Chapter 3

COMMON BEANS IN LATIN AMERICA AND THEIR CONSTRAINTS

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Introduction

Statistical information in Chapter 1 shows that Latin America ranks first in bean production and consumption among the tropical regions of the world. Beans are grown throughout the continent from the northern states of Mexico (30° N) down to regions as far south as the Chiloé Island in Chile (43° S). In Brazil, beans are grown in the Amazon basin where it is warm and humid, in the northeast where it is warm and dry, and in the subtropical highlands in the south. In Argentina, beans are grown in the northwestern provinces, from 150 km N to 600 km S of the Tropic of Capricorn, at 300 to 1000 m.a.s.l., and with 45 to 1000 mm of annual rainfall. In Chile, they are produced in the dry and warm central lowlands under irrigation. In Peru, beans are grown in the arid coastal valleys, the eastern and western valleys of the Andean highlands, and the Amazon basin. In Colombia, Ecuador, and Bolivia, beans are produced in the Andean valleys during two rainy and two dry seasons annually. In Venezuela, bean production takes place in the north coast at sea level where it is hot and humid, and in mountain valleys and tablelands which are subtropical. In Central America, they are grown on the dry and warm Pacific slopes, on mountain sides and cooler high valleys, and in the warm, moderately dry, interior lowlands.

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In Mexico, they are produced in the north which has a continental climate, in the warm central tablelands under irregular rainfall patterns, and in most areas at sea level.

Beans are not widely grown on the Atlantic side of Central America and the Carribbean area where rainfall is heavy and high humidities prevail. Neither are they grown above 3000 m.a.s.l. in Peru, Ecuador, or Bolivia. Considering the wide diversity of climates, soils, and socioeconomic environments found between the Tropics of Cancer and Capricorn, it is not surprising that bean production in Latin America is subject to numerous constraints that vary from region to region; nor that beans are produced under widely differing cropping systems (Andrews and Kassam, 1976), with different plant types, and seeds of varying colors and sizes (Voysest, 1983).

Beans as a Domestic and Export Product

Common beans marketed as dry beans are used entirely for consumption by humans in Latin America. However, consumption patterns show wide variation (Table 1). Argentinian or Chilean annual consumption is low compared with that of Brazil or Mexico but this does not prevent the former countries from devoting a considerable area to beans for export.

Latin American countries can be grouped into three categories:

Net exporters. Argentina is a typical case: the land area cultivated under common beans increased to 200,000 ha in the eighties and Argentina is the leading bean exporter in Latin America. Beans are grown in the northwestern provinces (Salta, Tucumán, Santiago del Estero, and Jujuy). About 5000 ha of beans are grown for local consumption in Misiones, a province neighboring Brazil and Paraguay.

Exporters and consumers. Chile is the most representative country in this category. Although figures vary annually, usually half of the Chilean bean production is for export (FAO, 1982). It consists mainly of pea, black, Red Mexican, Red Kidney, and pinto bean types. The locals, however, prefer other colors and sizes such as gray or light tan, and medium- to large-sized grains. For the other

Table 1. Annual per capita bean consumption (kg) in Latin America.

Country[a]	Annual per capita consumption (kg)								
	0-1	1-2	2-3	3-5	5-7	7-10	10-13	13-16	>16
Chile				X					
Argentina		X							
Uruguay	X								
Paraguay[b]									X
Brazil								X	
Bolivia	X								
Peru			X						
Ecuador				X					
Colombia				X					
Venezuela					X				
Panama			X						
Costa Rica							X		
Nicaragua									X
Honduras						X			
El Salvador						X			
Guatemala							X		
Mexico								X	
Dominican Republic						X			
Haiti						X			
Cuba			X						

a. Countries are listed from south to north.
b. Possibly includes cowpea (*Vigna unguiculata* (L.) Walp.).

SOURCE: FAO (Food and Agriculture Organization of the United Nations). Various issues. Food balance sheets. Rome, Italy.

Latin American countries of this category, export sales are more sporadic and not as significant.

Net consumers. This category embraces most Latin American countries among which there are large differences in annual consumption per capita. In Brazil and Mexico, during 1979-81, the average per capita consumption was between 14.0 and 16.5 kg of beans per year, while in Argentina and Uruguay, it was less than a kilogram. Table 1 shows that per capita bean consumption in Latin America declines as one moves south from Mexico to Chile, with Brazil and Paraguay being exceptions. In some countries such as Paraguay and Bolivia, the urban population consumes more beans in comparison with the rural population, particularly in Paraguay.

Usually, however, urban populations consume fewer beans than rural populations.

Classes of Beans Grown in Latin America

The types of beans grown in Latin America are listed in Table 2. The class most widely distributed is the black bean. The high daily consumption of black beans in Mexico, Guatemala, Cuba, Venezuela, parts of Brazil, Central America and the Caribbean, Misiones Province in Argentina, and Santa Cruz Department in Bolivia makes this class of bean attractive to countries such as Argentina and Chile, which grow black beans exclusively for export.

Small reds form another important bean class. These beans are grown in El Salvador, Honduras, Nicaragua, Costa Rica, Jamaica, Cuba, and Brazil. Although the small red beans have an attractive appearance, suitable for export markets, the diversity of preferences in color intensity, shape, size, and brightness means that they are rarely grown for export.

For the same reasons neither are red-mottled beans commonly exported. For example, in the Caribbean there is strong preference for the round, medium-sized, variegated beans (Miss Kelly in Jamaica, Pompadour in Dominican Republic), whereas in the Andean zone, particularly Colombia, the elongated large-sized grains such as Diacol Calima are preferred. Variation of consumer preference in this class is largely governed by the tones of colors involved, their patterns, and base colors. Other classes of red beans include the solid-red, large beans that are grown in the Caribbean, Colombia, and Ecuador and the Red Kidney types that are planted in the Caribbean and southern highlands of Peru for local use, and in Chile and Argentina for export.

The "bayo" class, a generalized name for a type of beans with a seed color ranging from cream to light tan, is also widely distributed—in Mexico, Brazil (where they are known as Mulatinhos), Ecuador, Peru, and Chile.

The sulfur-yellow class of beans are grown in coastal areas of Peru where they are known as Canarios and in Mexico where they are known as "Azufrados" or "Peruanos." Other types of yellow

Table 2. Classes of beans grown in Latin America.

Color	Country	Class	Equivalent U.S. class
White	Chile	Arroz	Navy
	Chile	Cristal Blanco	White Marrow
	Peru, Ecuador	Panamito	Small White
	Peru	Caballero	White Marrow
	Argentina	Alubia	
Cream	Brazil	Mulatinho	
	Brazil	Carioca[a]	
	Mexico	Bayo Gordo	
	Mexico	Bayo Blanco	
	Mexico	Ojo de Cabra[a]	
	Peru	Bayo Chimú	
	Peru	Cocacho	
	Chile	Bayo Titán	
	Chile	Cristal Bayo	
	Chile, Ecuador	Bayo Bolón	
	Chile	Hallados Alemanes 114	Pinto
	Mexico	Pinto Nacional	Pinto
	Colombia	Cargamanto[a]	Cranberry
	Uruguay	Frutilla[a]	Cranberry
Yellow	Brazil	Jalo and Jalinho	
	Brazil	Enxofre	
	Mexico	Azufrado	
	Mexico, Peru	Peruano	
	Mexico	Canario	
	Mexico	Garbancillo	
	Peru	Canario	
	Peru	Amarillo Gigante	
	Peru	Ucayalino	
	Ecuador	Canario Bolón	
Brown	Brazil	Chumbinho	
Pink	Brazil	Rosinha	
	Mexico	Rosita	Pink
	Mexico	Flor de Mayo[a]	
	Colombia	Andino[a]	
	Belize, Jamaica	Miss Kelly[a]	
	Argentina	Chaucha Colorada	
	Cuba	Mulangrí	
	Peru	Rojo Mollepeta	Red Kidney
	Chile	Red Kloud	Red Kidney
	Belize, Jamaica	Red Kidney	Red Kidney
	Cuba	Velasco Largo	Red Kidney

(Continued)

Table 2. (Continued).

Color	Country	Class	Equivalent U.S. class
Red	Central America	Small reds	Red Mexican
	Brazil	Roxinho, Roxão	
	Colombia	Calima, Nima	
	Colombia	Gualí, Catío[a]	
	Colombia	Radical, Sangretoro, Bola Rojo	
	Ecuador	Cargabello[a]	
	Dominican Republic	Pompadour[a]	
Purple	Colombia	Mortiño[a]	
Black	Central America, Mexico, Caribbean, Venezuela	Negro	Black Turtle Soup
	Brazil	Preto	Black Turtle Soup
Gray	Chile	Tórtola	

a. The color is not solid.

SOURCE: Voysest, 1983.

beans are also grown in the highlands of these countries—one of them, known in Mexico as "Canario," is also grown in Panama, Ecuador, Bolivia (under the name of "Manteca" or "Mantequilla"), and in Brazil where it is called "Jalo."

The white-seeded beans, large and small, are grown in Peru and Ecuador. Chile grows mainly the small white beans and Argentina the large ones. Brazil, in addition to black (Pretos), cream (Mulatinhos), and yellow (Jalo) beans, also grows a type of small-seeded beans known as Rosinha (pink), Roxinho (red), Chumbinho (brown), and the widely grown Carioca (cream with dark stripes). The production and consumption pattern of beans in Latin America is complicated by strong traditional consumer preferences for color and grain size. To further complicate the picture, farmers have their own preferences, especially with regard to plant types that most suit their particular production system.

Bean Production Structure

A large part of bean production in Latin America takes place on small farms ranging from 1-10 ha in size, often on sloping land of limited fertility. Some estimates suggest that perhaps 80% of the area planted with common beans in Latin America is found on hill sides. Moreover, these small holdings are dispersed and, in contrast to other crops, a main production area can seldom be determined (Aguirre and Miranda-M., 1973; Hernández-Bravo, 1973).

In Brazil, one of the largest bean producers of Latin America and which accounts for about half of the Latin American production, an estimated 34% of production is on farms of less than 10 ha. In Mexico, which contributes one-fourth of the Latin American bean production, an estimated 67% of its production comes from farms of less than 5 ha (Pachico, 1982). Even in Chile, an important bean exporter in the region, beans are produced by small to medium growers whose farms vary from 20-40 ha (Fassbender, 1967). Except for Argentina where beans are usually produced on large holdings with considerable technical input, Latin American beans are usually produced by small landholders. More than half the production occurs on farms smaller than 20 ha and more than 20% on farms of less than 5 ha (Pachico, 1984). The extreme cases are represented by countries such as Haiti, the Lesser Antilles, and Paraguay where production is almost exclusively done by small-farm families. In the remaining countries, production is usually done by small-farm families and small-scale commercial producers. In Mexico, Brazil, Chile, and Cuba, it is possible to find the three types of beans producers. Colombia, Venezuela, Dominican Republic, Peru, Guatemala, and Costa Rica have limited areas where large-scale, highly mechanized production occurs.

D. Pachico (unpublished data) classified bean-producing regions based on economic resources such as land, availability of labor, fertilizers, and pesticides. This gives a useful idea of the diversity in the structure of bean production in Latin America. These classes are:

Frontier, extensive: Land is plentiful relative to labor; large farms are mechanized; low investment put in fertilizers and

pesticides. Examples include Argentina (northwest), Costa Rica (Upala), Guatemala (Petén), and Brazil (Mato Grosso, Goiás).

Small farm, intensive: Labor is plentiful relative to land; moderate to favored environmental conditions; may invest in fertilizers and pesticides. Examples include Colombia (Antioquia, southern Nariño), Costa Rica (San Isidro del General), and Brazil (highlands of Espírito Santo, Paraná, Santa Catarina).

Small farm, extensive: Moderate to high ratio of labor to land; little capital investment; less favorable growing conditions (drought, poor soils). Examples include Peru (Chota), Mexico (arid highlands), and Brazil (Bahia).

Large farm, mechanized: Agrochemicals used in moderately favorable conditions. Examples include Brazil and Mexico.

Irrigated: Moderate to high labor and capital inputs. Examples include Chile (central valley), Peru (coastal regions), Mexico (Sinaloa), and Brazil (coastal Espírito Santo).

Another criterion can be used to classify bean-production regions, based on the cropping systems. Without attempting to establish a definitive classification, it is apparent that Latin American beans are grown under five main production systems:

Bush beans in monoculture: This system is common in low-to-medium altitude areas, chiefly in Brazil, Argentina, Mexico, Chile, Peru, Cuba, and the Dominican Republic.

Bush, semiclimbing, and climbing beans in relay systems with maize: The relay system is mainly found in low to intermediate altitudes of Colombia (Antioquia) and Central America.

Bush beans intercalated with maize: This system, where maize and beans are usually sown at the same time, is common in intermediate altitudes in Colombia, Venezuela, Brazil, and Central America.

Climbing beans in direct association with maize: The system is found in the higher altitudes (2000 m.a.s.l.) of Colombia, Ecuador, Guatemala, and Peru.

Covered bean ("tapado" system): This system is found in lower and intermediate areas with high precipitation such as Costa Rica, El Salvador, and Nicaragua.

The system of bush beans in monoculture can be used by both small and large farmers while the other four systems are used only by small farmers.

In Latin America beans are often grown in association, principally with maize, but also with cassava, coffee, potatoes, and other crops (de Andrade et al., 1974; Hernández-Bravo, 1973; Moreno-R. et al., 1973; Ruiz de Londoño et al., 1978). About 60% to 80% of Latin American bean production is in association with other crops (Gutiérrez-P., et al., 1975; Pinchinat et al., 1976). Whether relay or simultaneous planting system is adopted depends mostly on precipitation patterns. Where there is a unimodal rainfall distribution the relay system is usually employed: maize is planted in the first, more rainy, season; climbing beans are planted in the second season; the beans use the maize as a support. In Central America and in some areas of the Andean zone such as Antioquia in Colombia, this is the most common production system (Bastidas-Ramos, 1977).

In high, cool areas where the growth period of beans and maize is long during the single rainy period, associate cropping is the predominant system. This is the case in the highlands of southern Colombia, Ecuador, and Peru where maize and beans are planted simultaneously. Beans intercalated with maize is a system that is used in almost all bean-producing zones of Central America and Brazil.

The "covered bean" ("tapado") system is a primitive production system which predominates in regions of very high precipitation in Costa Rica and Nicaragua. Seed is broadcast over a plot covered by certain weeds. The weeds are then cut down by hand with machete and thrown over the seeds to cover them (Aguirre and Miranda-M., 1973). This system, primitive and low producing as it may be, is excellent on erosion-prone slopes and in the management of the splash-dispersed inoculum of web blight[1] (*Rhizoctonia solani*

1. Also caused by *Thanatephorus cucumeris* (Frank) Donk. which is the perfect stage of *Rhizoctonia solani*.

Kühn) which causes a serious foliar disease. The cut-down weeds form a mulch that covers the blight and prevents its dispersal. However, this system may favor slug survival and crop damage in some production regions in Central America.

Constraints to Production

Of the major world crops, beans are probably one of the most susceptible to diseases and insect attacks. In most production areas, diseases and pests constitute the major factor that significantly lowers onfarm yields. More than 200 diseases and 200-450 insects can affect bean productivity (CIAT, 1981b).

Bean production in Latin America suffers from many edaphic, climatic, and biotic stresses. However, the main factors responsible for low yields are high disease-and-insect pressure, drought, low plant density (to avoid high disease pressure) and farmer's economic inability or reluctance to use inputs.

Web blight is a disease, the importance of which has been underestimated. Previous reports (Costa, 1972; Crispín-Medina and Gallegos, 1963; Echandi, 1966 and 1976) mention it only as a devastating disease in the warm, humid areas of Mexico and Central America and lowlands of Colombia. However, recent reports have confirmed that this disease is widespread in many bean-producing regions of Latin America (Gálvez et al., 1980).

In some years and locations, bean golden mosaic virus (BGMV) is also severe. This virus has become a serious problem in many regions of southern and central Brazil (Minas Gerais, Goiás, north Paraná) (Costa, 1972; Costa and Cupertino, 1976); Central America (Gálvez, 1982; Gámez, 1971), the Caribbean, and the lowlands and eastern coast of Mexico (CIAT, 1981b). Recently, BGMV has also been observed attacking beans in Argentina.

In cooler regions, anthracnose is important, as are other fungal diseases, root rots, and halo blight (Cardona-Alvarez and Skiles, 1954; Echandi, 1966; Shands et al., 1964). Each of these diseases can cause yield losses as high as 80%-100%. Losses to bean common mosaic virus (BCMV) can range from 53%-96% (Crispín-Medina

and Campos-Avila, 1976; Echandi, 1966; Laborde-C., 1967); to bean rust from 18%-85% (Carrijo, 1975; CIAT, 1976); and to anthracnose as high as 95% (CIAT, 1976). Seed transmission of pathogens responsible for BCMV, anthracnose, angular leaf spot, halo blight, and common bacterial blight complicate the disease picture. Table 3 shows the major disease problems in different bean-producing regions in Latin America.

The most important insect pests in Latin America are the leafhoppers (*Empoasca* spp.) (van Schoonhoven and Cardona, 1980). Cutworms are also important in most Latin American bean-production zones (Bonnefil, 1965; Gutiérrez-P. et al., 1975). The pod weevil (*Apion godmani* Wagner), is a major pest in Mexico, Guatemala, El Salvador, and northern Nicaragua. The Mexican bean beetle (*Epilachna varivestis* Mulsant) is an important pest in Mexico, Guatemala, and El Salvador. Slugs (*Vaginulus plebeius* (Fisher) and *Limax maximus* L.) are particularly important in Central America (Bonnefil, 1965; Enkerlin-S., 1957; van Schoonhoven and Cardona, 1980). Leafhoppers have reduced yields of susceptible cultivars by as much as 90%; and reductions of 20%-50% are common on many farms even when insecticides are used (CIAT, 1985). Storage insects such as *Acanthoscelides obtectus* (Say) and *Zabrotes subfasciatus* (Boheman) inflict heavy losses on stored beans, forcing rapid sale of grain. This contributes to postharvest price declines and marked seasonal price fluctuations (van Schoonhoven, 1976). At least 28 other insects are reported to occur on stored beans but are of minor importance or migrate from nearby stored produce to beans (van Schoonhoven and Cardona, 1980).

Soil-related constraints become important as bean production is increasingly concentrated on more marginal land, with low pH and high phosphorus fixation. Associated aluminum toxicity reduces root development and increases sensitivity to water deficits (CIAT, 1985). Nitrogen deficiency is also a limiting factor in many soils where beans are grown. This is complicated by a low capacity for nitrogen fixation in most currently used cultivars (Graham and Halliday, 1977). Analysis of 110 Central American soils showed that 20% had a pH of less than 6.0 (Müller et al., 1968), 66% were highly deficient in phosphorus (FAO, 1982), and 75% were nitrogen deficient (Díaz-Romeu et al., 1970). A similar situation was demonstrated in Brazil (Malavolta, 1972) when 232 bean fertiliza-

Table 3. Major disease problems in different bean-producing regions of Latin America.

Country	Diseases[a]											
	Fungi						Bacterial blights		Viruses			
	Rust	WB	ANT	ALS	ASC	RR	CBB	HB	BCMV	BGMV	BYMV	BClMV
Argentina												
Warm zone (Salta, Tucumán, Stgo. del Estero)	x	x	x	x		x	x					x
Temperate zone: Humid (Rosario de la F., Metán)			x	x			x					
Temperate zone: Dry (Trancas)				x			x					
Temperate zone: (Sta. Isabel in Salta, Candelaria)			x									
Belize		x							x			
Bolivia												
Santa Cruz	x						x					
Brazil												
Parts of Amazonas, Pará, Acre, and Rondônia		x										
Pernambuco (mata), Bahia, Sergipe, Alagoas	x		x	x		x	x					
Parts of Minas Gerais, Espíritu Santo, Rio de Janeiro	x		x	x			x		x	x		
Parts of Minas Gerais, Goiás	x		x	x			x		x	x		

(Continued)

Table 3. (Continued).

Country	Diseases[a]											
	Fungi						Bacterial blights		Viruses			
	Rust	WB	ANT	ALS	ASC	RR	CBB	HB	BCMV	BGMV	BYMV	BClMV
São Paulo, Mato Grosso, parts of Paraná	x		x	x			x		x	x		
Rio Grande do Sul, Santa Catarina, parts of Paraná	x		x				x		x	x		
Colombia												
Warm (800-1300 m.a.s.l.)	x	x					x		x			
Medium (1300-1500 m.a.s.l.)			x	x			x					
Moderately cool (1700-2400 m.a.s.l.)			x	x	x	x		x				
Costa Rica												
Brunca Region (Perez Zeledon)		x	x									
Central Region (Valle Central)	x			x					x			
Cuba	x						x		x			
Chile									x		x	
Dominican Republic	x	x	x					x	x			
Ecuador												
Coast	x					x						
Highlands			x	x	x							

(Continued)

Table 3. (Continued).

Country	Diseases[a]											
	Fungi						Bacterial blights		Viruses			
	Rust	WB	ANT	ALS	ASC	RR	CBB	HB	BCMV	BGMV	BYMV	BClMV
El Salvador												
Balstein (Sta. Ana, Aliuachapán, Sonsonate)							x					
Central (La Libertad, San Salvador, Cuscatlán)							x		x			
Guatemala												
Oriente (Jutiapa)	x								x			
Altiplano (Chimaltenango)	x		x	x								
Central coastal region (Escuintla)		x				x						
North (Petén)		x										
Jamaica	x		x				x		x	x		
Mexico												
Warm, with dry winter (Sinaloa)	x					x				x		x
Warm, humid (Veracruz)	x	x						x	x	x		
Temperate, humid (Jalisco)	x		x	x	x	x	x					
Temperate, semiarid (Durango)	x		x			x						
Warm, arid (Chihuahua)	x					x			x			

(Continued)

Table 3. (Continued).

Country	Diseases[a]											
	Fungi						Bacterial blights		Viruses			
	Rust	WB	ANT	ALS	ASC	RR	CBB	HB	BCMV	BGMV	BYMV	BClMV
Nicaragua												
Region 1	x	x					x		x			
Region 4		x		x			x		x			
Region 5		x	x	x			x		x			
Region 6	x	x	x	x			x		x			
Panama	x	x					x		x			
Paraguay	x						x		x			
Peru												
Coastal region (Lambayeque, Chincha, Camaná)	x					x					x	
Highlands (Cajamarca, Cusco)			x	x	x				x			
Jungle (Pucallpa, Tarapoto)		x							x		x	

a. WB = Web blight; ANT = anthracnose; ALS = angular leaf spot; ASC = Ascochyta blight; RR = root rots; CBB = common bacterial blight; HB = halo blight; BCMV = bean common mosaic virus; BGMV = bean golden mosaic virus; BYMV = bean yellow mosaic virus; BClMV = bean chlorotic mottle virus.

SOURCE: CIAT Bean Team trip reports, unpublished data.

tion trials, covering eight states, reported responses to nitrogen (67 times), phosphorus (103 times), potassium (15 times), lime (31 times), and microelement combinations (17 times). Aluminum (Buol et al., 1975) and manganese toxicities, associated with the low soil pH (Döbereiner, 1966) and molybdenum deficiency (Franco, 1977), complicated fertilizer recommendations.

Drought is a serious threat to bean production in many areas of Latin America, rivaled in importance by soil fertility problems (White and Singh, n.d. In semiarid regions, large areas of beans are grown, exclusively dependent on irregular rains. North central Mexico, including the States of Chihuahua, Durango, Zacatecas, and Aguascalientes, and northeast Brazil, including the States of Pernambuco, Alagoas, Paraíba, Ceará, Rio Grande do Norte, and part of Bahia, represent almost 2 million hectares of beans and are the best examples of semiarid regions threatened yearly with severe droughts. Deserts may not constitute an important drought area in quantitative terms, but often support large areas of bean production. For example, the rainless coast of Peru where irrigation costs often limit farmers to a single irrigation, supports 50% of the country's bean production. Drought stress is even enhanced when farmers plant late in the rainy season to avoid disease pressure.

Besides these extreme examples of bean production in drought situations, most bean-producing regions experience periods of dryness with varying differences in frequency and severity of stress. Throughout the tropics, areas with apparently adequate mean precipitation frequently suffer from water deficits because of seasonal fluctuations in rainfall. Consequently, bean production is impaired. According to data so far obtained by the CIAT Agroecological Studies Unit (ASU) (CIAT, 1985), 73% of the total Latin American bean production occurs in microregions that have moderate to severe mean water deficits at some time during the cropping season. Little of this production is irrigated (Table 4).

Although serious water deficits are a major production constraint, high temperature is not. According to data from ASU, most beans (76%) in Latin America are produced at temperatures close to the optimum (20-23 ^{0}C) for *Phaseolus* species.

Table 4. Climatic classification of bean-production zones in Latin America.

Climatic type	General description of climatic type	Growing season mean temperature (°C)	Growing season daily water balance (WB)[a] (+ mm/day)	Latin American production zone	
				(t in thousands)	(total (%)
A	Average temperatures and adequate mean seasonal WB	22	-1.5 to 0.4	661	17
B	Average temperatures and slight excess in WB	23	0.4 to 4.0	118	3
C	Average temperatures and large deficits in WB (irrigated areas)	23	-5.6 to -5.1	528	14
D	Average to moderately low temperatures with possible deficit in WB toward end of the growing season	20	-2.7 to -1.6	1672	42
E	High temperatures with possible deficit in WB toward end of growing season	26	-4.1 to -0.3	262	6
F	Moderately low temperatures and moderate water stress	16	-2.3 to -1.9	451	11
G	Low temperatures and adequate mean seasonal WB	13	-0.09 to -0.05	45	1

a. Mean of conditions in the microregions constituting each production zone. Overall, 110 microregions have been defined.

SOURCE: CIAT, 1981a.

Low and unstable bean yields are, in some cases, caused by the use of cultivars whose physiological characteristics are not suitable for the production environments in which they grow. Cultivars with a determinate, erect, bush growth habit can be planted in areas well suited to intensive cultivation with a degree of mechanization. These types are characterized by early and intense flowering, which contributes to low and unstable yields, and by a reduced ability to compensate for low planting densities, which is common on most small farms. These cultivars do not have a mechanism for renewed flowering when stress is relieved (CIAT, 1985). They are grown extensively because farmers like their erectness, earliness, and large seed size. In contrast to mechanized production systems, most common bean producers in Latin America cultivate indeterminate types in complex multiple cropping systems (Andrews and Kassam, 1976). Many of these have prostrate plant types and, in monoculture, pods come in contact with soil at maturity. Some cultivars are too late, or are poorly adapted to row and relay intercropping with maize. Type II cultivars are the least competitive, whereas types IIIb, IVa, and IVb are progressively more competitive (Laing et al., 1984). Type IV is most favorably grown with maize (Adams et al., 1985).

Growth habit instability has been related to a phytochrome response to differences in spectral quality (Kretchmer et al., 1977 and 1979) and photoperiod (Kretchmer et al., 1977). Common beans are grown in the tropics under daylengths that vary from 11-15 hours (Masaya and White, 1986). In subtropical areas, as days become shorter, beans are often planted in relay cropping, using stalks of the preceding maize crop as physical support for the long and flexible bean stems. Photoperiod-insensitive types originate mainly from extreme latitudes and occur primarily in growth habits I and II, while large-seeded climbing types, mainly from the Andean zone, are rarely insensitive (CIAT, 1976 and 1977).

Equally important as the biotic and abiotic environmental stresses that affect crop production are socioeconomic constraints. A high proportion of Latin American bean production occurs on small farms and in associated cropping systems. This, in itself, imposes constraints to increased bean production. Although associated cropping usually is more efficient in the total exploitation

of environmental resources than beans grown by themselves, bean yields are reduced 30%-50% (Francis et al., 1978). The task of extending new technologies is likely to be more costly among many small farmers than among few large farmers. Development of an integrated system for the supply of agricultural inputs and marketing of the harvested products are therefore impeded. Furthermore, the costs of individual technical assistance will be prohibitively high. Statistics show that a substantial proportion of bean output is consumed by the producer. As much as 30% of Latin American bean production is estimated as subsistence (Pachico, 1982). When a crop is produced primarily for subsistence, cash is not generated from the production process, thereby making it less likely for growers to use bought inputs in production.

Conclusions

In Latin America, bean yields are low and the bean production environment complex. Efforts to increase bean yields must therefore be done at a regional level and aim to improve local production systems, understand local grain-type requirements, and research local production problems. Beans, being often a subsistence or small-farmer crop, do not receive the research attention that cash crops such as coffee or cotton, enjoy. Collaboration among bean research institutes among countries of an ecologically uniform region must therefore be encouraged.

Although the average bean yield is low, because of competition from associated crops, attacking the beans' disease susceptibility may be the most profitable venue for researchers aiming to increase yields. Because beans are disease susceptible, farmers consider them as a high-risk crop that does not merit good agronomy. With a multiple-pest-resistant variety farmers may find crop risk reduced and so respond with improved agronomy and thus obtaining higher yields. This concept has borne out in Costa Rica and Argentina where improved varieties have prompted farmers to improve their production agronomy.

Bean research is a challenge to scientists trying to improve the crop. The variability of cropping systems and of grain-type requirements, the difficulty to improving the potential yield of any

legume crop, and the need to improve the beans' digestibility are all challenges which need to be met, if the lives of millions of small farmers are to improve. This has to be achieved even though beans receive low priority in local government agricultural research financing.

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