~~TRENDS AND~~ YIELD CONSTRAINTS IN THE PRODUCTION SYSTEMS OF BEANS AND CASSAVA IN LATIN AMERICA WITH EMPHASIS ON RESEARCH DESIGN IMPLICATIONS

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Crop research in the International Centers is predominantly organized into commodity divisions with the principal output being high yielding[1] varieties. Within the commodity division the specific crop programs revolve around breeding. The breeding itself is a probability game with the following procedures:

a. A world wide collection of germplasm is obtained so that there is sufficient genetic variability that some interesting characteristics can be combined from different parental sources.

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* The authors are Agricultural Economists in the Bean and Cassava Programs of CIAT (Centro Internacional de Agricultura Tropical). The customary disclaimer that this paper reflects only the views of the authors and not necessarily of CIAT applies. We are indebted to Howard Schwartz, Douglas Laing, and Anthony Bellotti for comments on an earlier draft.

[1] Some combination of disease and insect resistances is often one of the primary objectives of breeding programs. By reducing the yield variance mean yields also increase over time. Similarly, those breeding exclusively for yields have to take diseases and insects into account at some point in their selection and evaluation program. Hence, much of the argument over breeding for high yields or resistances is largely semantic generating more heat than light. The techniques are different as resistance breeding involves exposing the plants to very high levels of the disease (or insect) whereas breeding for yields alone may not involve such high exposure levels. Nevertheless, breeding for yields still involves repeated trials to insure that sufficient exposure to the major yield constraining factors has occurred. Whether exposure is guaranteed through inoculation or obtained through repeated trials in representative environments, the final product should be the same, a high yielding variety with resistance or tolerance to the "relevant constraints". The process of identification of these "relevant constraints" is the subject of this paper.

b. The identification of the desired characters to overcome specific constraints to yield increase is made. The "relevant constraints" on the production side are some combination of disease and insect pests, soil and water conditions, and plant characteristics[2].

The "relevant constraints" can be imposed by consumer conditions, such as taste preferences[3], as well as production factors.

c. The germplasm is screened for the characteristics identified in B. The best potential parents are identified[4].

d. These parents then enter into a series of crossing and selection trials until varieties emerge with the maximum of the desired characteristics[5].

2/ For example, rice breeding at IRRI was principally concerned with building shorter, sturdier varieties to respond to higher fertilizer levels without lodging and with complete water control through irrigation. Breeding research was also directed at four diseases and three pests. Finally, nonphotoperiod sensitivity was desired; however, this is a different type of characteristic sought principally by International Centers in order to give wider adaptability to the new material.

See P.R. Jennings, "The Amplification..." p. 186; and P.R. Jennings, "Plant Type..." pp. 13-15.

3/ Consumers may not eat or may offer a lower price for a bean of a specific color, size, or texture. In the case of cassava consumers would be expected to prefer lower HCN content, a longer shelf life, and a high starch content.

4/ At this stage the selection process (before the initiation of the breeding program) may identify cultivars with a sufficient number of characteristics to be released into evaluation trials. Where there is high yielding ability but insufficient resistances to disease and soil factors, these cultivars can be tied to cultural practices and released as "improved varieties".

5/ There are two basic types of breeding programs involved in variety crosses. The pedigree methodology selects a best variety, the recurrent parent, and through the gene transfer techniques adds characteristics from other varieties. The alternative is bulk-breeding methodologies in which a group of selections are randomly crossed, the intent being through proper recurrent selection to shift the characteristics of the population toward those desired. In both cases with seed propagated crops pure lines, those in which the characteristics breed true and do not segregate in the next generation, are the end result. The choice between the two methodologies become especially important in breeding for disease resistance, and thus is dependent upon the identification of the releveant constraints and the most appropriate type of resistance.

e. The varieties (or segregants) are released to National Institution for either dissemination, trials in different agro-climatic conditions, or further crossing for desired region specific characteristics[6]. A critical component here is the feedback by the National Institutions into a better definition of the future "relevant constraints" and to a lesser extent their dispatching of new plant material, either their selections or new crosses. With these entries into B and A the process becomes circular.

The comparative advantage of the International Centers is that there are apparently economies of scale to germplasm collection, screening, and crossing[7]. The potential disadvantage of International Centers in relation to National Institutions is in their restricted ability to diagnose desired varietal characteristics for a series of specific regions in a large number

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6/ Another important output of International Centers is their collaboration with National Institution scientists. The International Centers are increasingly utilized for training younger scientists from various national organizations in developing countries. This process facilitates the contacts for the successful operation of E above.

7/ Part of the comparative advantage is physical. A larger breeding team can specialize more and thereby produce a much larger number of crosses. Similarly, the interaction between agricultural disciplines should be useful for problem definition and solving.

However, the most important advantage of International Centers may result from the "minimum critical investment". Breeding requires highly trained personnel and specialization in a specific crop, is expensive, and is a long term investment. National governments in developing countries generally have few trained agricultural scientists and have to be concerned with many crops. Moreover, research is generally given a low priority in public expenditures and decision makers in developing countries tend to prefer investments with a short payoff period.

The advantages of the International Centers are team size, specialization, large scale funding and continuity. This combination is considered by international donors to have a higher probability of reaching the "minimum critical investment" for breakthroughs in new varieties than similar funding of most national systems. Nevertheless, a functioning national research capability is necessary for the success of International Center research.

of developing countries[9].

The crucial decisions are in the definition of the "relevant constraints" and thus the breeding strategy. The rest is a more mechanical process of collecting germplasm (A), screening and crossing (C and D)[9], and disseminating (e). International Centers are continually in a process of gathering, refining and digesting this information about the "relevant constraints" for the critical breeding decisions.

8/ One dilemma of International Centers is the development of a methodology for obtaining more systematic definition of the "relevant constraints" from National Institutions before the new material is released. The present tactic is to begin releasing something as soon as possible such as the better selections (under C) or "intermediate technology".

The final product of International Centers is improved germplasm. These improved varieties, to the extent possible embody genetic solutions to overcoming the major constraints on productivity. However, in the process of mounting a breeding program, the other agricultural sciences genrally identify a series of practices, which increase yields under experiment station conditions. Examples of these "intermediate technologies" are clean seed production, fertilizer response and spacing alternatives, herbicide recommendations for different soild types, and insect and disease control measures.

By identifying intermediate technologies that are profitable at the farm level the International Centers can build up better institutional ties with National Institutions and encourage more National Center input into research design at International Centers in the early stages of the process.

Unfortunately, experiment station technology is not always relevant to farm level conditions. The technology may not be profitable, it may not fit into the existing farming systems, or it may increase risks much more than farmers are willing to accept. Hence, farm level testing is critical to evaluate whether the "intermediate technology" is relevant and the extent to which varietal characteristics are necessary to raise yields.

9/ Definiton of the "relevant constraints" determines the characteristics that are bred and selected for and in part the choice of breeding methodology. The choice of methodology becomes critical when a primary constraint is identified to be the stability of disease resistance. Where this requirement is critical a breeding strategy seeking stable horizontal resistance must usually employ a bulk breeding methodology. However, such a strategy in the early stages usually exludes development of high yielding genotypes along plant ideotype lines. For a discussion of the resistance issue as defined in terms of the dichotomy of horizontal versus vertical resistance see R.A. Robinson, Plant Pathosystems.

This information gathering can be divided into three stages:

1. Processing available country level data. The Macro Stage.
2. Undertaking farm level studies of production constraints in different agro-climatic zones and farming systems. The Micro Stage.
3. Supplementing the information above with the subjective judgement of program scientists based upon experimental data and knowledge of the target area. The Critical Inference Stage.

The objective of this paper is to provide case histories of the role of these three types of information in the design of research for beans and cassava in CIAT. Obviously, this process is continually evolving so that the paper is only our snapshot of the present situation.

The Macro Stage:

The available macro data is sketchy. Production data is unrealiable when home consumption is important or when there is little wholesale market bulking or storage and thus no comparative data collected in market channels. Area is rarely exactly measured and these crops are often produced in multiple cropping systems. Information on agricultural systems is rarely produced. Nevertheless, the macro data is useful to indicate trends and to make some inferences about strategy.

BEANS

The rate of increase of bean production in Latin America (0.5%) has not kept up with the population growth of 2.8 percent; hence per capita consumption has declined and imports into the region have increased by 30 percent over the last decade. Brazil dominated Latin America bean production with 54 percent of production and Mexico has 26 percent. Yields have been stagnant or decreasing in most of Latin America; hence production increases have come principally from area expansion. However, Mexico and Colombia have significantly increased their yields due apparently to the success of their national programs in producing new varieties[10]. (see Figure 1 and Table 1).

For all the Latin American countries mean yields show extreme fluctuation (see Figures 2-5). This extreme annual variability is the principal chracteristic of Latin American bean production.

Any research strategy for bean production in Latin America has to concentrate on Brazil and Mexico. The extreme yield variation indicates the riskiness of bean production[11]. The next step in bean information gathering is a more systematic identification of the factors responsible for these extreme yield fluctuations.

CASSAVA

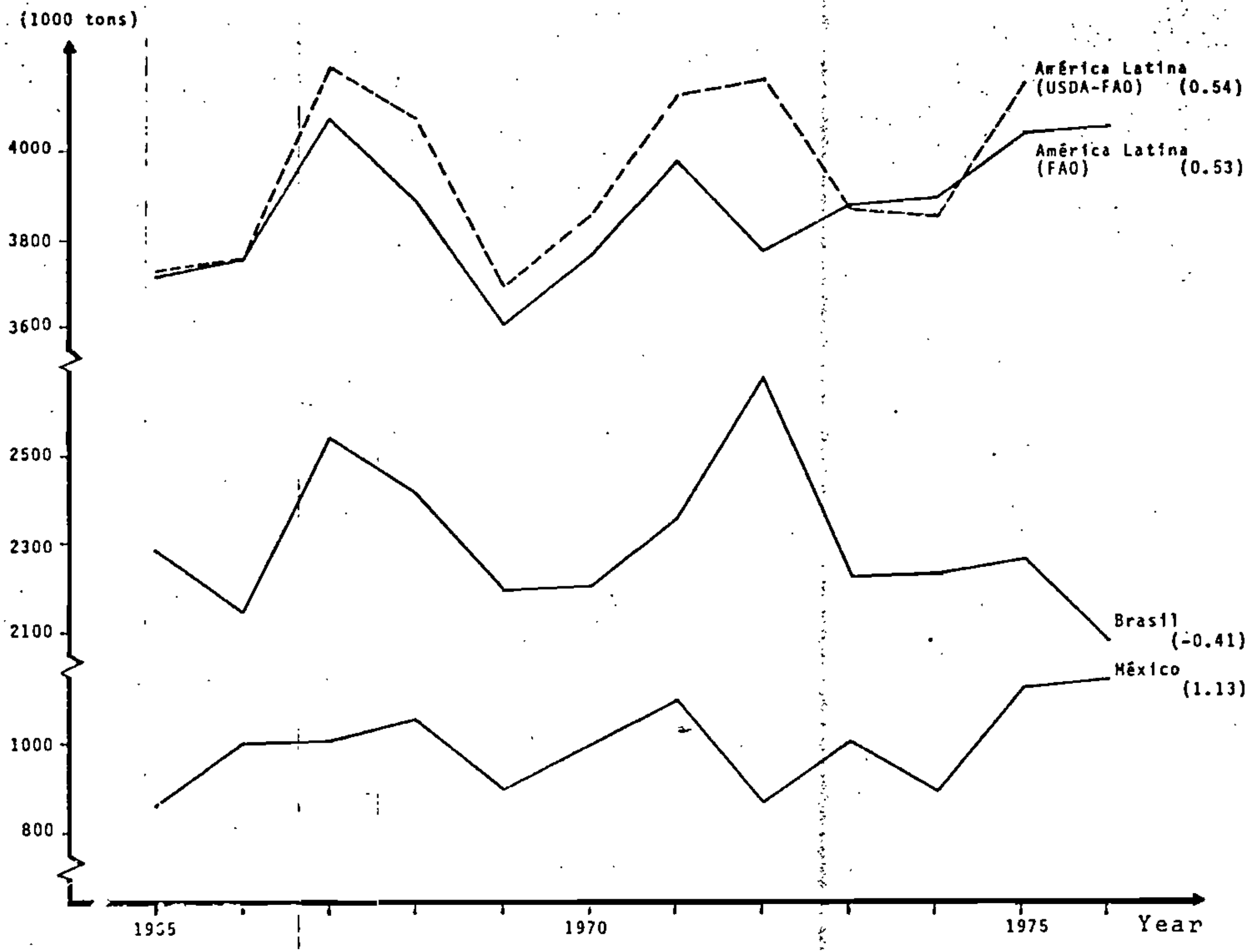
Cassava production in the 1963-75 period increased at an annual rate of 1.3%, well below the population growth rate. This rate of production increase was due to a more than proportional increase in area planted as yield levels declined on the average by 0.7% per year (see Table A-5 in the Appendix). Though the yield trend showed a slight decline there was little year-to-year yield variation, as is shown in figure 6. Moreover, average yield levels of approximately 13 tons per hectare were significantly below the genetic potential[12].

10/ J.H. Sanders y Camilo Alvarez P., pp. 18, 26.

11/ Bean area but not yields would be sensitive to changes in national policy or economic conditions. Substantial between year fluctuation in bean yields would not be expected in response to changes in relative or absolute profitability.

12/ Cassava yields in the CIAT regional trial network average approximately 25 to 30 tons per hectare.

Figure 1. Bean Production in Latin America, Brazil and Mexico, 1965-76[a].



(The number in parentheses is the geometric rate of increase over the period above).

a/Data on Bolivia, Cuba and Uruguay were omitted because of inconsistencies.

Source: J.H. Sanders y C. Alvarez P.

Table 1. Rates[a] of Increase of Bean Production, Area and Yields in Latin America, 1965-1976

Country	Rate of Increase of		
	Production	Area	Yield[b]
Brazil	-0.41	2.00	-2.41
Mexico	1.13	-2.07	3.20
Argentina	16.17	14.89	1.28
Guatemala	4.35	2.60	1.75
Colombia	6.77	3.26	3.50
Chile	-0.69	2.75	-3.45
Honduras	-0.48	1.72	-2.20
Nicaragua	0.79	-0.57	1.36
Haiti	1.01	0.24	0.77
El Salvador	8.93	6.27	2.66
Peru	-3.21	-2.04	-1.17
Paraguay	1.05	6.65	-5.59
Venezuela	-4.32	-1.75	-2.56
Dominican Republic	3.30	1.05	2.25
Ecuador	0.46	0.54	0.08
Cuba	0.35	0.58	0.93
Costa Rica	-2.21	-4.25	2.04
Panama	-6.33	-4.01	-2.32
Uruguay	-2.66	-0.65	-2.01
Latin America	0.54	0.84	-0.30

[a] These rates were estimated with a semi-log model,

$$LY = A+bX$$

where LY is the log to the base e,
"A" and "b" are parameters and
X is the trend

The "b" values are multiplied by 100 to give the percentage growth rates.

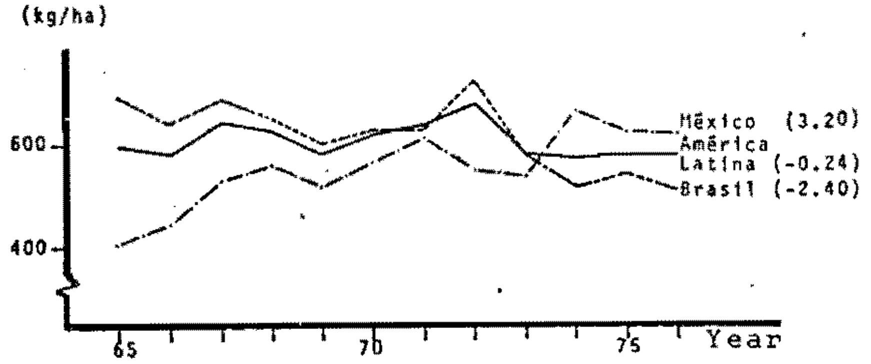
[b] Since $Y = A\frac{Y}{A}$ where Y is production, A is area, and $\frac{Y}{A}$ is yields, then $LY = LA + L\frac{Y}{A}$, where L is the log operator. Differentiating with respect to time gives

$$\frac{\partial Y/Y}{\partial t} = \frac{\partial A/A}{\partial t} + \frac{\partial (Y/A)/Y/A}{\partial t}$$

These are the rates of increase of production, area, and yields. The rate of increase of yields was calculated as the rate of increase of production minus the rate of increase of area.

Source: J.H. Sanders y C. Alvarez P.

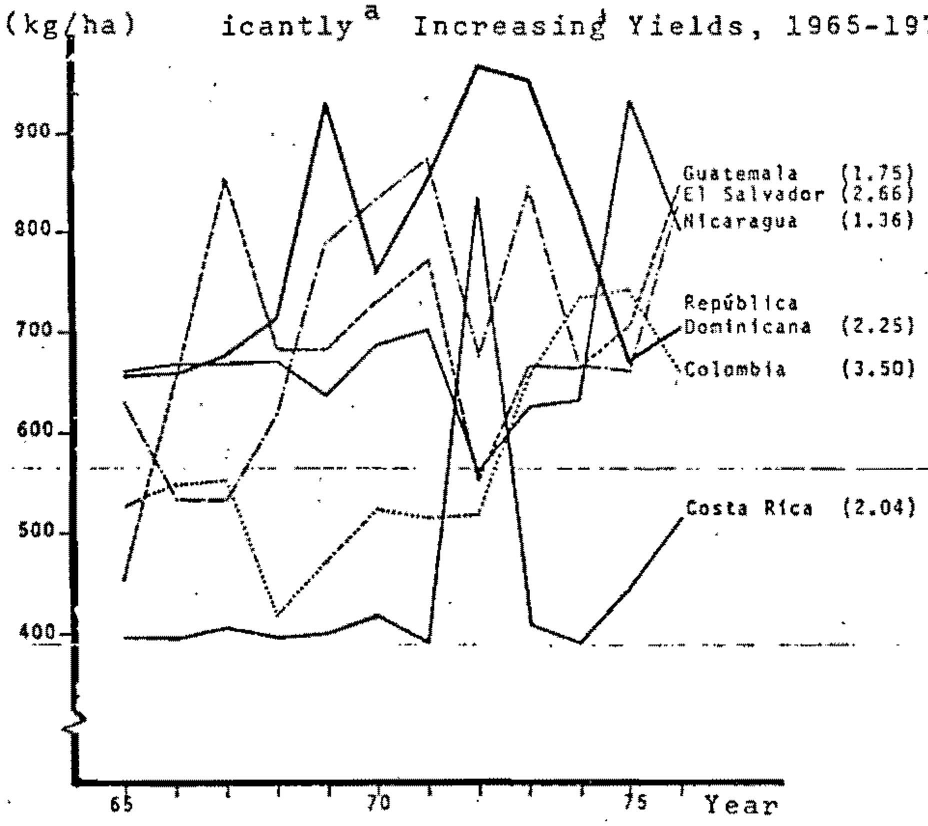
Figure 2. Bean Yields in Latin America, Brazil and Mexico, 1965-1976.



(The number in parentheses is the geometric rate of increase)

Source: J.H. Sanders y C. Alvarez P., op.cit., p.23

Figure 3. Bean Yields in Latin American Contries with Significantly[a] Increasing Yields, 1965-1974.

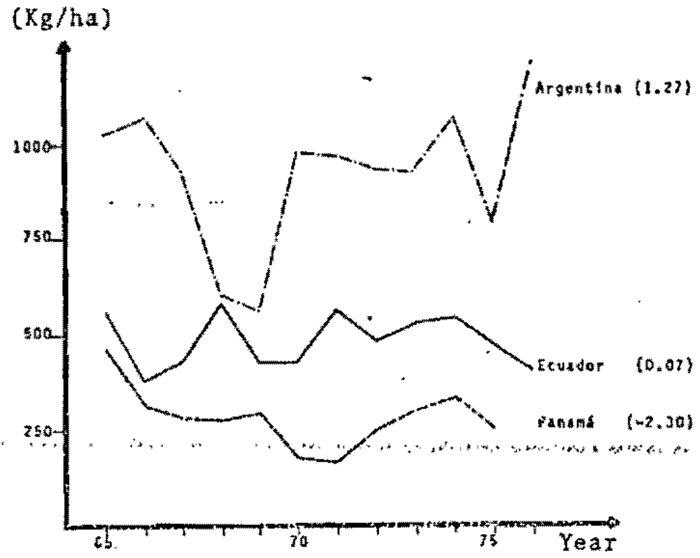


(The number in parentheses is the geometric rate of increase)

[a] The rates of increase were tested for statistical significance at the level of 80 percent with the "t" test. See the equation discussed below Table 1. Mexico also had statistically significant increasing yields but it was included in Figure 2.

Source: J.H. Sanders y C. Alvarez P., op.cit., p.23

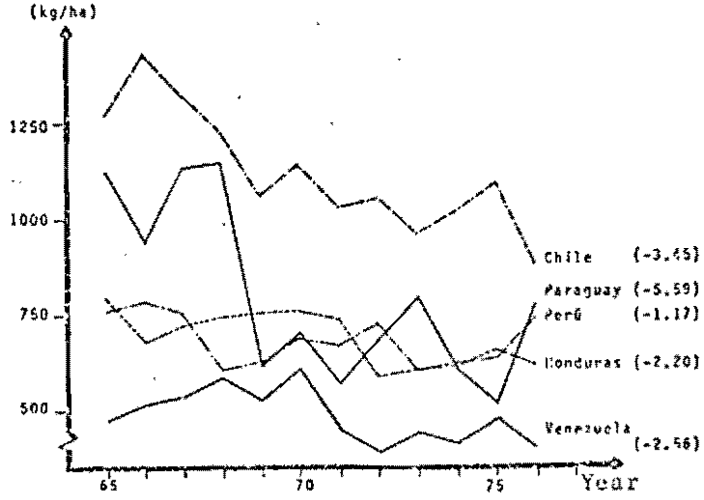
Figure 4. Bean Yields in Latin American Contries with Yields, 1965-76



(The number in parentheses is the geometric rate of increase).

Source: J.H. Sanders y C. Alvarez P., op.cit., p.24

Figure 5. Bean Yields in Countries with Significantly[a] Decreasing Yields, 1965-76



(The number in parentheses is the geometric rate of increase).

a/The rates of decrease were tested for statistical significance at the level of 80 percent with the "t" test. Brazil also belonged in this group.

Source: J.H. Sanders y C. Alvarez P., op.cit., p.24

Low and relatively static yield levels and marginal production increases through expansion in area, indicative of relatively low supply elasticities, are suggestive of a low level production equilibrium characteristic of much small-scale agriculture in developing countries.[13]

Cassava production, though widely distributed throughout the tropical region of Latin America, is concentrated in Brazil, whichaccounts for 85% of total production. Adding in the other two major producers, Colombia and Paraguay, raises this figure to 92% (see Table A-4 in the Appendix). Within each of these countries cassava production is further concentrated in particular regions, the Northeast of Brazil being the largest producing area in Latin America. Since cassava yields reasonably well under a wide range of agro-climatic conditions, competition with other crops heavily influences where cassava is grown. Low prices of cassava relative to other crops (see Table A-15 in the Appendix) would suggest that cassava's comparative advantage is in the poorer agricultural areas where there are few other cropping alternatives. As cassava is not easily mechanized, indications are that cassava tends to be concentrated not only in poorer agricultural areas but also where small-scale agriculture as well predominates, eg. in the Northeast of Brazil.

A low supply elasticity, falling per capita supplies, and declining yield levels would be a principal means of maintaining per capita consumption

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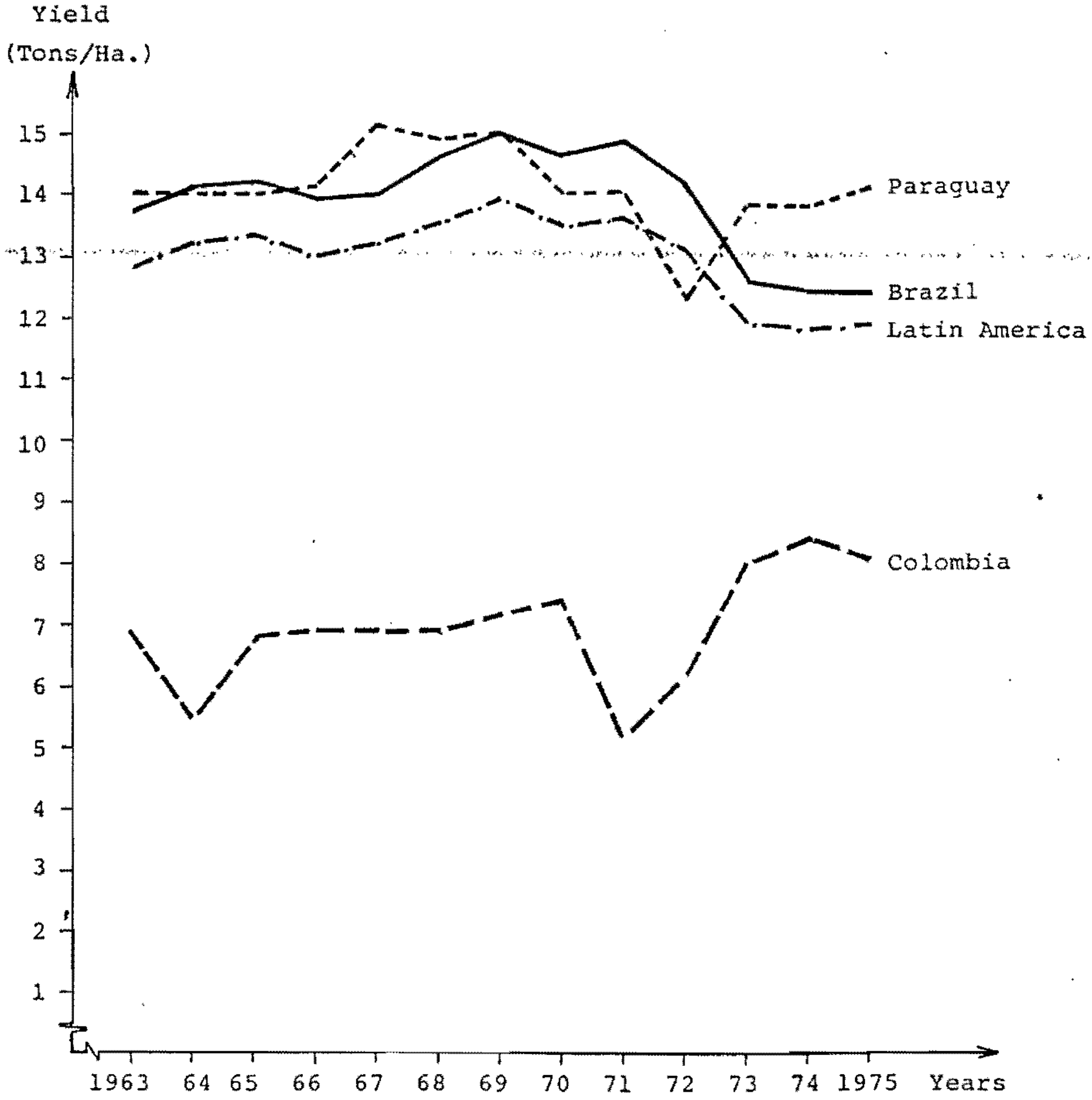
[13] Cassava, more so than most other annual crops in Latin America, is produced primarily on small-scale farms. See J.K. Lynam, "Options for Latin American Countries in the Development of Integrated Cassava Production Programs", p. 222-223.

Figure 6. AVERAGE CASSAVA YIELDS IN LATIN AMERICA AND THE THREE MAYOR PRODUCING COUNTRIES, 1963-1975.



Source: Food and Agricultural Organization of the United Nations (FAO), Anuario de Producción, Rome, 1973 and 1975.

levels[14]. However, such productivity increases must be derived from small-scale farm systems and under relatively unfavorable agricultural conditions. Improving productivity requires an understanding of the factors that are constraining yields and this must be done through farm level data.

The Micro Stage:

Farm level constraints to the introduction of new technology have been measured in two ways, the Benchmark and the Gap approaches. In the Benchmark approach variation in yields on farmers' fields with present cropping systems and varieties is analyzed in order to identify factors limiting yields 15/. The Gap approach attempts to explain the difference in the yields under the new technology between the experiment station and farmers' fields. This technique has been utilized in the Philippines in regions where the new rice varieties of IRRI have been disseminated 16/, but can also be undertaken with farm

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14/ It might be argued that area expansion is a possibly cheaper and more equitable means of expanding cassava production. The potential for on-farm area expansion is probably limited. Cassava is basically a small farm crop which implies that labor constraints at critical periods, farm diversification, and in some instances limited cultivable area are limiting factors to cassava area expansion. New land development for cassava, on the other hand, is restricted by cassava's high perishability, high transport price, and the long distances from urban centers. Productivity increases appear to be a more efficient means of maintaining per capita consumption levels.

15/ This technique is expected to understate the yield losses of new, higher yielding varieties unless the new variety were more resistant or tolerant to the specific constraint.

16/ R.W. Herdt and T.H. Wickham.

level experiments[17/]. At the time of CIAT's farm level survey in Colombia neither new varieties for release nor a clearly identified "intermediate technology" [18/] were available in the Bean and Cassava Programs. Hence, it was necessary in the initial phases of technology design to use the Benchmark approach.

Farm level surveying of productivity constraints in beans and cassava was undertaken in 1973-1975 with teams of agronomist trained by their respective programs to recognize and measure disease, insect, and weed incidence, to take soil tests, and to measure all inputs and yields.

BEANS

One hundred and seventy-seven farm interviews were made in the principal zones of Colombian bean production. Colombian bean production can be divided into two principal systems (Table 4). There is a large farm, single cropping, high input use system for export production (black beans) in the Valle. In the other three regions farms are smaller, there is less use of input and more use of multiple cropping, and production is for domestic consumption (red beans). There is surprizingly little difference in bean yield equivalents between the two systems in spite of the greater specialization and higher input use inf the Valle[19/].

[17/] For an example of the use of farm level experiments see International Rice Research Institute, Constraints to High Yields on Asian Rice Farms, An Interim Report, Los Baños, Philippines, 1977.

[18/] See footnote 7 for a description of "intermediate technology".

[19/] Elsewhere the single cropping and multiple cropping systems were compared. One explanation for a multiple cropping system or at least for diversification is as a risk avoidance mechanism. Large farmers due to greater wealth can take more risks. They utilize more inputs and specialize. See Camilo Alvarez P., "Análisis Económico..." for a description of the two systems.
The risk avoidance hypothesis was tested with two years of experimental data from CIAT from 20 experiments. It was found that at the Colombian prices single cropped beans were more profitable and riskier than the beans-corn crop combination. See C. A. Francis and J.H. Sanders.

Table 4. Characteristics of Bean Producers in the Four Colombian Regions Studied, 1974-75.

Mean Farm Characteristics	REGIONS			
	Valle	Huila	Nariño	Antioquia
Total area[1] (has)	91.7	29.5	9.2	4.4
Crop area (has)	40.5	6.8	3.1	1.7
Bean area (has)	22.6	4.1	1.8	1.5
Systems of Bean Production[2]	single cropped	30% single *(Level areas)* 70% beans/corn *(Sloping land)*	bean/corn	54% beans/corn 46% beans/corn/potatoes beans/corn/arracacha others
Type of bean	Black-Bush	Red-Bush	Red-Bush	Red-Climbing
Yields for single cropped beans (kg/ha)	906	805	-	-
Yields of bean equivalent (kg/ha)[3]	[4]	834	732	723[5] 2754[6]

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[1] This is the total area available to the farmer.

[2] With more than one system of beans, percentages refer to the number of farmers in each category.

[3] Bean equivalents are calculated by utilizing prices of other commodities relative to beans as follows:

$$\text{Yield(beans)} + \frac{\text{Price (corn)}}{\text{Price (bean)}}\,\text{Yield(maize)} = \text{Yield(bean equiv.)}$$

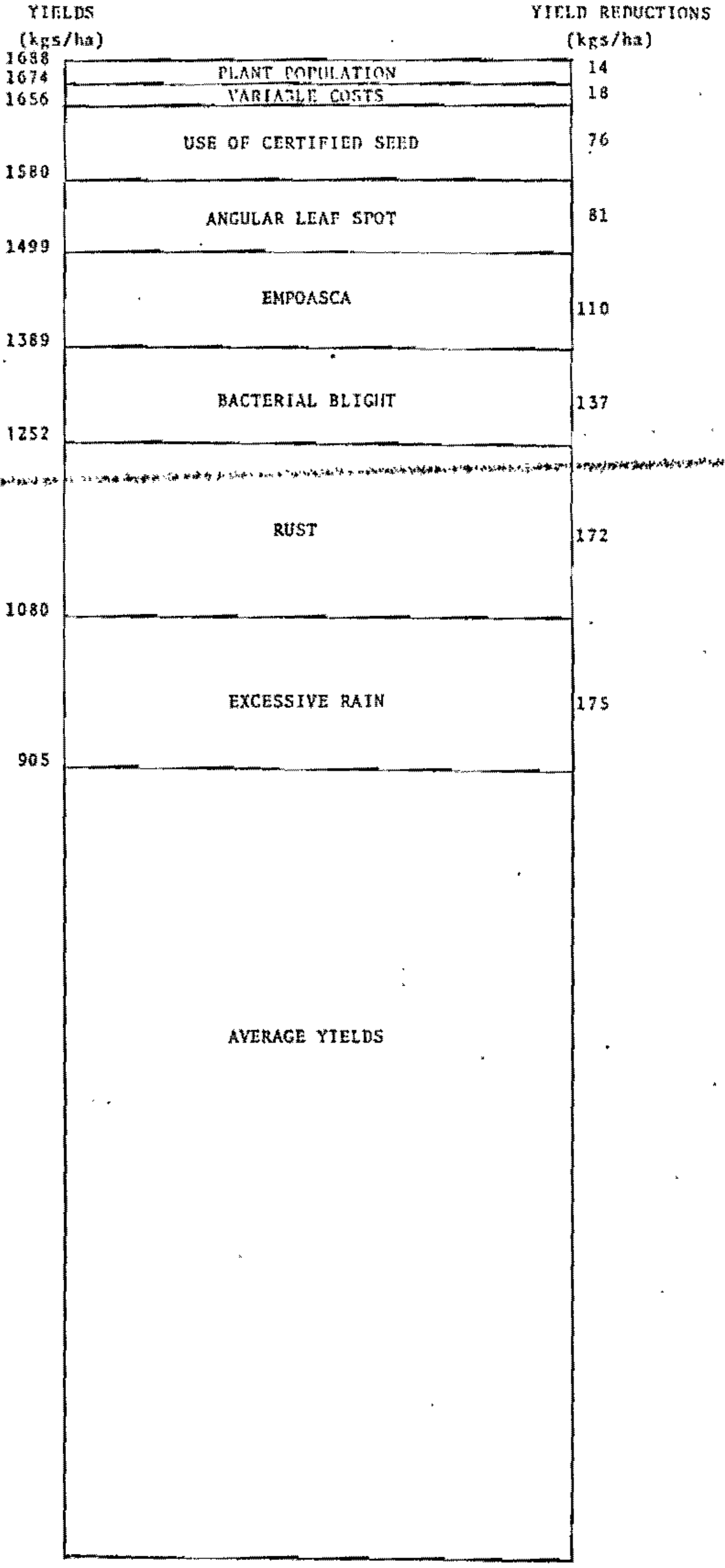
[4] The bean crop in the Valle region can be grown in 3.5 months and followed by another crop.

[5] Refers to the first intercropping combination of beans/maize.

[6] Refers to the second intercropping combination of beans/maize/potatoes, beans/maize/"arracacha" and others.

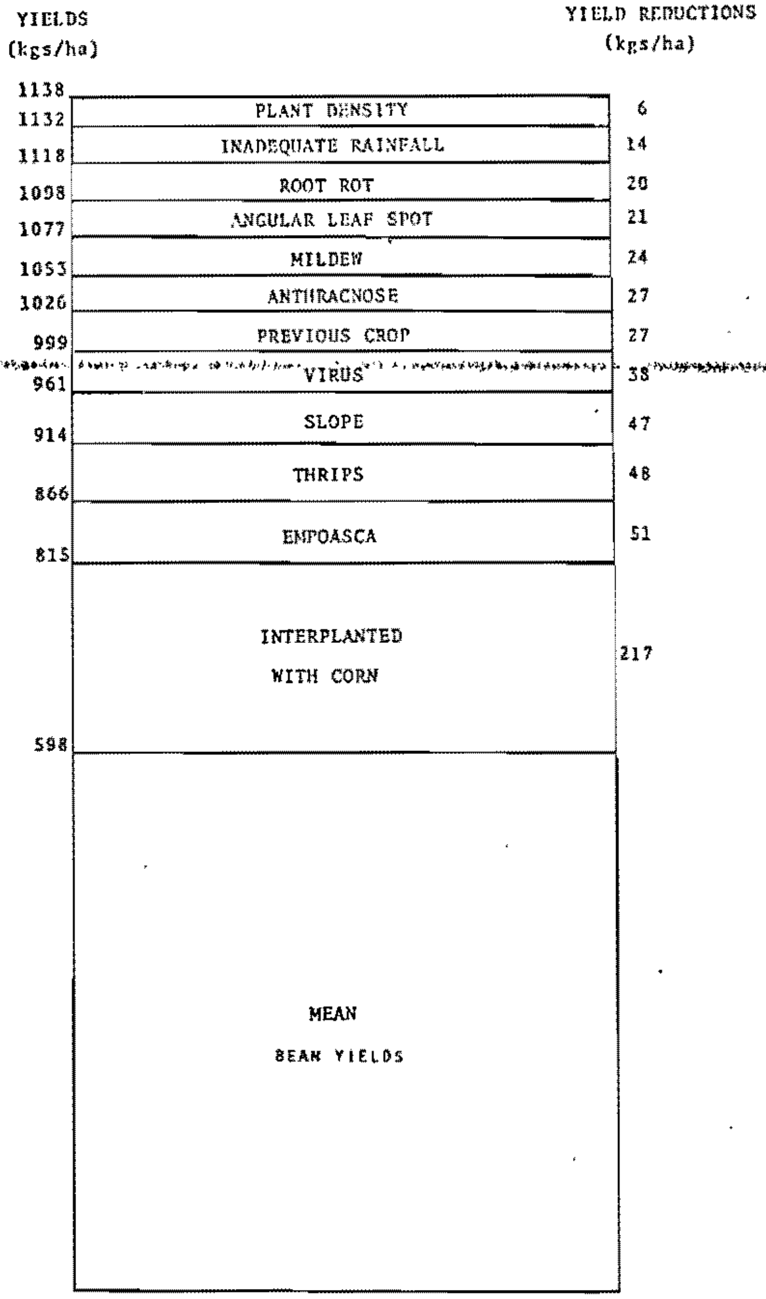
Source: CIAT, Annual Report 1976, Cali, Colombia, p.A-74.

FIGURE 7. BEAN YIELDS AND FACTORS RESPONSIBLE FOR YIELD REDUCTION, THE CAUCA VALLEY, 1974.



Source: P. Pinstrup-Andersen, N. de Londoño and M. Infante,

FIGURE 8. BEAN YIELDS AND FACTORS RESPONSIBLE FOR YIELD REDUCTIONS, HUILA-NARIÑO, COLOMBIA, 1975



Source: N.R. de Londoño et. al.

Table 5. The Estimated Value of the Production Losses from the Principal Diseases and Insects in Colombia, 1974-75.

	Estimated Value of Production Loss in	
	Valle	Huila and Nariño
Diseases	(1,000 dollars)	
Rust	1,171	
Bacterial Blight	933	
Angular Leaf Spot	552	222
Virus (Common Bean Mosaic[a])		400
Anthracnose		282
Powdery Mildew		250
Root Rot		207
Insects		
Empoasca	749	537
Thrips		510

a/This was not a positive identification as there are some subtle differences between the types of viruses, which the interviewing agronomists were unable to differentiate.

Source: N.R. de Londoño, et.al pp. 17, 18.

The constraints limiting bean yields in the types of systems were evaluated utilizing production function analysis (Figures 7 and 8). Assuming that the samples were representative of the regions the economic losses associated with the disease and insect pests in one production season in these regions were substantial (Table 5). There are a series of disease and insect pests attacking beans with differences between the two regions.[20] There appears to be a very high payoff of obtaining resistance to any one or a combination of the above constraints.[21]

Approximately, 95 percent of the beans produced were sold with home consumption less than one percent of production[22]. With the high bean prices in Colombia and the risk from storage insects the farmer did not obtain the nutritional benefits of increase bean consumption.

CASSAVA

Three hundred cassava producers in five different regions in Colombia were interviewed. Two regions (zones I and III) were mountain areas but where cassava was produced below 1500 meters. The other regions were a high, rolling valley region within the Andean range where coffee predominated (zone II), a coastal area (zone V), and a "new land" expansion area in the eastern jungle and savanna region (zone IV) (see Figure A-3 in the Appendiz). The sample incor-

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20/ Since these results are time and location specific, this type of snapshot of yield constraints would be much more useful if it could be obtained for a series of regions over a longer time period. However, these field surverys are expensive. Each of the 177 farms was interviewed three or four times by agronomist trained to identify the insect, disease and weed problems of beans.

21/ Norha Ruiz de Londoño, et al.

22/ Camilo Alvarez P., "Análisis Económico..." p. 14.

porated the diversity in agro-climatic conditions which prevails in Colombian cassava production[23].

The study found that cassava production was based upon a minimum of purchased inputs and relied principally upon farmer-owned resources. Purchased inputs (insecticides, fertilizers, purchased seed material, herbicides, fungicides and tractor rental) accounted for only 8 percent of the total variable costs, with family labor being costed at the prevailing wage rate (see Table 6). There were no clearly distinguishable categories of production systems, as was the case in beans. The only distinction useful in this context is between zones I, III and V which were predominately small-scale producing areas and zones II and IV which were predominately medium-to-large scale producing areas. The small-scale producers on the average had a higher per hectare labor utilization but operated at a lower cost level than large-scale producers. Multiple cropping with cassava tended to be more important in the small-farm areas although even in these areas monocropping predominated. However, the differences in input utilization and management systems between small and large farm areas were not large enough to account for the difference in yields that occurred.

The sample survey confirmed the low productivity of cassava production in Colombia. Average yield levels were 6.2 tons per hectare (fresh weight) as compared with consistent yield of over 25 tons per hectare of CIAT selections in the Colombian regional trials.[24] The variation around this mean was large, a standard deviation of 6.5 tons., which reflected principally the yield differences between producing regions (see Table 8). As differences in input utilization were not significant, other productivity constraints appeared to

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23/ Zones I and III accounted for 46 percent of total cultivated cassava area in Colombia; zone II, 8 percent; zone IV, 13 percent; and zone V, 33 percent.

24/ CIAT, Annual Report 1976, p. B-51.

Table 6. Characteristics of Cassava Production Systems in Colombia, 1973-75

	Unit	Zones					Average
		I	II	III	IV	V	
Farm Size	Ha.	6.1	39.1	11.1	59.4	18.3	26.9
Utilizable Land	Ha.	4.1	38.1	5.4	45.9	15.2	21.9
Area in Crops	Ha.	3.4	24.7	3.4	11.6	7.0	10.4
Area in Yuca	Ha.	2.8	6.9	2.0	9.5	4.0	5.1
Area in Pasture	Ha.	.7	13.4	2.0	34.3	8.2	11.5
Total Labor Utilization	Man-days/Ha.	105.4	81.2	82.1	65.4	90.8	85.2
Percent of Farmers Using Mechanized Land Preparation	%	0	76.6	3.4	76.4	54.5	41.3
Variable Cost	Col.Pesos/Ha.	3068	5019	3954	4096	3543	3968
Purchased Inputs as a Percent of Variable Cost	%	10	12	4	8	5	8

Source: Calculated from R.O. Diaz y P. Pinstrup-Andersen, p. B-12 (see Figure A-3 for a map of these Colombian production zones).

be responsible for the yield variation.

Table 8. Yields of Cassava by Colombian Zones, 1973-1975 (see Figure A-3 in the Appendix).

	Average	Standard Deviation of Yields
Zone I	4.4	3.3
Zone II	12.6	9.8
Zone III	3.0	2.6
Zone IV	6.2	3.8
Zone V	3.7	2.8
Average	6.2	6.5

Source: R.O. Díaz and P. Pinstrup-Andersen, p. I-2.

Estimating a detailed production function, the factors limiting yields of cassava were delineated. The "relevant constraints" were soil factors and diseases (see Table 9). Purchased inputs, plant population, and weed control were not significant, which would indicate that yield limiting factors were not due to differences in management and farming systems. Rather, interregional differences in soil and climate, which were in turn associated with favorable environments for different pathogens, appeared to be more important than variation in input use.[25]

Where the principle cassava diseases were found, there was a large reduction in yield, but none of these diseases were very widespread. Control of either Superelongation or Phoma Leaf Spot would result in an increase of almost 3.5 tons per hectare on affected farms. Control of Cassava Bacterial Blight would have added a further 0.75 tons to yields on affected farms. However, none of these diseases affected more than five percent of the cassava area. Thus, based on this single period sample, control of these diseases would increase average yields in the country by no more than 5 percent or 0.3 tons per hectare (see Figure 9). Only for individual farmers in areas where these diseases were prevalent would disease control have had a large impact on yield. Though not a major constraint on yields, pathogens did have the potential of becoming a serious constraint, especially with the introduction of new varieties.

Intercropping also resulted in a yield reduction of 1.8 tons per hectare. As 31 percent of the cassava area was grown in association with other crops, switching to monoculture added only 0.6 tons to national yield levels. Moreover, profitability and labor constraint considerations enter into whether such a recommendation should be made. If cassava and maize (the major form

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25/ Experimental trials at CIAT have shown that cultural practices such as plant population, weed control, and use of fertilizer do have a significant impact on yield. These findings would not contradict the conclusions here as variation in cultural practices would be expected to have an impact on yield levels of the high yielding varieties used at CIAT. Moreover, within this farm sample there was a relatively small variation in cultural practices. This would imply that cultural practices may become a much more important factor with the release of new high yielding varieties and that there is a potential impact with these intermediate technologies using regional varieties. See CIAT, "Cassava Production..."

Table 9. Yield Losses in Cassava for the Different Colombian Regions, 1973-1975.

Factors	Average Losses[1] (Ton/ha.)	Percent of Area Affected	Per Hectare Losses		Estimate of Total Losses	
			Ton/ha.	%[2]	Tons[3] (million)	Value (US$)[4] (million)
Superelongation	3.45	4	0.13	2.2	22.77	1.40
Leaf Spot	3.41	4	0.13	2.1	22.44	1.38
Lack of Phosphorus	2.21	63	1.39	13.2	229.84	14.15
Planting System in Association	1.89	31	0.59	8.6	97.02	5.97
Soil Acidity	1.74	58	1.01	13.9	166.65	10.26
Leaf Cutter Ants	1.20	2	0.02	0.4	3.96	0.24
Bacterial Blight	0.75	5	0.04	0.6	6.27	0.38
TOTAL			3.31	34.8	548.95	33.78
Soil Texture	1.46	75	1.09	14.9	180.67	11.13
Excess Rainfall	0.77	48	0.37	5.6	61.05	3.76

[1] Average losses for farmers with the problem.

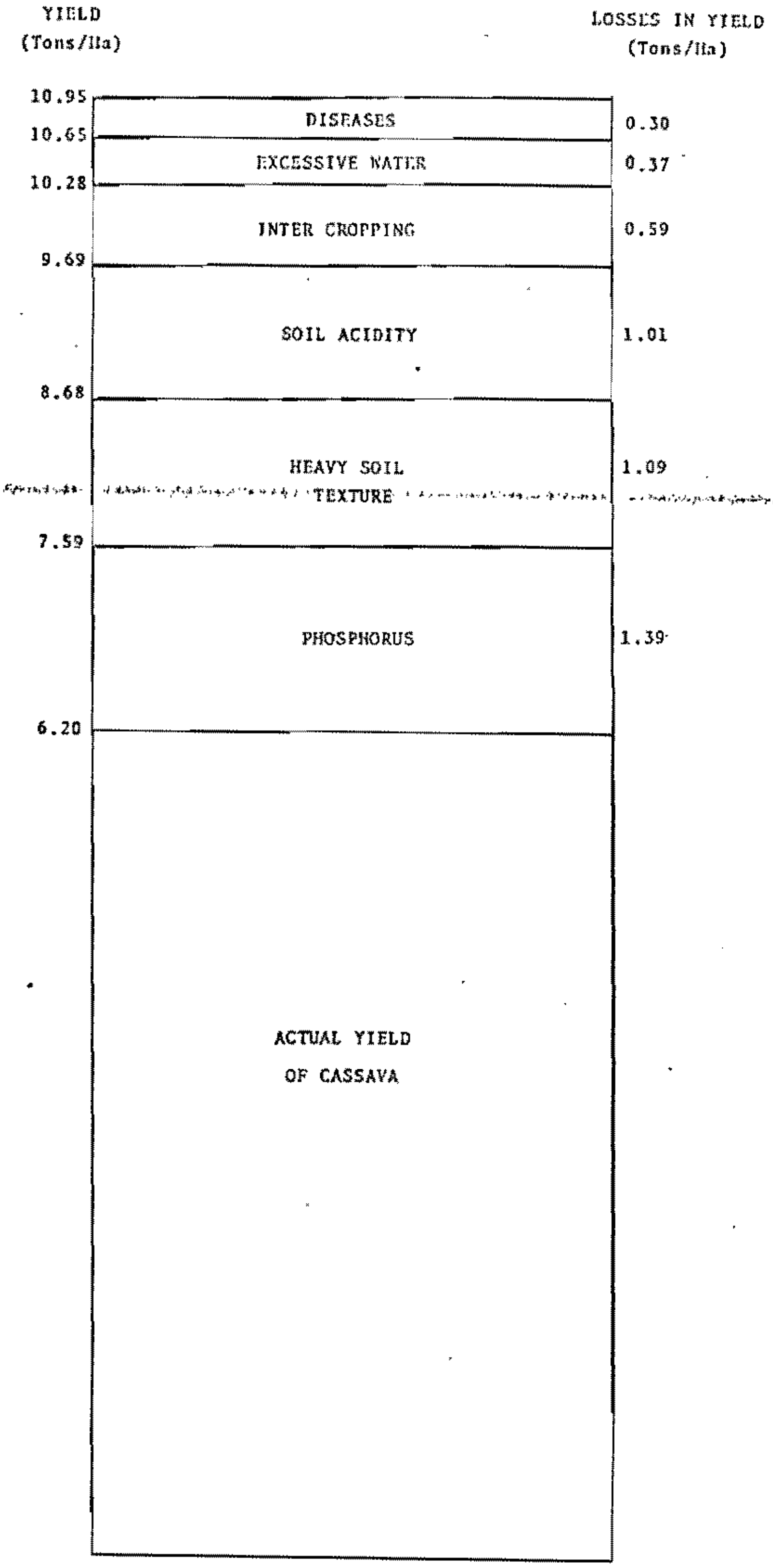
[2] This percentage was based upon the average yield plus losses due to the particular factor. The average yield for Colombia in this year was 6.2 tons/ha.

[3] This estimate was based upon the 165,000 hectares of cassava planted in Colombia in 1974.

[4] This estimate was based upon an exchange rate of Col.$25/dollar.

Source: R.O. Diaz and P. Pinstrup-Andersen p. J-5.

FIGURE 9. CASSAVA YIELDS AND FACTORS RESPONSIBLE FOR YIELD REDUCTIONS, COLOMBIA, 1973-1975.



Source: Calculated from R. O. Diaz and P. Pinstrup-Andersen, p.J-5.

of crop association) intercrop yields are expressed in terms of cassava equivalents, differences in yields between monoculture and intercropping were insignificant[26].

As Figure 8 illustrates, differences in soil factors accounted for much of the difference between current average yields and potential yields based upon current varieties and systems of production. High soil acidity, low levels of phosphorous, and heavy soil texture all contributed to lower yields.[27] From 60 to 70 percent of the cassava in the sample was grown under these conditions. The principal area where these poor soil conditions were not found was in zone II, the zone with the highest yields.[28]

Most cassava was thus grown on either highly acidic or low fertility status soils or both. Cassava does perform relatively well compared to most other crops under such adverse soil conditions. Since cassava is grown primarily on soils unsuitable for other crops, the crop appears to have a comparative advantage under such unfavorable agricultural conditions.

Removing all the factors that constrain productivity raises yields to only 11 tons/hectare, well below the 25 ton average of initial selections in CIAT's regional trials. The principal constraint on increasing productivity in cassava production appeared to be the genetic yielding ability of currently employed varieties. Moreover, cassava was grown under relatively poor

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26/ Camilo Alvarez P., "Análisis Comparativo..." pp. L-1-24.

27/ In the regression all three factors entered as dummy variables. Phosphorus was stratified above and below 15ppm, soil acidity above and below a soil pH of 5.0, and soil texture between the predominance of light or heavy texture soils.

28/ A dummy variable was put in the regression equation for zone II. As expected the coefficient was significantly different from zero.

agro-climatic conditions, especially acid, infertile soils. The program, therefore, faced a difficult choice in developing high yielding varieites: either selecting varieties for high genetic yield potential under very good agro-climatic conditions, thereby potentially tying yields to favorable production conditions or to fertilizer utilization, or selecting varieties for specific tolerances to unfavorable agricultural conditions.

In this case the probability of adoption of a high input technology had to be weighed in research design, especially any technical package that necessarily relied on high fertilizer inputs. Disease and climatic factors make fertilizer use a risky investment and, as well, cassava production areas were in general small-farm areas where capital constraints play a large role in adoption.[29] A minimum input breeding and selection strategy was therefore chosen. However, there was no empirical base for making a decision about the environmental conditions for selection, which thus had to be left to the critical inferences of the scientists.

The Critical Inference Stage

The available Macro and Micro data indicate some general directions in both programs but still leave gaps in the definition of the "relevant constraints". These gaps have to be bridged by inferences about Latin American production of these two commodities. These inferences come from members of the team

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[29] Only 20 percent of the farmers in the sample used fertilizer. Fertilizer utilization was at low dosage levels and was encountered primarily in the larger farm areas of zone II, where climatic conditions were as well both favorable and stable, and to a lesser extent among the farmers in zone IV. When there is adequate land for rotation or resettlement, high fertilizer prices, and an unknown response to fertilizer, it is not surprizing that most farmers do not utilize fertilizer. Some mining of the available nutrients would be expected, thereby requiring shifting land use. This was collaborated by the sample as only 15 percent of the farmers planted cassava on land that had previously been in this crop and 55 percent of the farmers planted cassava on land that had formerly been in pasture.

and others with experience in Latin America. Obviously, it is important to verify or reject these inferences with the collection of better field data in the future.

Finally, the definition of a "relevant constraint" is not sufficient for it to be included in research design. The other necessary component is the subjective decision of the breeder that the desired characteristics to overcome the "relevant constraint" can be successfully incorporated into the new material. For example, it is not possible to breed for vertical resistance to a given disease if none of the germplasm collection shows resistance.[30] Moreover, as the number of "relevant constraints" increases, the length of the breeding process is extended and the probability of success declines. Efficiency questions about the breeding process often arise and priorities must be set. Again the breeder must make the relevant judgement between number of characteristics sought and probability of success.

BEANS

The inferences for Latin America are the following:

A. Bean color preferences are very different between countries and fairly rigid.

B. Bean production is predominantly encountered on small farms. Exceptions to this are bean production in Chile and Argentina (3.6 percent of Latin

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[30] This potential gap between definition and incorporation of "relevant constraints" in the breeding process becomes especially crucial when breeding for disease and pest resistance. It is quite likely that the broad objectives of a breeding program at international centers - that is, biological efficiency in plant type, wide adaptability, and stable, multi-resistance- are inconsistent with one another because of differences in breeding methodologies necessary to achieve any one objectice.

American bean production) and on the Peruvian Coast. Occasionally with high export or domestic prices larger producers have temporarily moved into bean production. This occurred in the Valle of Colombia in the sixties and early seventies[31].

C. The small bean producers use few inputs but they locate on the more fertile soils. These farms are often on slopes with substantial inclines but bean producers avoid the lowland, tropical soils.

D. Most bean production is either in associated or relay cropping with corn. In the former system there is potentially direct competition for light and nutrients as the crops are planted at approximately the same time. At the low input levels customarily utilized the competition is resolved by very wide spacing. In the relay system the beans are planted alongside the mature corn to utilize the stalk for support. There is little competition in this system.

E. Beans can be divided into four ideotypes[32]:

   a) A short season bush bean to fit into a rotation with irrigation or to take advantage of a short rainfall period.

   b) A long season bush bean. This is a high yielding type suitable for large scale, mechanized production but sensitive to rainfall variation.

   c) A prostrate bean with more resistance to rainfall stress. This is very useful when water control is not available and rainfall is variable.

31/ N.R. de Londoño et al, pp. 4,5.

32/ This extremely useful division was made by Douglas Laing, Physiologist of CIAT Bean Program. For further detail see CIAT, Annual Report 1976, pp. A-67, 68.

d) A climbing bean. The long growing season enables high yields to be achieved. This type is predominantly encountered on small farms at higher altitudes.

F. The major disease problems in Latin America are Common Bean Mosaic, Common Bacterial Blight, Rust and Anthracnose. The major insect pests are Empoasca[33] and storage insects (Bruchids) (see Tables A-13 and A-14).

The crucial operating decisions of the Bean Program were that beans of many colors and plant types would be sought. Secondly, high input packages would not be relevant unless beans were able to move into the better soil areas of Latin America where large farmers predominated. Since beans had not been able to capture these areas previously and high value export crops with a long tradition of research and developed infrastructure for marketing would have to be displaced, the potential for beans to enter these areas on anything more than a short term basis was considered to be a "long shot". Hence, a diversification strategy was necessary to hedge against the possibility that a new Type B variety would not be sufficiently profitable to break into the prime agricultural areas or to stay in these areas when high prices declined.

Given the riskiness of bean production and the prevalence and seriousness of a series of diseases and one insect, the principal objective of the research strategy would be to achieve resistance to a multiplicity of diseases in beans

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33/ These inferences in F. were based upon the identification by the scientists working in bean production in Latin America of the diseases and insects in their respective countries (see Table A-13 and A-14). After this survey was taken Golden Mosaic became an important problem in the principal bean production regions of Brazil and Central America.

of various colors and ideotypes. Both vertical and horizontal resistances were sought depending upont the particular pest[34]. The use of some vertical resistances in beans can be justified for the following reasons:

1. the discontinuous nature of bean production and the multiplicity of ideotypes should provide sufficient epidemic control should a particular vertical resistance break down, and
2. there are a number of methodological problems with beans in breeding for horizontal resistance.

The first point stresses the fact that the spread of bean diseases is limited because beans in Latin America, unlike grains, are produced in widely separated pockets. Also, it is unlikely that any one bean variety will become widely distributed due to preferences for different colors and ideotypes. Thus, any breakdown of vertical resistance will tend to be localized and thus more easily managed with less economic stress. Secondly, sources resistance to many different species of diseases are available in beans. Even if a vertical resistance breaks down, the benefits of a few years of successful protection are often much greater than the costs of the resistance breeding. In one season in only the Valle area resistance to Rust would have increased the value of bean production by over one million dollars. Vertical resistance may be necessary for those diseases, such as Common Mosaic, Anthracnose, Bacterial Blight, and Angular Leaf Spot, which are seed transmitted.

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[34] In Rust and Empoasca tolerance or multi-gene resistance is presently being sought simultaneously with vertical resistance to Rust. For a discussion of the characteristics and trade-offs between vertical and horizontal resistances see R.A. Robinson, "The Pathosystem...".

CASSAVA

The inferences for cassava in Latin America are the following:

A. No sustained research on genetic improvement of cassava had been undertaken in Latin America. Moreover, the diversity of the germplasm collection suggested that there was substantial scope for increasing yielding ability through genetic means. The primary priority of the breeding program was to develop widely adapted, high yielding varieties.

B. Improving the efficiency, and thus the yield, of the plant by selection for harvest index (the ratio of root weight to total plant weight) became the major breeding objective. However, since this selection process reduced "excess" leaf formation and thus the tolerance of the plant to pathogen attack, disease (Cassava Bacterial Blight and Superlongation) and pest (thrips and mites) resistance became the second breeding priority.

C. The breeding methodology relied on stringent parent selection, controlled crosses, and one primary selection for genetic yielding ability under good agricultural conditions and a second selection in a high-pressure disease environment. The basis for genetic improvement with each cycle is principally proper selection of parent with desired characteristics and for disease resistance, selection under high pathogen pressure.

D. The principal target areas are the more unfavorable agricultural production zones. The principal target group is small-scale farmers. New technology thus was based on a minimal level of purchased inputs and promising varieties required evaluation under the range of typical production conditions. Thus, the regional and international yield trials were crucial to identification of high-yielding widely adapted varieties.

E. The fresh human consumption market is considered to be the primary source of demand and as such consumer characteristics are quite rigid. Post-harvest durability is a key factor influencing quality and therefore retail price. Other characteristics are HCN content, root size, and starch and fiber content. All, except root size to a limited extend, are genetic characteristics.

F. Given the genetic yield potential of cassava, the possibility existed of flooding urban markets for fresh cassava and causing prices to drop precipitously. Expansion of alternative markets appeared to be necessary requiring simultaneous development of processing and utilization technology.

Plant characteristics necessary for higher yielding ability under conditions of poor soils and climate and few inputs were perceived to be the principal "relevant constraints". Cassava was expected to have a reasonably high level of horizontal resistance to the major diseases and pests, thereby allowing the primay focus of the breeding program to be put on yielding ability[35]. The selection and breeding strategy for cassava is thus "to produce hundreds, or thousands, if possible, of recombinations which yield more than 50t/ha at CIAT from as many diverse parents as possible and to evaluate these hybrids

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35/ See R.A. Robinson, "The Pathosystem...", pp. 16-17. The reason for the high level of horizontal resistance in cassava is due to the fact that vertical resistance did not have a chance to evolve in cassava; rather, natural selection had to be based solely upon horizontal resistance. Because cassava is vegetatively propagated (a clone) and is not season bound, there is both spatial and sequential continuity of identical host tissue. If resistance were vertical and broke down there would have been no evolutionary survival value, thus the necessity for horizontal resistance in its evolution. This factor provides support for the usual generalization that cassava is highly resistant to diseases and pests, though as CIAT trials have shown this may not be so for any one particular cultivar against all pathogens. This result would be expected to be due to differences in the pathosystems in which the different varieties evolved.

under great environmental diversity, and at the same time, incorporating as much disease and pest resistance as possible in the whole population"[36]. This strategy thereby selects for high genetic yielding ability and is designed to select for yield stability and wide adaptability by evaluation over varied environmental conditions.

Research on low cost cultural practices including plant density, planting technique, disease, insect, and weed control, and fertility maintenance has also been stressed. All of these focus on the quick release of new technology packages that combined with the high yielding cultivar will be adaptable to a wide range of tropical conditions. The hybrids tested and selected under the diverse conditions of the regional trials will then be used in the second phase of the breeding program to incorporate disease resistances as well as characteristics important in final demand, especially high starch, low HCN content and post-harvest durability. Breeding for cassava characteristics that correspond to market preferences thereby becomes an important component of the research strategy. Post-harvest technology development as well becomes essential in order to ensure that increased yields and production are not constrained by a large price decline due to limited fresh market demand potential.

CONCLUSIONS

Information processing is a continual process in International Center Programs. The principal focus is to achieve a more solid empirical support (or rejection) of the critical inferences. First, these are made explicit as in this paper and then evaluated with more systematic data collection.

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[36] CIAT, Annual Report 1976, p. B-40

Since cassava is a simpler commodity than beans due to fewer ideotypes and fewer differences in taste preferences, fewer inferences were necessary. Beans require much more data collection to evaluate the relative importance of disease and insect pests, ideotypes, and tastes. Cassava will undoubtedly require more research on demand, marketing, and processing whereas none of these appears to be particularly pressing for beans. Moreover, identification of the major agro-climatic conditions under which cassava is produced and the evaluation of hybrids under these conditions appears to be essential. In the commodity programs there is a natural evolution to farm level data collection utilizing the Gap approach so that the programs can test the relevance of experiment-station-generated practices and new varieties (segregants or cultivars) under farm level conditions.

In the evolution of crop technologies there has been two highly emotional discussions. The first is over the income distribution consequences of the new technologies. The data in this paper indicate that both commodities are essentially produced by small farmers primarily outside of the prime agricultural areas of Latin America. Except for temporary circumstances of high prices the authors consider that these two commodities even with improved varieties will not break into the prime agricultural areas. There are just too many other more profitable commodities in these areas with long traditions of research and a developed marketing infrastructure[37]. Research

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[37] Another possible region for the expansion of cassava production is the unexploited frontier areas, such as the Llanos in Colombia and the Mato Grosso region in Brazil. There are many factors which will influence the movement of cassava into these areas, one of the pricipal ones being government policy. The recent establishment of large cassava areas in Mato Grosso by PETROBRAS (The national petroleum company) is a case in point. There the government has consciously selected large scale cassava production schemes, thereby giving little weight to the income distribution consequences. Technology design in this case cannot overcome the affect of government intervention in the choice of scale of production but on the other hand, neither should technology design be based on parameters set by government policy where they contradict those set by economic forces.

design for these two commodities therefore must reflect two objectives: increased productivity and maximizing technology adoption in the target area.

The second emotional issue is over the choice of breeding strategy, principally because it involves the interplay of so many disciplines. Nevertheless, a breeding strategy for varietal development at international centers needs to address three main concerns:

1. What particular emphasis will give the largest increase in expected yield levels,
2. What are the assumed input levels under which crosses are selected, and
3. Are the risks of pathogen epidemics upon release of new varieties sufficiently minimized?

The first issue usually involves a debate over yield vs. resistance breeding. The second issue is linked to the income distribution debate but essentially argues the efficiency question in terms of maximizing yields (under limited conditions) vs. maximizing adoption. The third issue has in the past not been so fiercely debated, but ranks as an emerging debate in the future, as the wide distribution of the new high yielding varieties reduce the variability of the genetic base and thereby increase disease pressure. This debate will probably be focused around horizontal vs. vertical resistance breeding strategies.

The debate over yield vs. resistance breeding in beans and cassava is well defined. Clearly, the two commodities are very different. Beans are an extremely risky crop subject to a series of disease and insect pests and very sensitive to water shortages in critical periods. Moreover, the seriousness of the bean diseases is aggravated over time by the seed transmission of the most important diseases. Hence, it appears of primary importance to reduce the yield variance of beans. Cassava yields do not show as much between year variation, there appear to be fewer insect and disease pests, and there is some tolerance of those pests in the existent cultivars. In cassava it is much easier to justify a principal emphasis on those plant characteristics leading to higher yields.

Where resistance strategy is chosen, the question of the stability of the resistance needs some consideration. Beans are a short season crop with a variety of colors and ideotypes, and scattered in widely distributed pockets of production throughout Latin America. It is doubtful that the problem of genetic uniformity will apply to beans. The optimum strategy for beans appear to be an integrated plant protection package designed around both sources of resistance. Simultaneously, physiology and breeding are collaborating to identify those plant characteristics which can be selected for in order to increase yields.

With the development of efficient high-yielding varieties, the cassava program must focus more of its attention on disease resistance. With the development of biologically efficient plant types, there is a tendency for plant tolerance to decline[38]. Moreover, cassava is a long season crop, making pesticides impractical. Pathogen control though cultural practices in most

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[38] The development of a biologically efficient plant attempts to achieve a balance between leaf and root production. In many varieties there is excess leaf production, which reduces potential root production. However, this excess leaf production provides the predominant tolerance mechanism. That is, these varieties can sustain severe leaf attacks with little decline in yield. See J.H. Cock.

cases requires maximal diffusion to be affective. Thus, resistance is usually the only practical solution. Furthermore, being a clone cassava is prone to the hazards of genetic uniformity. Thus, with the release of the new high-yielding varieties, yield variability will undoubtably increase without resistances to the important pathogens. The breeding program through choice of parents for crosses and through selection in a high-disease pressure site is responding to the problem.

With the development of widely adapted, high-yielding hybrids that can reenter the breeding process, more emphasis can be put on disease resistance. Hypothesized horizontal resistance, which substantially reduces heritability of resistance, a potentially broad spectrum of diseases that vary by environment, and the tendency for the genetic base of the breeding program to narrow, makes evaluation in a diverse network of regional trials essential. In the future high yielding lines may have to feed into a separate network of crossing and selection sites designed to ensure adequate pathogen resistances.

In summary, different relevant constraints and different crop characteristics point to different strategies for cassava and beans while nevertheless producing the same output, a stable high yielding variety not dependent on high levels of purchased inputs.

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Table A-1. Production of Dry Beans in Latin America, 1964-66 to 1974-76[a]

Country	Average (1964-66)	Average (1974-76)
	-------- 1000 tons	--------
Brazil	2129.7	2117.0
Mexico	917.3	1046.7
Argentina	32.3	131.7
Guatemala	44.0	77.7
Colombia	39.0	75.0[b]
Chile	87.6	73.3
Honduras	50.0	53.7
Nicaragua	39.0	52.7
Haiti	40.6	44.0
El Salvador	15.0	37.3
Peru	46.3	35.7
Paraguay	30.0	42.3
Venezuela	43.0	37.3
Dominican Republic	25.0	35.0
Ecuador	28.0	28.3
Cuba	25.0	23.7[c]
Bolivia	14.0	20.7[c]
Costa Rica	18.6	16.0
Panama	6.0	4.0
Uruguay	3.3	2.0[c]
Puerto Rico	2.0	2.0[c]
Latin America	3635.4	3956.1

a/ These arithmetic averages are estimated on the basis of data from the USDA-ERS. For those for which the USDA-ERS does not have information (Argentina, Haiti, Cuba, Uruguay and Puerto Rico) data from the FAO was used.

b/ These data were based on information from the Ministry of Agriculture (2), (3) and (4) below.

c/ Average 1974/75.

Source: Translated from J.H. Sanders y C. Alvarez P., "Tendencias de la Producción de Fríjol en América Latina-II", mimeo, CIAT, Cali, Colombia, Julio 1977, p.2

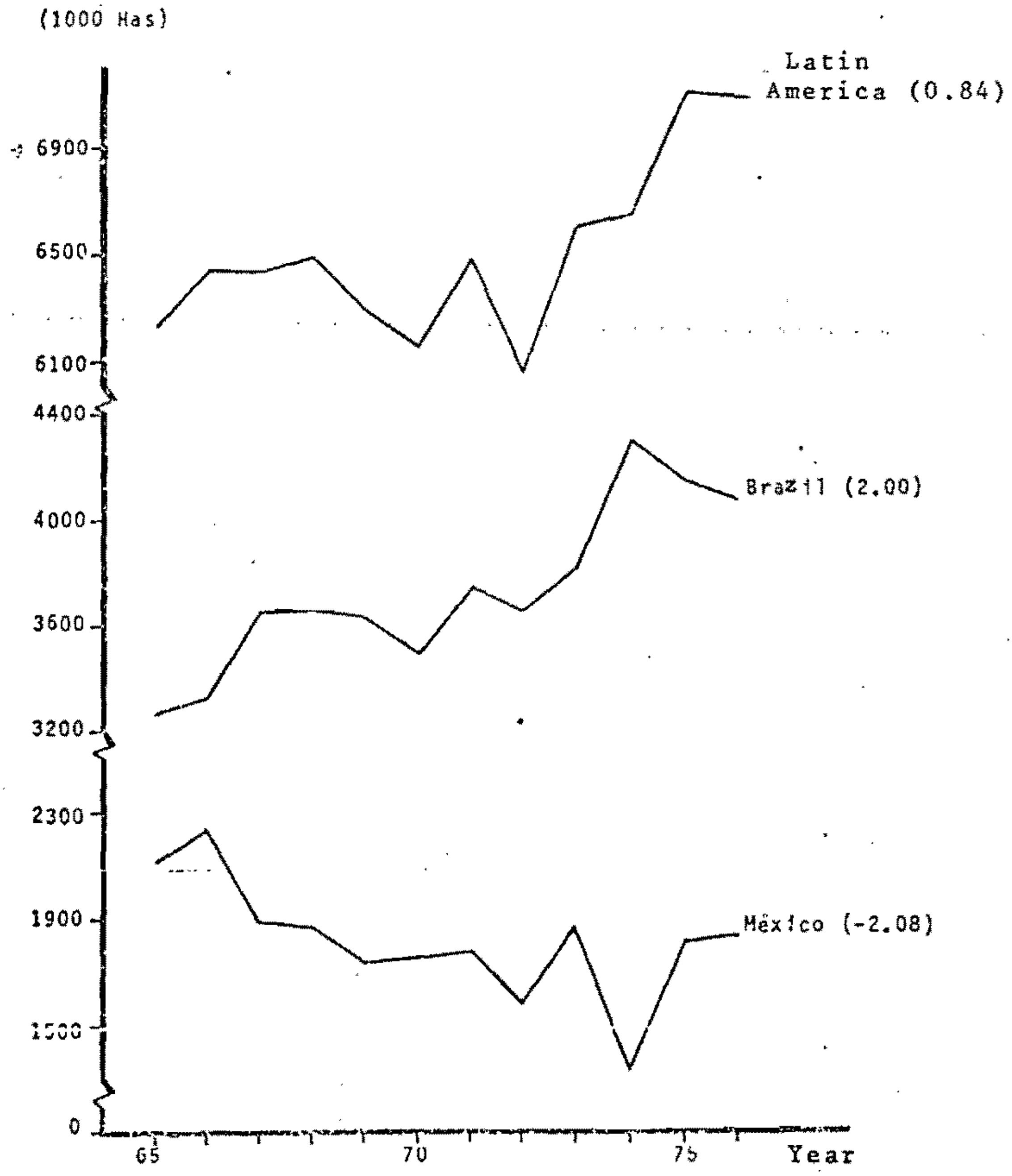
Table A-2. Production, Commerce and Consumption of Legumes[a] in Latin America.

	Average (1963-65)				Average (1973-75)			
	Production Total[b]	+Imports -Exports[c]	Net domestic consumption	Apparent per capita consumption[d]	Production Total[e]	+Imports -Exports[c]	Net domestic consumption	Apparent per capita consumption[d]
	----------- 1000 tons		--------	- kg/yr.-	----------- 1000 tons		--------	- kg/yr.-
Exporters:								
Argentina	85.0	-18.2	66.8	3.0	132.3	-58.4	73.9	2.9
Chile	106.0	-27.1	78.9	9.5	97.0	-25.1	71.9	7.2
Mexico	975.7	-22.9	952.8	23.1	1313.3	-12.4	1300.9	22.4
Honduras	48.7	-18.0	30.7	13.9	51.4	-4.4	46.9	15.1
Colombia	90.7	2.4	93.1	5.2	143.6[g]	-2.8	140.8	5.7
Peru	103.7	1.8	105.5	9.3	88.0	-1.7	86.3	5.7
Bolivia	21.0	0.3	21.3	5.3	29.3	-0.0[h]	29.3	5.7
Importers:								
Cuba	27.3	61.5	88.8	11.8	24.0	92.7	116.7	12.8
Venezuela	46.3	32.4	78.7	8.8	41.0	30.0	71.0	5.7
Costa Rica	18.3	1.0	19.3	13.4	13.7	17.3	31.0	16.0
Brazil	2123.0	7.9	2130.9	26.6	2332.7	17.0	2349.7	22.2
D. Republic	47.3	5.4	52.7	14.8	64.0	4.0	68.0	14.0
Panama	7.0	3.4	10.4	8.7	4.7	2.0	6.7	4.1
Guatemala	43.0	2.3	45.3	10.1	74.3	3.0	77.3	13.4
Uruguay	7.0	1.5	8.5	3.2	5.0	0.5	5.5	1.8
Nicaragua	35.7	-2.0	33.7	21.2	48.3	3.6	51.9	23.7
El Salvador	14.3	15.2	29.5	10.3	37.3	3.3	40.6	10.1
Haiti	43.3	0.5	43.8	10.6	83.3	0.0[h]	83.3	16.6
Paraguay	45.0	-1.0	44.0	22.7	52.0	0.0	52.0	20.7
Ecuador	65.3	0.1	65.4	13.3	53.7	0.1	53.8	7.6
Others[f]	18.7	23.2	41.9	5.2	16.0	21.9	37.9	4.0
Latin America	3972.3	69.7	4042.0	16.9	4704.9	90.6	4795.5	15.1

Table A-2. Production, Commerce and Consumption of Legumes[a] in Latin America.

	Average (1963-65)				*Average (1973-75)*			
	Production Total[b]	+Imports -Exports[c]	Net domestic consumption	Apparent per capita consumption[d]	Production Total[e]	+Imports -Exports[c]	Net domestic consumption	Apparent per capita consumption[d]
	----------- 1000 tons		--------	- kg/yr.-	----------- 1000 tons		--------	- kg/yr.-
Exporters:								
Argentina	85.0	-18.2	66.8	3.0	132.3	-58.4	73.9	2.9
Chile	106.0	-27.1	78.9	9.5	97.0	-25.1	71.9	7.2
Mexico	975.7	-22.9	952.8	23.1	1313.3	-12.4	1300.9	22.4
Honduras	48.7	-18.0	30.7	13.9	51.4	-4.4	46.9	15.1
Colombia	90.7	2.4	93.1	5.2	143.6[g]	-2.8	140.8	5.7
Peru	103.7	1.8	105.5	9.3	88.0	-1.7	86.3	5.7
Bolivia	21.0	0.3	21.3	5.3	29.3	-0.0[h]	29.3	5.7
Importers:								
Cuba	27.3	61.5	88.8	11.8	24.0	92.7	116.7	12.8
Venezuela	46.3	32.4	78.7	8.8	41.0	30.0	71.0	5.7
Costa Rica	18.3	1.0	19.3	13.4	13.7	17.3	31.0	16.0
Brazil	2123.0	7.9	2130.9	26.6	2332.7	17.0	2349.7	22.2
D. Republic	47.3	5.4	52.7	14.8	64.0	4.0	68.0	14.0
Panama	7.0	3.4	10.4	8.7	4.7	2.0	6.7	4.1
Guatemala	43.0	2.3	45.3	10.1	74.3	3.0	77.3	13.4
Uruguay	7.0	1.5	8.5	3.2	5.0	0.5	5.5	1.8
Nicaragua	35.7	-2.0	33.7	21.2	48.3	3.6	51.9	23.7
El Salvador	14.3	15.2	29.5	10.3	37.3	3.3	40.6	10.1
Haiti	43.3	0.5	43.8	10.6	83.3	0.0[h]	83.3	16.6
Paraguay	45.0	-1.0	44.0	22.7	52.0	0.0	52.0	20.7
Ecuador	65.3	0.1	65.4	13.3	53.7	0.1	53.8	7.6
Others[f]	18.7	23.2	41.9	5.2	16.0	21.9	37.9	4.0
Latin America	3972.3	69.7	4042.0	16.9	4704.9	90.6	4795.5	15.1

Figure A-1. Area of Beans in Latin America, Brazil and Mexico, 1965-1976.



(The statistic in parentheses represents the average annual growth rate for 1965-1976).

Source: J.H. Sanders y C. Alvarez P., op.cit., p.19.

Cont. Table A-2.

a/ Contains all the legumes as define by FAO in the Table A-2 in "Production tendencies of beans in Latin America-I".

b/ Arithmetic average estimated on the basis of USDA-ERS (1), (2) and FAO (3).

c/ Arithmetic average estimated on the basis of FAO (4).

d/ This statistic is estimated on the basis of USDA-ERS (1), (2) and FAO (3), (4) and (5).

e/ Arithmetic average estimated on the basis of USDA-ERS (1), (2) and FAO (3), and (5).

f/ Includes Guyana, Jamaica, Surinam, Trinidad and Tobago, Puerto Rico and other islands in the Caribbean not mentioned which produce and/or import legumes in Latin America.

g/ It is estimated on the basis of the Ministry of Agriculture (6), (7) and FAO (3).

h/ Less than 50 tons.

Note: In order to estimade (d), population data from USDA-ERS were used. When data were not available from USDA-ERS for some countries, data from FAO were used. The population average for Latin America in the two periods was:

1963-1965 = 239.156 (thousands)
1973-1975 = 316,035 (thousands)

Source: J.H. Sanders and C. Alvarez P., *op.cit.*, p.4

Table A-3. Bean Area in Latin America, 1964-1966 to 1974-1976[a].

	Average (1964-66)	Average (1974-76)
	----- 1000 has. ------	
Brazil	3243.0	4140.3
Mexico	2149.3	1679.7
Argentina	36.9	129.0
Chile	62.3	74.3
Guatemala	86.0	103.0
Colombia	72.0	104.3[c]
Honduras	74.0	78.0
Nicaragua	59.0	71.3
Haiti	40.0	41.3
El Salvador	27.0	52.7
Peru	58.3	56.7
Venezuela	88.7	83.0
Ecuador	64.7	65.7
Paraguay	32.0	59.0
Dominican Republic	38.3	43.7
Cuba	36.7	35.0[b]
Bolivia	9.0	9.0[b]
Costa Rica	49.3	35.7
Panama	19.0	14.0[b]
Uruguay	5.0	4.0[b]
Puerto Rico	4.0	4.0[b]
Latin America	6247.7	6882.6

[a] These arithmetic averages were estimated from Table A-7 of the "Bean Production Tendencies in Latin America-I".

[b] Average, 1974/75.

[c] This average was calculated on the basis of data from the Ministry of Agriculture in Colombia, (2), (3) and (4) cited below.

Source: J.H. Sanders y C. Alvarez P., op.cit., p.22

Table A-4. Per-Capita Production of Cassava (1973-75) and Production (1,000 tons) for Latin American Countries. 1963-1965 and 1973-1975.

Country	1973-75	1963-1965		1973-1975	
	Per-Capita Production of Cassava	Cassava Production	% Total Production	Cassava Production	% Total Production
	---kg.---	(1000 tons)		(1000 tons)	
Paraguay[a]	446.3	1320	4.8	1117	3.6
Brazil[e]	245.4	23866	85.9	25986	84.3
French Guyana[a]	69.0	6	0	4	0
Ecuador[c]	56.8	215	0.8	396	1.3
Colombia[d]	54.3	733	2.6	1353	4.4
Bolivia[a]	45.2	143	0.5	233	0.8
Dominican Republic[b]	35.0	153	0.5	169	0.5
Peru[a]	31.6	461	1.7	479	1.6
Haiti[a]	28.7	111	0.4	144	0.5
Cuba[a]	25.2	180	0.6	234	0.8
Panama[a]	24.7	19	0.1	40	0.1
Venezuela[a]	24.5	318	1.1	301	1.0
Guyana[a]	17.7	10	0	14	0
Honduras[a]	14.2	24	0.1	44	0.1
Argentina[a]	10.2	244	0.9	261	0.8
Jamaica[e]	9.4	9	0	19	0.1
Guadalupe[a]	8.6	5	0	3	0
Martinique[a]	8.4	3	0	3	0
Nicaragua[a]	8.2	13	0	18	0
Costa Rica[a]	5.2	10	0	10	0
Trinidad and Tobago[a]	5.2	4	0	5	0
Surinam[a]	4.9	2	0	2	0
Barbados[a]	4.1	1	0	1	0
El Salvador[a]	3.7	9	0	15	0
Puerto Rico[a]	1.7	6	0	5	0
Guatemala[a]	1.2	5	0	7	0
TOTAL	126.4	27870	100	30863	100

Cont. Table A-4

a/ FAO. Anuario de Producción, 1973, Vol.27, Roma, 1974 and FAO. Anuario de Producción, 1975, Vol.29, Roma, 1976

b/ Secretaría de Estado de Agricultura. Instituto Interamericano de Ciencias Agrícolas. Diagnóstico del Mercadeo de Víveres en la República Dominicana. Documento No.13, Versión Preliminar - Marzo 1977.

c/ Ministerio de Agricultura y Ganadería. Dirección de Planificación. Departamento de Estadísticas, undated

d/ Departamento Administrativo Natural de Estadística, (DANE), Boletín Mensual de Estadística, No.276, Julio, 1974.

e/ USDA-ERS. Indices of Agricultural Production for the Western Hemisphere, Excluding the United States and Cuba, 1963 through 1972, Statistical Bulletin 264, Washington, D.C., May 1973 and Indices of Agricultural Production for the Western Hemisphere, Excluding the United States and Cuba, 1966 through 1975, Statistical Bulletin 552, Washington, D.C., May 1976.

Table A-5. Cassava: Annual Production Growth Rate, Area and Yields from Latin American Countries, 1963 – 1975.

Country	Rate of Production Increase	Rate of Area Increase	Rate of Yield Increase
Barbados	0	-	-
Costa Rica	-0.6	-3.3	2.7
Cuba	2.4	3.0	-0.5
Dominican Republic	1.4	2.6	-1.2
El Salvador	4.9	1.9	3.0
Guadalupe	-2.9	-	-
Guatemala	3.1	2.4	0.7
Haiti	2.8	1.3	1.5
Honduras	6.0	3.6	2.4
Jamaica	5.2	-2.9	8.1
Martinique	0	-	-
Nicaragua	3.1	2.4	0.7
Panama	8.2	9.8	-1.6
Puerto Rico	-2.4	-7.6	5.2
Trinidad and Tobago	2.6	-	-
Argentina	0.7	0.1	-0.2
Bolivia	5.1	4.3	0.7
Brazil	1.2	2.1	-0.9
Colombia	5.5	3.8	1.6
Ecuador	7.5	5.2	2.2
French Guyana	-0.4	0	-3.9
Guyana	3.8	0	3.8
Paraguay	-1.1	-0.7	-0.4
Peru	0.4	-2.1	2.4
Surinam	1.1	-	-
Venezuela	-0.4	4.6	-5.1
TOTAL	1.3	2.1	-0.7

Source: Derived from the same sources as in Table A-4.

Table A-6. Departments Included in the Analysis, Number of Farmers, Height above Sea Level, Average Temperature, Area Under Observation and Area of the Projected Cassava Production Region

Zone	Departments Included	Area (has.)	No. of Farmers in the sample	Average height above sea level	Average Temp. (°C)	Protected Departments	Area (has.)	Total area of the region
				--(m)--				
I	Cauca	6.534	61	1230	22	Nariño	4.178	10.712
II	Valle, Quindio	6.529	64	1200	22	Risaralda y Caldas	6.271	12.800
III	Tolima	8.182	59	815	26	Cundinamarca, Huila Antioquia, Santander, Santander Norte	57.603	65.785
IV	Meta	11.167	55	370	27	Amazona, Arauca, Caqueta, Putumayo, Vaupes, Vichadada, Guainia, Boyaca	10.404	21.571
V	Atlantico Magdalena	9.110	44	30	30	San Andres, Sucre, Guajira, Choco, Cordoba, Cesar, Bolivar	45.022	54.132
TOTAL		41.522	283				123.478	165.000
PERCENTAGE		25					75	100

FIGURE A-2

GEOGRAPHIC LOCATION OF THE ZONES UNDER STUDY

"Agro-economic study of the processes of bean production"

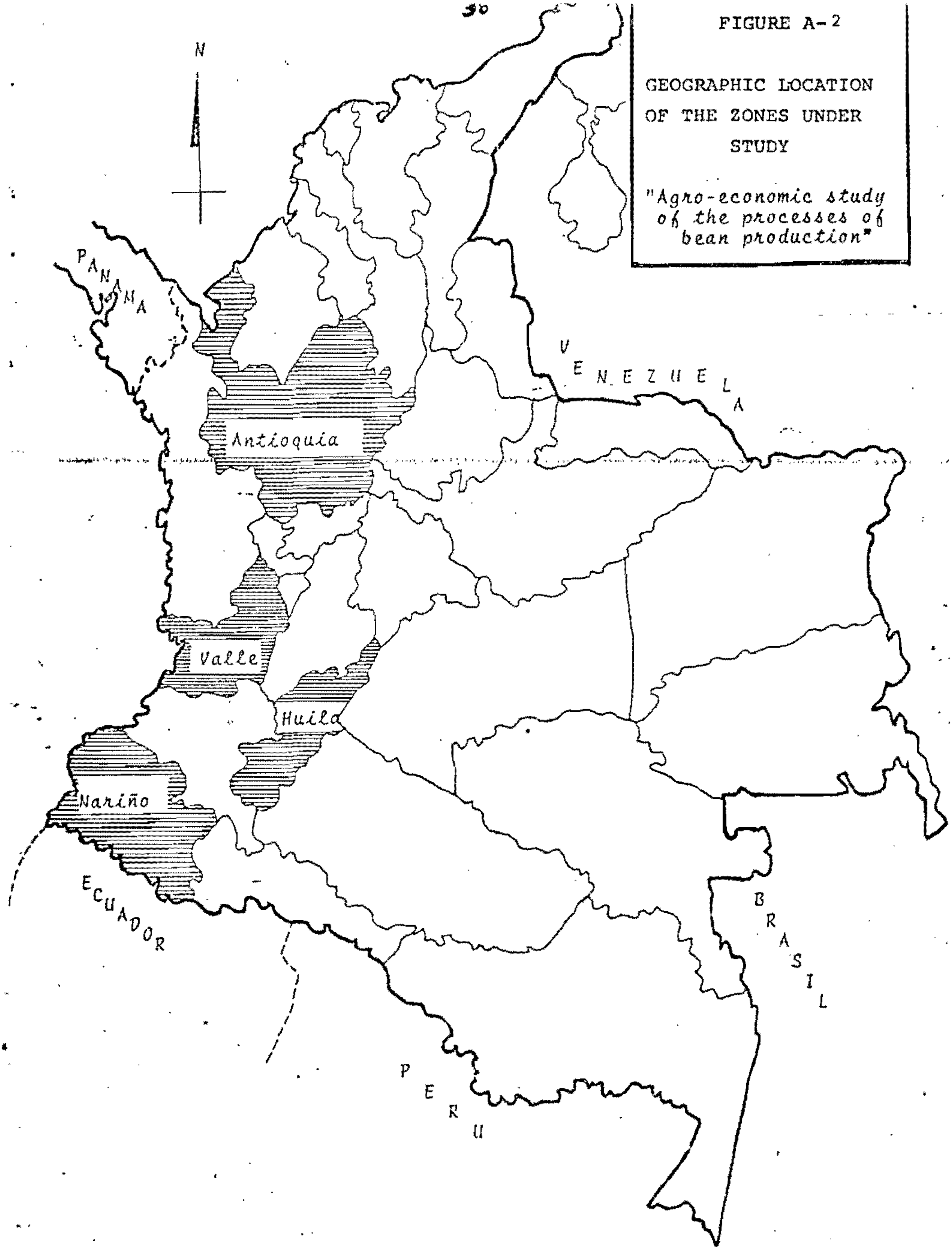


Table A-7. Technologies Characteristic of Two Systems of Bean Production, Valle and Huila-Nariño, 1974-75.

	Beans Alone (Valle)	Beans in Association (Huila-Nariño)
They use: (Percentage of farmers)		
Insecticides	87	8
Fungicides	100	3
Improved Seeds	52	2
Fertilizer	84	8
Herbicides	32	0
Irrigation	25	0
Mechanized land preparation	100	22
They receive:		
Credit	87	47
Technical assistance	70	12
Labor used:		
(Man-days/ha/harvest)	28.7	110
Type of labor used:		
Own (% total labor)	1	45
Contracted (% total labor)	99	55
Average yields:		
Beans (kg/ha)	906	599
Maize (kg/ha)	-	711
Bean equivalent (kg/ha) 1/	906	806

1/ Bean prices estimated at Col.$13.70/kg. and maize Col.$4.0/ /kg.

Source: Translated from N.R. de Londoño y P. Pinstrup-Andersen, "Barreras a los Incrementos de Productividad de Frijol a Nivel de Finca en Colombia", CIAT, Cali, Colombia, mimeo, Julio, 1977, p.8.

Table A-8. The Most Important Bean Diseases, Valle, Huila and Nariño, 1974-1975.

Diseases	*Beans Alone*		*Beans in Association*			
	Valle		Nariño		Huila	
	1st.V	2nd.V	1st.V	2nd.V	1st.V	2nd.V
	percentage of farms					
Rust (*Uromyces phaseoli*)	94	94	26	16	68	70
Grey Blotch (*Cercospora vanderysti*)	0	3	63	53	45	55
Floury Spot (*Ramularia phaseolina*)	0	0	10	47	12	74
Powdery Mildew (*Erysiphe polygoni*)	0	0	0	0	8	26
Anthracnosis (*Colletotrichum lindemuthianun*)	0	0	37	42	50	54
Root Rot*	39	13	37	5	8	0
Angular Leaf Spot (*Isariopsis griseola*)	74	100	32	79	27	76
Bacterial Blight (*Xanthomonas phaseoli*)	55	84	53	79	38	76
Virus**	10	19	21	11	26	3
Leaf Spot*** (*alternaria*)	0	0	16	5	19	8

* Rhizoctonia, Sclerotium

** Without identifying the type of virus, it could be a common mosaic or rugose mosaic.

*** Alternaria, Ascochyta.

Source: Translated from Norha R. de Londoño et al., op.cit, p.124

Table A-9. The Most Important Insects Identified in the Bean Cultivar, Valle, Huila and Nariño, 1974-1975.

Insects	Beans Alone		Beans in Association			
	Valle		Nariño		Huila	
	First Visit	Second Visit	First Visit	Second Visit	First Visit	Second Visit
	-------- *percentage of farms* -----------					
Foliage Suckers						
Thrips	39	36	68	63	81	77
Empoasca sp. (adults)	61	97	68	79	93	89
Empoasca sp. (nymphs)	36	87	63	95	88	100
Aphids	32	6	37	53	51	82
White Fly	62	26	47	26	47	42
Leaf Borers						
Agromyza sp., Lirionyza sp.	26	42	58	32	62	51
Hemichalepus sp.	0	43	47	5	65	35
Foliage Eaters						
Estigmene sp.	13	13	0	0	1	4
Trichoplusia sp.	0	55	5	0	16	34
Hedylepta sp.	6	16	0	0	7	24
Chrysomellida	36	52	53	16	11	5
Attack the Vines						
Heliothis sp.	0	16	0	16	0	3
Trichoplusia sp.	0	32	0	16	0	32
Maruca sp., Epinotia sp.	0	48	0	5	0	49
Diptera	0	0	0	26	0	7
Attack the Seedlings						
Earthworms	13	0	0	0	14	3
Crickets	13	0	0	0	7	0
Mites						
Tetranychus sp.	0	0	0	0	23	45

Source: Translated from Norha R. de Londoño et al, op.cit., p.13

Table A-10. Losses in Yield and Production of Beans due to Selected Factors. Beans Alone (Valle), 1974 (second semester).

Variable	Losses in the plot completely affected (kg/ha)	Percentage of area affected	Average Yield Losses		Production Losses (ton.)	Value of Losses US$[b] (1000)
			kg/ha	%[a]		
Rain	416	42	175	16.2	2168	1192
Rust	307	56	172	16.0	2130	1171
Bacterial Blight	total	12	137	13.1	1697	933
Empoasca kraemeri	315	35	110	10.8	1362	749
Angular Leaf Spot	538	15	81	8.2	1003	552
Certified Seed	186	41	76	7.7	941	517
Variable Costs	18	100	18	1.9	223	123
Plant Population	14	100	14	1.1	173	95

a/ The percentage was determined on the basis of average estimated yields plus the loss due to each factor (see Appendix A).

b/ At US$550/ton.

Source: Per Pinstrup-Andersen, Norha R. de Londoño and Mario Infante. "A Suggested Procedure for Estimating Yield and Production Losses in Crops". Pest Articles & News Summaries (PANS), 22(3), p.359-365.

Table A-11. Yield and Production Losses in Beans due to Selected Factors. Beans/Maize (Huila and Ñariño), 1975 (second semester).

Variable	Losses in the plot completely affected (kg/ha)	Percentage of area affected	Average Yield Losses kg/ha	Average Yield Losses %[a]	Production Losses (ton.)	Value of Losses US$[b] (1000)
Presence of maize	217	100.0	217.0	26.6	4991	2286
Topography	76	62.0	47.1	7.3	1083	496
Thrips	194	25.0	48.5	7.5	1115	510
Empoasca	c	100.0	51.0	7.8	1173	537
Virus	539[d]	32.0	38.0	5.9	874	400
Plot not previously cultivated	66	39.0	25.7	4.1	591	270
Anthracnosis	Total	4.7	26.8	4.2	616	282
Mildew	Total	3.4	23.7	3.8	545	250
Root Rot	Total	2.1	19.7	3.1	453	207
Angular Leaf Spot	Total	0.5	21.1	3.4	485	222
Inadequate rain	46	31.5	14.2	2.3	327	150
Population of Bean Plants	5	100.0	5.6	1.0	129	59

---

a/The percentage is calculated on the basis of the average estimated yield plus the loss due to each factor (See Appendix A).

b/A price of US$458/ton is estimated. (Col.Pesos 30 per each US$).

c/It is impossible to define what is a plot completely affected with Empoasca.

d/It was not possible in the function to estimate losses in a plot completely affected with the virus. The variable used only considered if there were an incidence or not of the virus. The data appear as experimental results of artificial inoculations. (See CIAT, Annual Report 1975, Cali, Colombia) p.C-42.

Source: CIAT, Informe Anual 1976, Cali, Colombia, p. A-77.

FIGURE A- 3

THE FIVE TYPES OF ZONES DEFINED BY THE CASSAVA PROGRAM

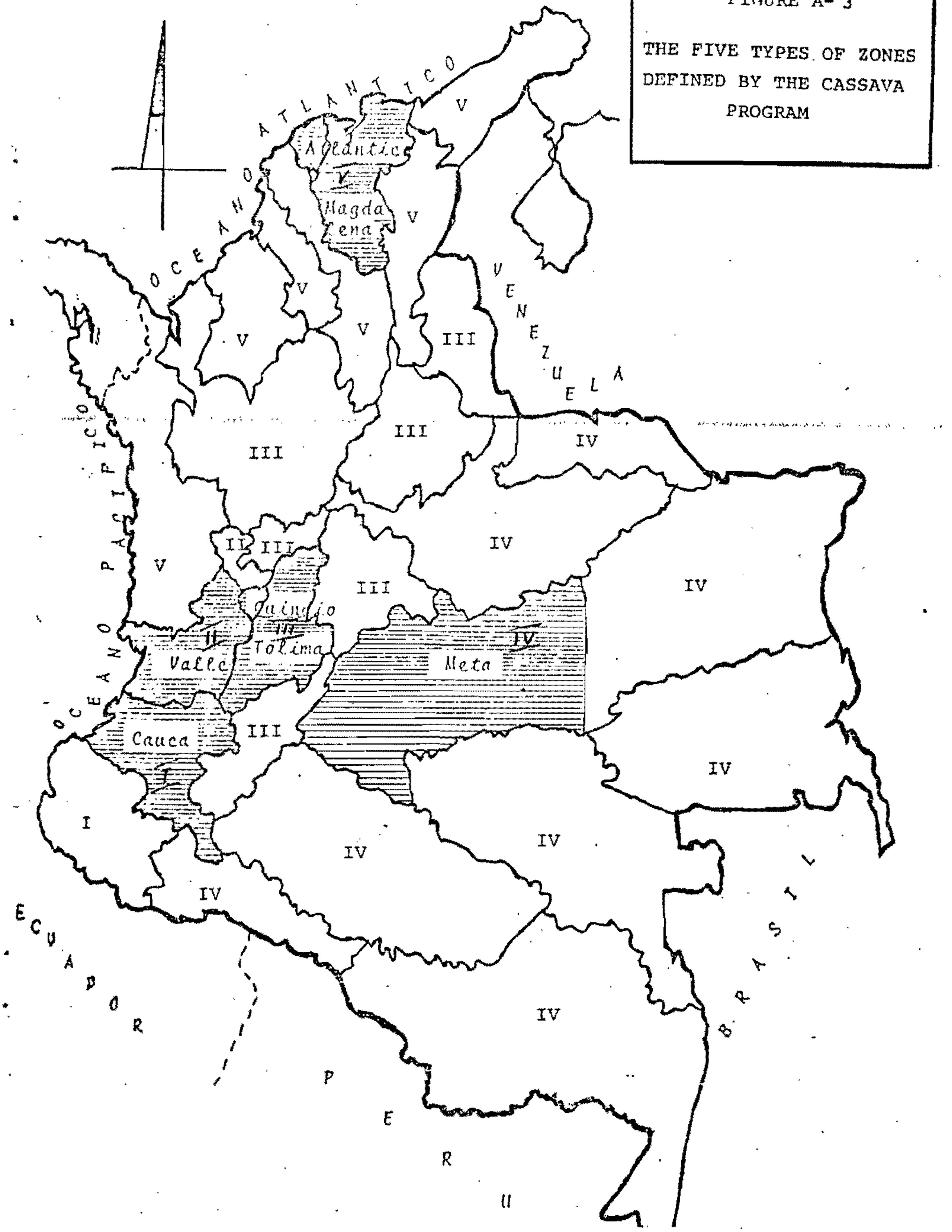


Table A-12. Selected Soil Characteristics on the Cassava Sampled (average by zone).

	I	II	III	IV	V
Organic matter (%)	5.22	3.69	5.33	3.53	1.93
Less than 4%*	26.20	75.00	32.20	60.00	97.70
Phosphorus (ppm)	1.78	32.89	2.62	21.36	69.66
Less than 15 ppm*	100.00	35.90	100.00	72.70	31.80
Potassium (meq|100g)	0.21	0.45	0.26	0.12	0.22
Less than 0.30 meq||100 g*	80.30	37.50	76.30	94.60	81.80
Aluminum (meq|100g)	4.37	0.06	0.84	2.84	0.06
pH					
Less than 5.5*	100.00	12.50	83.10	89.10	6.80
Sodium saturation (%)	1.46	0.46	0.18	0.48	5.16
Calcium|magnesium	1.66	5.42	2.67	2.65	4.37
Exchange capacity (meq|100g)	20.33	15.26	24.08	11.80	9.75

*Percentage of farms.

Source: CIAT, <u>Annual Report 1975</u>, Cali, Colombia, 1976, p.B-5.

Table A-13. Major diseases of Beans (Phaseolus vulgaris) and their importance by country in Latin America.

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

Source: CIAT, Bean Production Systems Program, Series FE-No.5, Cali, Colombia, May, 1975, p.7

\+ Disease is of major importance

\- Disease is of no particular importance

Table A-15. Prices Received by South American Producers of Cassava and Price Indices for Competing Crops, 1969

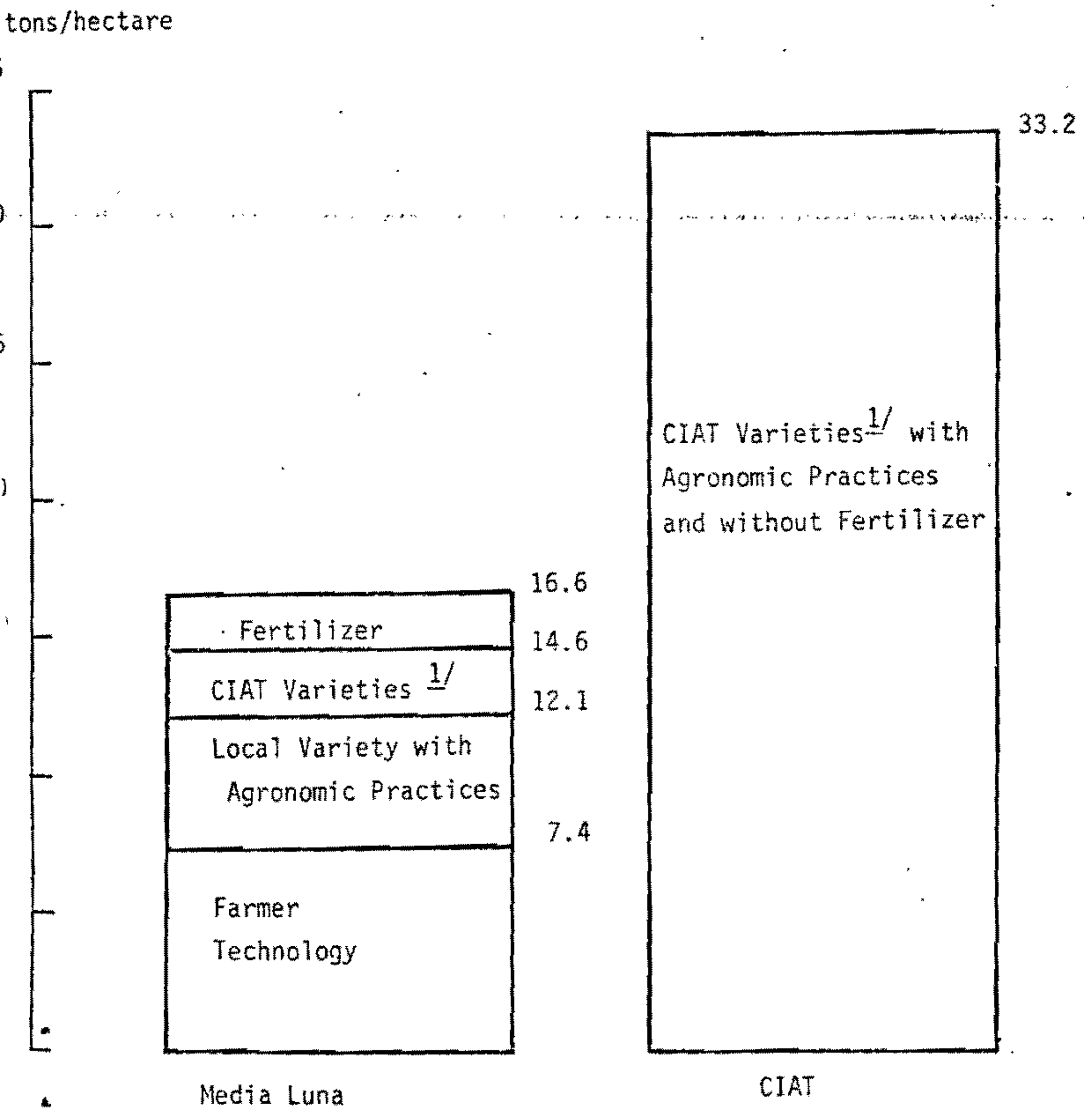
Country	Price of Cassava $US/M.T.	Price Indices[1]			
		Potatoes	Paddy Rice	Wheat	Maize
Argentina	24.3	95	270	177	166
Bolivia	36.6	175	198	230	320
Brazil	9.5	555	698	1147	350
Colombia	49.7	141	209	231	148
Ecuador	36.0	172	217	267	244
Paraguay	21.4	445	334	371	265
Peru	31.8	194	401	365	275
Venezuela	55.3	210	224	181	123
South America[2]	12.7	380	581	478	324

1/ Price indices based on cassava price in each country equal to 100.

2/ Prices weighted by production.

Source: Food and Agricultural Organization of the United Nations (FAO), Perspective Study of Agricultural Development for Latin America, Rome, 1972, p.II-94.

FIGURE : COMPARISON OF POTENTIAL YIELDS ON FARMERS' FIELDS WITH YIELDS AT CIAT.



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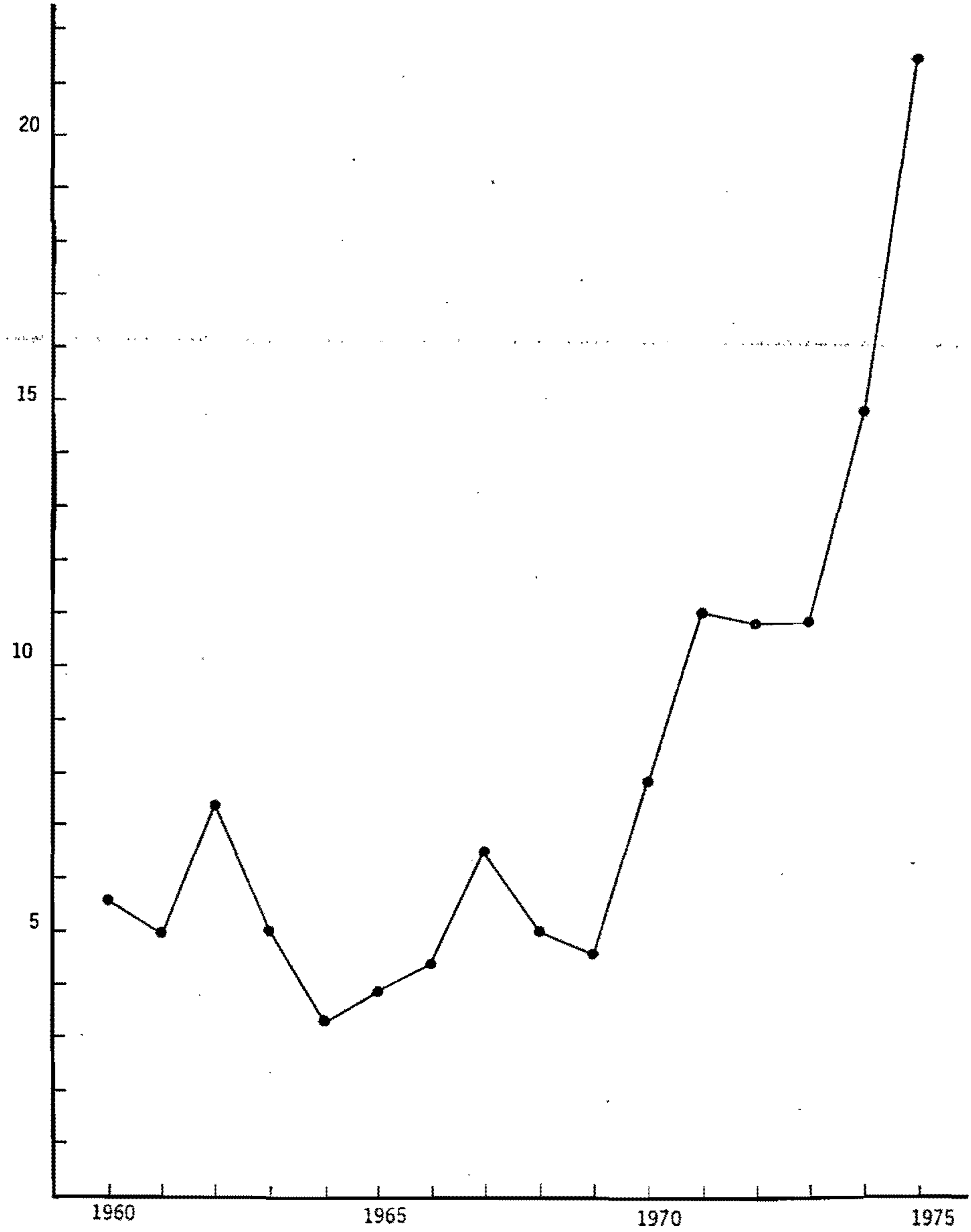
[1] CMC 40 and M COL 22

FIGURE : TRENDS IN PRICES OF CASSAVA FLOUR IN BRAZIL [a/]



[a/] Cassava flour, average wholesale price, Sao Paulo.