm could be used to form composite populations using a chain pyramid system. Dr. Colin Leakey commented that diverse germ plasm of wide geographic origin which showed good performance should be used to develop composite populations using a convergent or diallel breeding scheme. Dr. Kelly (USA) commented that it would be desirable to develop special purpose composites such as a protein composite. Different groups could develop different types of composites.

It was recommended that CIAT become involved in the development and improvement of source populations with a wide genetic basis. CIAT would not control population improvement or variety development in the different regions or separate countries, but would be supportive of those programs in different ways and would be able to coordinate information and materials. The national programs would continue to improve the local populations and would be able, in addition, to make use of germ plasm and improved populations provided by CIAT and the regional centers. Emphasis was placed on genetic management to ensure wide diversity for nuclear and cytoplasmic genetic elements.

5. **Importance of Sound Seed Production Programs:** The success of bean production in the USA rests on the production of disease-free seed produced under irrigation in the arid west outside of the main bean production areas. The need to establish a well organized and regulated bean seed production program was emphasized. The benefits from the improved high yielding varieties will not be obtained if seed stocks become infected with some bacterial, fungus and virus pathogens.

It is recommended that CIAT play an important role in the development of improved seed in different countries of South America by studying the potential of suitable areas for bean seed production. This could be a joint project with existing national programs.

REPORT OF WORK GROUP ON BEAN PHYSIOLOGY

Goals:

(1) Improve welfare of people - including subsistence and commercial farms.

(2) Increase yield - protein quantity and quality are definitely a prime component of our definition of yield.

Initial Cooperative Effort:

It is suggested that simplified growth analysis be conducted at all locations. This should include both mixed and monoculture growth of beans for both subsistence farmers and commercial farmers.

Simplified growth analysis is defined as an adjunct to standard yield trials. Date of maturity and biological yield are recorded in addition to seed yield. This should embrace a broad germ plasm base and some moderate and low yielding varieties.

Protein quantity and quality will be determined - including both laboratory, and biological analyses.

The cooperative simplified growth analyses are intended to help identify the physiological capabilities that limit yield, and to help determine superior ideotypes.

It will help to establish priorities for research in the following areas.

(1) Plant architecture and ideotypes (Wayne Adams & Chris Wien)

(2) Root system, rhizobium relationships, and mineral nutrition (Peter Graham & Johanna Dobereiner)

(3) Radiation induction of variation in yield, protein quantity and plant type (Raphael Trujillo & Julio Lugo)

(4) Control of flowering, including photoperiod and temperature effects (Josué Kohashi & Dermot Coyne).

(5) Photosynthetic efficiency, respiration, translocation (James Ozbun)

(6) Protein quality and quantity (CIAT)

(7) Water relations (Efraím Hernández)

(8) Developmental physiology: flower, pollen, seed growth and relationships (Alberto Taylor)

(9) Post harvest physiology (CIAT)

As a group we have designated contact persons for each of these topics, which in general correspond to the localities where the work can best be initiated. CIAT will work with these coordinators to move ahead rapidly to identify priorities within each area, consider financing mechanism, and assure implementation of research in the named areas.

PLANT PROTECTION

Main pests and diseases in Latin America

The main diseases are rust (**Uromyces phaseoli**), root rot, bacterial blight (**Xanthomonas phaseoli**), common mosaic (virus) and golden mosaic (vírus).

The main pests are small harvest flies (**Empoasca spp.**); lady bugs (**Diabrotica sp.; Ceratoma sp.**); cutworms (**Heliothis feltia, Prodenia sp.**); aphids (**Aphis sp.**); insects attacking stored grains (**Brucus, calandra, etc.**).

Research priorities

After analyzing each pest and disease in detail, research priorities were set for each one of them, suggesting in each case the approach to the problem, the place and the institution that can carry out this type of work.

Diseases

Rust

a. Identification of the strains of this pathogen in the tropics;

b. Establishment of an evaluation scale to determine the intensity of the disease;

c. Establishment of an international greenhouse for the evaluation of resistance to the disease.

It is suggested that a technical group of rust specialists be organized to establish the criteria for strain identification and evaluation of the seriousness of the disease.

CIAT could supply the materials of bean differentials required for identification work to those interested. It would be convenient to establish centers in the different bean producing regions of the tropics where strain identification can be made following the Central American example where the work has been centered at the University of Costa Rica. This would avoid moving strains from one region to another.

The international greenhouse for the evaluation of resistance could be operated by CIAT.

2. **Root rot and nematodes**

a. Identification of causal agents and variability.

b. Determination of their economic importance.

c. Development of control methods, cultural practices, disease-free seeds, chemical substances.

First of all, a general awareness of the problem by the specialist group is essential to determine the points listed in (a) and (b) above. This work should be cooperatively carried out, by areas or regions, by IICA, CIAT and other institutions or governments each one of which would work within their respective area of influence.

3. **Bacterial blight**

a. Identification of strains of this pathogen.

b. Control through disease-free seeds and resistant varieties.

As in previous cases, the identification of strains should be made at regional centers whose establishment should be promoted. The work and strain identification in the Caribbean could be centered at the Federal Experiment Station of the USDA in Puerto Rico.

4. **Common mosaic**

a. Strain identification.

b. Control through disease-free seeds and resistant varieties.

CIAT could lend its cooperation, supplying different materials for strain identification. The criteria for this identification could be easily established through cooperative work in the virus laboratories at CIAT and at the University of Costa Rica where strain identification has been made for Central America. The development of programs for virus-free seed production in countries such as Peru, Chile and others in South America, is a necessity and the programs could be coordinated by the international organizations.

The Central American germ plasm could supply sources of resistance to the virus strains that could be utilized to develop varieties in other countries.

5. **Viruses transmitted by white flies**

a. Identification of the viruses or strains of the same in the golden mosaic group.

b. Determination of wild hosts.

c. Control by resistance.

It is suggested that a technical group be formed to work cooperatively in the identification aspects. This group would include technicians from the Universities of Puerto Rico, Jamaica and Costa Rica, the Instituto Agronomico de Campinas, Brazil and CIAT.

It is convenient to reinforce programs working on resistance or tolerance to golden mosaic, such as those conducted in Central America and Puerto Rico.

General course of action for disease control

A. 1. Disease-free seed production program. The promotion and development of this type of program would bring about a decrease in the incidence of a great number of diseases presently causing severe bean losses.

2. Chemical treatments. The utilization of chemical substances to control some important diseases would be feasible after having conducted adequate research.

3. Cultural practices. With the cooperation of agricultural engineers, cultural practices for the crop could be designed or adapted to decrease the incidence of pests and diseases, at low cost.

4. Resistant varieties. The development of varieties in cooperation with plant improvement scientists and with plant pathologists would be an important control measure to be developed in the tropics.

B. **Insects**

1. **Periodic insect collection for classification.** CIAT or IICA could maintain a collection of the insect prototypes identified by competent sources.

2. **General information on biology, ecology and control.** A format should be prepared to compile information on biology, ecology and control of important pests. These formats could be jointly prepared by the University of Puerto Rico and CIAT.

3. **Inventory of wild host plants**

4. **Record of proven cases of resistance of certain bean varieties to pests.**

The information in points 2, 3 and 4 would be compiled by the entomologists of each country and could be condensed by the bean programs at CIAT or IICA to make it immediately available to those interested.

The establishment of an informal organization to group the entomologists dedicated to research work on protection against bean insects and nematodes would be recommended.

The publication or exchange of information on bean pests in Latin America should be stimulated. This could be accomplished through a periodic review of the work carried out, that could be presented during meetings at regional organizations such as the PCCMCA in Central America or to ALAF. Likewise, it would be convenient to release periodical publications on bean pest control.

AGRONOMY

General aspects

1. Two bean producer groups should be tentatively identified.

a. Small bean producers, generally having low incomes and working in the mountain areas. It is important to consider beans with other crops for this group.

b. Commercial bean producers having a larger availability of resources and working on the plains.

The work group considers that it is convenient to establish a differentiation in research and in the course of action related to the different agricultural practices of the previously mentioned groups.

Agricultural research among procedures in the second group is more developed than in the first group, but it has not attained a sufficient degree of development. In the first group, research is almost non-existent in several aspects such as the association of maize and bean crops.

2. **Specific aspects**

1. There is a lack of research relative to the variables that constitute what is known as the "water/soil/plant" relationship. The methods used to evaluate these variables seem to be inefficient.

2. It is believed that the small bean producers working on the hillsides lose considerable manpower when they use rudimentary tools. Research aimed at developing low cost machinery that makes the work of these producers more efficient should be undertaken. For instance, a seeding machine of the wheelbarrow type would be adequate.

3. It is important to work with the improvement group especially in the evaluation of materials resistant to the limiting conditions of water.

4. It is important to consider, on the whole, the agricultural factors of production (fertilization, irrigation, density, planting systems). Also, it is important to develop a close cooperation and opportune exchange of information with geneticists, plant pathologists, entomologists, etc.

5. It is important to conduct agricultural research related to the associated planting of maize and beans.

6. It is important to find systems to extrapolate in time and/or space, at minimum risk, the results of agricultural research. An example and possibility would be the extrapolation of research results on fertilizers based on soil analysis and classification.

7. Under certain soil conditions, it is important to develop research related to the effect of rotations and of green manure in the properties of the soil.

8. Under other soil conditions, it would be important to develop studies on the "minimum amount of tilling". This would save time and help maintain the

properties of the soil. In this way, three crops (two of beans and one of maize, for example) could be obtained per year instead of two in some regions.

Finally, the work group emphasized the basic importance of high quality improved seed, which is the starting point to reach the goals described above.

ECONOMICS AND NUTRITION

1. Beans and other grain legumes have good and highly beneficial nutritional characteristics.

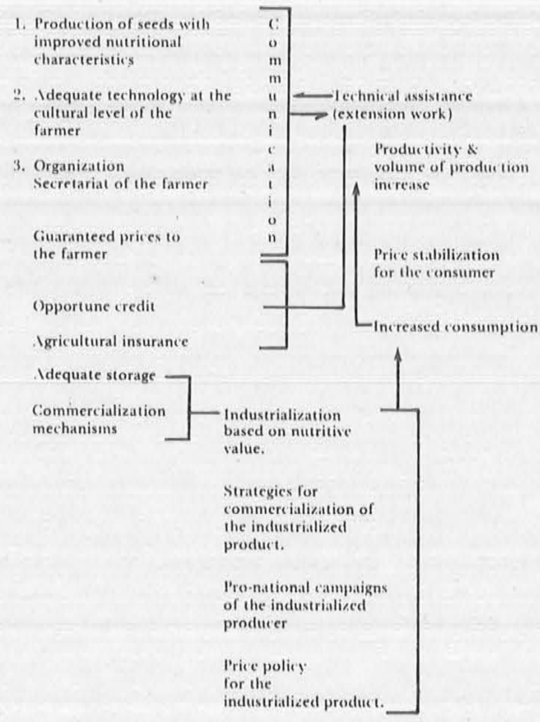
2. Production and price limit higher consumption.

3. Price stabilization mechanisms attractive to producers and consumers would favor the acceptance of beans by consumers who do not normally include these in their daily diets.

Therefore, it is recommended that:

1. Governments make policy decisions aimed to increase production of this crop.

Governmental action oriented towards:



2. The problems of bean production should be honestly approached giving emphasis to the physico-biological and socio-economic aspects. The approach and the team should be inter-disciplinary.

3. Establish a mechanism for recommendations to farmers.

a. Seed improvement in agronomic and nutritive value aspects;

b. Introduction of improved seeds preferred by certain groups of the population and of those that can possibly fulfill these requirements;

c. Other findings that the technicians may consider important to include in the technological packages;

d. Organization of farmers to facilitate training programs and education.

4. Conduct reliable statistical studies that allow the government or any other institution to program crops in certain areas to obtain stable prices.

5. Determine the products that compete with beans.

6. Determine the physical and chemical characteristics that influence acceptance by the consumer.

7. Establish adequate storage conditions for the most comnonly consumed varieties of legumes.

8. Study bean processing to determine stability, to guarantee availability, to favor consumption and to diversify utilization of beans.

9. Establish nutritional and chemical composition patterns according to eating habits. For instance, for Central America and other maize and bean consuming countries our recommendations (R. Bressani, INCAP) are: Protein, 25 percent; Lysine, 6.4 g/100 g. protein; Sulphur-containing amino acids 2.2 g/100 g. protein; Tryptophane, 1.2 g/100 g. protein; True digestibility, 85 percent.

10. Carry out educational programs aimed at increassing consumption of legumes especially among the most vulnerable segments of the population.

11. Select new varieties in chemical terms and in terms of the biological value of their protein. In this respect, it is essential to have a standard methodology.

12. Investigate the genetic effect of fertilizers, production systems and other factors related to the protein content, to the amino acids important in protein (lysine, sulphur-containing and tryptophane) and to nutritive value.

REPORTS OF GENERAL WORK GROUPS

GROUP I

Cooperative efforts should be made to study the field of food legumes and to emphasize the priority that national development plans determining policy in each country should have over any other topic.

It is proposed that:

a. Each national program make efforts to obtain the economic and human resources essential to efficient work;

b. The international centers, IICA and CIAT, concentrate their efforts in studying international problems, due to the basic nature of studies or the fact that the nature of the work can be applied practically to various countries.

We propose the following course of action:

1. That each national program, simultaneously with the work being conducted on genetics and on disease resistance, identify suitable areas for disease-free seed production.

2. CIAT and IICA serve as liaison among the different programs, facilitating the dissemination of information about the different national plans and projects and about their achievements and needs. This could be accomplished by:

a. Sponsoring conferences and meetings every two years, similar to the annual meeting of the Programa Cooperativo Centro Americano de Mejoramiento de Cultivos Alimenticios, PCCMCA (Central American Cooperative Program for Food Legume Improvement);

b. Publishing an information bulletin similar to that of the Bean Improvement Cooperative.

3. Each national program reinforce its own physical and human infrastructure by:

a. Requesting assistance from international agencies, foundations and/or private industry to raise the necessary funds. This involves presentation of well-defined projects;

b. Establishing close links with national extension programs. Lack of coordination among extension and research services is a widespread problem;

c. Facilitating personnel training through scholarships in foreign countries or through courses by invited professors.

4. The international agencies and centers must actively cooperate in the reinforcement of national programs.

a. The assistance of the agency should be given to long-term programs or to well-designed programs that have pre-established goals and terms. The closing down of many projects has been experienced simply because political measures have demanded they be discontinued.

b. The centers must maintain a germ plasm bank with a well-organized cataloguing system for subjects such as disease resistence, agricultural characteristics, protein quality and content. It should be available for consultation by national programs having specific requests. Also, experimental networks should be established in different countries based on cultivars of similar grain characteristics and preferences in order to reduce the number of varieties in tropical areas.

GROUP II

This group was aware of the convenience of establishing a communication network for cooperative efforts and exchange of materials among the existing organizations. It is recommended that ALIL (Latin American Legume Researchers' Association) be reinforced as a center grouping specialists in food legumes through national organizations with the support of international institutions. This would include the participation of specialists in other related organizations such as PCCMCA, BIC, ALF, and ALAF.

Once ALIL is reinforced, the starting point would be the establishment of a Communication Network Pattern for grain legumes.

Who are the members of ALIL?

1. Active voluntary members.
2. National institutions connected with grain legume research in each country.
3. International organizations having grain legume research and production programs.
4. International agencies financially capable of maintaining the organization in operation.

What will be the functions of ALIL?

1. To promote grain legume research at the local and regional levels in each participating country.
2. To compile, summarize, publish and distribute information obtained from research.
3. To be aware of the problems faced by national programs in each country and to make other members aware of them.

4. To encourage an active participation of the members in the solution of food legume cultivation problems.

5. To edit a periodic publication containing a summary of the work conducted and the progress made in the legume field.

6. To sponsor an annual or semi-annual meeting of technicians in the legume field.

The organization of a Latin American Bean Cooperative Program would be possible with the orientation and support of an international organization.

Activities to be developed

1. To maintain and operate a germ plasm bank at the world level and to cooperate in the maintenance and operation of those banks already established.

2. To evaluate outstanding materials, agricultural practices and any recommendations or any promising activity at the country level.

3. To sponsor training of personnel needed to improve the grain legume program in each country, at international organizations or universities. The sponsorship should include financial assistance.

4. To develop regional projects or programs aimed at rapidly increasing grain legume production (such as the Puebla Plan in Mexico and the rural development projects in Colombia, Honduras and Peru).

5. Marketing is a problem at the country level. International marketing will be ruled by regional agreements already established or in the way of being established.

GROUP III

Latin America lacks a more widespread publication of research results obtained by national and international organizations. There is an urgent need to disseminate information on the facilities, structure, financing and professional personnel in the different research and training centers.

This publication must be organized and coordinated by an international organization that can collect, process and distribute all the information related to food legumes in Latin America (genetic material, nutritional, agricultural and health aspects).

It should not be forgotten that many organizations have tried to reach this goal and have failed, perhaps due to the fact that they do not do research and dedicate all their efforts to the coordination of research and researchers. Their failure may be caused by the wide range of goals and peoples.

1. The establishment of a coordinated communication network is desirable, working through an international organization dedicated to agricultural research and to the study and solution of food legume problems in Latin America. Such an

institution should have the basic facilities to accomplish efficient collection, processing, summary and dissemination of information as well as distribution of genetic material.

This organization must be responsible for the establishment and functioning of an international system with uniform methods for evaluation, cataloguing, varietal classification and other pertinent aspects that help establish a common language for analysis of genetic material in the different collections. Operations should start with the present facilities in each country, complementing and unifying the national programs in common areas of work.

The international coordinating center would be in change of working out financial assistance through international institutions in order to carry out research projects. The degree of participation of the international agencies would depend on the personnel training, assitance in equipment purchases and qualified personnel they can offer.

The functions of the center would be:

a. Compilation of available information on the problems and progress made in Latin America. Once processed, this information should be sent to researchers in other countries and to the different governments;

b. Development of new techniques suggesting the unification of evaluation patterns and aiming at the solution of common problems in Latin America.

2. The market policy in Latin America should be based on aspects such as the characteristics of acceptability of materials (for instance, size, color and texture of the grain) depending on the preferences of different people.

a. The consumption needs will be based on the supplementation of foodstuffs obtained from other crops and sources of animal origin, in order to provide a balanced diet for the urban and rural population.

b. A price policy available to the different segments of the population should be developed.

c. The development of varieties preferred by consumers in most countries should be promoted.

3. To coordinate research and development activities:

a. A general coordinator should be nominated in each research and development area;

b. Local and regional coordinators should be available to act as an advisory committe for the institution;

c. Periodic meetings should be organized to discuss the results and the progress achieved in the programs and to set new goals.

4. To start the programs, different bean specialists must organize well-defined work plans.

5. The coordination of training should include training centers that meet the needs of the tropical countries.

Finally, it should be emphasized that Latin America has an unknown and unexplored food legume potential. Most of the research conducted to date has failed to cover the so-called marginal areas.

It is hoped that the agreements reached here will not stay written on a piece of paper but, that, insofar as possible, they become effective at the earliest date.

We suggest the establishment of a Latin American food legume society, whose main objective would be the periodic presentation of results from established programs, that facilitates personal contact for direct exchange of information. This could be done by reinforcing the Latin American Legume Researchers' Association.

GROUP IV

It is possible and desirable to establish a communication network for cooperative efforts and exchange of material and information in Latin America.

The proposed coordinating institution could be CIAT, IICA or an **ad hoc** organization. The national and international agencies coordinating food legume research will be affiliated to a coordinating organization. These would be the PCCMCA in Central America, ICA in Colombia, the bean national project in Brazil, INIA in Mexico, CENIAR in Venezuela and organizations in Peru and the Antilles.

The coordinating organization would have an advisory committee formed by a representative of each affiliated institution.

To minimize the problems of communication we propose:

1. Publication of an information bulletin with summaries of research results, information on germ plasm, etc.;

2. Periodic visits of technicians of the coordinating institution to the cooperating organizations;

3. Periodic, perhaps annual seminars.

The activities of the coordination network would be:

1. Under the supervision of the central coordinating organization, to coordinate the work at the germ plasm banks in relation to maintenance, evaluation, multiplication and cataloguing;

2. To operate a documentation center specialized in beans and other food legumes;

3. To make the coordinating organization responsible for the coordination of food legume specialist training;

4. To make it the duty of the coordinating organization to suggest and supplement research conducted in the national programs;

5. To reinforce the Latin American Grain Legume Researchers' Association;

6. To sponsor the publication of scientific and technological research developments in Latin America;

7. To coordinate a survey to determine the limiting factors of production and consumption of beans and other food legumes, as well as the available resources of the national research and technical assistance organizations;

8. To condense, evaluate and disseminate the results and suggestions of the previously mentioned survey;

9. Based on the survey, to determine short, medium and long-term priorities regarding research, technology, dissemination of information, etc. taking into account the increase in production and consumption of food legumes as a source of protein to improve the human diet;

10. To promote interdisciplinary integration in the organization and implementation of research.

GROUP V

1. The participants consider that it is convenient to establish a working network among the different people and institutions presently involved in bean cultivation in the American tropics. This regional cooperative program should serve:

a. To exchange information through appropriate systems of scientific documentation, reports of research being conducted and other media;

b. To exchange genetic materials through the establishment of germ plasm banks using uniform classification systems for the information they have available.

c. To exchange personnel working in specific research projects or being trained in different aspects of bean production;

d. To establish cooperative work including regional tests of promising materials that can be useful to all participants.

2. The group recognizes the complexity implied by the coordination of work in biological research with the studies of marketing and acceptance of new products by the consumer. This group, however, does not want to underestimate the importance of a global and integrated approach to the problem. It is suggested that, in order to establish the network, operations should start in the biological research aspects without excluding the participation of organizations or people involved in the socio-economic aspects.

3. In connection with point 2 above, the structure of the network will have to be sufficiently wide and flexible to allow the participation of public and private, international, regional and national institutions interested in bean problems in Latin America. Furthermore, the group believes that, at first, the field of study should be limited to **Phaseolus vulgaris** and that, when the network becomes operational, other food legumes can be included.It is believed that the PCCMCA which has been operating for several years, can be taken as a model for the proposed organization.

4. Technical and financial support of specific projects would be an essential part of this program. Therefore, it is imperative to have a small group working as the secretariat of the program. The responsibilities of this group would be:

a. To help design and increase the number of systems for exchange of information and materials;

b. To organize meetings, seminars and other activities that allow personal interaction among the participants;

c. To propose or suggest activities that can be cooperatively developed;

d. To support participating institutions so that they can meet their obligations within the program.

5. In order to make rapid and efficient advances in the organization of the program suggested, the organizers of this seminar should appoint a "working group" not to exceed three people, who will take the time to consult with specialists and with possible financing sources and to prepare a complete overall project including detailed information on the activities previously mentioned.

GROUP VI

1. There is an urgent need to establish a coordinated effort among the countries interested in **Phaseolus vulgaris** and to improve production and utilization.

2. To attain these objectives, an organization formed by a coordinating center for research, development and training activities should be established with the participation of regional groups represented by countries having common needs.

3. CIAT is proposed as the coordinating center.

4. The priority aspects of the work of the organization would be:

a. Technical personnel training;

b. Agricultural development programs (application of technology to the Andean zones);

c. Research on problems of economic importance.

5. The active participation of the following institutions would be required to make this organization function:

a. Ministries of agriculture;

b. Agricultural research institutions;

c. Agricultural development institutions.

6. The organization should immediately start:

a. To analyze the availability of financial sources;

b. To explain the project to cooperating countries;

c. To define the bases of cooperation, coordination and operation.

7. The continuous function of the organization would be ensured through:

a. Agreements clearly underlining the objectives of the projects and mutual operational responsibilities;

b. Continued effort.

8. Contact and communication among the cooperating parts will be maintained through:

a. Periodic meetings of the regional groups and the coordinating center;

b. Visits by CIAT bean specialists to regional groups to coordinate cooperating programs;

c. Publication of an information bulletin on the activities of the different divisions of the organization.

GROUP VII

1. The group would like to emphasize two main problems. First, the gap existing between the needs of the small farmers (who are the main bean producers) and the nature of research conducted at experiment stations. This gap results in little research aimed at improving the primitive bean production practices in most farms. The associated crop system, for instance, is the most common, but few experiments are being carried out to improve it.

Second, technological improvements have remained at the experiment stations and have not been introduced to the farm, which indicates the lack of intensive research to develop efficient systems that allow the introduction of new technology to the lot of the poor and ignorant farmer.

2. The group agrees on the establishment of a cooperative program which gives emphasis to the work of national institutions without trying to take over the responsibilities of the same.

3. The achievement and experience of PCCMCA should be taken into account and the positive results obtained should be applied whenever possible.

4. The group was divided according to the structure of the cooperative program. Some members preferred a federated structure with three sub-programs:

a. A reorganized PCCMCA for Central America, Mexico and the Caribbean;

b. A sub-program for Brazil;

c. An Andean sub-program for the rest of South America.

Other members of the group would form a structure centered in one organization. In the first case, there would be small groups of technicians in priority areas of each region, trying to form an interdisciplinary team, In the second case, there would be only one group of technicians working at a center.

5. Support and coordination would be accomplished through:

a. Continental, regional and national meetings;

b. Exchange of technicians;

c. Exchange of materials (germ plasm banks);

d. Advice to national institutions;

e. Training of national technicians in specific fields;

f. An information system including publication of a periodical bulletin.

6. Finally, it is suggested that a small work team be formed to incorporate all these suggestions into an active program.

GROUP VIII

1. Cooperation among countries is necessary to join efforts and to exchange materials. Special measures and precautions should be taken to avoid spread of diseases and pests in those countries free of them. This type of cooperation demands the establishment of a supranational organization that joins the efforts of all countries to accomplish an efficient task as it has been the case in the maize, wheat, rice and pigeon pea programs.

The primary goal of the organization should be the study of the specific needs of each country much as the socio-economic factors, food needs, crop problems in the area, profitability, etc.

2. The organization of a Latin American bean cooperative program would be justified in view of the fact that a high consumption of this legume in many of those countries can contribute to decrease the protein deficit in human nutrition.

The group suggests the establishment of a coordinating committee formed by those people involved in bean programs. The committee will function through the organizations elected by the same that can carry out their respective assignments. The committee decides on work coordination, formulates bean policy and obtains the necessary resources to be assigned to the program.

a. Compiles information on research and the results obtained in different experiment stations and makes it available to the members of the program.

b. Condenses and analyzes this information.

c. Makes recommendations to accomplish a certain number of common activities such as the organization of training programs, the establishment of germ plasm banks and the support that must be given to several countries to carry out their programs.

d. Promotes periodic meetings to evaluate the implementation of the program and to set future goals. If the establishment of the committee is approved, its nature, regulations and action mechanisms will be studied in detail. As a suggestion, bean cultivation should be considered in relation to other crops, rather than separately, to avoid affecting the socio-economic equilibrium of the Latin American countries.

GROUP IX

Role of International Agencies as We See It

1. Should be one of coordination, logistic support, and program planning of activities with national agencies. We should make every effort to substitute national capabilities for international effort. There is a definite need for coordination among international agencies in the process of working with national agencies.

2. It is highly desirable to develop a network of collaborating bean research centers in Latin America. This seems an effective mechanism for assembling the required research and development facilities for the improvement of the level of production, quality of grain and so on, that are necessary.

The network should make use of existing facilities and manpower to the maximum extent possible. It should reinforce existing stations, not supercede or duplicate them. It should assist the national centers to achieve their own local objectives and in no way attempt to impose decisions from the outside. At the same time, it should assure that national agencies would have full access to new results arising elsewhere.

The primary goal of the coordinated program would be:

a. To identify research areas of common interest;

b. To establish priorities among these;

c. To plan experimental work toward these objectives;

d. To seek additional funds when needed to carry out the indicated experiments;

e. To assist various cooperators to conduct the agreed upon research;

f. To evaluate and disseminate the results of the cooperative research effort.

The goals mentioned above could be achieved organizing the collaborating bean research centers or stations of the bean producing countries by groups according to their similarities of ecological and geographical conditions.

The organizations of these regional groups could be achieved through a Latin America Bean Commission, a collegiate body multidisciplinary in nature. Leading specialists in the different disciplines should form the Commission.

The Commission would establish problems policies, research priorities, analyze hemispheric programs, distribute responsibilities and seek funds.

A program coordinator should be chosen from each country to act as liaison between domestic efforts and its regional coordinator which in terms should be responsible to the higher body.

The regional groups should meet annually to review progress of work, evaluate results and set research and educational priorities.

In order to maintain contact and communication among various groups, some sort of secretariat would have to be established. The secretariat could also act as a clearing house and should be capable of backstopping national capabilities for data retrieval and publications.

The Latin America Bean Commission should seek the policy level support through a possible consulting body composed of people at the policy making level in the countries which could meet every three years to evaluate results and establish policy guidelines.

GROUP X

Considerations. Group working on bean improvement. Bean Seminar held in Cali, Colombia.

The considerations of this group regarded four main points: 1) germ plasm banks; 2) basic breeding materials; 3) obtainment of improved materials; 4) commercialization of improved seeds.

I. Germ plasm banks

The germ plasm banks –the number of seeds obtained from farmers, representing the primitive genetic variability of the species under study– are recognized as the main genetic source in plant improvement programs. The information available indicates that there is a general lack of organization in the existing bean banks in America and, therefore, it was suggested that attention be given to the following points:

a. Compilation of information on the location of banks and on existing material.

b. Formulation of guidelines for the operation of germ plasm banks including a documentation system with the best possible information on the morphological, agronomic and physiological characteristics of the collections and a rapid retrieval system. The problem of viability and reproduction of material should be studied to avoid loss of genetic variability and to avoid the effects of allogamy.

c. Biosystematic studies leading to a phylogenetic classification of material and including characteristics such as origin, areas of distribution and the mechanisms and effects of selection under domestication.

d. Planning for future ethnobotanical explorations taking into account the increase in genetic variability, and

e. Mechanisms for distribution of materials.

It was suggested that germ plasm banks be continually maintained in the following places and areas:

a. Chapingo, Mexico - Middle America region and the Caribbean

b. Central America

c. Palmira, Colombia - Venezuela, Ecuador, Colombia

d. La Molina, Peru - Peru, Chile, Bolivia

e. Brazil - Brazil, Guyanas

It was deemed convenient to choose Fort Collins, Colorado, U. S. A., as the storage place for a complete set of representative samples, for an extended period as a precautionary measure.

II. Basic breeding materials

The evaluation and selection of primitive materials of the germ plasm banks will generate basic material for a) the next phases of plant improvement, and b) material identified by **sui generis** genetic characteristics. The first type of material will have to be kept in "working germ plasm banks" in the plant improvement centers. It is suggested that representative samples of the second type of material be deposited in a germ plasm bank in Pullman, Washington, U.S.A.

A more advanced phase of the plant improvement work will lead to the formation of genetic compounds obtained by controlled crossing of selected components according to different objectives. These compounds will have to be kept in "working germ plasm banks" and should be made available to plant improvement scientists upon request. The definition of a center for production of the required compounds according to the overall needs of a coordinated program for international plant improvement was pending a decision.

III. Obtention of improved regional material

The convenience of the use of selection in regional plant improvement programs starting with compounds formed in the various plant breeding centers was pointed out. Theoretically, materials can be obtained starting from compounds, with the characteristics of adaptation, earliness, soundness, grain color and others that satisfy the regional objectives and requirements.

IV. Commercialization of improved materials

The need to give attention to commercialization mechanisms was stressed in order to take advantage of the use of improved seeds in the different agricultural production processes.

GROUP XI

1. It is desirable to establish a communication network in Latin America because:

a. The work being conducted in different countries is unknown to others and there is difficulty exchanging bibliographical material;

b. In many cases, some countries reject genetic material that could be utilized in others;

c. PCCMCA, working in Central American countries, has had positive experiences.

This communication network can be established through leading regional organizations.

2. The role of the leading regional organization would be to establish an agreement with national organizations in order to coordinate and carry out specific tasks related to marketing, production improvement and acceptance of food legumes and coordination of research, development and training work.

3. The international agencies would have the opportunity of participating in regional programs through:

a. Establishment of a germ plasm bank;

b. Establishment of an information center;

c. Establishment of a personnel training and technical assistance center;

d. Sponsorship of interdisciplinary national and international meetings;

e. The established center should serve to channel technical and financial assistance for specific research projects.

4. Specific projects could be financed by establishing a production tax, and planning specific projects to seek the financial support of agencies that may be interested in them.

GROUP XII

The suggestions of the participants are summarized in the following points:

1. To reinforce the Latin American Association of Food Legumes and the existing cooperative programs (PCCMCA);

2. To maintain contacts with similar associations and programs in other continents;

3. To reinforce national legume programs;

4. Where non-existent, to establish regional programs to coordinate national efforts;

5. To establish extensive and continuous communication, in the form of publications and news on legumes, with all the members of the association;

6. To intensify training of technicians dedicated to legume work, at all levels;

7. To reinforce the existing germ plasm banks both technically and financially;

8. To centralize and distribute information on materials available in all the germ plasm banks.

Appendix IV.

SUMMARY OF THE ANSWERS TO THE POST-SEMINAR EVALUATION QUESTIONNAIRE

This summary is based on the replies given by 90 participants, as detailed below:

1. This question asked them to group their expectations recording to the degree in which each one was realized, as per the following scale:

/5/	Realized completely
/4/	Realized highly
/3/	Realized in medium fashion
/2/	Realized poorly
/1/	Not realized

Tabulation indicates that the expectations were realized highly, as can be seen by the average showing after every question, below:

	Average	No. of replies
Establish personal contacts with other specialists and to take part in work groups to interchange information and ideas.	4.09	90
Learn about the problems that together limit food legume production in the tropics.	4.02	90
Obtain information about the consumption and utilization of legumes.	3.82	85
Establish priorities and increase knowledge of food legume research.	3.79	90
To learn of the conclusions and solutions proposed by seminar participants.	3.68	81

2. The second question consisted in asking participants to qualify to what degree negative results were obtained. Although this question presented administrative problems, data is presented as follows:

	Average	No. of replies
Did not expect negative results.	3.17	47
That cooperation between regional researchers not be promoted, due to lack of an organization to centralize and divulge research developments.	2.65	63
That clear decisions not be made on plans of action and that the conclusions not be carried out.	2.56	67
Lack of an integral approach on production.	2.55	64
That some papers not be absorbed properly, due to lack of time and, consequently, expected contributions will not be received.	2.53	66
That directive objectives be received from people foreign to the environment.	2.26	50

3. Consisted in qualifying the degree to which the following problems are limiting to high production, per area unit, in Latin American legumes.

The summary was as follows:

/ 5 / Totally limiting

/ 4 / Highly limiting

/ 3 / Limiting, but only partly

/ 2 / Very slightly limiting

/ 1 / Do not consider limiting

Low technological and economical level of producers.	3.86	88
Plant health problems.	3.77	87
Deficient production techniques	3.70	88
Low quality seed	3.63	88
Deficient governmental support for producers and researchers	3.59	86

	Average	No. of replies
Low crop profitability	3.56	87
Failures in technological communication	3.55	88
Lack of scientific information	3.21	88

4. Consisted in indicating which, in participants' opinion, institutions are the most appropriate for conducting and coordinating, in Latin America, research on the following problem areas:

	Number of replies
4.1 Plant health problems:	
CIAT	35
IICA	15
University of Costa Rica	7
ICA	6
University of Campinas	3
ALF	1
INCAP	1
ENA, Chapingo	1
INIA (México)	1
Michigan University	1
Viçosa	1
4.2 Economic studies on production and marketing:	
IICA	21
CIAT	17
PCCMCA	6
INCAP	3
SIECA	3
ILMA	2
Corporación de Mercadeo	1
CEPAL	1
CIRA	1
ICA	1
FAO	1
4.3 Plant Breeding and adaptation:	
CIAT	46
IICA	24
ICA	12

ENA, Chapingo	3
University of Campinas	2
INIAP	2
University of Vicosa	2
PCCMCA	2
ALIL	1
INIAP	1
INCAP	1
ICTA (El Salvador)	1
IITA	1

4.4 **Study of farmers' technologies:**

CIAT	31
IICA	16
ICA	4
IITA	3
PCCMCA	3
ENA, (Chapingo)	2
INIA, (Mexico)	2
CIMMYT	2
INIAP	1
INCAP	1
ABCAR (Brazil)	1
ICTA (El Salvador)	1
FAO	1

4.5 **Production practices:**

CIAT	41
IICA	17
University of Campinas	6
ICA	3
PCCMCA	2
INIAP	2
CIMMYT	1
INCAP	1
ALAF	1

4.6 **Potential of legumes in human diets:**

INCAP	43
CIAT	13
PCCMCA	5

IICA	5
Universidad del Valle	4
FAO	2
INIAP	1
ICA	1

4.7 **Certified seed production:**

CIAT	20
IICA	7
ICA	6
CIMMYT	4
PRONASE, (Mexico)	4
Ministries of Agriculture	3
INCAP	1
ENA, (Chapingo)	1
INIAP	1
PCCMCA	1
ABCAR, (Brazil)	1
INIA, (Mexico)	1
University of Campinas	1
Zamorano	1

4.8 **Appropriate method to take technology to the farmer:**

CIAT	20
IICA	18
ICA	4
Ministries of Agriculture	4
ENA, (Chapingo)	3
ABCAR, (Brazil)	3
C. P.	1
INCAP	1
FAO	1
INA	1

4.9 **Plant architecture and physiology:**

CIAT	33
Universities	12
IICA	11
ENA, (Chapingo)	4
ICA	4

IITA	3
INCAP	1
ALAF	1
INIA	1
MSU	1
PCCMCA	1

5. Consisted in classifying seminar's organization, according to the following scale:

5. Excellent
4. Good
3. Fair
2. Bad
1. Terrible

The following is the summary:

	Average	No. of replies
Officers' efficiency	5.00	5
Coordination and order	5.00	1
Interest of national participants	5.00	1
Opportunity to meet other participants at informal meetings (meals, cocktail parties, etc.)	4.11	87
Hotel facilities	4.00	1
Evaluation questionnaires	4.00	1
Work in disciplinary groups	4.00	2
Opportunity to highlight specially important aspects during meetings	3.92	82
Opportunity to clarify aroused enquiries during conferences	3.87	86
Secretarial help	3.83	6
Coffee service too slow. This caused delay in starting meetings	3.50	2
Simultaneous interpretation	3.46	86
Quality of sound system	3.18	86
Banquet organization	3.00	2
Definition of objectives	3.00	1
Classification of problems	3.00	1
Time for paper presentation	3.00	1
Break times	3.00	1

General session work	2.00	1
Too cold air conditioning	2.00	1
Speakers' presentations	2.00	1
Currency exchange service	2.00	1
Control of lights	1.50	2
Opportunity to discuss economical aspects	1.00	1
Some presentations too long	1.00	2
Water service	1.00	2

Appendix V.

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