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TRENDS AND YIELD CONSTRAINTS IN THE PRODUCTION SYSTEMS OF BEANS AND CASSAVA IN LATIN AMERICA WITH EMPHASIS ON RESEARCH DESIGN IMPLICATIONS 1/

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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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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 non-photoperiod 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

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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 her bicide 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 require ment 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 Micro Stage

The available macro data is sketchy Production data is unreliable 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 prin

cipally 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

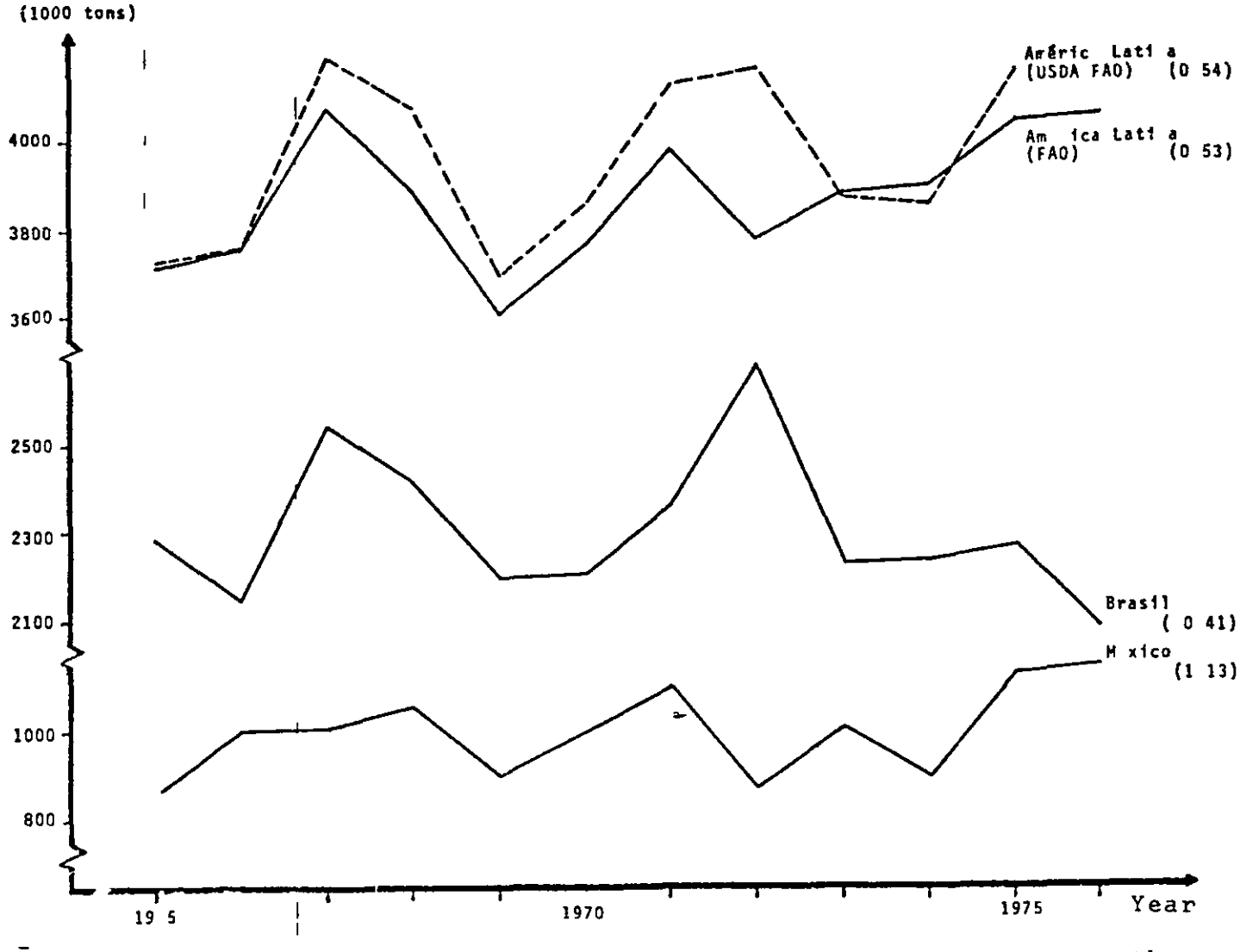
Cassava production in the 1963-75 period increased at an annual rate of 1 3% well below the population growth rate This rate of production increase was due to a more than proportional increase in area planted as yield levels declined on the average by 0 7% per year (see Table A-5 in the Appendix) Though 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 ar 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

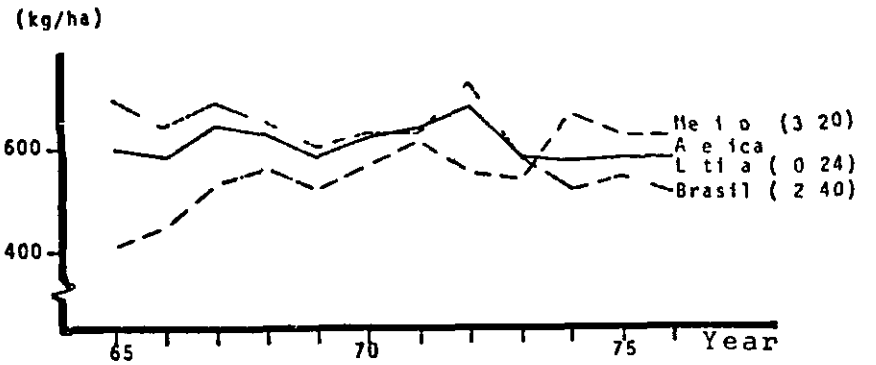
Differentiating with respect to time gives

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

These are the ra of increa of product on ar a and yields Tl e rate of increa e of yi ld was calculat d a the rate of increa e of production mi u tl e ate of in crease of area

Source J H Sander y C Alvar P

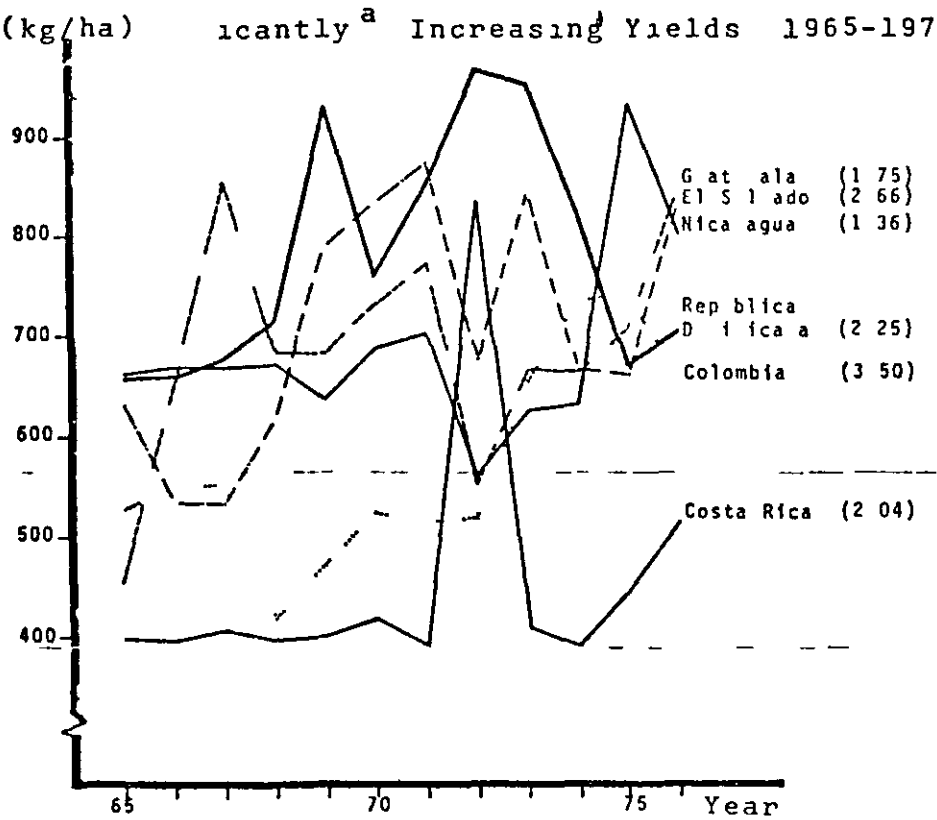
Figure 2 Bean Yields in Latin America Brazil and Mexico 1965-1976



(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 Signif icantly[a] Increasing Yields 1965-1974 (kg/ha)

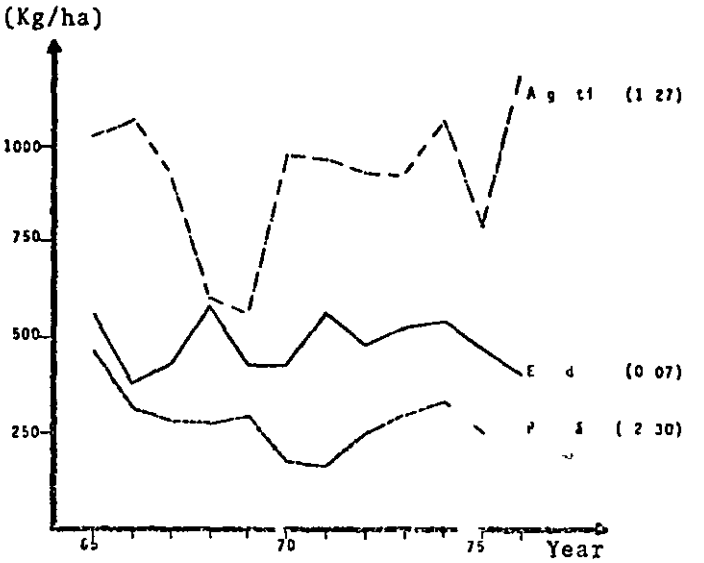


(The number in parentheses is the geometric rate of increase)

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

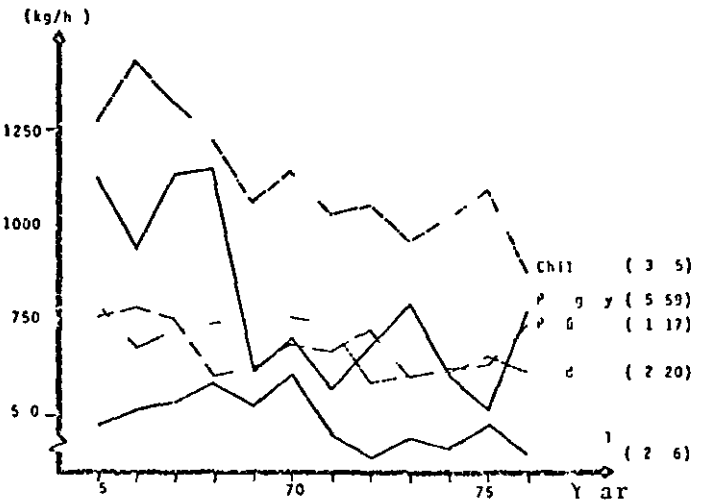
Figure 4 Bean Yields in Latin American Contries with Yields 1965 76



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

Source J H S ders y C Alva P p t p 24

Figure 5 Bean Yields in Countries with Si nificantly[1] Decreasing Yields 1965 76



(The numl r in parentheses is the geometric rite of in rease)

1/ll e rates of lecrea e were tested for stati tical significance at the level of 60 per nt with the t test Brazil al o b longe l in this group

o r J H S d s y C Al c P op 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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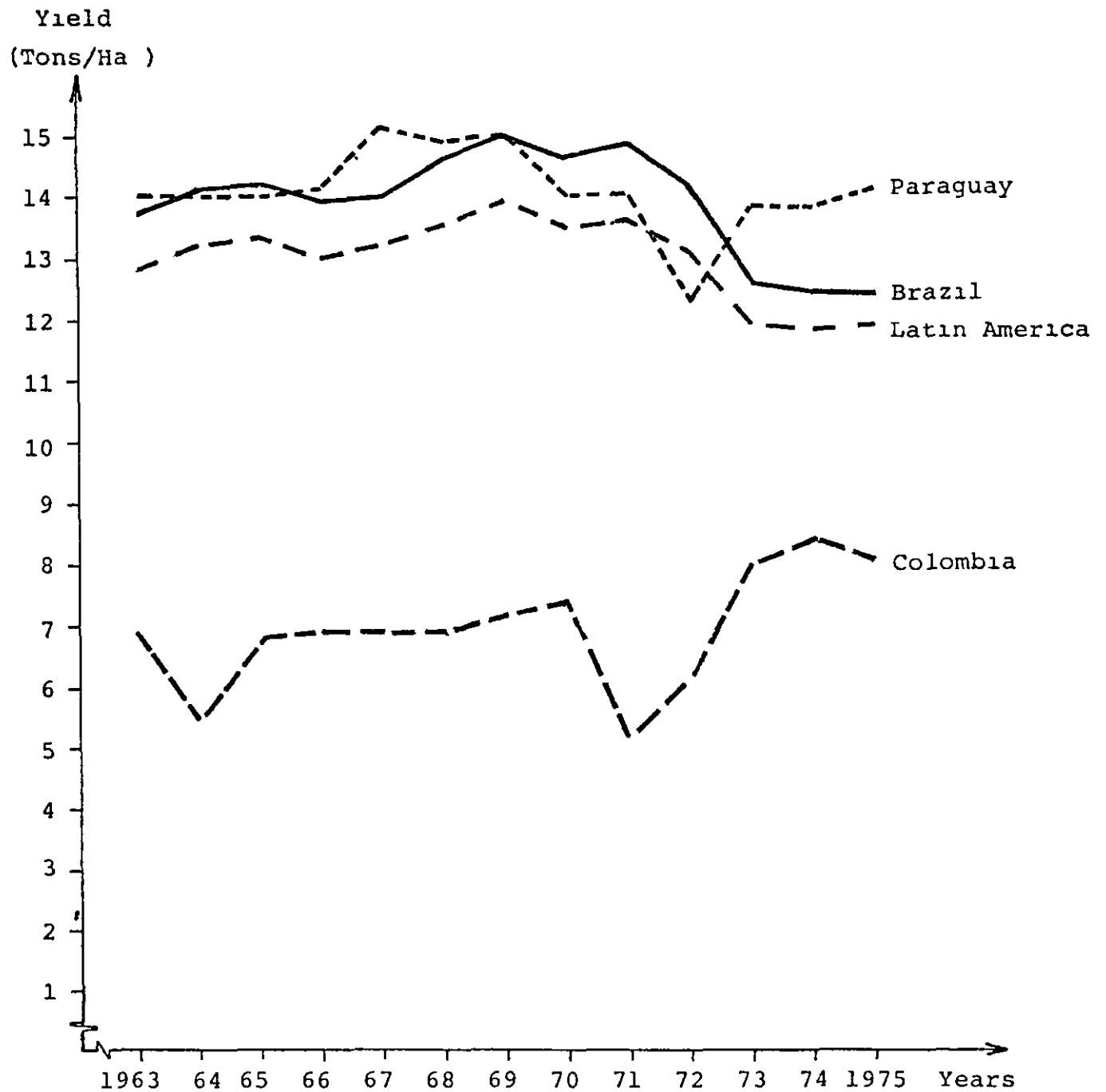
13/ Cassava more so than most other annual crops in Latin America is produced primarily on small scale farms See J K Lynam Options for Latin American Countries in the Development of Integrated Cassava Production Programs p 222 223

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



Source Food and Agricultural Organization of the United Nations (FAO) Anuario de Produccion 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 cas sava 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 Bench mark 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 Analisis Economico 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 9	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]

[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 YIELD AND FACTORS RESPONSIBLE FOR YIELD REDUCTION THE CAUCA VALLEY 1974

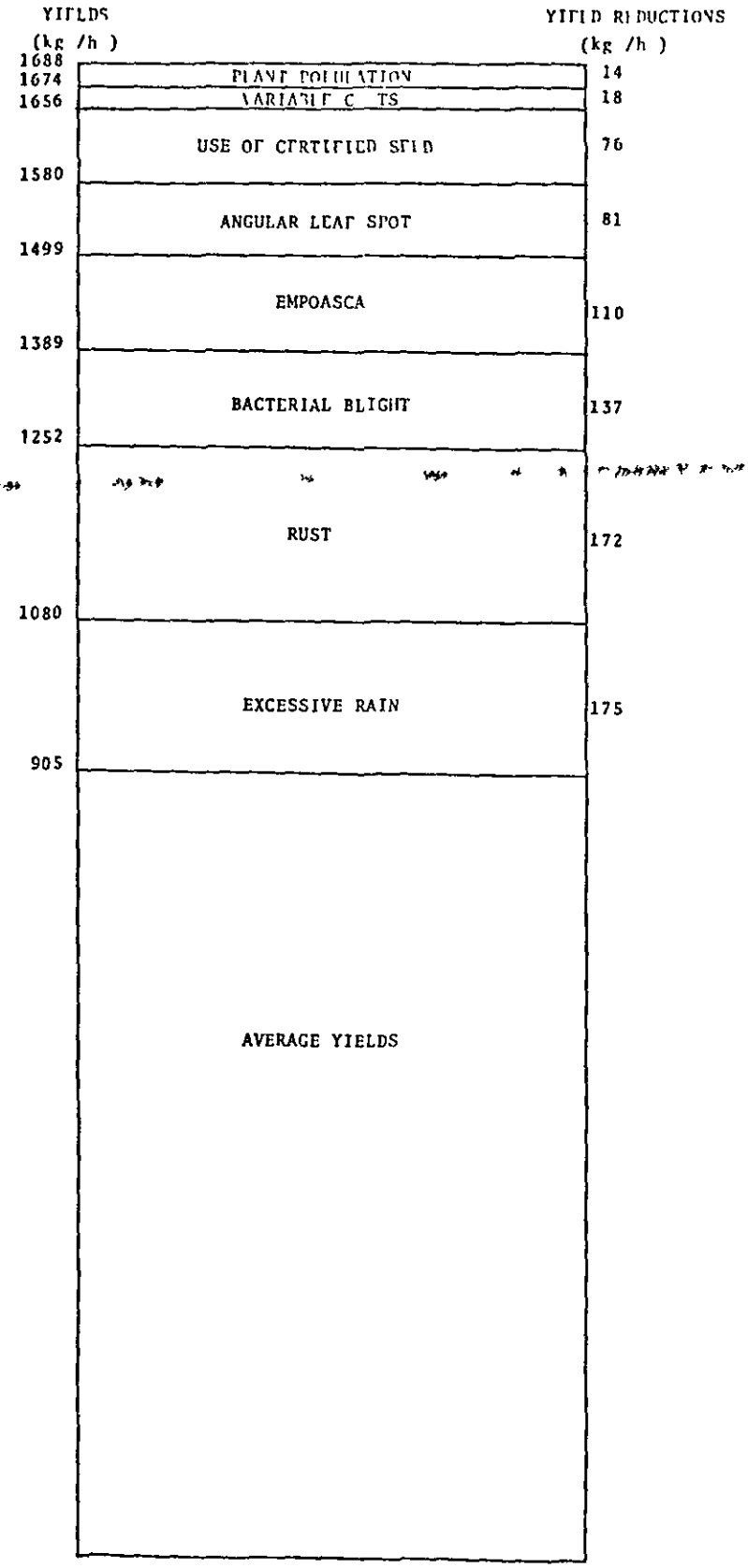
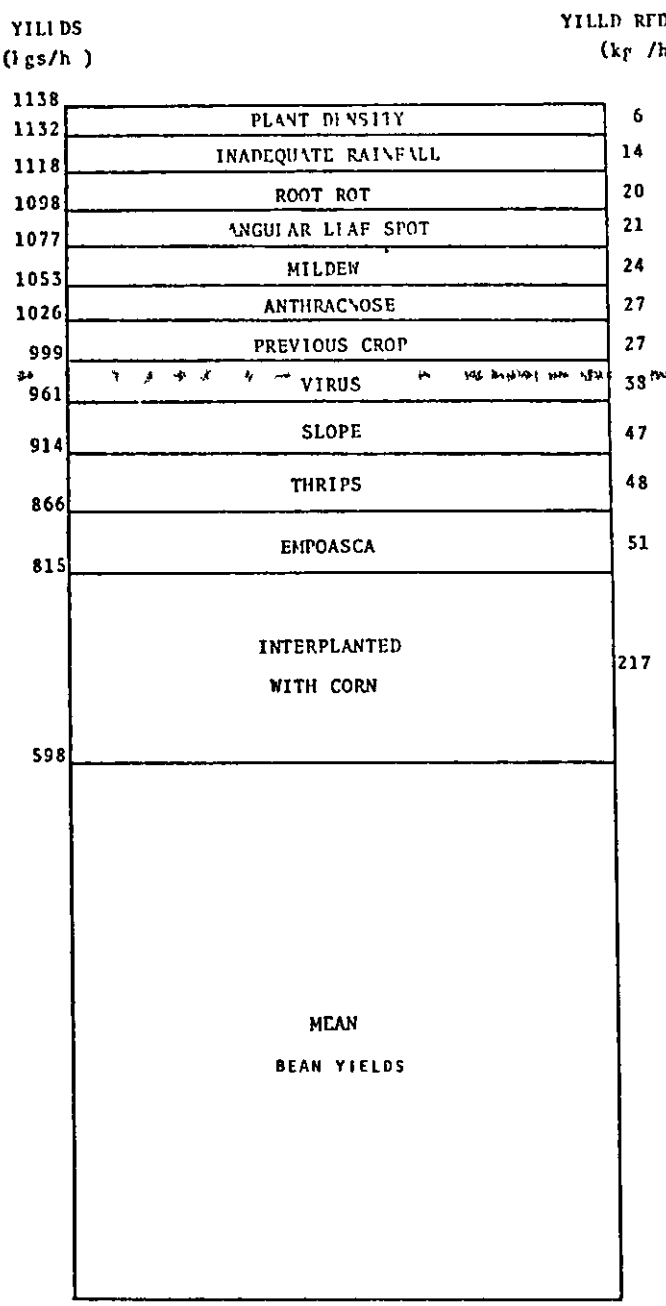


FIGURE 8 BEAN YIELD AND FACTORS RESPONSIBLE FOR YIELD REDUCTIONS HUILA NARIÑO COLOMBIA 1975



S N R d L d n 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 rutritional 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 Appendix) 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 Analisis Economico 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
Utili able Land	Ha	4 1	38 1	5 4	45 9	15 2	21 9
Area in Crops	Ha	3 4	21 7	3 4	11 6	7 0	10 4
Area in Yuca	Ha	2 9	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 Diaz 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 inter regional 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

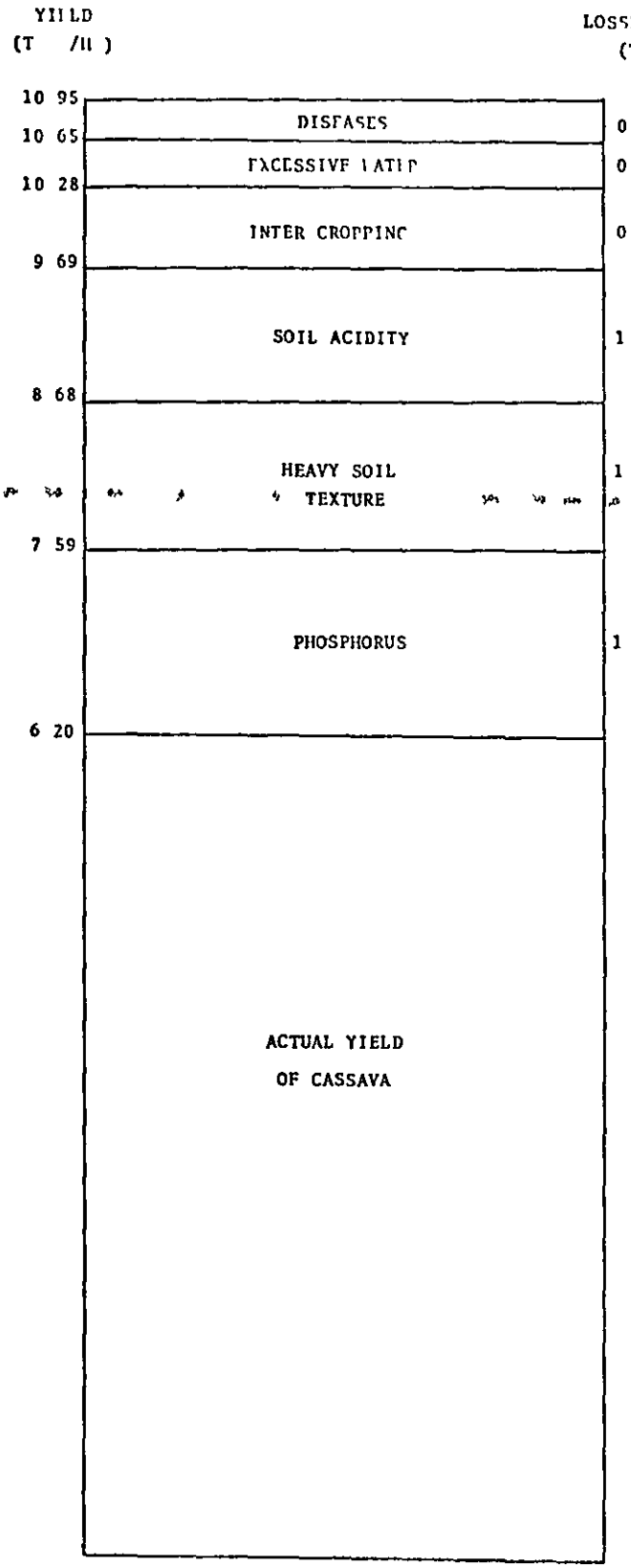
Table 9 Yield Losses in Cassava for the Different Colombian Regions 1973-1975

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



S c C l l f O ? d P P t f A d

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 current ly employed varieties Moreover cassava was grown under relatively poor

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26/ Camilo Alvarez P Analisis 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 ard 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 along side 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

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31/ N R de Londono 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 dependıng upont the particular pest[34] The use of some vertical resistances ın beans can be justified for the followıng 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 ın breedıng for horizontal resistance

The first point stresses the fact that the spread of bean diseases is limited because beans ın Latın America unlike grains are produced ın widely separated pockets Also ıt 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 ın beans Even ıf a vertical resistance breaks down the benefits of a few years of successful protection are often much greater than the costs of the resistance breedıng In one season ın only the Valle area resistance to Rust would have ıncreased the value of bean production by over one million dollars Vertical resistance may be necessary for those diseases such a 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 usual ly 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 Hypothe sized horizontal resistance which substantially reduces heritability of re-sistance 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 Produccion de Frijol en America Latina-II mimeo CIAT Cali Colombia Julio 1977 p 2

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

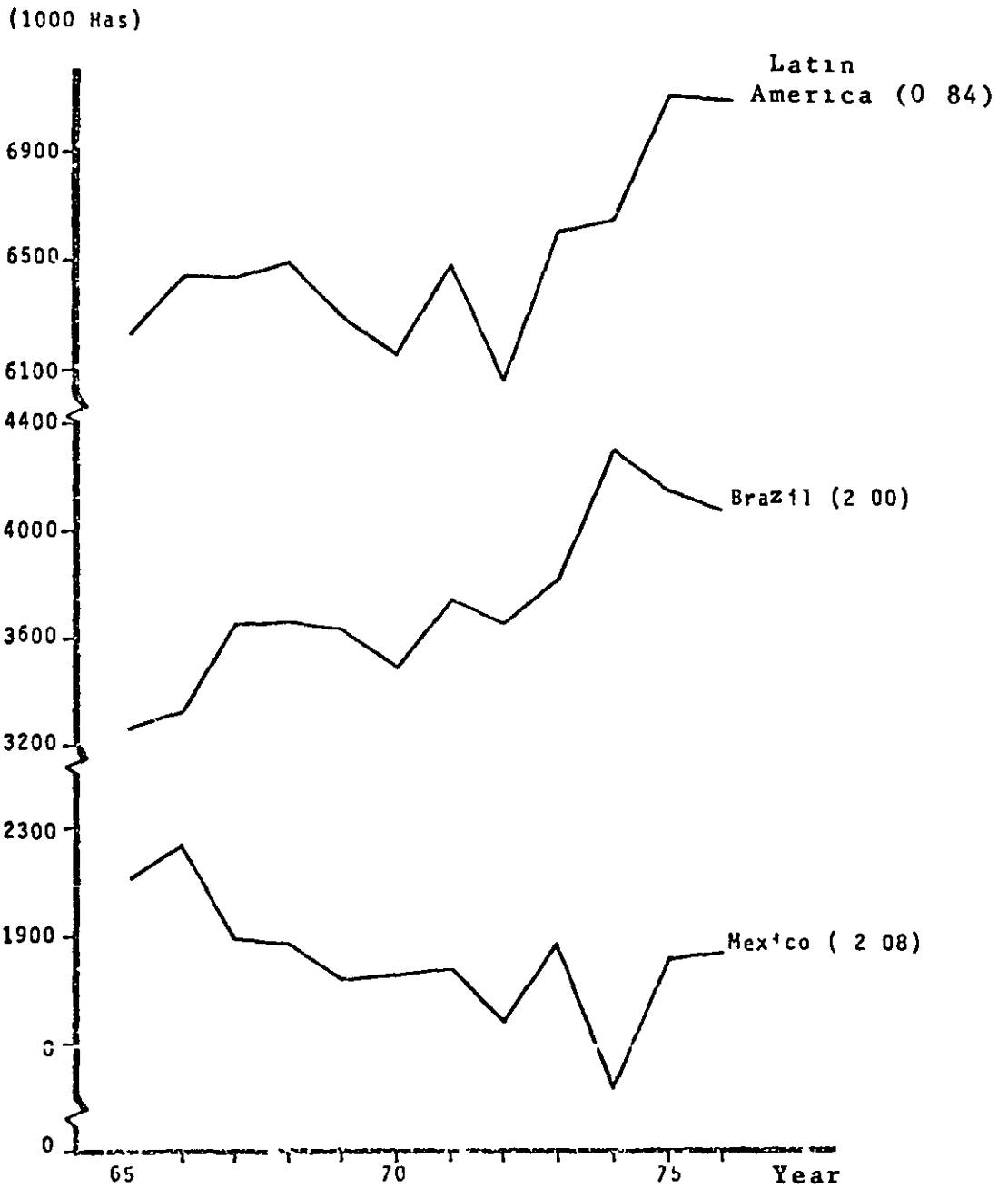
	Average (1963 65)				Average (1973 75)			
	Production Total[b/]	+Imports -Exports[c/]	Net domestic consumption	Apparent per capita consumption[d/]	Production Total[e/]	+Imports -Exports[c/]	Net domestic consumption	Apparent per capita consumption[d/]
	1000 tons			- kg/yr -	1000 tons			- kg/yr -
Exporters								
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[f]
	1000 tons			kg/yr	1000 tons			kg/yr
Exporters								
Argentina	850	-182	668	30	1323	-584	739	29
Chile	1060	-271	789	9	970	-251	719	72
Mexico	9757	-229	9528	231	13133	-124	13009	224
Honduras	487	-180	307	139	514	-44	469	151
Colombia	907	24	931	52	1436[g]	-28	1408	57
Peru	1037	18	1055	93	880	-17	863	57
Bolivia	210	03	213	53	293	-00[h]	293	57
Importers								
Cuba	273	615	888	118	240	927	1167	128
Venezuela	463	324	787	88	410	300	710	57
Costa Rica	183	10	193	134	137	173	310	160
Brazil	21230	79	21309	266	23327	170	23497	222
D Republic	473	54	527	148	640	40	680	140
Panama	70	34	104	87	47	20	67	41
Guatemala	430	23	453	101	743	30	773	134
Uruguay	70	15	85	32	50	05	55	18
Nicaragua	357	-20	337	212	483	36	519	237
El Salvador	143	152	295	103	373	33	406	101
Haiti	433	05	438	106	833	00[h]	833	166
Paraguay	450	-10	440	227	520	00	520	207
Ecuador[f]	653	01	654	133	537	01	538	76
Others[f]	187	232	419	52	160	219	379	40
Latin America	39723	697	40420	169	47049	900	47950	151

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"

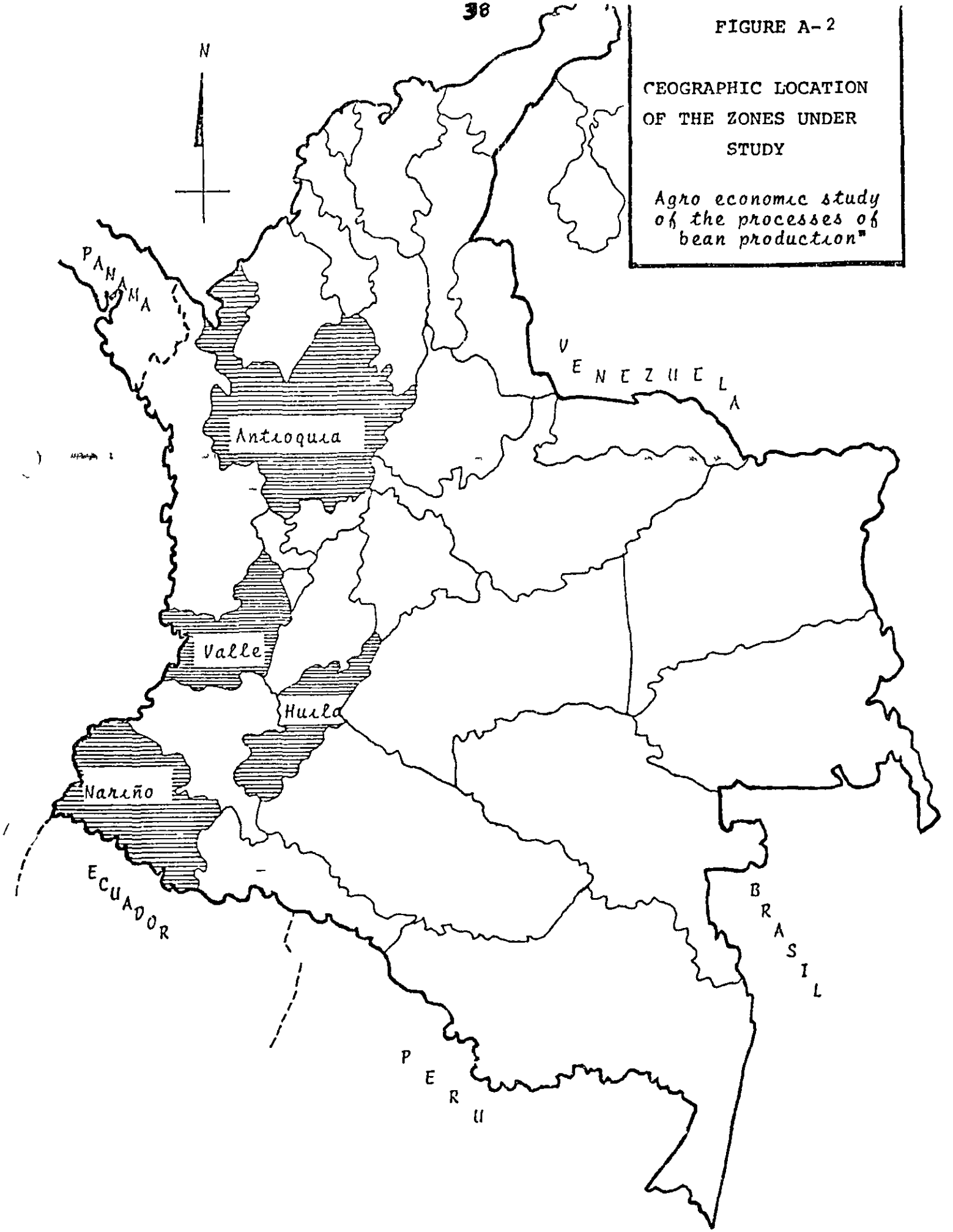


Table A-7 Technologies Characteristic of Two Systems of Bean Production Valle and Huila-Nariño 1974-75

	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 Londono 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 vanderystii*)	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

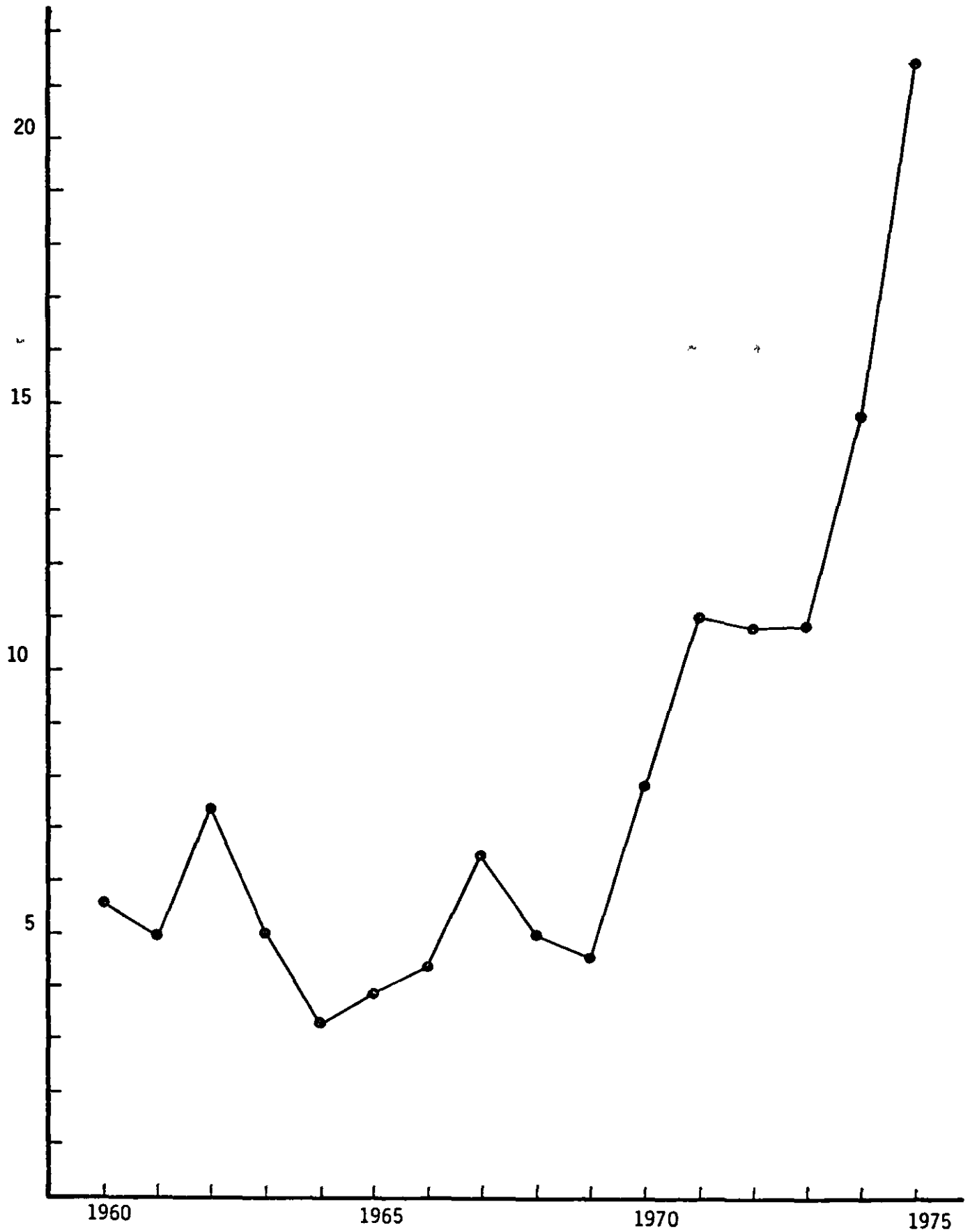
Source Translated from Norha R de Londoño et al , op cit p 124

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						
Liriomyza 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

FIGURE TRENDS IN PRICES OF CASSAVA FLOUR IN BRAZIL a/



a/ Cassava flour average wholesale price Sao Paulo

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 Nariño) 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

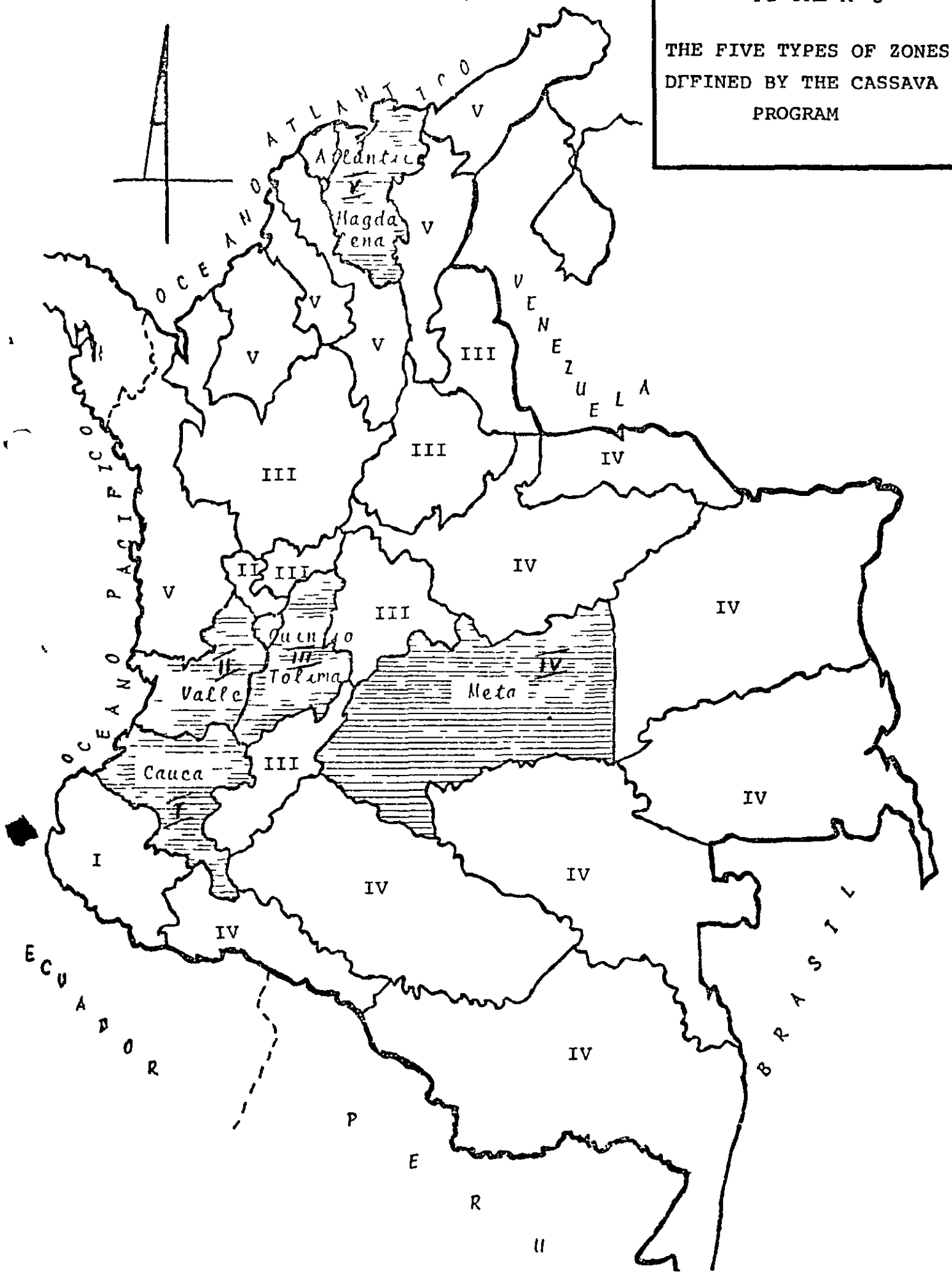


Table A-12 Selected Soil Characteristics on the Cassava Sampled (average by zone)

	I	II	III	IV	V
Organic matter (%)	5 22	3 69	5 33	3 53	1 93
Less than [illegible]**	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 18	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 Annual Report 1975 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)	+	+	+	+	+	+	+	+	+	+	+	+	1
Mosaic (Yellow)	–	–	+	+	+	–	–	+	–	–	–	–	4
Common Blight (*Xanthomonas*)	+	+	+	–	+	–	+	+	–	–	–	+	7
Rust (*Uromyces*)	+	+	+	+	+	+	+	+	+	–	+	+	11
Web Blight (*Thanatophorus*)	+	+	–	+	–	–	–	+	+	–	–	–	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

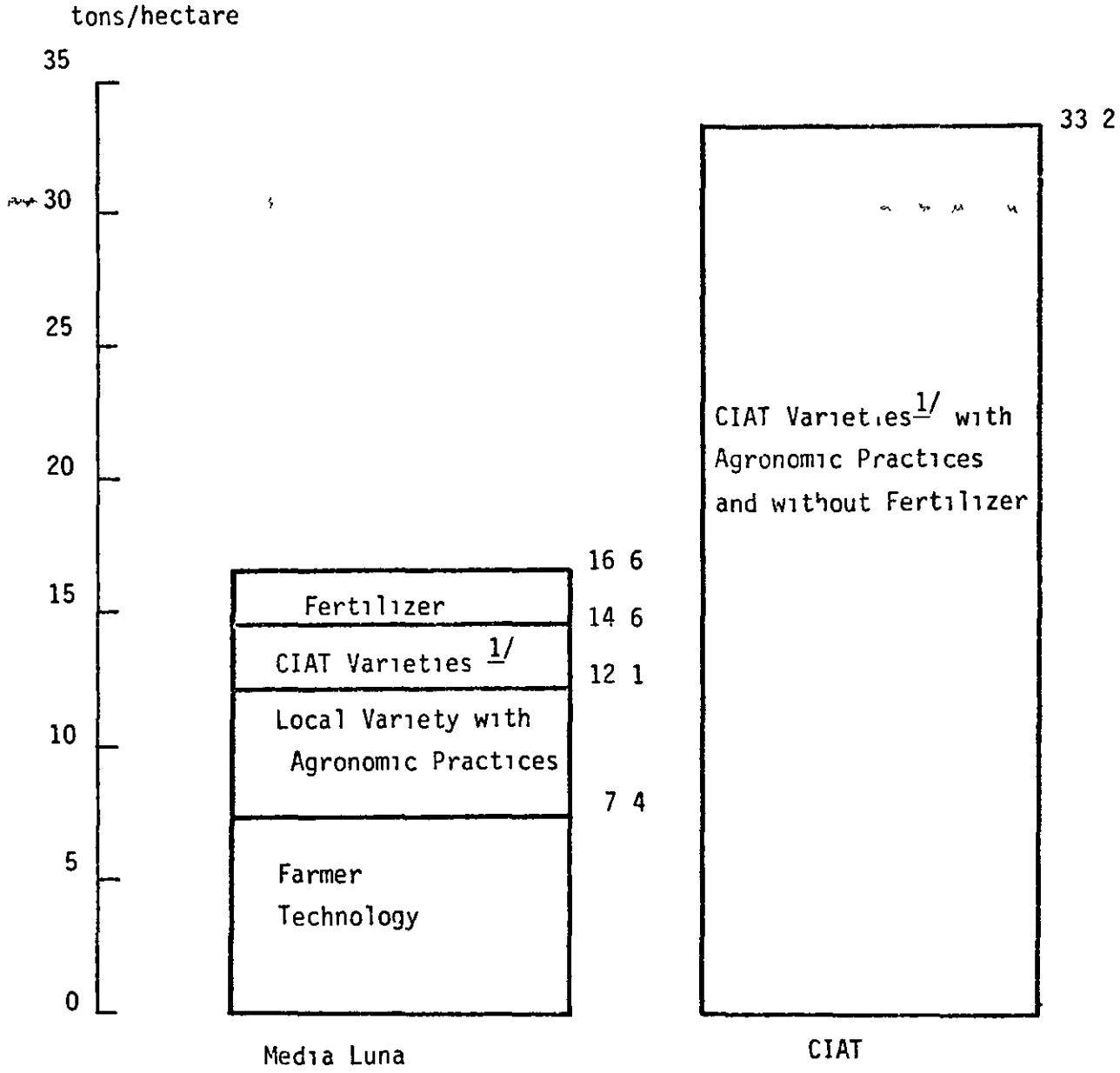
Country	Price of Cassava $US/M T	Price Indices[1]			
		Potatoes	Paddy Rice	Wheat	Maize
Argentina	24 3	95	270	177	166
Bolivia	36 6	175	198	230	320
Brazil	9 5	555	698	1147	350
Colombia	49 7	141	209	231	148
Ecuador	36 0	172	217	267	244
Paraguay	21 4	445	334	371	265
Peru	31 8	194	401	365	275
Venezuela	55 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 COMPAPISON OF POTENTIAL YIELDS ON FARMERS FIELDS WITH YIELDS AT CIAT



1/ CMC 40 and M COL 22